A COMPARITIVE STUDY OF HETEROSIS IN SINGLE, DOUBLE AND THREE WAY CROSS HYBRIDS OF SUNFLOWER (*Helianthus annuus* L.)

By

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Thesis submitted to the CCS, Haryana Agriculural University in partial fulfilment of the requirements for the degree of:

MASTER OF SCIENCE

IN

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DEDICATED

TO

MY PARENTS

CERTIFICATE - I

This is to certify that this thesis entitled "A comparative study of heterosis in single, double and three way cross hybrids of sunflower (*Helianthus annuus* L.)" submitted in partial fulfilment of Master of Science in the subject of Plant Breeding, of the CCS, Haryana Agricultural University, is a bonafide research work carried out by Shri Harpreet Singh Gill under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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25.9.93

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Major Advisor

CERTIFICATE-II

This is to certify that the thesis entitled "A comparative study of heterosis in single, double and three way cross hybrids of sunflower (Helianthus annuus L.)" submitted by Shri Harpreet Singh Gill to the CCS, Haryana Agricultural University in partial fulfilment of the requirements for the degree of Master of Science, in the subject of Plant Breeding has been approved by the Student's Advisory Committee after an oral examination on the same, in collaboration with an External Examiner.

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(Harpreet Singh Gill)

Hisar

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CHAPTER-I

INTRODUCTION

Sunflower is one of the four major annual crops in the world, grown for edible oil. Sunflower performs well in most temperate regions of the world, with significant production occuring in each of the six crop producing continents. Sunflower is native to North America, and in the 16th century it was introduced in Spain, from where it spread throughout the world. Among the continents, Europe is the leading producer of sunflower seed. Russia is the largest producer of sunflower seed in the world followed by Argentina, USA, China, Spain, France, Bulgaria, Romania and India.

The first attempts at breeding in sunflower started simultaneously with the development of sunflower as an important source of oil during the early 1800s in Russia. Around the end of 19th century 'popular selection' was intensively practised in sunflower in Russia to improve the populations in production.

The begining of scientific breeding of sunflower dates back to 1912 when a programme of varietal development was established at kruglik research station in the Kuban province, Russia and the first variety of commercial importance saratovsky 169 was developed. The first methods in sunflower breeding involved mass and individual selection for certain traits from local populations. In the late 1940's, Putt started a programme of sunflower selection in Canada. By the 1960s, intensive breeding programmes were being persued in several research centres around the world and as a consequence of these activities world sunflower area has expanded to 14.5 million ha in 1992.

The practical use of heterosis in sunflower became possible only after suitable sources of male sterility was identified by Leclercq (1969). In 1950s heterosis and inbreeding in sunflower was studied by Putt in Canada, Habura and Schuster in West Germany and Gundaev in USSR for the most important traits. Development of the first sunflower hybrid based on cytoplasmic male sterility in the early 1970s intensified the interest of farmers to grow the crop and the sunflower yield increased manifolds.

Fehr (1987) stated that the first step in a breeding programme for any crop is the determination of characteristics that are important for a new cultivar. According to miller (1987) the objectives may vary greatly with the production area, relative prevalance of disease, economic returns based on oil or protein percentage, environmental stress, and the growers preference. After deciding which objectives are most important, a breeder must investigate the heritability of the desired traits as a guide to developing an effective breeding strategy.

The main objectives in sunflower breeding should be directed toward a limited number of economically important traits listed as under

1) Component of seed and oil content viz. the number of seeds/plant, test weight, low husk content and high oil concentration in seed.

2) architecture of sunflower plant viz. plant height, head size and shape, angle of head, leaf area and leaf canopy.

3) Increased harvest index, oil quality, protein content and its quality, early maturation, short stem and uniform height.

4) resistance to disease and drought using wild sunflower species.

Keeping this information in view the present study was taken up with the following objectives;

1. To compare the heterosis for different character among single, double and three way crosses.

2. To work out the general combining ability of different parents and specific combining ability of their crosses.

3. To work out the association between different morphological characters.

CHAPTER-II

REVIEW OF LITERATURE

Sunflower (Helianthus annuus L.) having chromosome number 2n = 34 belongs to family compositae. The genus Helianthus is composed of 49 species and 19 sub-species with 12 annual and 37 perennial species. These diverse species represent considerable genetic variability which can be utilised for improvement of cultivated sunflower. The taxonomy of Helianthus is somewhat confusing due to the complicated natural interspecific hybridization and different ploidy level of several species. Inter specific hybridization has become important as a mean of introducing genetic variability into the cultivated sunflower. The wild species continue to serve as a source of cytoplasmic male sterility for the cultivated sunflower. The wild species are the important source for resistance to diseases and insects.

Heterosis

The term "heterosis" refers to the phenomenon of increased or decreased vigour of the hybrid in comparison to its parents. This has been defined by several research workers from time to time. Shull (1914) for the first time proposed the term heterosis to denote the phenomenon of increased size and vigour resulting from hybridization. Hayman (1957) described heterosis as the expression of genes at different loci. In sunflower the heterotic effects have been observed to a considerable extent for most of plant characters (Unrau, 1947; Putt, 1962, 1966). A brief resume of the work done in relation to studies on heterosis in sunflower is presented here.

Putt (1966) studied heterosis for eight plant and seed characters. Maximum heterosis was observed for seed yield and plant height. Anashchenko and Rozhkova (1975) studied the production of F_1 heterotic hybrids with particular emphasis on the method used. Heterosis was studied in sunflower using hybrids MS257, MS353 and MS127 exceeding the standard VNIIMK 8931 by 19-30% in seed yield and the hybrid MML-41 obtained by crossing mutant lines, exceeds VNIIMK 8931 in oil yield by 13% (Voskoboinik and Saldatov, 1976).

Stoyanova and Velkov (1976) studied heterosis in 2500 interline hybrids and observed that 90% of the hybrids had marked heterosis, but only 3% exceeded the standard Peredovik in oil yield/ha. Many of the F_1 hybrids were close to the low protein parent in protein content.

Bounnit and Stoenescu (1978) compared heterosis for single, double and three way cross hybrids and concluded that double and three way cross hybrids were similar to single hybrids in seed yield, oil content and oil yield but they showed better adaptability. Heterosis for oil content was 5-10 times less than that for seed yield and oil yield.

Voskoboinik (1978) studied heterosis in sunflower hybrids and observed that the interline hybrid ML3 (NA 234 x VK 66) repened in 97 days, three days before peredovik. It yields 33.3 q/ha of seed and 16.7 q/ha of oil respectively 4.4 q/ha and 2.6 q/ha more than peredovik.

Gorbochenko (1978) studied heterosis in 520 F_1 interlines, variety line and inter varietal hybrids produced by diallel crosses between short and tall varieties. The hybrid obtained by crossing short lines, families and varieties with the variety Chernyanka 66 produced highest yield. The best hybrid 3/102 yielded upto 30.7 q/ha. Six short forms having high gca were selected. The best F_1 hybrid which had Donskoi nizkoroslyi 47 as short parent gave a 15-24% higher seed yield than better parent.

Using lines derived from Bulgaria, USSR, USA, France and Canada 320 interline hybrids were developed, some of them outyielding standard variety Peredovik by 10.7-33.8%. Whereas, the single interline hybrid 5(485 x 1485) outyielded peredovik by 14-15% over three years of varietal trial (Voskoboinik, 1978).

Zazharskii (1978) studied heterosis and inheritance of growth period duration in intervarietal sunflower hyrbids. Among F_1 hybrids between varieties differing in length of growth period, early forms predominated 46.2%, 14% showed overdominance of earliness. Intermediate inheritance was found in 33.3%, while 18.3% showed dominance of late parent.

Singh and Yadava (1978) studied four yield components in ten intervarietal hybrids. The variety EC 93611-1 produced good hybrids if used as male parent. P21 ms x EC 93611-1 were superior to the control variety for seed yield, number of filled seeds and 100-seed weight. The firsttwo of these were superior in seed yield over the better parent.

Heterosis for 13 quantitative characters including seed yield was studied in hybrids from 27 crosses involving 9 inbreds and three testers and its value overmid-parents ranged upto>41% for yield and 31% for oil content (Sudhakar, 1979).

Vranceanu and Stoenescu (1979) studied heterosis in single, double and three way sunflower hyrbids and concluded that all types of hybrids have similar values for 5 yield and quality characters and days to flowering. The double cross hybrids were taller than others. Comparisons with parental lines showed that average level of heterosis were similar in each type of hybrid. The double and three way hybrids were less affected by differing environmental conditions than the parental lines and single hybrids.

Bochkovoi (1982) examined the breeding of hybrid varieties and provided information on the methods of producing maternal lines and fertility restoring pollen parent and submitted two hybrids 311 and 314 for state variety trial.

Gupta and Khanna (1982) studied heterosis for oil yield and component characters in sunflower and observed additive, dominance and epistatic gene action in crosses involving two selection from peredovik and a dwarf selection from Smena. They recommended recurrent selection as the most suitable method of improvement for indian conditions. Heterosis for seed yield , oil content and eight traits related to yield from 21 crosses involving seven inbreds was also studied by Pathak and Singh (1983). Heterosis for seed yield was positively correlated with heterosis for 1000-seed weight (Vagvolggi, 1984).

Chaudhary and Anand (1984) studied heterosis in 100 F_1 hybrids from 77 crosses involving 20 inbred lines and 5 pollen parents in a line x tester design and observed heterosis value over better parent for 1000 seed weight (66.23%), the heterosis value was 69.89 per cent for seed yield, 64.65 per cent for head diameter, 23.17 per cent for oil content, 18.47 per cent for head diameter, 23.17 per cent for oil content, 18.47 per cent for number of leaves and -7.69 per cent for days to flowering. High yielding hybrids with 10-24% higher oil yield than VNIIMK 1646 were developed from crosses of lines adapted to local conditions (Buchuchanu and Rottaru, 1984).

Heterosis for yield and 8 related traits was studied in 66 crosses and heterosis in F_1 was correlated with the performance of the better parent for days to maturity, head diameter and shelling per cent. The range of heterosis was 47-206% for yield and 5.55 per cent for other traits (Singh and Labana, 1984).

Heterobeltiosis was observed for seed yield in 46 hybrids and oil percentage in 41 hybrids, out of 49 hybrids developed by crossing 7 cms lines with 7 restorer lines. In 8 hybrids heterosis for seed yield exceeded 10 per cent over better parent (Reddy and Lawrence, 1985).

Sheriff and Appadurai (1985, 1985) reported that out of 20 cross combination involving 5 females and 4 males parents which were studied for plant height, capitulum diameter, seed/capitulum and seed yield/capitulum, seven crosses exceeded their respective better parent in seed yield per capitulum. The best EC 85826 xBSH-1 did so by 147½. The following crosses viz. Morden x Col, EC75276 x Col, EC 4428 x Morden and Suf x Morden were found to be heterotic for seed yield.

Cruz (1986) studied heterosis for yield and yield component in 24 F_1 hybrids involving 8 S_1 lines and 3 open pollinated testers CLSUN 1, VNIIMK and romsun HS 52. Average heterosis for yield/plant was highest in crosses involving Sigco 37, Contiflor and cross 5. Most of the heterotic effect for head diameter were positive, while significant heterosis for 1000-seed weight was exhibited only by Romson HS 52 x Contiflor.

Heterosis for yield and 5 components was studied in a diallel cross involving 6 genotypes. Heterosis for yield/plant, seed oil content and 100-seed weight showed a close positive correlation with the gca of the parents. Heterosis for various character showed a negative correlation with heritability and heterosis could be predicted from the heritability value of the trait concerned (Sun, 1986).

Naik and Pawar (1988) studied seed yield and 11 yield components in 36 F_1 hybrid involving 3 cms lines and 12 restorers. Appreciable heterosis was observed for almost all characters. The highest heterosis (52.34) was recorded for 100-seed weight in the cross MS40A x EC75194, followed by yield/plant (34.57) in MS22A x Morden. Heterosis for yield/plant was mainly attributed to heterosis for percentage of filled seed/head and head diameter Heterosis for decreased husk percentage was reported by Cherzhentseva (1989).

Wang et al. (1990) reported negative heterosis for husk percentage while studying 11 parents and their 30 hybrids.

Combining ability

Anaschenko and Rozhkova (1974) studied combining ability for seed yield in 39 forms of sunflower and observed that best gca was shown by K2140 from Australia. Polycross, diallel cross and top cross method were used to study the gca of 30 Soviet varieties and good gca was shown by Voronezh 151, Chakinskii 269, Chernyanka 66 and Enisel while medium gca was shown by Peredovik, Armavir 3497, VNIIMK 6540, and VNIIMK 1646 (Klimov, 1974).

In a analysis of line x tester, involving 10 inbred line and 2 open pollinated sunflower varieties it was observed that the nature of gene action for flowering, head diameter, seed filling, husk content and seed yield was predominantly non-additive but was additive for maturity and plant height. Among females CM 365 and CM 379 were good combiners for yield and yield components and CM 323 was good combiner for plant height and maturity (Shetty and Singh, 1974).

Alba and Porceddu (1974) estimated combining ability in 96 combinations involving 6 male sterile lines and 16 normal inbreds for height, stem diameter, yield/plant, head diameter and flowering date. The male sterile lines BA001 (Enisel), BA004 (Kenia) BA005 (Peredovik) and BA007s (VNIIMK 8931) and the normal lines BAD20 (Chernyanka), BA027 (Mayak), BA034A (Ireg early striped), BA079 (Kenia) and BA007F (VNIIMK 8931) all had good gca for all the characters. The gca of 64 inbred lines was determined by means of top cross using 4 testers. A line from the variety Sputnik showed high gca as did 18 other forms including peredovik and a line from the variety G22. Some reciprocal differences in gca was found, when used as female, the line Zns 17 gave a more heterotic progeny than when used as male (Rozhkova, 1978).

Burlov and Buntovskii (1979) studied the gca of inbred lines of sunflower in diallel crosses and polycrosses and reported that the gca of 8 lines for seed yield and oil yield/ha depended more on environmental condition than that of gca for oil content. The lines Od 2586 and K395 which had a high gca for most characters were the most promising for further breeding work. The gca of short stemmed inbreds were determined by top crosses with tall Mayak and Zenit and the short Donskoinizkoroslyi 47 and the chernyanka 66. High gca for seed yield was shown by inbreds 3/95, 3/102, 4/13 and 3/11 and also by chernyanka 66 Intervarietal hybrids between the short and the tall testers also proved promising. The best for seed yield was Doskoinizkoroslyi x chernyanka 66. In respect of oil yield the best hybrids were 4/8 x Mayak, 4/13 x chernyanka 66 and 3/45 x chernayanka 66 (Alekseev and Voskoboinik, 1979).

Sindagi and Kulkarni (1980) carried out linextester analysis to study combining ability of the material comprising of 11 selfed lines and three open pollinated varieties. Among the lines, S_2RR234 and $S_3$698-7941 had good gca for yield and yield components and $S_2$161 had the best gca for oil content, husk percentage and test weight. The best gca for the number of seed, yield, capitulum diameter, oil content and test weight was observed in $S_2$415-1/64 x Morden, $S_3$698-7491 x Ramson record and $S_2$415-2/151 x EC 68415. The gca in I_6-I_9 lines was evaluated indicating that a single assessment, using the top cross method is sufficient to determine gca for 1000-seed weight, husk percentage and oil content (Buntovskii, 1980).

Furedi and Frank (1981) studied combining ability in sunflower lines in a 10 x 10 complete dialle. Lines 195, 196 and 273 were significantly superior in gca for seed yield/10 plants. Maternal effects were significant and positive in three lines and paternal effect in two. Gca effects were higher than sca effects for oil percentage of the seed. Lines 195, 196 and 137 were significantly superior in gca. Four parents were superior as seed parents and five as pollen parents.

Combining ability of 43 sunflower varieties was evaluated by top cross method using Sputunk F_1 Klem K2046 x Peredovik and Zns 17 as testers and revealed that 21% of the varieties had high gca with peredovik having the most stable gca effects. As regard the sca the best cross involved Sputunik with K1914 and K2031 (Rozhkova, 1981).

Tuberosa and Alba (1982) studied combining ability in 24 sunflower hybrids obtained by corssing six cytoplasmically male sterile lines with four fertility restorer lines. GCA effects in the seed parents were significant for every character except oil yield and seed yield and gca effects in pollen parents were significant for all characters studied. SCA effects were significant for all the characters except oil yield and plant height.

Burlov and Red'ko (1982) worked on possibility of combining short growth period with high yield in sunflower hybrids from a complete 6 x 6 diallel involving I_6 - I_8 lines derived from Soviet and foreign varieties or hybrids and indicated that the fertility restoring line 40 was the most promising for use in breeding for earliness combined with heterosis for yield, leaf number and flower number.

The data on yield and yield related traits was analysed from crosses involving 22 foreign inbreds and the testers, Morden and EC 68415. Inbreds 275, 276, 284, 289, 263A and 256 showed good gca for most important yield related traits (Shankara, 1983).

Dua and Yadava (1983) evaluated combining ability among 12 varieties on seed yield/plant and 9 yield related chracters over seven environments and they observed that the gca and sca variance were highly significant for all the characters and all environments with the former predominating.

Recurrent selection for high gca was carried out in 4 inbred populations derived respectively from Record, Peredovik, Talinay and Iregi Gikos line 300A being used as recurrent tester and observed that seed yield increased by between 1.06% and 64% but oil content by not more than 2.6% (Rincon and Barreda, 1983).

Alba and Barsanti (1985) analysed combining ability in 12 hybrids involving four CMS lines and three restorer lines. The restorer line MGBHR 3 and the CMS line MGBH504 and MGBH506 showed good gca for seed yield and oil content.

Combining ability of inbred lines of sunflower was studied for capitulum diameter. Ten lines were crossed with six testers. The highest gca effects were found in lines 3 and 7. High sca was shown by 7 x Armavirskii 14, 8 x Armaverts and 9 x Armaverts (Cherzhentseva, 1985). Combining ability for yield and 9 yield related characters for 7 inbreds and their 21 F_1's and two controls was studied and it was reported that PL 2965 was the best general combiner for yield and yield component and, PIL2358 and PIL 3741 were also good; several cross combinations showed positive specific combining ability for yield and seed/plant (Pathak and Singh, 1985).

Combining ability was also studied for plant height, capitulum diameter, seed/capitulum and seed yield/capitulum among 20 hybrids of sunflower obtained by crossing 5 lines and 4 testers and it was observed that one line and 2 testers were identified as the best combiners for seed yield and 3 hybrids showed significant SCA effects (Sheriff and Appadurai, 1985).

Shankara (1986) evaluated sunflower inbreds for their combining ability and provided information on combining ability, for oil yield/plant and 9 related characters in crosses of 22 exotic breeds with each pollinated tester varieties Morden and EC68415.

Kadkol and Anand (1986) studied combining ability for oil yield/ plant in a line x tester design for 14 inbreds and reported that the inbreds EC 68415, EC 68414 and EC 68413 were best general combiner for oil yield. The cross EC 68415 x ES 353 showed the highest sca.

Giriraj and Shantha (1987) estimated combining ability of converted male sterile lines of sunflower and observed that Cms 234, and amongest seven converted cms line F-48, F-75 and F-89 were the most desirable parents with high x low and low x low gca effects. Among the males PR-1 and RHA 274 were good general combiner for oil content and seed yield respectively. F50 x PR1 were the best specific combiner for seed yield/plant and oil content (Giriraj and Hiremath, 1989).

Naik and Pawar (1987) studied line x tester design for working out the combining ability of 3 male sterile lines and 12 open pollinated varieties. Among females MS40A was a good combiner for all the character except oil content, while MS43A proved to be best combiner for oil content. Among males EC 42661 and EC 5D277 were good combiners for yield and its components. The cross MS4DA x EC 100163 was best for yield/plant and 100-seed weight and the cross MS22A x EC 93403 for oil content.

Vanisree and Ananthasayana (1988) studied combining ability for yield components in 10 sunflower genotypes and their F_1 hybrids EC 68415, EC 68414 and Inbred 303 had high gca for most characters and Karlic 11-8 x Inbred 303, EC 68415 x Irrage export and Browski x EC 110673 had significant positive sca for seed yield/plant.

Cherzhentseva (1990) studied combining ability for seed yield in 10 inbred lines using top cross method. The testers used were Armaverts, A14, A15, A3497, Sputnik and VIVIIMK 1646. The lines 194, 235, 237 and 255 showed maximum gca.

Combining ability in 6 cms lines and 3 fertility restorer lines and their 18 F_1s was also studied and it was observed the hybrids from the cross L15 x RHA Toretta gave best agronomic performance (Pirani and Sampaolesi, 1990). Petkov (1992) reported that to assess the gca of new lines it was most promising to use oil yield per unit area as the criterion and to use a single male sterile hybrid as tester.

Correlations and path coefficient analysis

Fick and Zimmer (1974) studied correlation of oil content in sunflower with other plant and seed characteristics in open pollinated and hybrid varieties and observed a positive correlation of oil content with number of days to 50 per cent flowering, plant height and test weight, and a negative correlation with rust reaction. Correlation of a number of morphological characters with yield and oil content were studied and established that shortening the emergence-flowering and flowering-ripening phases had a negative effect on oil content (Baldzhi, 1976).

Vashnkey and Bas udeo (1977) observed that seed yield was positively correlated with days to 75 per cent maturity, height, head diameter and 1000-seed weight. Head diameter, height and seed filling directly effected yield, while maturity and 1000-seed weight affected yield indirectly apparently via height.

In the hybrids derived from Peredovik and Simena it was reported that height significantly effects oil yield/ha and also seed yield/ha, while in hybrids derived from VNIIMK lines leaf number/plant had a significant effect on oil yield/ha and leaf area had a significant effect on seed yield/ha (Skoric, 1977).

Giriraj (1980) studied 326 elite progeny lines and observed that seed weight, plant height and capitulum diameter were the characters affecting seed yield most directly. Leaf number and oil content are also positively associated with yield.

In the analysis of six I_6-I_8 lines derived from Soviet and foreign varieties for duration of different growth phases and total growth period, number of leaves/plant, height, seed yield/plant, inflorescence diameter, 1000 seed weight and number of flowers/inflorescence it was observed that growth period was correlated closely with durations of period from emergence to flower bud formation (r = 0.78) and from flowering to physiological maturity (r = 0.57). Number of flowers/inflorescence was closely related with yield (r= 0.63) and leaf number (r = 0.66) (Burlov and Redko, 1982).

Pathak and Kukadia (1983) studied yield and its six related characters in seven inbreds, 21 single crosses, and reported that seed/plant and 1000-seed weight had highest positive direct effect on yield.

Seven cultivars differing significantly in 1000 seed weight and oil content, but not in height, head diameter, stem thickness or seed yield were studied, and it was reported that seed yield was strongly correlated with height, stem thickness, head diameter and 1000-seed weight in all cultivars (Caylack and Emirogliv, 1984).

A comparative analysis of the correlation between yield characters in sunflower hybrids revealed a close correlation between percentage of oil in seed and husk percentage and between duration of growth period and plant height (Rostova and Anaschenko, 1984).

Dhaduk and Desai (1985) analysed data on yield and nine yield related characters from twenty geographical diverse varieties and concluded that to improve yield more emphasis should be on capitulum diameter and 1000-seed weight followed by number of filled seeds/capitulum. A positive association of head diameter, percentage of filled seeds and 100-seed weight was observed with seed yield/plant in a study involving 36 genotypes of sunflower (Singh and Yadava, 1985).

Pathak and Kukadia (1986) reported phenotypic and genotypic correlation among seed yield/plant and nine related characters in seven inbreds and their twenty one single crosses and two standard varieties.

Partial correlation and path coefficient were used for selection of recombinant progenies for earliness in a four line dialle cross in sunflower. The phases in days from sowing to rosette stage and rosette stage to flowering were treated as distinct complementary components. Out of 33 progenies for earliness, four were identified as best and of these two from the cross 61 x 62, between two late lines were especially noteworthy (Skaloud and Kovacik, 1986).

Phenotypic correlation and path coefficient were worked out for agronomic characters in sunflowers. The closest possible correlation with seed yield/plant among six characters were observed for head diameter and number of seed/head. Seed/head and 200 seed weight had the greatest direct effect on yield (Carrasco and Lopez, 1986).

Rao (1987) studied correlation and path coefficient analysis in 21 hybrids and one variety of sunflower and indicated that seed yield was correlated positively with capitulum diameter, seed oil content, 100-seed weight, total dry matter content and harvest index, and negatively with days to maturity and husk percentage. Path coefficient analysis revealed that harvest index had the greatest positive direct effect on seed yield through plant height and total dry matter, oil content, mean leaf area and number of leaves/plant had direct negative effect on seed yield.

Sheriff and Rangaswamy (1987) studied eight characters from 23 genotypes identifying stem circumstances and dry matter content, capitulum diameter and dry matter content, and number of seeds/capitulum as the characters most closely related to seed yield. Vanisree and Ananthasayana (1988) reported that head diameter, stem diameter, 100-seed seight, leaves/ plant and plant height were positively and highly significant correlated with yield.

Khan and Muhammad (1989) in a study of correlation among nine sunflower hybrids and a control for plant height, head diameter, 1000-seed weight and yield/plant indicated a positive correlation between yield and yield components as well as within yield components. Head size was highly correlated with seed yield.

Singh and Labana (1990) studied correlation and path analysis in 157 families representing variety x 17 inbred crosses and concluded that seed yield was positively correlated with days to maturity, plant height, head diameter, grain filling and 1000 grain weight. Path coefficient analysis indicated that head diameter had the maximum direct effect on seed yield followed by days to maturity and plant height.

Wang (1990) reported heterosis for husk percentage was highly correlated with sca of the female parents and negatively correlated with their phenotypic values. Correlation between yield and duration of growth stage from flowering to maturity and between yield and 1000-seed weight was also reported by Visic (1991).

CHAPTER-III

MATERIAL AND METHODS

The present investigation was carried out at the Research Farm of Department of Plant Breeding, CCS Haryana Agricultural University, Hisar during the year 1992-93.

The experimental material consisted of 63 genotypes involving 45 crosses (9 single crosses, 18 double crosses and 18 three way crosses), 15 parents and 3 standard checks. For the purpose of combining ability, 9 crosses were studied in Line x Tester (L x T) design. All these genotypes were grown in 2 rows of 3m length with spacing 60 x 30 cm in a randomized block design with three replications. The data was recorded on 5 randomly selected plant. All the recommended package of practices were followed to raise the crop. The experimental material for the present study is listed in Table 1.

Recording of observation

Data was recorded on 5 randomly selected plants in each genotype per replication for the following characters.

1. Days to flowering
2. Days to 50 per cent flowering
3. Maturity (days)
4. Plant height (cm)
5. Stem diameter (cm)
6. Head diameter (cm)

Table 1. Details of crosses and Parents

Single crosses

1. Cms 300A x RHA 298
2. Cms 300A x RHA 272
3. Cms 300A x RHA 273
4. Cms 336A x RHA 857
5. Cms 336A x RHA 856
6. Cms 336A x RHA 274
7. Cms 336A x RHA 271
8. Cms 336A x RHA 296
9. Cms 7-1A x RHA 297

Double crosses

10. (Cms 336A x RHA 857) x (Cms 300A x RHA 298)
11. (Cms 336A x RHA 856) x (Cms 300A x RHA 298)
12. (Cms 336A x RHA 274) x (Cms 300A x RHA 298)
13. (Cms 336A x RHA 271) x (Cms 300A x RHA 298)
14. (Cms 336A x RHA 296) x (Cms 300A x RHA 298)
15. (Cms 7-1A x RHA 297) x (Cms 300A x RHA 298)
16. (Cms 336A x RHA 857) x (Cms 300A x RHA 272)
17. (Cms 336A x RHA 856) x (Cms 300A x RHA 272)
18. (Cms 336A x RHA 274) x (Cms 300A x RHA 272)
19. (Cms 336A x RHA 271) x (Cms 300A x RHA 272)
20. (Cms 336A x RHA 296) x (Cms 300A x RHA 272)
21. (Cms 7-1A x RHA 297) x (Cms 300A x RHA 272)
22. (Cms 336A x RHA 857) x (Cms 300A x RHA 273)
23. (Cms 336A x RHA 856) x (Cms 300A x RHA 273)
24. (Cms 336A x RHA 274) x (Cms 300A x RHA 273)
25. (Cms 336A x RHA 271) x (Cms 300A x RHA 273)
26. (Cms 336A x RHA 296) x (Cms 300A x RHA 273)
27. (Cms 7-1A x RHA 297) x (Cms 300A x RHA 273)

Three way crosses

28. (Cms 336A x RHA857) x IB2
29. (Cms 336A x RHA 856) x IB2
30. (Cms 336A x RHA274) x IB2
31. (Cms 336A x RHA 271) x IB2
32. (Cms 336A x RHA 296) x IB2
33. (Cms 7-1A x RHA 297) x IB2
34. (Cms 336A x RHA 857) x IB28
35. (Cms 336A x RHA 856) x IB28
36. (Cms 336A x RHA 274) x IB28
37. (Cms 336A x RHA 271) x IB28
38. (Cms 336A x RHA 296) x IB28
39. (Cms 7-1A x RHA 297) x IB28

40. (Cms 336A x RHA 857) x IB43
41. (Cms 336A x RHA 856) x IB43
42. (Cms 336A x RHA 274) x IB43
43. (Cms 336A x RHA 271) x IB43
44. (Cms 336A x RHA 296) x IB43
45. (Cms 7-1A x RHA 297) x IB43

Parents

46. Cms 300A
47. Cms 336A
48. Cms 7-1A
49. IB 2
50. IB 28
51. IB 43
52. RHA 271
53. RHA 272
54. RHA 273
55. RHA 274
56. RHA 296
57. RHA 297
58. RHA 298
59. RHA 856
60. RHA 857

Checks

61. A PSH-11
62. MSFH-8
63. EC68415C

Table 1a. For combining ability following 9 crosses were studied:

1. Cms 300A x RHA 273
2. Cms 300A x RHA 296
3. Cms 300A x RHA 298
4. Cms 336A x RHA 273
5. Cms 336A x RHA 296
6. Cms 336A x RHA 298
7. Cms 7-1A x RHA 273
8. Cms 7-1A x RHA 296
9. Cms 7-1A x RHA 298

7. Unfilled seeds (%)
8. 100-seed weight (g)
9. Number of seeds per head
10. Seed yield per plant (g)
11. Oil content (%)

Discription of characters

1. Days to flowering: The number of days were counted from the data of sowing to the day when the capitulum came to blooming i.e. the day when the ray floret open.

2. Days to 50 per cent flowering: The number of days were counted from the date of sowing to the day when 50 per cent of the plants in each genotype in each replication came to blooming.

3. Days to maturity: The number of days were calculated from the date of sowing to the day of maturity of the head i.e. when the head turned yellow and the involucral tracts began to turn brown.

4. Plant height : The plant height was measured in centimeters from the base of the stem to the head at the time of maturity.

5. Stem diameter: The diameter of the stem was measured in centimeters with the help of varnier's calliper at about one foot from the ground level.

6. Head diameter: The diameter of the head was measured in centimeters with the help meter tape.

7. Percent unfilled seeds: The percentage of unfilled seeds was calculated by counting the total number of seeds and unfilled seeds by the formula

$$\frac{\text{Unfilled seeds}}{\text{Total seeds}} \times 100$$

8. 100-seed weight: 100 filled seeds were taken from individual plant and the weight was recorded in grams.

9. Seed yield per plant: The average yield of filled seeds per plant was calculated in grams after weighting the sun dried filled seeds from each plant.

10. Number of seeds per head: The number of seeds/head were calculated by counting the number of filled seeds per head.

11. Oil content: The per cent oil content of the oven dried seeds was determined by Nuclear Magnetic Resonance (N.M.R).

Statistical methods

Following statistical methods were applied for analysis of data. For statistical analysis, mean values for each character were used.

1. ANOVA (Analysis of variance): The data for different characters were statistically analysed on the basis of following model (Panse and Sukhatame, 1967).

$Y_{ij} = m + ai + bj + e_{ij}$

where,

Y_{ij} = any observation in ith treatment and jth block,

m = *general mean,*

ai = ith treatment effect

bj = jth block effect and

e_{ij} = random error associated with ith treatment and jth block assumed to be NID (0,02).

Analysis of variance tables for all the characters under study is as follows:

Table 2.

Source	d.f.	Sum of squares	Mean square	Expected mean square	R
Replications	(r-1)	RSS	Mr	$\sigma_e^2 + \frac{t \sum bk^2}{r-1}$	
Treatments	(t-1)	TSS	Mt	$\sigma_e^2 + \frac{r \sum gi^2}{t-1}$	$\frac{mt}{me}$
Error	(r-1) (t-1)	ESS	Me	σ_e^2	

Where,

t = number of treatments,

r = number of replications or blocks

σ_e^2 = error mean squares, and

σ_t^2 = treatment mean squares

Each mean square of progeny was tested against corresponding error mean square and the calculated F was compared with table values of F at 1 per cent and 5 per cent level of significance.

2. Estimation of heterosis

Heterosis is the increase or decrease in F_1 performance over better parent (heterobeltiosis) as:

$$\text{Per cent heterosis over better parent (BP)} = \frac{\overline{F}_1 - \overline{BP}}{\overline{BP}} \times 100$$

Superiority over best check was also calculated for all the characters as:

$$\text{Per cent superiority over best check (BC)} = \frac{\overline{F_1} - \overline{BC}}{\overline{BC}} \times 100$$

For comparing the heterobeltiosis and superiority over best check, the critical difference (CD) was calculated as:

$$CD = SE_d \times t$$

where,

SE_d = standard error of difference of mean = $\sqrt{\frac{2me}{r}}$

t = tabulated value of 't' at error degree of freedom at 5 per cent level of significance.

The level of significance was given to the corresponding values of heterosis, by comparing CD values with $(\overline{F}_1-\overline{BP})$ and $(\overline{F}_1-\overline{BC})$.

3. Combining ability analysis

The combining ability effects were estimated according to the method suggested by Kempthorne (1957).

The analysis of combining ability was based on this model:

$$X_{ijk} = m + g_i + g_j + s_{ij} + e_{ijk} + b_k$$

Where,

X_{ijk} = phenotypic value of the ijkth observation,

m = general mean,

g_i = general combining ability of ith male parent,

g_j = general combining ability of jth female parent,

s_{ij} = specific combining ability of cross between ith male and jth female.

b_k = kth block (replication) effect and

e_{ijk} = environmental error.

Each character was analysed for combining ability in the form given below:

Table 3. Analysis of variance for combining ability

Source	d.f.	Mean squares	Expected mean square	F
Replications	r-1			
Hybrids	(mf-1)			
Lines	(f-1)	M_1	$\sigma^2_e + \frac{rm}{(f-1)} \sum_i fi^2$	$\frac{M_1}{M_3}$
Testers	(m-1)	M_2	$\sigma^2_e + \frac{rf}{(m-1)} \sum_j mj^2$	$\frac{M_2}{M_3}$
Lines x Testers	(m-1) (f-1)	M_3	$\sigma^2_e + \frac{r}{(f-1)(m-1)} \sum_i \sum_j fm(ij^2)$	$\frac{M_3}{M_4}$
Error	(r-1) (mf-1)	M_4	σ^2_e	

Where,

r	=	number of replications,
m	=	number of males
f	=	number of females and
σ_e^2	=	error variance

Mean squares due to line x tester were tested against error variance, whereas mean squares due to lines as well as due to testers were tested against line x tester component.

Combining ability effects

The individual general and specific combining ability effects were calculated as follows:

Population mean (u) = $\frac{X...}{mfr}$

Where,

X... = total of all observations

GCA effects of male parents (g_i) = $\frac{X_{i..}}{fr} - \frac{X...}{mfr}$

Where,

$X_{1..}$ = total of ith male parent over all female parents and replications.

GCA effects of female parents (g_j) = $\frac{X.j.}{mr} - \frac{X...}{mfr}$

where,

X.j. = total of jth female parent over all male parents and replications.

SCA effect of ijth cross (s_{ij}) = $\frac{X_{ij.}}{r} - \frac{X_{i..}}{fr} - \frac{X.j.}{mr} - \frac{X...}{mfr}$

where,

$X_{ij.}$ = total over all replications for ijth combination.

4. Parameters of variability

i) Mean

The mean value of each character was worked out by dividing total sum of all the values by number of corresponding observations.

$$\bar{X} = \frac{X_i}{n}$$

ii) Range

Range was calculated by taking the lowest and the highest value for each character.

iii) Standard error

S.E. of difference between two means were calculated with the help of error mean square from ANOVA table.

$$S.E.(d) = \sqrt{\frac{2EMS}{r}}$$

where,

S.E.(d) = Standard error of difference between two means.

EMS = Error mean square

r = Number of replications

iv) Critical difference

Critical difference (C.D.) of all characters was calculated to compare the variation among genotypes. It was computed with the help of S.E. (d) and tabulated value of t at 5% level of significances and error degree of freedom,

$$C.D. = \sqrt{\frac{2EMS}{r}} \times t$$

In all cases C.D. is calculated at 5% level of significance.

v) Coefficient of variation

Genotypic and phenotypic coefficient of variations were calculated by the formula suggested by Burton and De Vane (1953).

$$\text{Genotypic coefficient of variation (GCV)} = \frac{\sigma_g}{\bar{x}} \times 100$$

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{\sigma_p}{\bar{x}} \times 100$$

vi) Heritability (in broad sense)

The heritability in broad sense was calculated using the formula suggested by Hanson et al. (1956).

$$H\ (\%) = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

Where,

H = Heritability in broad sense

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

vii) Genetic advance

Genetic advance was computed by the following formula proposed by Lush (1949) and Johnson et al. (1955).

$$GA = \frac{\sigma^2_g}{\sqrt{\sigma^2_p}} \times K$$

Where,

GA = Genetic advance

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

K = Selection differential

At 5% selection pressure the value of K is 2.06 (Lush, 1949 and Allard, 1960).

viii) Expected genetic gain

Genetic gain represents, genetic advance expressed as per cent of mean. It was calculated by the method suggested by Johnson et al. (1955).

$$\text{Expected genetic gain} = \frac{GA}{\bar{X}} \times 100$$

Where,

GA = Genetic advance

$\bar{X}$ = Mean of the character under study.

5. Correlation coefficients

Correlation coefficients at genotypic, phenotypic and environmental level were calculated from the variance and co-variance tables as already obtained according to Johnson et al. (1955). The formula applied were:

1. Phenotypic correlation $r(X1,X2)\ P = \dfrac{COV\ X1.\ X2\ (P)}{\sqrt{\sigma^2_p\ (X1).\sigma^2_p\ (X2)}}$.

where,

COV X1.X2 (P) = Phenotypic covariance between character X1 and X2.

σ_p^2 (X1) =Phenotypic variance of character X1

σ_p^2 (X2) = Phenotypic variance of character X2.

2. Genotypic correlation $r(X1.X2)\ g = \dfrac{COV\ X1.X2(g)}{\sqrt{\sigma_g^2 (X1).\ \sigma_g^2 (X2)}}$

where,

COV X1, X2 (g) = Genotypic co-variance between character X1 and X2.

σ_g^2 (X1) = Genotypic variance of character X1.

σ_g^2 (X2) = Genotypic variance of character X2.

3. Environmental correlation = $r(X1.X2)\ e = \dfrac{COV.X1.X2(e)}{\sqrt{\sigma_e^2 (X1)\sigma_e^2 (X2)}}$

where,

COV X1, X2 (e) = Environmental covariance between character X1 and X2.

σ_e^2 (X1) = Environmental varianceof character X1.

σ_e^2 (X2) = Environmental variance of character X2.

Phenotypic and environmental correlation coefficients were tested at 5% and 1% level of significance against the expected value from Fisher's table at n-2 degree of freedom.

6. Path-coefficient analysis

The genotypic correlation coefficients were used to work out path coefficient analysis. The path coefficient were obtained according to Dewey and Lu (1959) solving a set of simultaneous equations of the form:

$$r_{ny} = P_{ny} + r_{n2}P_{2y} + r_{n3}P_{3Y} + \ldots\ldots r_{nx}P_{xy}$$

where,

r_{ny} = represent correlation coefficient between one character and yield.

P_{ny} = Stands for path coefficient between the character and yield.

rn2,rn3 = represent correlation coefficient between that character and each of other yield component in turn.

The following matrices were prepared:

Matrix A	Matrix B			
r_{1y}	1	r_{12}	r_{13}....	r_{1n}
r_{2y}	r_{21}	1	r_{23}....	r_{2n}
'	'	'	'	'
'	'	'	'	'
'	'	'	'	'
r_{ny}	r_{ny}	r_{n1}	r_{n3}...	1

Where,

r_{12} = r_{21} and soon

r_{1y} = Correlation coefficient between main character and one component character.

The technique given by Goulden (1964) was followed for inversion $(B)^{-1}$ of B matrix and path coefficient (P_{jy}) were obtained as follow:

$$P_{jy} = (B)^{-1} \quad (A)$$

The indirect effect for a particular character through other character was obtained by multiplication of direct paths and particular correlation coefficients between those characters respectively:

Indirect effect = rij x Pij

where,

i = 1 to n

j = 1 to X

Pij = Ply, P2y . . . . Pny

The residual effect i.e. the variation in yield uncounted for those associated, were calculated by the following formula:

Residual effect (X) = $1-R^2$

where,

R^2 = Ply rly + P2y r2y + ... Pny rny.

R^2 is the squared multiple correlation coefficient and is the amount of variation in yield that can be accounted for by the yield of that component characters.

CHAPTER-IV

EXPERIMENTAL RESULTS

Studies were conducted at the Experimental Research Area of the Department of Plant Breeding during the year 1992-93. The material consisted of 63 genotypes involving 45 F_1's hybrids, their 15 parents and three standard checks. Data were recorded on eleven characters and the performance of each hybrid was compared with its respective parents and the standard checks.

Analysis of variance

The analysis of variance for all the eleven characters is presented in table 4. The mean square values were found to be significant for all the characters, thereby indicating presence of genetic variability in the genotypes studied.

Mean performance

The mean values, range, standard error of difference S.E. (d) and critical difference (C.D.) for different character are presented in table 5. The results for different characters are as under.

1. Days to flowering

The maximum number of days to flowering (67.67) were observed in case of single cross Cms 336 x RHA 274 and the minimum (53.0) in double cross (Cms 336 x RHA 856) x (Cms 300A x RHA 298). The population mean for this character was 59.13 ± 1.46. The three crosses viz. Cms 336 x RHA 271, (Cms 336A x RHA 856) x (Cms 300A x RHA 298) and (Cms 336A x RHA

Table 4: Analysis of variance for different characters in sunflower

Source	d.f.	Flowering (days)	50% flowering (days)	Maturity (days)	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	Unfilled seed (%)	100-seed weight (g)	No. of seeds/ head	Seed yield/ plant (g)	Oil content (%)
Replication	2	1.18	1.72	5.88**	4.21	0.002	1.11	6.18	1.18	47437-85**	381.46**	6.5**
Genotypes	62	27.21**	30.61**	17.06**	1345.5**	4.21**	48.64**	99.73**	3.56**	72069.52**	405.69**	7.06**
Error	124	3.23	2.60	2.79	6.07	0.03	0.51	7.83	0.47	7464.44	37.71	2.10

* Significant at 5%

** Significant at 1%

856) x IB 43 were found to be significantly superior over their better parents for early flowering.

2. Days to 50 per cent flowering

The maximum number of days (69.67) for 50 per cent flowering were observed in three way cross (Cms 7-1A x RHA 297) x IB2 and the minimum (54.67) in the double cross (Cms 336A x RHA 856) x (Cms 300A x RHA 298). The population mean for this character was 60.72 ± 1.32. The two crosses (Cms 336A x RHA 271) and (Cms 336A x RHA 856) x (Cms 300A x RHA 298) were found to be significantly superior over their better parents for earliness to 50 per cent flowering.

3. Days to maturity

The F_1 hybrid of the cross (Cms 336A x RHA 857) took maximum days to maturity (99.43) and the three way cross (Cms 336A x RHA 856) x IB 43 the minimum (88.27) days to maturity. Population mean for this character was 94.15 ± 1.36. The crosses (Cms 336A x RHA 856) x (Cms 300A x RHA 298), (Cms 336A x RHA 271) x (Cms 300A x RHA 272) and (Cms 336A x RHA 856) x IB43 were found to be significantly superior over their parents for early maturity.

4. Plant height (cm)

The highest plant height (155.83 cm) was observed in case of single cross (Cms 336A x RHA 857) and the lowest (39.0 cm) in the single cross (Cms 336A x RHA 271). The population mean for this character was 119.97 ± 2.01. The single cross (Cms 336A x RHA 271) was found to be significantly superior over its parents and best check APSH-11 for dwarfness.

Table 5: Mean values, range, S.E. (d) and C.D. for various characters in sunflower

Sr. No.	Genotype	Flowering (days)	50% flowering (days)	Maturity (days)	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	Unfilled seeds (%)	100 -seed weight (g)	Number of seeds/ head	Seed yield/ plant (g)	Oil content (%)
		1	2	3	4	5	6	7	8	9	10	11
	Single crosses											
1.	Cms300A x RHA 298	56.33	56.33	93.40	123.17	2.50*	17.57	6.93	6.51	624.33	41.60	34.23
2.	Cms300A x RHA 272	57.00	57.00	92.87	109.67	2.33*	16.17	8.43	5.58	534.67	30.06	32.37
3.	Cms300A x RHA 273	61.53	64.00	99.33	109.00	2.16	20.53*	7.40	6.76	663.33	37.97	32.33
4.	Cms336A x RHA 857	63.70	64.00	99.43	153.33	3.02	23.40*	6.77*	7.24	795.00*	55.01*	33.77
5.	Cms336A x RHA 856	64.37	64.33	98.30	119.33	2.36	23.43	9.97	7.20	599.00	41.92	34.90
6.	Cms336A x RHA 274	67.67	69.00	94.73	152.67	1.48	18.30	4.80*	5.53	663.67	36.91	33.70
7.	Cms336A x RHA 271	54.87*	55.33*	93.87	39.00*	1.86	7.63	12.67	5.60	233.00	20.00	33.00
8.	Cms336A x RHA 296	57.67	57.33	94.53	124.33	1.51	13.57	8.30*	6.23	570.67	35.92	34.43
9.	Cms 7-1A x RHA 297	57.47	58.00	93.80	111.42	1.66	20.43*	8.32	6.81	477.67	36.16	32.77
	Double crosses											
10.	Cms336A x RHA 857 x Cms300A x RHA 298	56.07	58.00	92.80	122.33	2.14	16.97	6.57	6.57	613.00	40.65	33.95
11.	Cms336A x RHA 856 x Cms300A x RHA 298	53.00*	54.67*	89.47*	116.40	1.89	17.40	6.03	7.66*	566.63	41.41	33.90

Table contd....

Sr. No.	Genotype	1	2	3	4	5	6	7	8	9	10	11
12.	Cms336A x RHA274 x Cms300A x RHA298	54.07	55.33	89.47	122.87	2.02	17.80	6.03	7.37	641.67	48.17	30.95
13.	Cms336A x RHA271 x Cms300A x RHA298	58.80	59.67	94.40	104.60	1.90	15.97	14.10	5.25	479.00	24.39	32.80
14.	Cms336A x RHA296 x Cms300A x RHA298	58.80	63.67	93.47	117.47	2.00*	16.90*	14.10	7.08	629.00	45.55	34.25
15.	Cms7-1A x RHA297 x Cms336A x RHA298	63.60	63.33	96.27	135.87	2.58*	19.73*	6.95	6.09	465.00	28.65	34.77
16.	Cms336A x RHA857 x Cms300A x RHA272	61.87	63.33	97.20	144.07	2.48	19.03	13.37	6.33	645.67	42.05	36.15*
17.	Cms336A x RHA856 x Cms300A x RHA272	54.67	56.00	90.60	124.00	1.65	16.13	8.80	6.93	549.67	38.35	35.30
18.	Cms336A x RHA274 x Cms300A x RHA272	57.00	58.00	93.07	127.27	1.99	16.57	9.13	5.16	562.67	29.28	28.63
19.	Cms336A x RHA271 x Cms300A x RHA272	55.13	56.33	89.13*	132.60	2.24	14.17	20.00	6.52	430.33	28.39	35.75
20.	Cms336A x RHA296 x Cms300A x RHA272	56.00	57.67	92.73	125.67	2.42	13.73	8.65	6.07	505.00	30.76	34.23
21.	Cms7-1A x RHA297 x Cms300A x RHA272	57.87	59.00	94.33	112.20	2.40*	17.27	10.05	5.91	539.00	32.28	33.50
22.	Cms336A x RHA857 x Cms300A x RHA273	57.40	59.00	91.87	133.47	2.40	16.00	6.70	6.23	593.67	37.43	34.10
23.	Cms336A x RHA856 x Cms300A x RHA273	59.73	58.67	95.40	115.13	2.09	14.33	7.13	6.33	432.00	27.50	31.83

Table contd....

Sr. No.	Genotype	1	2	3	4	5	6	7	8	9	10	11
24.	Cms336A x RHA274 x Cms300A x RHA273	58.53	60.00	93.27	130.40	2.32	16.97	6.85	5.44	539.67	29.98	35.03
25.	Cms336A x RHA271 x Cms300A x RHA273	59.07	60.33	95.07	133.80	2.00	17.23	9.55	6.44	528.67	37.63	32.20
26.	Cms336A x RHA296 x Cms300A x RHA273	57.00	58.33	95.13	117.13	2.16	16.97	7.14	6.35	417.67	27.09	32.12
27.	Cms7-1A x RHA297 x Cms300A x RHA273	59.73	62.00	95.33	128.93	2.25	17.47	8.57	5.97	367.67	22.05	31.60
	<u>Three way crosses</u>											
28.	(Cms336A x RHA857)xIB2	60.27	62.00	93.80	133.80	1.66	18.17	10.00	6.51	538.33	36.13	34.50
29.	(Cms336A x RHA856)xIB2	59.07	60.33	94.53	133.73	2.32	19.00	7.33	7.30	367.67	26.74	32.30
30.	(Cms336A x RHA274)xIB2	58.13	60.00	94.93	131.40	1.86	16.97	6.67	5.32	519.00	23.24	32.40
31.	(Cms336A x RHA271)xIB2	57.53	58.67	93.60	116.60	1.96	14.97	5.50	6.87	620.33	42.70	32.30
32.	(Cms336A x RHA296)xIB2	58.40	59.33	96.07	130.40	1.93	17.67	8.23	5.73	411.00	23.52	35.50
33.	(Cms7-1A x RHA297)xIB2	67.13	69.67	95.33	144.53	2.62	17.73	12.47	6.66	547.33	36.50	33.70
34.	(Cms336A x RHA857)xIB28	61.20	64.33	94.40	145.73	2.54	20.57*	4.90*	6.92	494.67	34.71	33.73
35.	(Cms336A x RHA856)xIB28	57.67	60.33	97.00	124.60	2.66	16.23	9.00	7.30	605.00	44.67	32.65

Table contd.....

Sr. No.	Genotypes	1	2	3	4	5	6	7	8	9	10	11
36.	(Cms336A x RHA274)xIB28	59.27	61.00	93.47	112.40	2.32	14.80	7.03	6.44	496.00	32.03	32.80
37.	(Cms336A x RHA271)xIB28	61.97	63.33	95.00	126.07	1.81	12.40	8.90	5.60	636.00	36.09	33.25
38.	(Cms336A x RHA296)xIB28	60.13	60.57	94.13	129.33	2.12	17.33	9.83	6.72	568.00	38.20	29.27
39.	(Cms7-1A x RHA297)xIB28	61.87	62.00	95.37	121.00	2.06	18.10	10.37	6.13	541.67	32.04	34.03
40.	(Cms336A x RHA857)xIB43	63.07	64.67	94.47	124.80	2.07	15.60	6.10	6.17	564.67	29.18	34.70
41.	(Cms336A x RHA856)xIB43	55.13*	56.00	88.27*	119.07	2.02	15.73	9.80	7.10	488.33	27.61	32.73
42.	(Cms336A x RHA274)xIB43	60.40	62.67	93.93	151.20	2.00	16.63	6.13	7.29	693.67	43.80	32.73
43.	(Cms336A x RHA271)xIB43	59.73	61.00	94.93	140.20	2.28	17.93	5.53	6.43	717.67*	42.54	34.73
44.	(Cms336A x RHA296)xIB43	60.80	62.33	94.93	139.60	2.55	21.33*	10.11	6.44	630.67	41.46	32.10
45.	(Cms7-1A x RHA297)xIB43	64.27	65.67	97.80	141.60	2.64	16.63	7.67	4.80	425.33	25.36	31.93
	Parents											
46.	Cms300A	56.87	59.67	94.27	108.13	1.66	17.20	9.40	6.62	618.00	41.15	32.63
47.	Cms336A	62.23	65.00	95.00	125.63	3.20	18.50	13.37	6.27	593.67	40.59	33.13
48.	Cms 7-1A	56.67	58.33	92.13	119.57	2.05	16.40	8.30	6.43	438.67	28.48	33.23
49.	IB2	59.93	63.00	94.73	92.67	1.97	13.20	8.87	6.47	297.67	20.59	32.80
50.	IB28	59.73	60.00	94.30	132.67	2.13	19.80	14.13	7.17	583.67	42.18	32.33

Table contd...

Sr. No.	Genotypes	1	2	3	4	5	6	7	8	9	10	11
51.	IB43	58.40	61.67	94.80	141.73	2.28	18.40	7.77	7.07	644.00	46.36	32.30
52.	RHA271	58.40	59.67	96.46	89.00	1.49	8.27	13.40	5.40	237.33	13.01	34.43
53.	RHA272	58.33	60.67	97.13	76.80	1.80	10.17	12.53	5.19	227.00	12.00	28.93
54.	RHA273	59.70	60.33	90.47	74.90	1.43	9.67	11.77	3.56	267.67	11.53	33.70
55.	RHA274	57.27	59.33	91.60	90.53	1.40	7.23	16.80	2.77	210.00	7.74	33.00
56.	RHA296	56.27	56.33	91.43	94.33	1.70	7.83	22.80	3.68	164.00	6.07	33.80
57.	RHA297	60.57	64.33	96.80	111.23	1.78	8.13	31.83	3.21	130.33	6.26	34.70
58.	RHA298	63.33	65.00	96.87	106.73	1.96	7.03	29.10	3.37	230.67	7.50	36.03
59.	RHA856	58.90	61.67	89.90	68.73	1.60	5.10	30.30	4.27	123.00	9.18	31.90
60.	RHA857	58.07	59.67	92.12	111.87	2.28	13.80	8.70	5.83	386.67	22.88	33.73
	<u>Standard check</u>											
61.	APSH-11	58.00	60.00	94.00	96.90	2.03	15.20	11.30	6.30	488.00	30.86	33.50
62.	MSFH-8	65.00	66.00	99.00	116.90	1.99	16.10	11.30	5.60	543.00	35.29	28.80
63.	EC68415C	53.00	55.00	91.00	108.30	2.10	17.30	8.30	6.80	549.00	36.24	30.60
	G.M.	59.13	60.72	94.15	119.97	2.12	15.83	10.35	6.07	494.75	31.32	33.24

Table contd.....

Sr. No. Genotypes	1	2	3	4	5	6	7	8	9	10	11
Range	53.00-67.67	54.67-69.67	88.27-99.43	39-155.33	1.4-3.2	5.10-23.43	4.80-31.83	2.77-7.66	164.-795	6.07-55.01	28.63-36.15
S.E.(d)	1.46	1.32	1.36	2.01	0.15	0.58	2.28	0.56	70.54	5.01	1.18
C.D. 5%	2.86	2.58	2.66	3.94	0.29	1.14	4.46	1.09	138.25	9.82	2.31

* Significant at 5%

5. **Stem diameter (cm)**

The genotype (parent) showing maximum (3.2 cms) stem thickness was Cms 336 and the minimum (1.4 cm) Stem thickness was shown by the genotype (parent) RHA 274. Population mean for this character was 2.12 ± 0.15. The crosses (Cms 300A x RHA 298), (Cms 300A x RHA 272), (Cms 300A x RHA 273), (Cms 7-1A x RHA 297) x (Cms 300A x RHA 298) and (Cms 7-1A x RHA 297) x (Cms 300A x RHA 272) were found to be significantly superior over their respective parents and best check EC68415C for stem diameter.

6. **Head diameter (cm)**

For head diameter the maximum value (23.43 cm) was recorded for the single cross (Cms 366A x RHA 856) and the minimum (7.23 cm) for the genotype RHA 274.The population mean for this character was 15.83 ± 0.58. The crosses (Cms 300A x RHA 273), (Cms 336A x RHA 857), (Cms 336A x RHA 856), (Cms 7-1A x RHA 297) and (Cms 7-1A x RHA 297) x (Cms 300A x RHA 298) were found to be significantly superior over their better parents and best check EC68415C for head diameter.

7. **Percent unfilled seeds**

The maximum percentage of unfilled seeds (31.83) were observed in the parent RHA 297 and the minimum (4.8) in the single cross (Cms 336A x RHA 274). The population mean was 10.35 ± 2.28 for this character. The four crosses viz. (Cms 336A x RHA 274); (Cms 336A x RHA 857) x IB28, (Cms 336A x RHA 857) and (Cms 336A x RHA 296) were found to be significantly superior over their better parents and best check EC68415C for per cent unfilled seeds.

8. 100-seed weight (g)

For this character, the highest weight (7.66 g) was recorded for the double cross (Cms 336A x RHA 856) x (Cms 300A x RHA 298) and the lowest (2.77 g) for the genotype (parent) RHA 274. The population mean for this character was 6.07 ± 0.56. The double cross (Cms 336A x RHA 856) x (Cms 300A x RHA 298) was found to be significantly superior over its better parent and better check EC 68415C for 100-seed weight.

9. Number of seeds per head

Highest number of seeds per head (795) were observed for the single cross Cms 336A x RHA 857 and the lowest (123) for the genotype (parent) RHA 856. The population mean for this character was 494.75 ± 20.54. Crosses viz. Cms 336A x RHA 857 and (Cms 336A x RHA 271) x IB43 were found to be significantly superior over their parents and best check EC 68415C for number of seeds per head.

10. Seed yield per plant

The highest yield (55.01 g) was recorded for the single cross Cms 336A x RHA 857 and the lowest (6.07) for the genotype (parent) RHA 296. The population mean for seed yield was 31.32 ± 5.01. The single cross Cms 336A x RHA 857 was found to be significantly superior to its parents and better check EC 68415C for seed yield per plant.

11. Oil content (%)

The highest oil content (36.15%) was recorded in the double cross (Cms 336A x RHA 857) x (Cms 300A x RHA 272) and the lowest (28.63%)

in the double cross (Cms 336A x RHA 274) x (Cms 300 A x RHA 274) x (Cms 300A x RHA 272). The population mean for this character was 33.24 ± 1.18. The double cross (Cms 336A x RHA 857) x (Cms 300A x RHA 272) was found to be significantly superior to its parents and best check ASPH-11 for per cent oil content.

Heterobeltiosis and superiority over best check

1. Days to flowering

Heterobeltiosis and superiority over best check for days to flowering is presented in table 6. The heterobeltiosis for single crosses ranged from -3.57 to 19.30 per cent (Table 6). The hybrids Cms 336A x RHA 296 (-3.57) and Cms 336A x RHA 271 (-3.50) recorded significant negative heterobeltiosis indicating earliness for flowering. Superiority over best check EC68415C varied from -7.54 to 28.30 per cent (Table 6). The hybrids Cms300A x RHA 298 (-7.54) and Cms 7-1A x RHA 297 (-7.54) were significantly superior over best check indicating earliness for flowering.

Among the double crosses, the heterobeltiosis ranged from -7.01 to 12.28 per cent (table 7). The hybrids (Cms 336Ax RHA 856) x (Cms 300A x RHA 298), (-7.01) and (Cms 336A x RHA 274) x (Cms 300A x RHA 298) (-5.26) produce significant negative heterobeltiosis. Superiority over best check varied from -5.66 to 20.75 per cent (table 7). The hybrid (Cms 336A x RHA 857) x (Cms 300A x RHA 298) (-5.66) was best for superiority over best check EC 68415C.

Table 6: Estimation of heterosis in single cross hybrids of sunflower

Sr. No.	Crosses	Flowering (days) Over		50% flowering (days)		Maturity (days) Over		Plant height(cm) Over		Stem diameter(cm) Over		Head diameter(cm) Over	
		BP	BC	BP	BC	BP	BC	BP	BC	BP	BC	BP	BC
1.	Cms300A x RHA298	0	7.54**	-3.50	5.76*	-1.06	2.19	15.46**	27.14**	27.55**	19.04**	2.33	1.73
2.	Cms300A x RHA272	0	7.54**	-1.75	7.69*	-1.06	2.19	42.83**	13.20**	29.44**	10.95	-5.81	-6.35
3.	Cms300A x RHA273	7.01**	15.09**	0	9.61**	10.00**	8.79**	45.53**	1.16	30.12**	2.85	19.18**	18.50**
4.	Cms336A x RHA857	12.20**	20.75**	8.77**	19.29**	7.60**	8.79**	43.27**	60.26**	-5.62	43.81**	26.48**	35.26**
5.	Cms336A x RHA856	12.28**	20.75**	8.47**	23.07**	8.88**	7.69**	73.65**	23.12**	-26.25	12.38	26.48**	35.26**
6.	Cms336A x RHA274	19.30**	28.30**	15.78**	26.92**	4.39**	4.39**	68.61**	57.48**	-55.62**	-29.52**	-1.08	5.78
7.	Cms336A x RHA271	-3.50*	3.77*	-7.27*	-1.92	-1.06	3.29*	-63.44**	-59.75**	-41.87**	-11.43	-58.92**	-56.07**
8.	Cms336A x RHA296	-3.57*	9.43*	-3.70	7.69*	4.39**	4.39**	31.71**	28.17**	-52.81**	-28.09**	-26.48**	-21.38**
9.	Cms7-1A x RHA297	0	7.54**	5.45*	11.53**	2.17	3.29*	0.20	15.06**	-19.02	-20.95**	10.27**	23.70**
	SE ±	1.47		1.31		1.36		2.01		0.81		0.58	

* Significant at 5%; **Significant at 1%

BP = Better parent

BC = Best check

Table contd.....

Table 6 contd.....

Sr. No.	Crosses	Unfilled seed(%) Over		100-seed weight(g) Over		Number of seeds/head Over		Seed yield/plant(g) Over		Oil content(%) Over	
		BP	BC	BP	BP	BP	BC	BP	BC	BP	BC
1.	Cms300A x RHA298	-26.59	-16.87	3.82	4.26	6.67	13.66	15.07	14.74	2.96	2.09
2.	Cms300A x RHA272	-10.63	1.20	-11.00	-17.94	-8.55	-2.55	-16.85	-17.05	-0.92	-3.37
3.	Cms300A x RHA273	-21.27	10.84	7.65	0.74	8.20	15.30	5.03	4.77	0.39	2.08
4.	Cms336A x RHA857	-49.25**	-18.07	15.47	6.47	26.44**	38.80**	35.43**	51.79**	-0.15	0.45
5.	Cms336A x RHA856	-25.37	20.48	14.83	5.88	0.50	9.28	3.20	15.67	5.28	4.03
6.	Cms336A x RHA274	-64.17**	-42.16	-16.46	-18.67	11.22	20.95	-9.13	1.84	-1.76	-0.30
7.	Cms336A x RHA271	-75.22**	-53.11*	-16.46	-19.11	-6.26	1.82	-50.76**	-44.81**	-4.11	-1.49
8.	Cms336A x RHA296	-38.06*	0	-0.63	- 6.91	-4.52	3.82	-11.40	-0.88	2.02	4.47
9.	Cms7-1A x RHA297	-37.91*	0.24	5.90	0	8.88	-12.93	26.96	-0.22	-5.21	-2.38
	S.E. ±	2.28		0.56		70.5		5.01		1.19	

* Significant at 5%

** Significant at 1%

Table 7: Estimation of heterosis in double cross hybrids of sunflower

Sr. No.	Crosses	Flowering(days) Over		50% flowering (days) over		Maturity(days) over		Plant height (cm) over		Stem diameter (cm) over		Head diameter (cm) over	
		BP	BC	BP	BC	BP	BC	BP	BC	BP	BC	BP	BC
1.	Cms336A x RHA857 x Cms300A x RHA298	-1.75	-5.66*	-3.50	5.66*	2.22	-2.19	15.56**	27.24**	-33.12	1.90	-8.1**	-1.73
2.	Cms336A x RHA856 x Cms300A x RHA298	-7.01**	0	-8.77**	0	-3.26*	1.09	69.43**	20.43**	-40.93	-10.00	-5.94	0.68
3.	Cms336A x RHA274 x Cms300A x RHA298	-5.26*	-1.87	-8.77**	0	-2.19	-2.19	35.80**	16.51	-37.87	-3.80	-3.78	2.89
4.	Cms336A x RHA271 x Cms300A x RHA298	3.50	11.30**	1.75	11.53**	0	3.29*	17.52**	7.94**	-40.62	-9.50	-13.51	-7.51**
5.	Cms336A x RHA296 x Cms300A x RHA298	5.35*	11.30**	16.36**	23.07**	2.19	2.19	24.60**	21.25**	-37.50	04.76	-8.60**	2.31
6.	Cms7-1A x RHA297 x Cms300A x RHA298	12.28**	20.75**	16.36**	23.07**	4.35**	5.49**	25.36**	40.24**	28.85**	22.86**	-2.90	-3.40
7.	Cms336A x RHA857 x Cms300A x RHA272	8.77**	16.98**	7.01**	17.30**	5.43**	6.59**	87.63**	48.71**	-22.50	18.09**	2.70	9.83**
8.	Cms336A x RHA856 x Cms300A x RHA272	-3.50	3.77	-5.26**	3.85	0	-1.09	80.49**	27.96**	-48.44	-21.43**	-12.97**	6.93
9.	Cms336A x RHA274 x Cms300A x RHA272	0	7.54**	-1.75	7.69	2.19	2.19	65.75**	31.37**	-37.81	-5.24	-10.27**	-4.04

Table con[illegible]

Table 7 contd....

Sr. No.	Crosses	Flowering(days) Over		50% flowering (days) over		Maturity (days) over		Plant height (cm) over		Stem diameter (cm) over		Head diameter (cm) over	
		BP	BC	BP	BC	BP	BC	BP	BC	BP	BC	BP	BC
10.	Cms336A x RHA271 x Cms300A x RHA278	-3.50	3.77	-5.26**	3.85	-5.32**	-2.19	72.65**	36.84**	-30.00	6.66	-23.24**	-17.91**
11.	Cms336A x RHA296 x Cms300A x RHA272	0	5.66**	1.85	5.76	2.19	2.19	63.67**	29.72**	-24.37	15.23*	-20.34**	-20.80**
12.	Cms7-1A x RHA297 x Cms300A x RHA272	1.75	9.43**	1.81	7.69	2.17	3.29**	46.09**	15.78**	-17.07*	14.29*	0.58	0
13.	Cms336A x RHA857 x Cms300A x RHA273	0	7.54**	-1.75	7.69	2.22	1.09	78.10**	37.66**	-25.00	14.29*	-13.51**	7.51**
14.	Cms336A x RHA856 x Cms300A x RHA273	0	7.54**	-1.75	7.69	5.55**	4.39**	67.54**	18.78**	-34.69	-0.48	22.70	-17.34
15.	Cms336A x RHA274 x Cms300A x RHA273	1.75	9.43**	0	9.61**	3.33**	2.19	74.09**	34.57**	-27.50	10.48	-8.10**	-1.73
16.	Cms336A x RHA271 x Cms300A x RHA273	5.35*	11.30	0	9.61*	5.55**	4.39	78.65**	38.08	-37.50	-4.76	-7.02*	0.57
17.	Cms336A x RHA296 x Cms300A x RHA273	1.75	7.54	1.85	5.76	5.55**	4.39	56.34	20.85	-46.68	2.86	-8.10**	-1.73
18.	Cms7-1A x RHA297 x Cms300A x RHA273	5.26	13.20	7.27	13.46*	5.55**	4.39	72.09	33.02	9.75	7.14	0.58	1.15
	S.E. ±	1.47		1.31		1.36		2.01		0.81		0.58	

Table 7 contd.....

Sr. No.	Crosses	Unfilled seed(%) over		100-seed weight (g) over		Number of seeds/ head over		Seed yield/plant(g) over		Oil content (%) over	
		BP	BC	BP	BC	BP	BC	BP	BC	BP	BC
1.	Cms336A x RHA857 x Cms300A x RHA298	-24.48	-20.84	-0.30	-2.94	-0.81	11.66	4.08	2.72	-5.69	1.34
2.											
2.	Cms336A x RHA856 x Cms300A x RHA298	-35.85*	-27.34	16.31*	13.24*	-8.36	3.15	1.52	13.00	-5.83	1.19
3.	Cms336A x RHA274 x Cms300A x RHA298	-35.85*	-27.34	11.78	8.82*	3.83	16.76	18.59	32.92*	-14.02**	-4.62
4.	Cms336A x RHA271 x Cms300A x RHA298	51.38**	71.44**	-20.69*	-22.80*	-22.49	-12.75	-39.95**	-32.70	-8.88**	2.08
5.	Cms336A x RHA296 x Cms300A x RHA298	-20.21	-9.64	6.95	4.12	1.45	14.57	12.14	25.69	-4.86	2.24
6.	Cms7-1A x RHA297 x Cms300A x RHA298	-16.26	-16.26	-5.44	10.59	24.75	-15.30	-20.74	-20.94	-3.33	3.61
7.	Cms336A x RHA857 x Cms300A x RHA272	53.45**	60.84**	-4.38	-6.91	4.47	17.49	3.52	16.03	7.27*	7.91*
8.	Cms336A x RHA856 x Cms300A x RHA272	-6.38	6.02	4.68	1.91	-11.00	0.12	-5.58	5.82	6.64	5.37
9.	Cms336A x RHA274 x	-2.66**	10.34	-21.90**	-23.97	-8.90	2.55	-27.91*	-19.20	-14.85**	-13.58**

Table 7 contd....

Table 7 contd......

Sr. No.	Crosses	Unfilled seed(%) over BP	Unfilled seed(%) over BC	100-seed weight(g) over BP	100-seed weight(g) over BC	Number of seeds/ head over BP	Number of seeds/ head over BC	Seed yield/plant(g) over BP	Seed yield/plant(g) over BC	Oil content (%) over BP	Oil content (%) over BC
10.	Cms336A x RHA271 x Cms300A x RHA272	-116.49**	145.18**	-3.47	-6.03	-30.42*	-21.67	-30.15	-21.71	3.92	6.72
11.	Cms336A x RHA296 x Cms300A x RHA272	7.97	4.22	1.66	-1.03	-18.28	- 8.01	-24.27*	-15.12	1.18	2.09
12.	Cms7-1A x RHA297 x Cms300A x RHA272	21.08	21.08	28.08	13.09	-12.78	-1.82	-10.23	-10.95	-2.90	0
13.	Cms336A x RHA857 x Cms300A x RHA273	-29.85	-19.28	-5.59	-6.61	-3.93	8.56	- 7.63	3.83	2.37	2.98
14.	Cms336A x RHA856 x Cms300A x RHA273	-23.40	13.25	-4.38	-6.91	-30.10	-21.31	-32.30**	-24.12	-3.92	-5.07
15.	Cms336A x RHA274 x Cms300A x RHA273	-27.12	-17.47	-17.82*	-20.00	- 9.55	- 1.64	-26.20*	-17.27	2.94	4.48
16.	Cms336A x RHA271 x Cms300A x RHA273	1.59	15.06	-2.72	- 5.29	11.39	3.64	- 7.36	3.93	-6.40	-3.83
17.	Cms336A x RHA296 x Cms300A x RHA273	-24.04	-13.97	- 7.15	-12.20	-30.31*	-24.23	-33.30*	-25.34	-5.92	-5.07
18.	Cms7-1A x RHA273 x Cms300A x RHA273	-8.82	3.25	- 4.38	- 6.91	-37.09**	-32.97*	-39.00**	-32.11**	-11.01**	-8.36*
	S.E. ±.	2.28		0.56		70.5		5.01		1.19	

* Significant at 5%; ** Significant at 1%

Table 8. Estimation of heterosis in three way cross hybrids of sunflower

Sr. No.	Crosses	Flowering (days) over		50% flowering (days)		Maturity(days) over		Plant height (cm) over		Stem diameter (cm)		Head diameter (cm) over	
		BP	BC	BP	BC	BP	BC	BP	BC	BP	BC	BP	BC
		1	2	3	4	5	6	7	8	9	10	11	12
1.	Cms336A x RHA857 x IB2	3.44	13.20**	3.50	13.46**	2.17	3.29*	44.33	38.08**	-48.12	20.95	-1.66	5.20
2.	Cms336A x RHA856 x IB2	0	11.32**	-3.38	9.61*	4.44**	3.29*	94.61**	37.47**	-27.50	-10.48	2.70	9.82**
3.	Cms336A x RHA274 x IB2	1.75	9.43**	0	9.61*	4.39**	4.39**	45.19**	35.60**	-41.87	11.43	-8.10**	-1.73
4.	Cms336A x RHA271 x IB2	-1.75	7.54**	1.75	7.69	-1.06	3.29*	31.01**	20.33**	-38.75	6.66	-18.91**	-13.29
5.	Cms336A x RHA296 x IB2	-3.57	9.43**	3.70*	7.69	5.49**	5.49**	40.67**	34.70**	-39.69	8.09	-4.32	-2.31
6.	Cms7-1A x RHA297 x IB2	9.83**	26.41**	23.04**	28.34**	3.26*	4.39**	55.98**	49.12**	28.30**	24.76**	2.90	-2.31
7.	Cms336A x RHA857 x IB28	5.17*	15.09**	7.01**	9.61**	2.17	3.29*	30.22**	50.36**	-20.62	-20.95**	-12.43**	-6.35
8.	Cms336A x RHA856 x IB28	-1.75	-9.43**	0	9.61*	7.77**	6.59**	81.36**	28.98**	-16.88	-31.42**	11.35**	19.07**
9.	Cms336A x RHA274 x IB28	3.50	11.32	1.75	11.53**	2.19	2.19	25.43**	16.00**	-27.50	-10.98	20.00**	-14.45**
10.	Cms336A x RHA271 x IB28	6.89**	16.98**	-7.01**	9.61*	1.06	4.39**	41.69**	30.13**	-43.40	13.81	-32.97**	-28.32**
11.	Cms336A x RHA296 x IB28	7.14*	13.20**	6.89**	11.53**	3.29**	3.29*	37.12**	33.43**	-33.75	0.95	-6.46	0
12.	Cms7-1A x RHA297 x IB28	1.75	6.98**	3.63**	9.61*	3.26*	4.39**	30.52**	24.87**	-3.20	-1.90	5.23	-4.62

Table contd.....

Table contd.....

Sr. No.	Crosses	Flowering (days) over		50% flowering (days) over		Maturity(days) Over		Plant height(cm) Over		Stem diameter (cm) Over		Head diameter(cm) Over	
		BP	BC	BP	BC	BP	BC	BP	BC	BP	BC	BP	BC
13.	Cms336A x RHA857 x IB43	8.62**	8.86**	3.50	13.46**	2.17	3.29**	11.62**	28.79**	-35.31	-4.43	-15.67**	-9.82**
14.	Cms336A x RHA856 x IB43	-51.7*	3.77	10.17**	1.91	-2.22	-3.29	73.36**	22.91**	-36.87	-3.81	-15.13**	-9.25**
15.	Cms336A x RHA274 x IB43	5.26*	3.20**	5.26**	15.38**	3.29*	3.29*	120.07**	56.03**	-37.50	-4.76	-10.27**	-4.04
16.	Cms336A x RHA271 x IB43	3.44	3.20**	-1.75	7.69	0	4.39**	57.52	44.68**	-23.75	-8.57	- 3.24	3.46
17.	Cms336A x RHA296 x IB43	8.92**	5.09**	9.25**	13.46**	4.37**	4.39**	48.04**	44.06**	-20.31	-51.90**	15.13**	23.12**
18.	Cms7-1A x RHA297 x IB43	4.91	15.09**	1.61	21.15**	6.52**	-7.69**	27.34	46.13	-11.84*	-54.29**	-10.27**	-4.04
	S.E.	1.47		1.31		1.36		2.01		0.81		0.58	

Table contd.....

Sr. No.	Crosses	Unfilled seeds(%) over		100-seed weight(g) over		Number of seed/head over		Seed yield/plant over		Oil content(%) over	
		BP	BC	BP	BC	BP	BC	BP	BC	BP	BC
1.	Cms336A x RHA857 x IB2	14.94	20.48	-1.66	-4.26	-15.41	-8.01	-11.05	-0.30	1.78	2.39
2.	Cms336A x RHA856 x IB2	-21.34	15.06	-4.83	-7.35	-38.26**	-32.97	-34.17**	-26.21	-2.42	3.58
3.	Cms336A x RHA274 x IB2	-31.46	-26.50	-17.67	-19.85**	13.06	-5.46	-42.74**	-35.81**	-4.41	-2.98
4.	Cms336A x RHA271 x IB2	-38.20	-33.73	3.78	1.03	3.85	12.93	5.36	18.10	-6.10	-3.58
5.	Cms336A x RHA296 x IB2	-7.86	-1.20	-12.99**	-15.29	-32.16	-26.23	-41.99**	-34.98	5.32	6.27
6.	Cms7-1A x RHA297 x IB2	50.60	50.60	3.25	-1.91	29.46	-1.27	28.16	0.70	-2.32	0.59
7.	Cms336A x RHA857 x IB28	-34.48*	-31.13*	-3.25	1.76	-17.25	-9.83	-17.70	-4.22	0	0.59
8.	Cms336A x RHA856 x IB28	1.12	3.43	1.95	7.35	1.34	10.20	5.90	23.66	-1.35	-2.53
9.	Cms336A x RHA274 x IB28	-35.07	4.82	-10.06	5.29	-17.25	-9.83	-24.06	-11.61	-3.23	1.73
10.	Cms336A x RHA271 x IB28	30.58	6.74	-21.78*	-17.65	- 6.53	15.84	-14.41	- 0.38	-3.34	-0.75
11.	Cms336A x RHA296 x IB28	10.11	18.07	- 6.84	1.91	- 4.86	3.46	- 9.41	5.43	-13.04	-12.53**
12.	Cms7-1A x RHA297 x IB28	25.30**	25.30**	-14.52*	-10.00	- 7.19	-1.27	-24.06	-11.61	1.47	1.49

Table contd.....

Table contd.....

Sr. No.	Crosses	Unfilled seeds(%) over BP	Unfilled seeds(%) over BC	100-seed weight(g) over BP	100-seed weight(g) over BC	Number of seed/head over BP	Number of seed/head over BC	Seed yield/plant over BP	Seed yield/plant over BC	Oil content(%) over BP	Oil content(%) over BC
1.	Cms336A x RHA857 x IB2	14.94	20.48	-1.66	-4.26	-15.41	-8.01	-11.05	-0.30	1.78	2.39
2.	Cms336A x RHA856 x IB2	-21.34	15.06	-4.83	-7.35	-38.26**	-32.97	-34.17**	-26.21	-2.42	3.58
3.	Cms336A x RHA274 x IB2	-31.46	-26.50	-17.67	-19.85**	13.06	-5.46	-42.74**	-35.81**	-4.41	-2.98
4.	Cms336A x RHA271 x IB2	-38.20	-33.73	3.78	1.03	3.85	12.93	5.36	18.10	-6.10	-3.58
5.	Cms336A x RHA296 x IB2	-7.86	-1.20	-12.99**	-15.29	-32.16	-26.23	-41.99**	-34.98	5.32	6.27
6.	Cms7-1A x RHA297 x IB2	50.60	50.60	3.25	-1.91	29.46	-1.27	28.16	0.70	-2.32	0.59
7.	Cms336A x RHA857 x IB28	-34.48*	-31.13*	-3.25	1.76	-17.25	-9.83	-17.70	-4.22	0	0.59
8.	Cms336A x RHA856 x IB28	1.72	8.43	1.95	7.35	1.34	10.20	5.90	23.66	-1.35	-2.53
9.	Cms336A x RHA274 x IB28	-35.07	4.82	-10.06	5.29	-17.25	-9.83	-24.06	-11.61	-3.23	1.73
10.	Cms336A x RHA271 x IB28	30.58	6.74	-21.78*	-17.65	- 6.53	15.84	-14.41	- 0.38	-3.34	-0.75
11.	Cms336A x RHA296 x IB28	10.11	18.07	- 6.84	1.91	- 4.86	3.46	- 9.41	5.43	-13.04	-12.53**
12.	Cms7-1A x RHA297 x IB28	25.30**	25.30**	-14.52*	-10.00	- 7.19	-1.27	-24.06	-11.61	1.47	1.49

Table contd.....

Table contd.....

Sr. No.	Crosses	Unfilled seeds(%) over		100-seed weight(g) over		Number of seed/head over		Seed yield/plant over		Oil content(%) over	
		BP	BC	BP	BC	BP	BC	BP	BC	BP	BC
13.	Cms336A x RHA857 x IB43	-20.78	-26.51	3.32	0.58	-7.52	2.91	-28.16*	-19.48	2.96	1.99
14.	Cms336A x RHA856 x IB43	26.58	12.04	7.25	4.41	-21.76	11.11	-32.03**	-30.81	0	1.20
15.	Cms336A x RHA274 x IB43	20.38	26.14	13.54	7.35	13.42	26.23**	7.56	0.56	-4.11	-2.68
16.	Cms336A x RHA271 x IB43	-28.18	-33.37	-2.72	-5.29	17.51	30.78**	4.72	17.38	0.29	2.98
17.	Cms336A x RHA296 x IB43	31.29	21.80	-2.72	-5.29	3.27	14.93	2.04	14.37	-5.18	-2.98
18,	Cms7-1A x RHA297 x IB43	30.18	-7.70	-25.34	-29.41	-30.43	-22.58	-35.56**	-30.03*	-7.97**	-5.22
	S.E.	2.28		0.56		70.05		5.01		1.19	

*Significant at 5%

**Significant at 1%

Table contd.....

Sr. No.	Crosses	Unfilled seeds(%) over		100-seed weight(g) over		Number of seed/head over		Seed yield/plant over		Oil content(%) over	
		BP	BC	BP	BC	BP	BC	BP	BC	BP	BC
13.	Cms336A x RHA857 x IB43	-20.78	-26.51	3.32	0.58	-7.52	2.91	-28.16*	-19.48	2.96	1.99
14.	Cms336A x RHA856 x IB43	26.58	12.04	7.25	4.41	-21.76	11.11	-32.03**	-30.81	0	1.20
15.	Cms336A x RHA274 x IB43	20.38	26.14	13.54	7.35	13.42	26.23**	7.56	0.56	-4.11	-2.68
16.	Cms336A x RHA271 x IB43	-28.18	-33.37	-2.72	-5.29	17.51	30.78**	4.72	17.38	0.29	2.98
17.	Cms336A x RHA296 x IB43	31.29	21.80	-2.72	-5.29	3.27	14.93	2.04	14.37	-5.18	-2.98
18,	Cms7-1A x RHA297 x IB43	30.18	-7.70	-25.34	-29.41	-30.43	-22.58	-35.56**	-30.03*	-7.97**	-5.22
	S.E.	2.28		0.56		70.05		5.01		1.19	

*Significant at 5%

**Significant at 1%

For three way crosses, the heterobeltiosis ranged from -5.17 to 9.83 per cent (table 8). The hybrid (Cms 336A x RHA 856) x IB 43 produced significant negative heterobeltiosis (-5.17). Superiority over best check ranged from -9.43 to 26.41 per cent (table 8). The hybrid (Cms 336A x RHA 856) x IB 28 produced significant superiority (-9.43) over best check.

2. Days to 50 percent flowering

Heterobeltiosis and superiority overbest check for days to 50 per cent flowering is presented in table 6. The heterobeltiosis for single crosses ranged from -7.27 to 15.78 per cent. The hybrid Cms 336A x RHA 271 showed significant negative heterobeltiosis (-7.27) indicating earliness for 50 per cent flowering. Superiority over best check ranged from -7.69 to 26.92 per cent, with the hybrid Cms 336A x RHA 296 producing significant superiority (-7.69) over best check EC 68415C.

The heterobeltiosis for double crosses ranged from -8.77 to 16.36 per cent (table 7). The hybrids (Cms 336A x RHA 856) x (Cms 300A x RHA 298) and (Cms 336A x RHA 274) x (Cms 300A x RHA 298) (-8.77). superiority over best check varied from 1.85 to 23.07 per cent (table 7) with none of the hybrid showing significant superiority for earliness to 50 per cent flowering.

For three way crosses, the heterobeltiosis ranged from -10.17 to 23.04 per cent (table 8). The hybrids (Cms 336A x RHA 856) x IB43 (-10.17) and (Cms 336A x RHA 271) x IB 28 (-7.01) exhibited significant negative heterobeltiosis. Superiority over best check ranged from -9.61 to 28.34 per cent (table 8) with the hybrid (Cms 336A x RHA 271) x IB 28 (-9.61) producing significant superiority over best check.

3. Days to maturity

Heterobeltiosis and superiority over best check for days to maturity for the single crosses is presented in table 6. Heterobeltiosis for single crosses varied from -1.06 to 10.00 per cent. None of the hybrids showed significant negative heterobeltiosis. The hybrid Cms 300A x RHA 273 produced highest significant positive heterobeltiosis (10.0) indicating that it matures late. The superiority over best check EC 68415C ranged from 2.19 to 8.79 per cent, with the hybrid Cms 300A x RHA 273 taking maximum days to mature.

Among the double crosses, the heterobeltiosis ranged from -5.32 to 5.65 per cent (table 7). The hybrid (Cms 336A x RHA 271) x (Cms 300A x RHA 272) produced the highest (-5.82) significant negative heterobeltiosis indicating earliness in maturity. Superiority over best check ranged from -2.19 to 6.59 per cent (table 7). Not a single hybrid showed significant superiority over best check for earlier maturity.

For the three way crosses, heterobeltiosis and superiority over best check ranged from -2.22 to 7.77 per cent and -7.69 to 6.59 per cent (table 8) respectively. The hybrid (Cms 7-1A x RHA 297) x IB43 (-7.69) showed significant superiority over best check for early maturity.

4. Plant height (cm)

For plant height, heterobeltiosis and superiority over best check ranged from -63.44 to 73.65 per cent and -59.75 to 60.26 per cent (table 6) respectively among single crosses. The hybrid Cms 366A x RHA 271 produced significant negative heterobeltiosis (-63.44) and superiority (-59.75) over best check APSH-11, indicating dwarfness. All other hybrid exhibited significant positive heterosis.

Among the double crosses, the range for heterobeltiosis and superiority over best check varies from 15.56 to 87.63 per cent and 7.94 to 48.71 per cent (table 7) respectively. All the hybrids produced significant positive heterobeltiosis and superiority over best check indicating tallness. The hybrid (Cms 336A x RHA 857) x (Cms 300A x RHA 272) produced highest heterobeltiosis (87.63) and superiority (48.71) over best check.

For the three way crosses, the range for heterobeltiosis and superiority over best check varies from 11.62 to 94.61 per cent and 16.0 to 56.03 per cent (table 8) respectively. All the hybrid produced significant positive heterobeltiosis and superiority over best check.

5. Stem diameter (cm)

Among single crosses, the range for heterobeltiosis and superiority over best check EC68415C for stem diameter varies from -55.62 to 30.12 per cent and -29.52 to 43.81 per cent (table 6) respectively. The hybrids Cms 300A x RHA 273 (30.12), Cms 300A x RHA 272 (29.44) and Cms 300A x

RHA 298 (27.55) produced significant positive heterobeltiosis. The hybrids Cms 336A x RHA 857 (43.81) and Cms 300A x RHA 298 (19.04) were significantly superior than best check.

For double crosses, the range for heterobeltiosis and superiority over best check varies from -48.44 to 28.85 per cent and -21.43 to 22.86 per cent (table 7) respectively. The hybrid (Cms 7-1A x RHA 297) x (Cms 300A x RHA 298) produced significant positive heterobeltiosis (28.85) and superiority over best check (22.86). The hybrid (Cms 336A x RHA 857) x (Cms 300A x RHA 272) also produced significant positive heterobeltiosis (18.09).

Among the three way crosses, the range for heterobeltiosis and superiority over best check varies from -48.12 to 28.3 per cent and -31.42 to 24.76 per cent (table 8) respectively. The hybrid (Cms 7-1A x RHA 297) x IB2 produced significant positive heterobeltiosis (28.3) and superiority (24.76) over best check.

6. Head diameter (cm)

For the single crosses, the range for heterobeltiosis and superiority over best check EC 68415C varies from -58.92 to 26.48 per cent and -56.07 to 35.26 per cent (table 6) respectively. The hybrids Cms 336A x RHA 857 and Cms 336A x RHA 856 produced highest significant positive heterobeltiosis (24.48) and superiority (35.26) over best check. The hybrids Cms 300A x RHA 273 also produced significant positive heterobeltiosis (19.18) and superiority (18.50) over best check.

For the double crosses, the heterobeltiosis and superiority over best check ranged from -23.24 to 2.7 per cent and -20.8 to 9.83 per cent (table 7) respectively. None of the hybrid was also to produce significant positive heterobeltiosis. The hybrids (Cms 336A x RHA 857) x (Cms 300A x RHA 272) (9.83) and (Cms 336A x RHA 857) x (Cms 300A x RHA 273) (7.5) produced significant superiority over best check.

Among the three way crosses, the range for heterobeltiosis and superiority over best check varies from -32.97 to 15.13 per cent and -28.32 to 23.12 per cent (table 8) respectively. The hybrids (Cms 336A x RHA 296) x IB43 produced highest significant positive heterobeltiosis (15.13) and superiority (23.12) over best check followed by the hybrid (Cms 336A x RHA 856) x IB28.

7. Percent unfilled seeds

The heterobeltiosis and superiority over best check for per cent unfilled seeds among single crosses varies from -75.22 to 10.63 per cent and -53.11 to 1.2 per cent (table 6) respectively. The hybrid Cms 336A x RHA 271 produced highest significant negative heterobeltiosis (-75.22) and superiority (-53.11) over best check EC 68415C indicating high percentage of filled seeds. The hybrids Cms 336A x RHA 274 (-64.17) and Cms 336A x RHA 857 (-49.24) also produced significant negative heterobeltiosis.

For double crosses, the range for heterobeltiosis and superiority over best check varies from -35.85 to 116.49 per cent and -27.34 to

145.18 per cent (table 6) respectively. The hybrids (Cms 336A x RHA 856) x (Cms 300A x RHA 298) and (Cms 336A x RHA 274) x (Cms 300A x RHA 298) produced significant negative heterobeltiosis (-35.85), whereas none of the hybrid was significantly superior to best check.

Among the three way crosses, the range for heterobeltiosis and superiority over best check varies from -38.2 to 50.6 per cent and -33.73 to 50.6 per cent (table 6) respectively. None of the hybrids produced significant negative heterobeltiosis or superiority over best check.

8. 100-seed weight (g)

For the single crosses, the range for heterobeltiosis and superiority over best check EC 68415C varies from -16.46 to 8.76 per cent and -19.11 to 6.47 per cent (table 6) respectively. None of the hybrid was able to produce significant heterobeltiosis or superiority over best check.

The range for heterobeltiosis and superiority over best check among the double crosses varies from -21.9 to 16.31 per cent and -23.97 to 13.24 (table 7) respectively. The hybrid (Cms 336A x RHA 856) x (Cms 300A x RHA 298) produced significant positive heterobeltiosis (16.31) and superiority over best check (13.24).

For the three way crosses, the range for heterobeltiosis and superiority over best check varies from -25.34 to 13.54 and -29.41 to 7.35 per cent (table 8) respectively. Among three way crosses none of the hybrid was able to produce significant positive heterobeltiosis or superiority over best check.

9. Number of seeds per head

For the single crosses, the range for heterobeltiosis and superiority over best check EC 68415C varies from -8.55 to 26.44 per cent and -12.93 to 38.8 per cent (table 6) respectively. Only one hybrid Cms 336A x RHA 857 produced significant positive heterobeltiosis (26.44) and superiority (38.80) over best check.

The range for heterobeltiosis and superiority over best check among the double crosses varies from -37.09 to 11.39 per cent and -32.97 to 17.49 per cent (table 7) respectively. None of the hybrid produced significant heterobeltiosis or superiority over best check.

Among the three way cross the range for heterobeltiosis and superiority over best check varies from -38.26 to 23.46 per cent and -32.97 to 30.78 per cent (table 8) respectively. The hybrids (Cms 336A x RHA 271) x IB43 (30.44) and (Cms 336A x RHA 274) x IB43 (26.23) were significantly superior than best check.

10. Seed yield per plant

For seed yield per plant among the single crosses, the range for heterobeltiosis and superiority over best check EC 68415C varies from -50.76 to 35.43 per cent and -44.81 to 51.79 per cent (table 6) respectively. The hybrid Cms 336A x RHA 857 produced significant positive heterobeltiosis (35.43) and superiority (51.79) over best check indicating higher yields than parents and best check.

For the double crosses, the heterobeltiosis and superiority over best check ranged from -39.95 to 18.59 per cent and -32.7 to 32.92 per cent (table 7) respectively. The hybrid (Cms 336A x RHA 274) x (Cms 300A x RHA 298) produced significant superiority (32.92) over best check.

Among three way crosses, the range for heterobeltiosis and superiority over best check varied from -42.74 to 28.16 per cent and -35.81 to 23.66 per cent (table 8) respectively but none of the hybrids was able to produce significant positive heterobeltiosis or superiority over best check.

11. Per cent oil content

Among the single crosses, none of the hybrid produced significant positive heterobeltiosis or superiority over better check APSH-11, although their range varied from -4.11 to 5.28 per cent and -3.37 to 4.47 per cent (table 6) respectively.

For double crosses, the range for heterobeltiosis and superiority over best check varied from -14.85 to 7.27 per cent and -13.58 to 7.91 per cent (table 7)respectively. The hybrid (Cms 336A x RHA 857) x (Cms 300A x RHA 272) produced significant positive heterobeltiosis (7.27) and superiority (7.91) over best check indicating high percentage of oil for this hybrid.

For the three ways crosses, the range for heterobeltiosis and superiority over best check varied from -23.04 to 5.32 per cent and -12.53 to 6.27 per cent (table 8) respectively. Not even a single hybrid was able to produce significant positive heterobeltiosis or superiority over best check.

Table 9. A comparison of heterosis among single, double and three way cross hybrids.

Characters		Single cross hybrids	Double cross hybrids	Three way cross hybrids
Flowering (days)	BP	-3.57-19.3	-7.01-12.28	-5.17-9.83
	BC	3.77-28.30	-5.66-20.75	3.77-26.41
50% flowering (days)	BP	-7.27-15.78	-8.77-16.36	-7.01-23.04
	BC	-1.92-26.92	3.85-23.07	1.92-28.84
Maturity (days)	BP	-1.06-10.00	-5.32-5.55	-2.22-7.77
	BC	2.19-8.79	-2.19-6.59	-3.29-7.69
Plant height (cm)	BP	-63.44-73.65	15.56-87.63	11.62-120.1
	BC	-59.75-60.26	7.94-48.71	-16.00-56.03
Stem diameter (cm)	BP	-55.62-30.12	-48.44-28.85	-48.12-28.3
	BC	-28.09-43.81	-21.43-22.86	-54.29-24.76
Head diameter (cm)	BP	-58.92-26.48	-23.24-2.70	-32.97-15.13
	BC	-56.07-35.26	-20.80-9.83	-28.32-23.12
Unfilled seeds (%)	BP	-75.22-10.63	-35.85-116.49	-38.20-50.61
	BC	-53.11-20.48	-27.34-145.8	-33.78-50.6
100-seed weight (g)	BP	-16.46-15.47	-21.9-16.3	-25.34-13.64
	BC	-19.11-6.47	-23.7-13.24	-29.41-7.35
Number of seeds/ head	BP	-8.35-26.44	-37.09-11.39	-38.26-23.46
	BC	-12.93-38.8	-32.97-17.49	-32.97-30.78
Seed yield/plant (g)	BP	-50.76-35.43	-39.95-18.59	-42.74-28.16
	BC	-44.81-51.79	32.7-32.92	-35.81-23.26
Oil content (%)	BP	-5.21-5.28	-14.85-7.27	-13.04-5.32
	BC	-3.37-4.47	-13.85-7.91	-12.53-6.27

For all the 11 characters studied a comparison of heterosis among the single, double and three way cross hybrid is presented in table 9 and is explained as follows:

1. Days to flowering

For days to flowering, the double cross hybrids were found to be best as they produced the highest significant negative heterobeltiosis (7.01) and significant superiority (-5.66) over best check, an indication of earliness to flowering. The single cross hybrids were poorest among all the three type of crosses.

2. Days to 50 per cent flowering

For days to 50 per cent flowering, the double cross hybrids were found to be best owing to their highest negative heterobeltiosis (-8.77) but were unable to produce significant superiority over best check. The other two type of hybrids were also unable to produce significant superiority over best check.

3. Days to maturity

For days to maturity, again double cross hybrids were found to be best as they produced the highest negative heterobeltiosis (-5.32) indicating earliness in maturity, but these hybrids were unable to produce significant superiority over best check. Similarly the single and three way cross hybrids were also unable to produce significant superiority over best check.

4. **Plant height (cm)**

For plant height, single cross hybrids were found to be best. The single cross hybrids produced highest significant negative heterobeltiosis (-63.44) and significant superiority (-59.75) over best check indicating dwarfness for the hybrid.

5. **Stem diameter (cm)**

For stem diameter, all the three viz. single, double and three way crosses showed significant positive heterobeltiosis and significant superiority over best check, but the single crosses produced highest heterotic effects as compared to others.

6. **Head diameter (cm)**

For head diameter, single crosses produced the highest significant positive heterobeltiosis (26.48), and significant superiority (35.26) over best check. The three way crosses also produced significant heterotic effect but not to the level, as produced by single crosses.

7. **Per cent unfilled seeds**

For per cent unfilled seeds, the highest significant negative heterobeltiosis (-75.22) and superiority (-53.11) over best check was produced by single crosses thereby indicating high percentage of filled seeds in the single crosses.

8. 100-seed weight (g)

For 100-seed weight, the double crosses were found to be best as they produced significant positive heterobeltiosis (16.3) and significant superiority (13.24) over best check.

9. Number of seeds per head

Single crosses were found to be best for number of seeds per head as these crosses produced highest significant positive heterobeltiosis (26.44) and significant superiority (38.8) over best check, whereas double and three way crosses were unable to produce significant heterotic effects.

10. Seed yield per plant

For seed yield, the single crosses were found to be best as these crosses produced the highest significant positive heterobeltiosis (35.43) and superiority (51.79) over best check.

11. Percent oil content

For percentage of seed oil, the double crosses were found to be best as these crosses produced significant positive heterobeltiosis (7.27) and superiority (7.91) over best check whereas the single and three way crosses were unable to produce significant heterotic effects.

Analysis of variance for combining ability

All the eleven characters studied in the line x tester design were subjected to combining ability analysis following Kempthorne (1957) method. The ANOVA for combining ability (table 10) revealed that mean

Table 10. Analysis of variance for combining ability

Source	d.f.	Flowering (days)	50% flowering (days)	Maturity (days)	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	Unfilled seed (%)
Replication	2	11.74**	3.1	1.52	61.22**	0.01	1.66	0.97
Hybrids	8	15.51**	29.58**	14.32**	3069.22**	0.57**	55.04**	20.30**
Line	2	8.05**	33.44**	11.74**	2789.51**	0.64**	32.85**	7.51*
Tester	2	13.03**	22.11**	12.18**	3757.90**	0.14**	69.55**	2.11
Line x Tester	4	20.48**	31.39**	16.70**	2864.94**	0.77**	58.89**	35.79**
Error	16	5.21	7.99	5.28	19.56	0.01	2.06	12.50
S.E.		1.86	2.30	1.87	3.61	0.81	1.17	2.88

Table 10 contd......

Source	d.f.	100-seed weight (g)	Number of head	Seed yield/ plant (g)	Oil content (%)
Replication	2	0.23	14655.82**	145.34**	4.48**
Hybrids	8	0.40*	55819.00**	138.90**	1.89**
Line	2	0.05	73803.70**	98.43**	1.71**
Tester	2	0.59*	24766.93**	70.80**	0.19*
Line x Tester	4	0.48*	62352.70**	193.34**	2.83*
Error	16	0.27	6467.44	34.81	2.64
S.E.		0.42	65.60	4.81	1.32

*Significant at 5%; **Significant at 1%

Table 11. Mean values, range, S.E. (d) and C.D. for various characters in sunflower

Sr. No.	Genotypes	Flowering (days)	50% flowering (days)	Maturity (days)	Plant height (cm)	Stem diam. (cm)	Head diam. (cm)	Unfilled seed (%)	100-seed weight (cm)	No. of seeds/ head	Seed yield/ plant (g)	Oil content (%)
1	2	3	4	5	6	7	8	9	10	11	12	13
1.	Cms300A x RHA273	61.53	63.00	92.33	102.00	2.14*	20.53*	7.40	6.76	663.33	42.97	32.33
2.	Cms300A x RHA296	54.87*	56.33*	92.33	124.67	2.72*	17.80	14.87	6.40	611.00	39.93	34.07
3.	Cms300A x RHA298	56.53	58.33	93.40	123.17	2.49	17.57	6.51	6.51	624.00	41.60	34.23
4.	Cms336A x RHA273	59.77	61.00	94.73	143.67	2.50	21.40*	12.30	6.80	644.67	43.17	33.30
5.	Cms336A x RHA296	57.53	60.00	93.80	111.42	1.55	20.43*	3.97	6.81	477.67	36.16	32.77
6.	Cms336A x RHA298	57.70	60.00	93.87	99.00*	1.51	7.63	12.67	5.60	233.00	20.00	33.00
7.	Cms7-1A x RHA273	58.10	62.66	91.80	137.00	2.19*	20.50*	12.00	6.40	491.00	30.47	34.87
8.	Cms7-1A x RHA296	57.80	62.33	93.13	144.33	2.14*	19.40	11.00	6.57	503.00	33.60	33.17
9.	Cms7-1A x RHA298	61.87	63.67	93.33	117.33	2.38*	21.00*	10.83	6.40	634.00	33.40	33.63
	<u>Parents</u>											
10.	Cms300A	56.87	59.67	94.27	108.13	1.66	17.20	9.40	6.62	618.00	41.15	32.63
11.	Cms336 A	62.23	65.00	95.00	125.63	3.20	18.50	13.37	6.27	593.67	40.59	32.13

Table contd......

Table contd.....

1	2	3	4	5	6	7	8	9	10	11	12	13
12.	Cms7-1A	56.67	58.33	32.12	119.07	2.05	16.40	6.30	6.43	438.67	28.48	33.23
13.	RHA273	59.70	60.33	90.47	74.90	1.43	9.67	11.77	3.56	267.67	11.53	33.70
14.	RHA296	56.27	56.33	91.43	94.33	1.70	7.83	22.80	3.68	164.00	6.07	33.80
15.	RHA298	63.33	65.00	96.87	106.73	1.96	7.03	29.10	3.37	230.67	7.50	36.03
	G.M.	58.72	61.67	93.70	111.90	2.12	16.19	12.68	5.88	479.69	30.44	33.59
	Range	54.87-63.33	56.33-65.00	91.43-99.33	99.0-144.33	1.43-3.20	7.03-21.40	6.93-29.10	3.37-6.81	164.0-633.33	6.07-43.17	32.13-36.03
	S.E.	1.85	1.93	1.87	3.26	0.07	0.92	0.88	0.46	77.23	5.38	1.33
	C.D. 5%	3.89	4.06	3.94	6.86	0.16	1.93	6.06	0.98	162.19	11.31	2.80

Table 12. Analysis for general combining ability effects of the parents.

Parents	Flowering (days)	50% flowering (days)	Maturity (days)	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	Unfilled seeds (%)	100-seed weight (g)	Number of seeds/ head	Seed yield/ plant (g)	Oil content (%)
Females											
Cms300A	0.18	-0.44	1.05	2.36	0.25**	0.16	-1.04	0.08	90.37*	3.80	0.06
Cms336A	-1.02	-1.66	0.16	18 -16.66**	-0.28**	-1.99**	0.37	-0.07	-90.74*	-1.59	-0.46
Cms7-1A	0.84	2.11	-1.22	16.31**	0.03	1.83**	0.67	-0.01	0.37	-2.21	0.40
S.E.	1.07	1.33	1.08	2.08	0.05	0.68	1.67	0.24	37.91	2.78	0.77
Males											
RHA273	1.39	1.44	1.32	13.31**	0.14	2.34**	-0.04	0.18	57.37	2.50	0.02
RHA296	-0.73	0.22	-0.88	10.22**	-0.07	0.74	0.50	0.12	-11.85	0.532	-0.15
RHA298	-0.66	-1.67	-0.44	23.53**	-0.08	-3.07**	-0.46	-0.29	-45.52	-3.03	0.14
S.E.	1.07	1.33	1.08	2.08	0.05	0.68	1.67	0.24	37.91	2.78	0.77

*Significant at 5% ; **Significant at 1%

Table 13. Estimation of specific combining ability effect of the crosses.

Sr. No.	Combinations	Flowering (days)	50% flowering (days)	Maturity (days)	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	Unfilled seed (%)	100-seed weight (g)	No.of seeds/ head	Seed yield/ plant (g)	Oil content (%)
1.	Cms300A x RHA273	1.55	-0.11	2.99	-23.25**	-0.95**	-0.48	-2.12	0.02	-26.93	-3.03	-1.27
2.	Cms300A x RHA296	-1.16	1.78	-1.81	-4.50	0.33**	-1.57	4.30	-0.27	-10.04	-3.10	0.67
3.	Cms300A x RHA298	-1.40	-1.67	-1.19	27.75**	0.18	2.01	-2.17	0.25	36.96	6.13	0.55
4.	Cms336A x RHA273	0.99	2.11	-0.72	32.44**	0.64**	2.57*	1.36	0.22	135.92	7.56	0.26
5.	Cms336A x RHA296	0.88	0.33	0.55	3.28	-0.30	3.21*	-3.52	0.29	37.74	2.52	0.10
6.	Cms336A x RHA298	-1.87	-2.43	0.17	35.72**	-0.34**	-5.78**	2.15	-0.51	-173.26*	-10.98*	-0.16
7.	Cms7-1A x RHA273	-2.54	-2.00	-2.27	- 9.19*	-0.19*	-2.14	0.76	-0.24	108.54	-4.52	0.96
8.	Cms7-1A x RHA296	-0.72	-2.11	1.25	1.22	-0.03	-1.64	-0.78	-0.02	-27.70	0.58	-0.57
9.	Cms7-1A x RHA298	3.72	4.11	1.11	7.97*	0.22*	3.77	0.02	0.26	138.30*	3.94	-0.39
	S.E.	1.86	2.31	1.86	3.61	0.08	1.17	2.88	0.42	65.60	4.81	1.33

*Significant at 5% ; **Significant at 1%

squares due to general combining ability effects (GCA) and specific combining ability (SCA) effects were found to be highly significant for all the characters, thereby indicating presence of genetic variability among the genotypes studied.

Estimation of gca and sca effects

The characterwise estimates of general combining ability (gca) effects and specific combining ability (sca) effects presented in table 12 and 13 respectively are described as follows:

1. Days to flowering

Non-significant positive gca effects were obtained for days to flowering in case of parents Cms 7-1A (0.84) and Cms 300A (0.18) among females and RHA 273 (1.34) among males on the other hand negative gca effects were observed in case of parents Cms 336A (-1.02) among females and RHA 296 (-0.73) and RHA 298 (-0.66) among males, but these effects were not upto the level of significance.

The cross Cms 7-1A x RHA 273 exhibited highest (-2.54) negative sca effect followed by Cms 336A x RHA 298 (-1.87), Cms 300A x RHA 298 (-1.40) and Cms 300A x RHA 298 (-1.40). The cross Cms 7-1A x RHA 298 showed the highest (3.72) positive sca effect indicating a poor combination for earliness in flowering, however, results are non-significant.

2. Days to 50 per cent flowering

For 50 per cent flowering, negative gca effects were obtained in case of genotype Cms 336A)-1.66) among females and RHA (-1.67) among males, however, these were non-significant. Similarly non-significant positive gca effects were observed for parent Cms 7-1A (2.11) among females and RHA 273 (1.44) among males indicating their poor combining ability for days to 50 per cent flowering.

The crosses with negative sca effects were Cms 336A x RHA 298 (-2.44), Cms 7-1A x RHA 296 (-2.11) and Cms 7-1A x RHA 273 (-2.0) but these were not upto level of significance. The crosses Cms 7-1A x RHA 298 (4.11) and Cms 336A x RHA 273 (2.11) indicates that they are poor combiner for earliness to 50 per cent flowering.

3. Days to maturity

The estimates of gca effects in respect of days to maturity indicated that parents viz. Cms 7-1A (-1.22) among females and RHA 296 (-0.88) among males had negative effects but these were non-significant. On the other hand, parent RHA 273 produced the maximum (1.32) non-significant positive gca effect.

Among the crosses, none was able to produce significant sca effects, although the cross Cms 7-1A x RHA 273 produced the highest negative (-2.27) sca effects.

4. Plant height (cm)

For plant height, the female parent Cms 336A produced significant negative (-18.66) gca effect indicating that the parent is a good combiner for dwarfness. Significant positive gca effects were observed in all the males with highest (23.53) gca effect for RHA 298 followed by RHA 273 (13.31) and RHA 296 (10.22).

The desirable cross combinations showing significant negative sca effects were Cms 300A x RHA 273 (-23.55) and Cms 7-1A x RHA 273 (-9.19) whereas significant positive sca effects were exhibited by 4 cross combination with the highest (35.72) in the cross Cms 336A x RHA 298.

5. **Stem diameter (cm)**

For this character significant positive (0.25) gca effect was observed for female parent RHA 300A indicating it to be good combiner for stem diameter.. Significant negative (-0.28) gca effect observed for parent Cms 336A indicate it to be poor combiner. Among males none of the parent was able to produce significant gca effects.

For specific combining ability effects, the cross Cms 336A x RHA 273 produced the highest (0.64) significant positive sca effect followed by Cms 300A x RHA 296 (0.33) and Cms 7-1A x RHA 273 (0.22) pointing to be the best combinations for stem diameter whereas the crosses Cms 300A x RHA 273 (-0.95) and Cms 336A x RHA 298 (-0.34) were poor combiner for stem diameter owing to their significant negative sca effects.

6. **Head diameter (cm)**

Significant positive gca effects were observed for female parent Cms 7-1A (1.83) and male parent Cms 273 (2.34) pointing that these are good combiners for head diameter. Significant negative gca effects were observed for female parent (-1.99) and male parent RHA 298 (-3.07) indicating their poor combining ability for head diameter.

The results pertaining to specific combining ability effects indicated crosses Cms 336A x RHA 273 (2.57) and Cms 336A x RHA 296 (3.21) were best combinations for head diameter owing to their significant positive sca effects. On the other hand the cross Cms 336A x RHA 298 (-5.78) was poor combiner for head diameter owing to its high significant negative sca effects.

7. **Percent unfilled seeds**

Negative gca effects were observed for female parent Cms (-1.04) and male parent RHA 298 (-0.46) but these were non-significant.

Among the crosses Cms 336A x RHA 296 was the best, owing to its negative (-3.52) sca effects, but it was not upto level of significance. On the other hand the cross Cms 300A x RHA 296 (4.30) was the poorest combiner for this trait but the sca effect was non-significant.

8. **100-seed weight (g)**

The examination of gca effects in respect of 100-seed weight led to conclude that none of the parent was good or poor general combiner for this trait as they do not produced significant positive or negative gca effects.

Among crosses also, none of the cross combination was able to produce significant positive or negative effects.

9. Number of seed per head

For this character the female parent Cms 300A produced significant positive (90.37) gca effects pointing it to be a good general combiner for number of seed per head whereas the parent Cms 336A was poor combiner for this character owing to its significant negative (-90.74) gca effects. Among males none of three parents was able to produce significant positive or negative gca effects.

While considering the specific combining ability effects, the cross Cms 336A x RHA 298 was the poor specific combiner owing to its significant negative (-173.26) sca effect. Only one cross Cms 7-1A xRHA 298 produced significant positive (138.3) sca effect indicating it to be a good specific combiner for this character.

10. Seed yield per plant

For seed yield none of the parent was able to produce significant positive and negative gca effects.

For specific combining ability the cross Cms 336A x RHA 296 was the most undesirable combination as it produced significant negative (-10.98) sca effect. None of the cross was able to produce significant positive sca effects.

11. Percent oil content

An examination of gca effects in respect of per cent oil content reveals that none of the male or female parents were either good or poor general combiner as they do not produce significant positive or negative gca effects.

Similarly none of cross combination was able to produce significant sca effects.

Coefficient of variation

Table 14 indicated that the maximum phenotypic as well as genotypic coefficient of variability was observed in case of per cent unfilled seed (53.50 and 59.94) followed by seed yield per plant (35.36 and 40.43), number of seeds per head (29.66 and 34.42) while minimum phenotypic and genotypic coefficient of variability was observed in case of days to maturity (2.31 and 2.92).

Heritability estimates

Heritability in broad sense was worked out and presented in table 14. Among various characters the highest heritability was shown by plant height (98.66%) followed by stem girth (97.71%) and head diameter, while the oil content recorded lowest heritability (43.94%).

Genetic advance

The genetic advance as per cent of mean expected genetic gain was calculated for yield and other characters and presented in table 14.

Table 14. Coefficient of variation (Phenotypic and genotypic), heritability, genetic advance and expected genetic gain for various characters.

Character	Genotypic coefficient of variation	Phenotypic coefficient of variation	Heritability (%)	Genetic advance (%)	Expected genetic gain (genetic advance as % of mean)
Flowering (days)	4.78	5.67	71.19	4.91	8.31
50 per cent flowering (days)	5.28	5.98	78.19	5.57	9.62
Maturity (days)	2.31	2.92	63.08	3.57	3.79
Plant height (cm)	17.61	17.73	98.66	43.23	36.04
Stem diameter (cm)	17.68	17.88	97.71	2.40	35.99
Head diameter (cm)	25.29	25.69	96.89	8.12	51.28
Unfilled seeds (%)	53.50	59.94	79.65	10.18	98.35
100-seed weight (g)	16.73	20.16	68.32	1.73	28.58
Number of seeds/head	29.66	34.42	74.60	260.50	52.65
Seed yield/plant (g)	35.36	40.43	76.49	19.95	63.70
Oil content (%)	3.87	5.83	43.94	1.75	5.28

Table 15. Phenotypic, genotypic and environmental correlation for yield and other characters.

Character		Flowering (days)	50% flowering (days)	Maturity (days)	Plant height (cm)	Unfilled seeds (%)	Stem diam. (cm)	Head diam. (cm)	Oil content (%)	100-seed weight (g)	Number of seed/ head	Seed yield/ plant (g)
		1	2	3	4	5	6	7	8	9	10	11
Flowering (days)	P		0.9124**	0.6481**	0.3376**	0.0644	0.4022**	0.2347	0.1012	-0.0803	0.1308	0.0658
	G		0.9692	0.6674	0.4097	0.0698	0.4745	0.2763	0.2055	-0.1156	0.1805	0.0978
	E		0.7592**	0.7541**	0.0925	0.2123	0.0795	0.0554	-0.0341	0.0020	-0.0013	0.0265
50% flowering (days)	P			0.6185**	0.3137**	0.0928	0.4126**	0.2220	0.0978	-0.0814	0.0907	0.0461
	G			0.6203	0.3632	0.0972	0.4618	0.2467	0.1605	-0.1183	0.1189	0.0532
	E			0.6444**	-0.9774**	0.0762	0.1258	0.0891	0.0105	0.0209	0.0002	0.0218
Maturity	P				0.1884	-0.0286	0.3072**	0.2642*	-0.0092	0.0437	0.1306	0,1052
	G				0.2387	-0.1047	0.3756	0.3287	0.0308	0.0483	0.1591	0.1175
	E				0.0019	-0.1644	0.1340	0.1034	-0.0558	0.0349	0.0705	0.0798
Plant height (cm)	P					-0.4034**	0.6060**	0.7225**	0.1194	0.4246**	0.6402**	0.5733**
	G					-0.4491	0.6165	0.7355	0.1918	0.5157	0.7434	0.6571
	E					-0.1018	0.0384	0.1625	-0.0794	-0.0062	0.0669	0.0448

Table contd.....

Table contd.....

Character		1	2	3	4	5	6	7	8	9	10	11
Unfilled seeds (%)	P						-0.2677*	-0.6189**	0.1361	-0.5624**	-0.5640**	-0.5085**
	G						-0.3054	-0.6889	0.1773	-0.7198	-0.7411	-0.6790
	E						0.0249	-0.0804	0.0923	-0.1171	0.0259	0.0978
Stem diameter (cm)	P							0.6207**	0.0760	0.3659**	0.4541**	0.4508**
	G							0.6385	0.1287	0.4455	0.5360	0.5267
	E							0.0507	-0.0738	0.0068	-0.0333	-0.6261**
Head diameter (cm)	P								-0.0285	0.6569**	0.7076**	0.7204**
	G								-0.0878	0.7984	0.8489	0.8392
	E								0.4227**	0.0408	-0.1019	-0.0238
Oil content (%)	P									-0.0285	0.0013	0.0003
	G									-0.0878	-0.0598	0.0090
	E									0.4227**	-0.9317	-0.0135
100-seed weight (g)	P										0.6265**	0.7154**
	G										0.7758	0.9125
	E										0.2538**	0.1973

Table contd......

Table contd.....

Characters		1	2	3	4	5	6	7	8	9	10	11
Number of seeds/head	P											0.9155**
	G											0.9428
	E											0.8334

* Significant at 5%

** Significant at 1%

Maximum expected genetic gain was observed for per cent unfilled seed (98.35%) followed by seed yield per plant (63.70%). Lowest expected genetic gain was recorded in case of days to maturity (3.79%).

Correlations

Correlation studies were carried out to find out relationship between different characters at genotypic, phenotypic and environmental levels and correlation coefficients are presented in table 15.

In most of the cases the magnitude of correlation coefficient at genotypic level was higher than the corresponding phenotypic and environmental levels. Thus it reveals a good amount of strong inherent association between different attributes.

Days to flowering exhibited highly significant and positive association for days to 50 per cent flowering and days to maturity at all the three levels and for plant height at both genotypic and phenotypic levels.

Days to 50 per cent flowering had high positive significant association with days to flowering and days to maturity at all the three level and it also exhibited high positive significant effect for plant height and stem diameter at genotypic and phenotypic levels. It also recorded highly negative and significant association with plant height at environmental level.

Days to maturity had high positive and significant correlation with days to flowering and days to maturity at all the three levels.

It had also high positive and significant association with stem diameter and head diameter at both genotypic and phenotypic levels.

Plant height had high positive and significant correlation with days to flowering, days to 50 per cent flowering, stem diameter, head diameter, 100-seed weight, number of seeds per head and seed yield per plant at both genotypic and phenotypic levels. It also had high negative and significant correlation with per cent unfilled seed at genotypic and phenotypic levels. Percent unfilled seeds had high negative and significant correlation with plant height, stem diameter, head diameter, 100-seed weight, number of seeds per head, and seed yield per plant at genotypic and phenotypic levels.

Stem diameter exhibited high positive and significant association with days to 50 per cent flowering, days to maturity, plant height, head diameter, 100-seed weight, number of seeds per head and seed yield per plant at both genotypic and phenotypic levels.

Head diameter exhibited highly positive and significant correlation with days to maturity, plant height, 100-seed weight, number of seeds per head and seed yield per plant at both genotypic and phenotypic level. It also had high positive and significant association with percent oil content at environmental level.

Percent oil content had high positive and significant association with 100-seed weight at environmental level. It also had high negative and significant correlation with number of seeds per head at the environmental level.

100-seed weight had high positive and significant correlation with plant height, stem diameter, head diameter, number of seeds per head and seed yield per plant at both genotypic and phenotypic level. It also had high negative and significant effect for per cent unfilled seeds.

Number of seeds per head had high positive and significant correlation with plant height, stem diameter, head diameter, 100-seed weight and seed yield at both genotypic and phenotypic level. It also had high negative and significant correlation with per cent unfilled seeds at both genotypic and phenotypic levels.

Seed yield per plant had high positive and significant correlation with number of seeds per head at all the three levels and with plant height, head diameter, stem diameter and 100-seed weight at both genotypic and phenotypic level. It also exhibited high negative and significant correlation with per cent unfilled seeds at both genotypic and phenotypic levels.

Path-coefficient analysis

Simple correlation coefficients showed the relationship between any two characters. These correlation values, however, do not make a complete picture of rather complex situation. For two characters whose relationships is measured do not exist by themselves but are

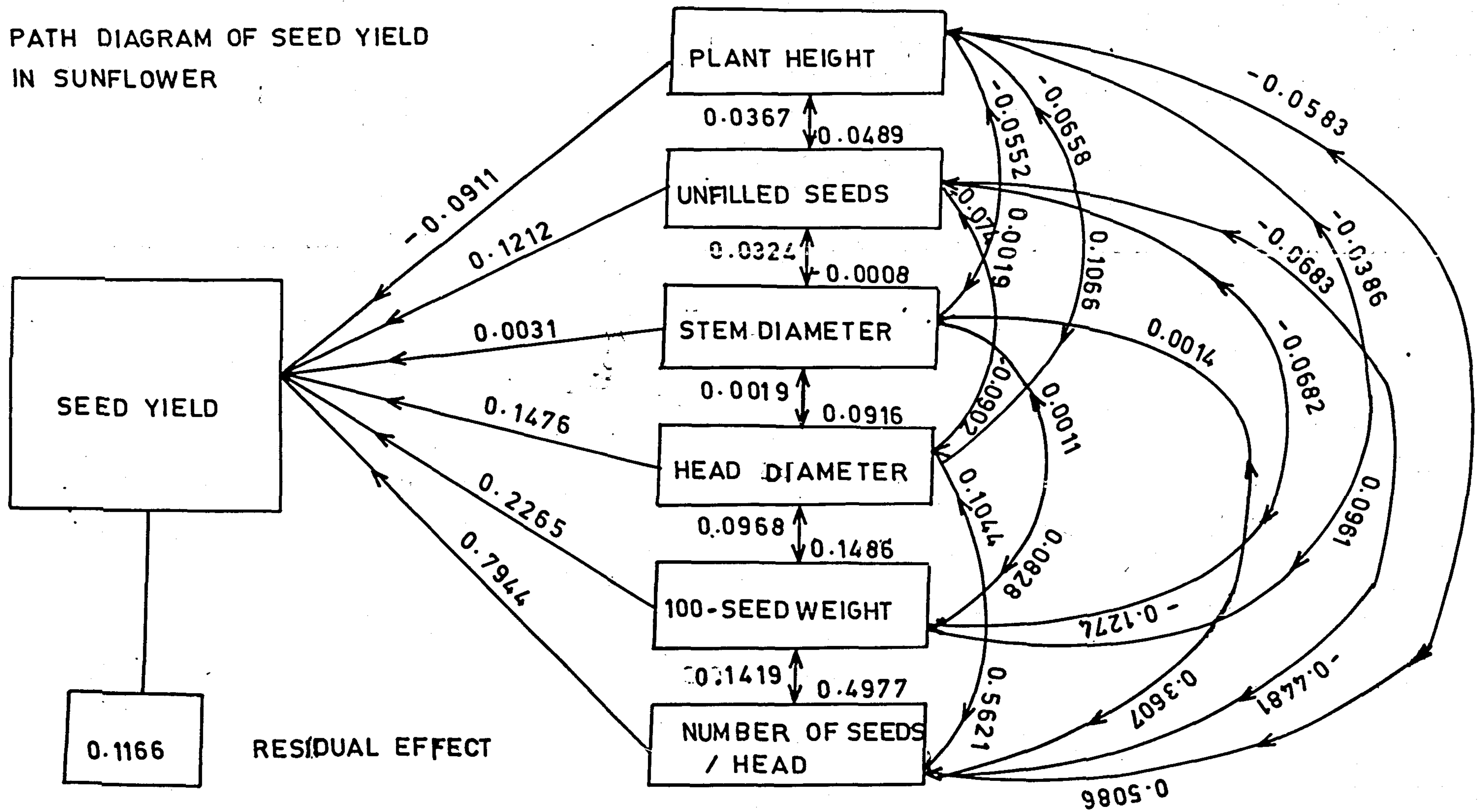
Table 16. Path coefficient analysis for yield V/S other characters.

Combination		Path coefficient
Seed yield/plant v/s Plant height		
Direct effect		-0.0911
Indirect effect via-		
Percent unfilled seeds		-0.0489
Stem diameter		0.0019
Head diameter		0.1066
100-seed weight		0.0961
Number of seeds/head		0.5086
	Total	0.5733
Seed yield/plant v/s per cent unfilled seeds		
Direct effect		0.1212
Indirect effect via-		
Plant height		0.0367
Stem diameter		-0.0008
Head diameter		-0.0902
100-seed weight		-0.1274
Number of seed/head		-0.4481
	Total	-0.5085
Seed yield/plant v/s stem diameter		
Direct effect		0.0031
Indirect effect via-		
Plant height		-0.0552
Percent unfilled seeds		-0.0324
Head diameter		0.0916
100-seed weight		0.0828
Number of seeds/head		0.3607
	Total	0.4507

Table contd....

Combination		Path-coefficient
<u>Seed yield/plant v/s Head diameter</u>		
Direct effect		0.1476
Indirect effect via-		
Plant height		-0.0658
Percent unfilled seeds		-0.0740
Stem diameter		0.0019
100-seed weight		0.1486
Number of seeds/head		0.5621
	Total	0.7204
<u>Seed yield/plant v/s 100-seed weight</u>		
Direct effect		0.2265
Indirect effect via		
Plant height		-0.0386
Percent unfilled seeds		-0.0682
Stem diameter		0.0011
Head diameter		0.0968
Number of seeds/head		0.4977
	Total	0.7153
<u>Seed yield/plant v/s Number of seeds/head</u>		
Direct effect		0.7944
Indirect effect via-		
Plant height		-0.0583
Percent unfilled seeds		-0.0683
Stem diameter		0.0014
Head diameter		0.1044
100-seed weight		0.1419
	Total	0.9155
Residual effect		0.1166

PATH DIAGRAM OF SEED YIELD
IN SUNFLOWER



part of complicated pathways in which other attributes are also interwoven. Thus path coefficient analysis provides more reilistic picture of the relationship between characters as it takes into consideration, direct as well as indirect effects of the different characters. Direct and indirect effects of various characters on seed yield were therefore computed.

Seed yield per plant and its components

Path analysis for seed yield was computed with six characters which were highly significantly associated with seed yield per plant viz. Plant height, per cent unfilled seeds, stem diameter, head diameter, 100-seed weight and number of seeds per head. The direct and indirect effects were worked out and presented in table 16.

Plant height had a negative direct effect (-0.0911) on seed yield. It had a very high positive indirect effect (0.0586) via number of seeds per head followed by head diameter (0.1066), 100-seed weight (0.0961). It had a negative indirect effect (-0.0489) via per cent unfilled seeds. Per cent unfilled seeds had a positive direct effect (0.1212) on seed yield. It had a positive indirect effect of low magnitude (0.0367) via plant height. It had a high negative indirect effect (-0.4481) via number of seeds per head followed by 100-seed weight (-0.1274), head diameter (-0.0902). Stem diameter had a very low direct effect (0.0031) on seed yield. It had a high positive indirect effect (0.3607) via number of seeds per head followed by head diameter (0.0916) and 100-seed weight (0.0828).

It had negative indirect effects (-0.0552 and -0.0324) via plant-height and per cent unfilled seeds respectively.

Head diameter had a moderate positive direct effect (0.1476) on seed yield. It has a high positive indirect effect (0.5621) via number of seeds per head followed by 100-seed weight (0.1486). It also had a negative indirect effects (-0.0740 and -0.0658) via per cent unfilled seeds and plant height respectively.

100-seed weight had a moderate positive direct effect (0.2265) on seed yield. It had a high positive indirect effect (0.4977) via number of seeds per head followed by head diameter (0.0968). It had negative indirect effects (-0.0682 and -0.0386) via per cent unfilled seeds and plant height, respectively.

Number of seeds per head had a very high positive direct effect (0.7944) on seed yield. It had positive indirect effect (0.1419) via 100-seed weight followed by head diameter (0.1044). It had negative indirect effects (0.0683 and 0.0583) via per cent unfilled seeds and plant height respectively.

CHAPTER-V

DISCUSSION

Plant breeding revolves around continuous efforts to evolve genotypes that have ever greater value over parents. The information on genetic basis of economic characters is valuable and helpful for result oriented breeding programme. Seed yield being a complex character depends upon other component characters. Due to their higher yields, morphological uniformity and relatively better tolerance to various biotic and abiotic stresses, the value of hybrid and heterosis breeding in sunflower is well established. Emphasis is, therefore, always to develop superior hybrids combining desirable attributes.

Sunflower being a highly cross pollinated crop, offers lot of scope for developing new and superior high yielding hybrids and varieties through heterosis breeding. Studies on heterosis have revealed considerable gain for seed and oil yield (Chaudhary and Anand, 1984; Singh and Labana, 1984). However, information on exploitation of heterosis in sunflower is too meagre. For the development of hybrids in sunflower although much emphasis has been given on the development of single cross hybrids, but it is very important to develop double cross and three way cross hybrids in order to compare their heterosis for different characters in order to utilise these crosses for future breeding programme.

Single cross hybrids have shown high heterosis for plant height, unfilled seeds (%), stem diameter , number of seeds per head and seed yield per plant as compared to double and three way cross hybrids. Similar results have also been reported earlier by Chaudhary and Anand (1984), Singh and Labana (1984), Sheriff and Appadurai (1985) and Naik and Pawar (1988).

The double crosses have shown high heterosis for the following characters viz. days to flowering, days to 50 per cent flowering, day to maturity, 100-seed weight and oil content (%) as compared to single crosses and three way crosses. So it is evident from the study that the important characters like earliness and 100-seed weight can be improved through such crosses. Although heterosis has also been shown by three way cross hybrids for the different characters, but it was less than single and double cross hybrids. Therefore it is evident from our study that three way cross hybrids do not have any significance so far as hybrid development programme is concerned. However, Bounnit and Stoenescu (1978) and Vranceanu and Stoenescu (1979) reported that double and three way cross hybrids were similar to single crosses in seed yield, oil content, oil yield and days to flowering.

From the ongoing results it is evident that for seed yield and its major component, single cross hybrids are more suitable for exploiting heterosis to the maximum level as compared to double and three way crosses. However, in case of oil content (%), only one double cross hybrid (Cms 336A x RHA 857) x (Cms 300A x RHA 272) have shown high heterosis, which may be due to sampling error. Therefore, it is difficult to generalize that double crosses are better for oil content.

Combining ability

The evaluation of the parents for general combining ability and that of the crosses for specific combining ability could be made use of in three ways: firstly, for developing the synthetics/hybrids from the good combining parents; secondly for genetic upgrading of material after designing a population from the good combining parents and crosses; thirdly for obtaining transgressive segregants from the crosses with high sca effects, involving both the good combining parents.

The results of the present investigation on combining ability studies of the six parents and nine hybrids revealed that the female parent Cms 300A exhibited high gca for stem diameter, number of seeds per head and seed yield per plant. Cms 336A was a good general combiner for dwarfness, but it was a poor general combiner for stem diameter, head diameter and number of seeds per head, whereas the female parent Cms 7-1A was a good combiner for head diameter.

Among testers, RHA 273 had good gca effects for head diameter and tallness. The other two testers RHA 296 and RHA 298 were poor combiners for yield and its related traits.

Out of 9 hybrids, only two exhibited significant negative sca effects for dwarfness. The maximum sca effect was exhibited by Cms 300A x RHA273 (-23.15) followed by Cms 7-1A x RHA 273 (-9.19).

Two hybrids showed significant positive sca effects for stem diameter Cms 336A x RHA 273 exhibiting maximum (0.64) sca effect for stem diameter. Interstingly the same hybrid exhibited significant positive sca effect for head diameter also. The highest significant positive sca effect for head diameter was produced by the hybrid Cms 7-1A x RHA 298.

For number of seeds per head the hybrid Cms 7-1A x RHA 298 produced highest (138.3) significant positive sca effect.

Several workers Sindagi (1979), Shankara (1983), Pathak et al. (1985), Sheriff et al (1985), Vanisree et al (1988) and Giriraj et al (1989) reported combining ability studies on sunflower. They found good gca for seed yield and its components.

Burlov and Buntovskii (1978), Naik et al. (1987) and Giriraj et al (1989) identified some promising lines with better performance in specific combination for various characters in sunflower.

Coefficient of variability, heritability (Broad sense) and expected genetic gain

The magnitude of coefficient of variability was higher at the phenotypic level as compared to the genotypic level, suggesting the role of environmental factors on various attributes of economic importance.

The heritability estimates were quite high for seed yield and its component characters. Same was also reported by Shabana (1974), Pathak (1974) and Kloczowski (1975). The characters plant height and stem diameter were found to be highly heritable, as also reported by Shabana (1974). Besides these; head diameter, percent unfilled seeds and number of seeds per head were also found to be highly heritable.

The highly heritable characters are of immense importance to the plant breeder as it permits the selection at phenotypic level, as high heritability coupled with high expected genetic gain is more useful in predicting the resultant gain from selection.

The highest expected genetic gain for percent unfilled seed (98.35%), seed yield per plant (63.70%), number of seeds per head (52.65%) and head diameter (51.28%) indicated that these characters can possibly be improved upto extent of 98.35%, 63.70%, 52.65% and 51.28% respectively.

Correlation studies

It was felt that it would be of great help in selecting the desirable genotype for yield if certain reliable association of these dependent attributes are indicated with certain easily measureable plant characters. Correlation study revealed that high magnitude of genotypic correlations in relations to their corresponding phenotypic values form a sound basis for their practical implications.

Table 15, revealed that the character days to flowering, days to 50 per cent flowering and days to maturity were highly and significantly correlated among themselves at both genotypic and phenotypic levels, with the 'r' value ranging between .61 and .96. The days to flowering and days to 50 per cent flowering also depicted significant positive correlation with plant height.

With seed yield per plant, days to flowering, days to 50 per cent flowering and days to maturity did not give any clear picture of their association.

The characters plant height, stem diameter, head diameter, 100-seed weight; number of seeds per head were significantly correlated among themselves and with seed yield per plant as reported by Giriraj (1980), Dhaduk and Desai (1985), Singh and Yadava (1985), Vanisree and Ananthasayana (1988), Khan and Muhammad (1989) and Singh and Labana (1990).

Percentage of unfilled seed showed significant negative correlation with plant height, stem diameter, head diameter, 100-seed weight, number of seeds per head and seed yield per plant. Similar results have also been reported by Dhaduk and Desai (1985), Singh and Yadava (1985). The character oil content had a significant negative correlation with head diameter, 100-seed weight and number of seeds per head at environmental level.

The following characters viz. number of seeds per head, 100-seed weight, head diameter and unfilled seed (%) were found to be highly and significantly correlated with seed yield per plant, pinpointing these as important component characters.

Path analysis

Seed yield is a complex character and depends upon a large number of component characters. The association of different component character among themselves and with seed yield is important for devising an effective selection criteria for seed yield. When many characters are affecting a given character, the splitting of total correlation into direct and indirect effects would provide a more realistic picture to the cause of association.

So path coefficient analysis was worked out for the characters significantly correlated with seed yield and are presented in table 16.

Path coefficient analysis for seed yield revealed that the number of seeds per head had the highest direct effect on seed yield followed by 100-seed weight, head diameter and unfilled seeds (%). The direct effect of stem diameter on seed yield was of low magnitude, while the plant height had a negative direct effect on seed yield. The same was reported by Pathak and Kukadia (1983) and Carrasco and Lopez (1986).

Numbers of seeds per head had the highest magnitude of indirect effect on seed yield through head diameter followed by plant height, 100-seed weight and stem diameter. Where as the direct effects of all these four characters on seed yield was less than their indirect effect on seed yield through number of seeds per head.

Therefore out of six components which were associated with seed yield, number of seeds per head and 100-seed weight appeared the important components of seed yield, as their direct effect on seed yield was high. Moreover head diameter and plant height were also important components of seed yield which contributed indirectly through number of seeds per head.

The path coefficient analysis appeared to have made the situation look more realistic than on the basis of correlation coefficients. For example plant height was positively correlated with seed yield but path coefficient indicated that this character was affecting the seed yield indirectly through number of seeds per head.

Therefore it may be concluded from the combined results of correlation coefficients and path coefficient analysis that selection for high number of seeds per head along with 100-seed weight and head diameter would be more effective for improving seed yield.

CHAPTER-VI

SUMMARY

The present study involving "A comparitive study of heterosis in single, double and three way cross hybrids of sunflower" was conducted at oilseed section of the Department of Plant Breeding, CCS Haryana Agricultural University, Hisar during the year 1992-93. A total of 63 genotypes consisting 45 F_1 hybrids, their 15 parents and 3 standard checks, planted in Randomized Block Design with three replication were studied.

The objectives were to compare heterosis among single, double and three way cross hybrids and to study combining ability and association between different morphological characters.

Analysis of variance showed considerable variability for all the characters.

The single cross hybrids were the best for seed yield per plant, number of seeds per head, stem diameter, head diameter, percent unfilled seeds and plant height whereas the double cross hybrids produced highest heterotic effects for earliness and 100-seed weight. The three way cross hybrids also exhibited heterosis for some of the characters, but it was not upto the extent as produced by single and double way crosses. The best cross for the seed yield and its component character was single cross hybrid Cms 336A x RHA857, outyielding the better parent and best check by 35.43 per cent and 51.79 per cent respectively. The same hybrid also

produced significant heterosis for number of seeds per head, head diameter, unfilled seeds (%) and stem diameter.

For earliness, the double cross hybrid (Cms 336A x RHA 856) x (Cms 300A x RHA 298) was found to be the best. Interstingly the same hybrid produced the highest heterosis for 100-seed weight also.

On the basis of the present study, it can be concluded that the single crosses, Cms 336A x RHA 856 and Cms 336A x RHA 857 were found to be the best, as the former produced considerable heterosis for earliness and was involved in the double cross exhibiting significant heterosis for 100-seed weight, whereas the later one produced considerable heterosis for seed yield and its component character and was also involved in the double cross exhibiting heterotic effect for oil content. So these two genotypes may be used in future for breeding for higher seed yields and earliness.

The evaluation of combining ability among six parents and nine hybrids revealed that the female parent Cms 300A was found to be a good general combiner for stem diameter and number of seeds per head. Cytoplasmic male sterile line 7-1A was found to be good combiner for head diameter and Cms 336A was a good combiner for dwarfness.

Among the testers, RHA 273 was found to be a good combiner for head diameter.

Among the crosses, Cms 336A x RHA 273 exhibited highest sca effects for stem diameter, head diameter, number of seeds per head and seed yield per plant.

Heritability estimates (broad sense) were generally high for seed yield and its component characters and low for earliness. Expected genetic gain indicated that seed yield can possibly be improved upto a considerable extent.

Correlation studies revealed that plant height, stem diameter, head diameter, 100-seed weight and number of seeds per head, were having a positive and significant association for seed yield per plant whereas unfilled seeds (%) had a significant negative correlation with seed yield per plant.

Path coefficient analysis revealed that number of seeds per head and 100-seed weight were the most important components of seed yield per plant. contributing directly towards seed yield, whereas, head diameter and plant height were also important components contributing indirectly to seed yield via number of seeds per head.

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