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Evaluation of combining ability and heterosis for seed yield in breeding lines of sunflower (*Helianthus annuus* L.) using line x tester analysis

KD Bhoite, RB Dubey, Mukesh Vyas, SL Mundra and KD Ameta

Abstract

The present investigation was undertaken with a view to estimate extent of heterosis, *per se* performance, combining ability, genotype x environment interactions and stability parameters in sunflower. The experimental material comprised of diverse 3 CMS lines and 14 testers crossed in line x tester mating design to obtain 42 F$_1$s. The resultant hybrids along with their parents and 3 checks were evaluated in randomized block design with three replications for combining ability. The results revealed that the magnitude of SCA variance was higher as compared to GCA for all the characters indicated the predominance of non-additive gene inheritance of most of the traits. The line CMS-17A and the testers HAM-183, 3376-R, IB-19 x R-274, KOP –I x RHA-856, KOP-I x 15 NB-7, R-348 x R-274 and RHA-6D-1 x R-272-4 were found good general combiners for head diameter, per cent seed filling and seed yield per plant. The best crosses based on the heterosis, SCA effects and *per se* performance the crosses CMS-17A x (RHA-6D-1 x R-272-4), CMS-234A x (R-348 x R-274), CMS-234A x (KOP-I x RHA-856), ND-2A x (RHA-6D-1 x R-272-4) and CMS-17A x 3376-R posses good seed yield per plant over best checks DRSH-1, KBSH-44 and Phule raviraj. These crosses can be used for further heterosis breeding programme and needs to be evaluating for genotype x environment interactions.

Keywords: combining ability, heterosis, sunflower, yield

Introduction

Sunflower (*Helianthus annuus* L.) is the fourth important oilseed crop in the world next to soybean, groundnut and rapeseed. It belongs to the genus *Helianthus*, family Asteraceae, tribe Heliantheae, sub-tribe Helianthae which includes 20 genera with 400 sub-species, originated in USA (Heiser, 1978) [8]. It has 2n=34 and cross pollinated in nature. Sunflower, being a highly cross-pollinated crop is ideally suited for exploitation of heterosis. Commercial exploitation of heterosis has been possible using cytoplasmic male sterility- restorer system. However, commercial cultivation in India started with open pollinated varieties like EC 68414 (Peredovik), EC 68415 (Armaviriski, 3497) and Morden (Cermianka-66). Heterosis breeding has evolved successfully in sunflower breeding ever since the discovery of first cytoplasmic male sterility (CMS) source by Leclercq (1969) [14] from the interspecific cross *H. petiolaris* Nutt, x *H. annuus* and fertility restoration by Kinman (1970) [12] that gave the required momentum for commercial hybrid seed production in sunflower using CMS source.

In heterosis breeding, the selection of parents or inbreds with good combining ability is very important in producing superior hybrids. The estimation of general combining ability (GCA) and specific combining ability (SCA) helps in identifying the potential parents in the production of superior hybrids for seed yield and oil content. It is useful in knowing the type of gene action controlling various characters and development of suitable breeding strategies. The line x tester analysis (Kempthorne, 1957) [11] is one of the simplest and efficient method of evaluating large number of inbreds for combining ability and *per se* performance.

To initiate hybrid breeding programme it is prerequisite to develop inbred lines with good combining ability. Information on GCA of lines to be used as parents as well as on their specific combining ability would be of immense value in formulating efficient breeding strategy Vikas *et al.*, (2015) [30]. Combining ability study elucidates the nature and magnitude of gene action involved in the inheritance of character by providing the information on the two components of variance *viz*; additive genetic variance and dominance variance, which are important to decide upon the parents and crosses to be selected for eventual success. Thus, this investigation was undertaken to determine magnitude of heterosis for yield and other quantitative traits and general and specific combining ability effects using L x T mating design.

Materials and Methods

The crossing programme was undertaken during *kharif* 2016 by adopting line x tester mating design consisted 3 lines (CMS-17A, CMS-234A and ND-2A) and 14 testers {HAM-183, IB-19, IB-2M, PISF-110-8-1, 3376-R, (IB-19 x R274), (KOP-I x RHA-856), (KOP-I x 15 NB-7), (P-356 x R-274), (R-296 x 15 NB-7), (R-348 x R-274), (RHA-6D-1 x R-272-4), (15 NB-7 x HRA-5) (15 NB-7 x R-35)}. The resultant 42 hybrids along with their 17 parents and three checks *viz*; DRSH-1, KBSH-44 and Phule raviraj were evaluated in randomized block design with three replication at Botany Instructional Farm, Department of Plant Breeding and Genetics, Rajasthan College of Agriculture, MPUAT, Udaipur during *rabi* 2016-17. Observations were recorded in each entries on randomly selected ten plants for twelve characters *viz*; days to 50 per cent flowering, days to physiological maturity, plant height (cm), head diameter (cm), per cent seed filling, seed yield per plant (g), 100 grain weight, volume weight (g/100 ml), hull content (%), oil content (%), biological yield per plant (g) and harvest index (%).

Results and Discussion

Presence of genetic variability is the basic requirement for developing high yielding and better adapted hybrids in sunflower. However, in present investigation mean sum of squares due to lines were significant for head diameter, per cent seed filling, seed yield per plant, 100 grain weight, volume weight, oil content and biological yield per plant indicated considerable amount of variation existing for these traits among female lines which can be exploited for combining ability analysis. The sum of squares due to testers were significant for head diameter, per cent seed filling, seed yield per plant, 100 grain weight, volume weight, hull content and oil content. The analysis of variance due to line x tester were highly significant for most of the traits except days to physiological maturity suggesting contribution of SCA effects towards variation among the crosses.

General combining ability (GCA) and specific combining ability (SCA) effects

Line x tester analysis can evaluate more number of genotypes as compared to diallel and partial diallel mating design. This technique can be used even when the inbred lines have self-incompatibility and male sterility where diallel crosses entirely fail to such abnormal conditions. The success of any breeding programme largely depends on selection of suitable parental lines. Information regarding different types of gene action, relative magnitude of genetic variance and combining ability estimates are important genetic parameters for the improvement of sunflower Sher *et al*., (2009) [26]. The presence of non-additive genetic variances and effects, presumably dominant genes are the primary justification for initiating the hybrid development programme in sunflower. Higher GCA effects are more desirable for self-pollinated crops and varieties released as pure lines while, SCA is more important for the production of hybrids in cross pollinated crops (Hallaur and Miranda, 1986) [7]. The magnitude of SCA variance was greater than GCA variance for most of the traits except oil content indicating predominance of non-additive variance controlling the expression of these traits. Similar results were reported by Madhavilatha *et al*., (2005) [16] and Longanthan and Gopalan (2006) [15].

General combining ability (GCA) effects

The estimates of GCA effects of parents are the important criteria because parents with high mean value may not necessarily be able to transmit their superior traits to their progenies. The line CMS-17A might be considered the best general combiner for plant height (shorter), head diameter, per cent seed filling, seed yield per plant, 100 grain weight, volume weight, hull content and biological yield per plant, CMS-234A for days to 50 per cent flowering and days to physiological maturity, oil content per cent and harvest index per cent.

Achieving higher commercial yield the basic objective for most of the breeding programmes in any of the crop plants, however, per cent seed filling and head size play major role in sunflower. Among the testers, HAM-183, 3376-R, IB-19 x R-274, KOP –I x RHA-856, KOP-I x 15 NB-7, R-348 x R-274 and RHA-6D-1 x R-272-4 were found good general combiners for head diameter, per cent seed filling and seed yield per plant whereas, IB-19, PISF-110-8-1, IB-19 x R-274, RHA-6D-1 x R-272-4, 15 NB-7 x HRA-5 and 15 NB-7 x R-356 may be selected as a donor for oil content per cent. The tester P-356 x R-274 exhibited negative desirable GCA effects for days to 50 per cent flowering and days to physiological maturity (Table 2) indicating the importance of additive gene action advocating both these characters. Similar results were also reported by Sawargaonkar and Ghodke (2008) [24] and Neelima and Paremshwarappa (2009) [17]. Whereas, Tavde *et al*., (2009) observed that no parents were found to contain all favourable or unfavourable genes for all the characters as in the case of present study. Therefore, for improvement in specific character, the parents showing high GCA in desirable direction can be used as good donors for improvement of those characters. Hence, based on GCA effects CMS-17A, CMS-234A, HAM-183, IB-19 x R-274, 3376-R and RHA-6D-1 x R-272-4 can be considered as superior parents for future breeding purposes.

Specific combining ability (SCA) effects

In contrast to GCA effects being attributed to additive genetic effects, SCA denotes dominance and epistatic gene effects. The results of SCA effects of crosses (Table 3) depicted that CMS-17A x (RHA-6D-1 x R-272-4), CMS-234A x (KOP-I x RHA-856), CMS-234A x (R-348 x R-274), ND-2A x PISF-110-8-1, ND-2A x (15 NB-7 x R-356), and ND-2A x (RHA-6D-1 x R-272-4) were recorded good combination for seed yield per plant, where as CMS-17A x (R-296 x 15 NB-7), CMS-183 x HAM-183, CMS-234A x (P-356 x R-274), ND-2A x IB-2M, and ND-A x (KOP-I x RHA-856) for oil content per cent. These crosses expressed relatively higher positive SCA effects indicating of dominant and over dominant effect. These results are in agreement with the reports of Karasu *et al*., (2010) [10], Sharma *et al*., (2013) [25] and Kulkarni and Supriya (2017) [13] for seed yield and Kang *et al*., (2013) for oil content. The hybrids which expressed negative SCA effects for days to 50 per cent flowering and days to maturity contribute favourable additive genes for earliness (Patil *et al*., 2017) [19]. Out of 42 crosses only two crosses CMS-17A x IB-2M and CMS-234A x (RHA-6D-1 x R-272-4) exhibited higher negative SCA effects for days to 50 per cent flowering and days to physiological maturity. However, five crosses namely CMS-17A x (KOP-I x 15 NB-7), CMS-17A x (P-356 x R-274), CMS-234A x 3376-R, ND-2A x HAM-183 and ND-2A x (KOP-I x RHA-856) depicted significantly negative SCA effects for plant height. Results indicated that these crosses possess dominant or over dominant type of genes with decreasing effect hence may be exploited for reduced number of days to flowering and plant height (Table 3). Similar result was observed by Kulkarni and Supriya (2017) [13] for days to 50% maturity and plant height.

Parents are classified as high or good, medium or average and low or poor combiners on the basis of their GCA effects (Table 5). Parents with desirable and significant GCA effects were considered high or good combiners while parents showing non-significant estimates but in desirable direction were classified as average or medium combiners. Poor or low combiners had undesirable GCA effects. The estimates of SCA effects revealed that, none of the cross recorded higher SCA effect for all the traits. The cross CMS-234A x (KOP-I x R-356) recorded significant positive SCA effects for seed yield per plant, head diameter, per cent seed filling and 100 grain weight. In above listed traits the high x low GCA cross combination of parents was observed to be desirable cross combinations, indicating the predominance of non-additive gene action. Similar results were also reported by Ashok *et al*. (2000) [1], Radhika *et al*. (2001) [21], Sharma *et al*. (2003) [25], Parameswarippa *et al*. (2004) [18], Reddy and Madhavilatha (2005) [16] and Tavde *et al*. (2009).

Contribution of lines, testers and line x tester interactions to total variance

As far as the proportionate contribution towards expression of these traits are concerned the analysis revealed that the contribution of tester was higher than line for all the characters except for biological yield (Table 1). The line x tester interaction was higher than their parents for days to 50 per cent flowering, days to physiological maturity, plant height, biological yield and harvest index which showed preponderance of dominant genes for these traits.

Heterosis

Heterosis is the measure of deviation of progeny means from parental means. For exploitation of hybrid vigour, high degree of heterosis for yield and its components is a prerequisite in crop improvement programme. The negative heterosis is also important for characters *viz*; flowering, maturity and plant height in sunflower. In the present investigation two types of heterosis *viz*; heterobeltiosis or better parent heterosis and standard or economic heterosis have been studied. Major objectives of the present study were to identify promising hybrids which may give high degree of useful (economic) heterosis.

The variation for days to 50 per cent flowering ranged from 73 days in CMS-234A x (P-356 x R-274) to 90 days in (Phule raviraj) and for days to physiological maturity ranged from 111 days in CMS-234 x (RHA-6D-1 x R-272-4) to 124 days in CMS-17A x (KOP-I x RHA-856). Out of forty two crosses, fourteen and four crosses recorded negatively significant standard heterosis over the best check DRSH-1 in days to 50 per cent flowering and days to physiological maturity, respectively. Among them three crosses *viz*; CMS-234A x (P-356 x R-274), ND-2A x (15 NB-7 x R-356) and CMS-234 x (RHA-6D-1 x R-272-4) depicted highly significant standard heterosis in negative direction. In sunflower dwarf to medium tall plant is required because tall plants are prone to lodging therefore, negative heterosis in this case is desirable. In the present investigation, none of the cross showed negative heterobeltiosis; whereas, 40 crosses recorded significant positive heterobeltiosis. The highest positive significant heterobeltiosis 88.16 per cent was observed in the cross ND-2A x (P-356 x R-274). Out of forty two crosses, 13 crosses manifested negatively significant standard heterosis over the best check DRSH-1; among them two crosses viz; ND-2A x (RHA-6D-1 x R-272-4) and CMS-17A x (KOP-I x RHA-856) recorded negative standard heterosis (-17.22, -10.48) coupled with significant positive seed yield per plant. The predominance of the tallness over dwarfness indicates tallness to be dominant character as reported by Patil *et al*., (2017) [19] and Vikas *et al.*, (2015) [30]. However, Habib *et al*., (2009) [26] reported dominance of negative heterosis for plant height.

Lager head size is a desired trait to affect more yields in sunflower crop. In the present study 19 crosses exhibited significantly positive heterobeltiosis. The maximum heterobeltiosis percentage (48.29, 45.21, 44.90 and 42.87 %) for head diameter was depicted by the crosses CMS-17A x 3376-R, CMS-17A x (15 NB-7 x HRA-5), CMS-17-A x (IB-19 x R-274) and CMS-17A x (R-296 x 15 NB-7). The positive and significant standard heterosis were manifested in four cross combinations viz; CMS-17A x 3376-R, ND-2A x (RHA-6D-1 x R-272-4), CMS-17A x (15 NB-7 x HRA-5) and CMS-17-A x (IB-19 x R-274) with the values of 11.37, 9.52, 9.05 and 8.82 respectively for head diameter. Habib *et al*., (2005) [6] and Patil *et al*., (2017) [19] also found high positive heterosis for head diameter. Percent filled seeds in sunflower were positively correlated with seed yield. Total 14 crosses manifested positive heterosis over the better parent value. Considering the economic heterosis, none of the hybrids depicted positive significant heterosis in seed filling percent. The cross CMS-234A x (P-356 x R-274) (-21.15 %) and CMS-17A x (R-296 x 15 NB-7) (14.27 %) exhibited the minimum and maximum heterobeltiosis, respectively. However, the cross 234A x (P-356 x R-274) (-31.27 %) and CMS-17A x 3376-R (0.76) exhibited the minimum and maximum standard heterosis, respectively.

Among 42 crosses, 11 crosses exhibited highly significant positive economic heterosis over the best check KBSH-44. The maximum standard heterosis percentage for seed yield per plant was manifested by the crosses CMS-17A x 3376-R, CMS-17A x (RHA-6D-1 x R-272-4), CMS-17-A x (IB-19 x R-274) and CMS-17A x HAM-183 with a value of 31.46%, 25.34%, 19.23% and 17.15%, respectively. The positive and highly significant heterobeltiosis was manifested by 29 cross combinations. The crosses viz; CMS-17A x 3376-R, CMS-17A x (RHA-6D-1 x R-272-4), CMS-17-A x (IB-19 x R-274) and CMS-17A x HAM-183 showed highest heterobeltiosis with the values of 78.22%, 69.91%, 61.63% and 58.82% respectively for seed yield per plant (Table 4a). The presence of non-additive type of gene action in determining seed yield per plant has been reported by Sawargaonkar and Ghodke (2008) [24], Sujata and Reddy (2009) [28], Datta *et al*. (2011) [5], Rathi *et al*. (2016) [22] and Dhootmal (2017) [3]. Heterosis studies for 100 grain weight revealed that 14 cross combinations showed positive economic heterosis over the best check Phule raviraj. The cross combinations CMS-17A x 3376-R, CMS-17A x (RHA-6D-1 x R-272-4), CMS-17A x HAM-183 and CMS-234A x (KOP-I x RHA-856) displayed the highest economic heterosis percentages (30.25, 24.76, 20.88 and 20.23) for 100 grain weight. Whereas, positive and significant heterobeltiosis (54.74, 48.16 and 41.91 %) was observed in the crosses, CMS-234A x (KOP-I x RHA-856), CMS-17A x 3376-R and CMS-17A x (RHA-6D-1 x R-272-4), respectively. Similar conclusion has been drawn by Karasu *et al*. (2010) [10].

High volume weight is having direct relation to increase the weight of seed. Among 42 crosses only one cross CMS-17A x (RHA-6D-1 x R-272-4) exhibited positive significant (7.11%)

economic heterosis over the best check Phule raviraj. However, 21 crosses depicted positive and significant heterobeltiosis for volume weight. Harvest index is directly correlated with the seed yield. In present study 18 crosses manifested significant positive heterobeltiosis and 10 crosses depicted significant positive economic heterosis for harvest index. The highest economic heterosis for harvest index showed by the crosses CMS-234A x 3376R (38.71%) and CMS-17A x (RHA-6D-1 x R-272-4) (32.25%). A similar finding on significant heterosis for this trait was reported by Singh and Dhiraj Kumar (2017).

Low hull content in seed is having direct relation to increase the oil content per cent. The desirable negative heterosis was manifested by the crosses viz; CMS-234A x (P-356 x R-274) (-36.74), CMS-234A x (15 NB-7 x R-356) (-21.49), CMS-234A x (RHA-6D-1 x R-272-4) (-20.25) and CMS-234A x PISF-110-8-1 (-14.70) over the best check DRSH-1. In any oilseed crop, oil is an ultimate and the most important economic end product. In present investigation highest values of heterobeltiosis was 9.11 per cent {CMS-17A x (IB-19 xR-274)} followed by 7.73 per cent (ND-2A x IB-19) and 7.64 per cent {ND-2A x (IB-19 x R-274)}. Out of 42 crosses, 9 crosses recorded significant positive economic heterosis for oil per cent. The highest significant positive economic heterosis showed by CMS-234A x PISF-110-8-1 (13.25) followed by CMS-234A x (15 NB-7 x R-356) (10.24) for oil content (Table 4b). Such type of high heterosis for oil content was reported by Dudhe *et al.* (2009) [4] and Chandra *et al.* (2013) [2].

Based on the *per se* performance, SCA effects and extent of heterosis, five best crosses viz; CMS-17A x (RHA-6D-1 x R-272-4), CMS-234A x (R-348 x R-274), CMS-234A x (KOP-I x RHA-856), ND-2A x (RHA-6D-1 x R-272-4) and CMS-17A x 3376-R posses good seed yield per plant over best check Phule raviraj. (Table 6). These better performing crosses can be used for exploiting hybrid vigour and need to be evaluated for stability parameter.

Table 1: Analysis of variance for twelve characters of sunflower

Source of variation	**d.f.**	**Days to 50 per cent flowering**	**Days to physiological maturity**	**Plant height (cm)**	**Head diameter (cm)**	**Seed filling (%)**	**Seed yield per plant (g)**	**100 grain weight (g)**	**Seed volume weight (g/100 ml)**	**Hull content (%)**	**Oil content (%)**	**Biological yield per plant (g)**	**Harvest index (%)**
Replications	2	14.28	34.89	16.11	0.56	2.86	1.70	0.05	5.59	0.74	0.28	5.85	0.51
Parents(P)	16	11.91	15.26	672.46**	15.84**	97.02**	65.83**	0.45**	29.71**	64.74**	21.62**	1003.43**	31.75**
Parents vs Crosses	1	78.56*	79.61	68910.95**	897.36**	356.34**	6238.76**	52.52**	912.02**	539.44**	64.78**	30500.05**	946.72**
Crosses	41	38.28**	29.41	445.89**	21.29**	168.84**	123.96**	2.02**	63.48**	41.46**	16.73**	1245.52**	157.59**
Line effect	2	29.06	30.53	314.98	52.32**	389.52*	480.88**	9.01**	174.48*	36.36	33.52**	9623.83**	412.54
Tester effect	13	25.17	19.23	629.65	32.84*	295.20**	167.44*	2.60*	91.27*	77.88**	38.10**	524.37	172.08
Line x Tester effect	26	45.54**	34.42	364.07**	13.14**	88.68**	74.78**	1.19**	41.04**	23.64**	4.76**	961.60**	130.74**
Error	116	11.54	21.71	98.42**	0.97	10.68	7.23	0.04	2.86	3.08	0.71	38.53	6.44
Estimates													
Var. GCA		0.62	0.13	14.67*	1.64**	13.01**	12.43**	0.23**	5.1**	2.12**	1.38**	197.48**	11.22**
Var. SCA		11.34**	4.24	88.56**	4.06**	26.01**	22.52**	0.39**	12.73**	6.86**	1.35**	307.7**	41.44**
Var. GCA /Var. SCA		0.06	0.04	0.17	0.41	0.51	0.56	0.59	0.41	0.31	1.03	0.65	0.28
Contribution % of													
Lines		3.71	5.07	3.45	11.99	11.26	18.93	21.79	13.41	4.28	9.78	37.7	12.77
Testers		20.86	20.73	44.78	48.9	55.44	42.83	40.9	45.6	59.56	72.21	13.35	34.63
Lines x Testers		75.45	74.21	51.78	39.13	33.31	38.26	0.02	41.01	36.17	18.03	48.96	52.61

*Significant at 5% level and **significant at 1% level

Table 2: Estimates of general combining ability effects of lines and testers for seed yield and its component traits in sunflower

Sources	**Days to 50 per cent flowering**	**Days to physiological maturity**	**Plant height (cm)**	**Head diameter (cm)**	**Seed filling (%)**	**Seed yield per plant (g)**	**100 grain weight (g)**	**volume weight (g/100 ml)**	**Hull content (%)**	**Oil content (%)**	**Biological yield per plant (g)**	**Harvest index (%)**
Lines												
CMS-17A	0.96	0.98	-3.16**	1.29**	3.49**	3.89**	0.53**	2.29**	1.00**	-0.87**	14.18**	-1.01*
CMS-234A	-0.49	-0.47	1.45	-0.62**	-2.11**	-2.19**	-0.28**	-1.58**	-0.83**	0.91**	-15.93**	3.51**
ND-2A	-0.47	-0.52	1.71	-0.67**	-1.38**	-1.70**	-0.25**	-0.71**	-0.16	-0.03	1.75	-2.49**
SE for lines	0.52	0.72	1.53	0.15	0.50	0.41	0.03	0.26	0.27	0.13	0.96	0.39
CD at 5%	1.04	1.43	3.04	0.30	1.00	0.82	0.06	0.52	0.54	0.26	1.91	0.78
CD at 1%	1.38	1.90	4.04	0.40	1.33	1.09	0.08	0.69	0.71	0.34	2.53	1.03
Testers												
HAM-183	-0.26	-0.87**	7.63*	0.75*	5.15**	2.89**	0.18**	5.18**	1.19*	-0.27	9.34**	-1.08
IB-19	0.52	-0.54	1.16	-0.97**	-6.84**	-4.40**	-0.21**	-3.71**	3.58**	0.68*	11.40**	-7.79**
IB-2M	1.18	0.13	-10.66**	-3.13**	-10.34**	-7.41**	-1.13**	-3.77**	-0.70	-1.04**	-15.15**	-1.30
PISF-110-8-1	-0.71	1.35	3.51	-0.34**	-0.77	0.36	-0.07	0.53	0.04	3.44**	1.73	-0.56
3376-R	-0.60	-0.54	11.44**	2.09**	5.32**	5.69**	0.58**	2.58**	5.75**	0.47	-2.37	6.50**
(IB-19 x R274)	-0.60	-0.32	8.50*	1.48**	4.07**	2.98**	0.46**	1.86**	-0.19	0.56*	-6.41**	4.33**
(KOP-I x RHA-856)	2.86*	2.46	-3.75	0.80*	0.44	2.49**	0.54**	-0.47	-4.25**	-1.49**	4.70*	0.79
(KOP-I x 15 NB-7)	2.18	2.13	6.19	1.59**	5.02**	3.80**	0.31**	2.24**	-0.07	-0.38	-3.85	4.36**

(P-356 x R-274)	-3.38**	-2.09**	-0.32	-1.77**	-6.41**	-3.54**	-0.46**	-0.86	-5.59**	-0.30	8.29**	-3.98
(R-296 x 15 NB-7)	-1.37	-0.98**	-1.79	0.52	4.14**	0.54	0.38**	-1.12*	-0.24	-5.17**	3.46	-0.97
(R-348 x R-274)	-0.82	-0.21**	-3.31	2.03**	5.06**	2.86**	0.23**	2.45**	0.93	-1.55**	-1.46	3.02**
(RHA-6D-1 x R-272-4)	1.53	1.02	-10.82**	1.77**	4.97**	4.18**	0.37**	2.81**	2.01**	1.82**	-7.08**	5.86**
(15 NB-7 x HRA-5)	1.19	1.02	8.49	-1.01**	-1.88	-3.87**	-0.29**	-1.10	0.66	1.02**	5.30*	-5.36**
(15 NB-7 x R-356)	-1.71	-2.54**	-16.28**	-3.82**	-7.93**	-6.58**	-0.88**	-6.63**	-3.12**	2.21**	-7.90**	-3.82**
SE for testers	1.13	1.55	3.31	0.33	1.09	0.89	0.06	0.56	0.58	0.28	2.07	0.85
CD at 5%	2.25	3.09	6.58	0.65	2.17	1.78	0.12	1.12	1.16	0.56	4.12	1.68
CD at 1%	2.99	4.09	8.72	0.87	2.87	2.36	0.17	1.49	1.54	0.74	5.46	2.23

*Significant at 5% level and **significant at 1% level

Table 3: Estimates of specific combining ability effects of crosses for seed yield and its component traits in sunflower

Crosses	DFF	DPM	PH	HD	SF	SYPP	TW	VW	HC	OC	BYPP	HI
(CMS-17A x HAM-183)	1.26	1.01	3.64	0.50	0.32	2.21	0.48**	-1.71	1.47	0.22	-2.23	2.51
(CMS-17A x IB-19)	4.15*	2.68	3.68	2.29**	5.40**	-3.5*	0.58**	5.23**	-5.06**	-0.08	2.97	4.52**
(CMS-17A x IB2M)	-5.51**	-5.65*	4.82	-1.10	-6.03**	-0.79	-0.32**	-0.03	-0.61	-1.02*	7.13*	-4.36**
(CMS-17A x PISF-110-8-1)	-3.29	-1.87	0.92	-2.37**	-9.59**	-3.04*	-0.33**	3.32**	-0.25	-0.27	-27.70**	1.96
(CMS-17A x 3376-R)	-1.73	-1.98	12.67*	0.81	2.01	2.60	0.57**	-2.38*	-1.26	0.04	4.54	0.63
{CMS-17A x (IB-19 x R-274)}	-2.73	-0.54	-5.89	0.98	-0.42	-1.22	0.09	0.79	0.67	0.87	2.95	0.80
{CMS-17A x (KOP-I x RHA-856)}	1.81	2.34	5.99	-2.10**	-6.15**	-2.06	-1.01**	-1.39	0.14	-1.28**	6.39	-6.78**
{CMS-17A x (KOP-I x 15 NB-7)}	1.48	1.01	-11.51*	-0.90	-0.31	1.20	-0.54**	-1.94	1.87	0.21	-0.16	-1.55
{CMS-17A x (P-356 x R-274)}	1.04	-0.42	-18.37**	-2.00**	3.76*	-0.06	-0.52**	-4.56**	-0.27	-0.19	25.61**	-9.03**
{CMS-17A x (R-296 x 15 NB-7)}	1.37	0.12	-10.13	1.67**	1.81	2.61	0.18	4.03**	-0.48	1.60**	2.77	0.68
{CMS-17A x (R-348 x R-274)}	-2.51	-2.31	1.44	-1.20*	-0.81	-1.15	-0.36**	-4.76**	-0.47	0.41	5.40	-5.78**
{CMS-17A x (RHA-6D-1 x R-272-4)}	3.48	3.46	17.85**	-0.01	1.93	5.50**	0.49**	1.89	2.00	0.69	-17.26**	10.09**
{CMS-17A x (15 NB-7 x HRA-5)}	3.15	3.79	-7.68	3.50**	6.24**	1.06	0.83**	4.87**	3.15**	-0.94	6.38	4.75**
{CMS-17A x (15 NB-7 x R-356)}	-1.9	-1.65	2.55	-0.04	1.83	-3.30*	-0.15	-3.34**	-0.94	-0.26	-16.80**	1.54
(CMS-234A x HAM-183)	2.04	1.80	11.47*	-1.25*	1.95	-1.82	-0.36**	0.04	1.83	2.04**	8.36*	-5.07**
(CMS-234A x IB-19)	-2.73	-1.53	2.17	-0.68	-2.25	-0.88	-0.02	0.90	1.62	-0.08	28.30**	-9.31**
(CMS-234A x IB2M)	4.27**	3.46	-5.25	-0.21	1.43	0.93	-0.01	-0.01	-2.62*	-0.91	-20.04**	7.96**
(CMS-234A x PISF-110-8-1)	3.15	3.24	1.14	1.96**	9.41**	-0.06	0.86**	-4.84**	-0.84	0.79	6.88	0.46
(CMS-234A x 3376-R)	2.04	0.80	-11.77*	1.29**	3.05	1.07	0.03	1.02	1.42	-0.23	-7.73*	7.31**
{CMS-234A x (IB-19 x R-274)}	2.71	1.91	1.19	-1.81**	-2.01	-3.74*	-0.02	2.85*	0.60	-1.12*	2.75	-5.29**
{CMS-234A x (KOP-I x RHA-856)}	-1.73	-1.53	11.31	2.78**	7.27**	5.46**	0.90**	0.39	0.78	-0.08	4.05	-2.73
{CMS-234A x (KOP-I x 15 NB-7)}	-1.73	-2.19	2.77	0.37	-1.75	0.62	-0.01	0.91	-0.23	-1.18*	9.49**	7.58**
{CMS-234A x (P-356 x R-274)}	-5.50**	-3.31	0.61	-0.04	-9.46**	1.30	-0.20	1.66	-3.22**	1.21*	-23.38**	3.30*
{CMS-234A x (R-296 x 15 NB-7)}	0.15	-0.08	-1.90	0.85	1.87	2.38	0.27*	-0.71	4.29**	-2.23**	-3.48	1.06
{CMS-234A x (R-348 x R-274)}	0.93	2.13	3.20	1.75**	3.55	5.22**	0.28*	3.36**	1.60	0.92	10.41**	-12.69**
{CMS-234A x (RHA-6D-1 x R-272-4)}	-8.39**	-7.75**	-7.48	-2.76**	-6.01**	-7.18**	-0.85**	-4.12**	-4.82**	-0.44	14.57**	2.85
{CMS-234A x (15 NB-7 x HRA-5)}	-1.39	-1.75	0.60	-0.61	-2.42	-0.53	-0.21*	0.09	-0.265	0.32	-13.70**	1.28
{CMS-234A x (15 NB-7 x R-356)}	6.15**	4.80	-8.08	-1.64*	-4.64*	-3.45*	-0.66**	-1.59	-0.14	0.98	-16.51**	2.56
(ND-2A x HAM-183)	-3.31	-2.81	-15.11**	0.74	-2.28	0.18	-0.12	1.67	-3.30**	-2.26**	-6.12	4.79**
(ND-2A x IB-19)	-1.42	-1.15	-5.85	-1.60**	-3.15	-3.58*	-0.55**	-6.14**	3.38**	0.16	-31.28**	-3.61*
(ND-2A x IB2M)	1.24	2.18	0.42	1.32*	4.60*	2.29	0.33**	0.05	3.23**	1.94**	12.90**	-2.43
(ND-2A x PISF-110-8-1)	0.13	-1.37	-2.07	0.41	0.17	3.43*	-0.53**	1.52	1.09	-0.51	20.82**	-7.94**
(ND-2A x 3376-R)	-0.31	1.18	-0.89	-2.10	-5.07**	-6.45**	-0.60**	1.35	-0.15	0.18	3.18	4.49**
{ND-2A x (IB-19 x R-274)}	0.02	-1.37	4.70	0.83	2.43	1.82	-0.07	-3.65**	-1.27	0.25	-5.71	3.54*
{ND-2A x (KOP-I x RHA-856)}	-0.08	-0.81	-17.30**	-0.67	-1.11	0.51	0.10	1.00	-0.92	1.37**	-10.45**	4.28**
{ND-2A x (KOP-I x 15 NB-7)}	0.24	1.18	8.74	0.52	2.07	0.63	0.54**	1.02	-1.63	0.96	-9.32*	1.45
{ND-2A x (P-356 x R-274)}	4.46*	3.73	17.75**	2.04**	5.69**	3.08	0.72**	2.90*	3.49**	-1.02*	-2.23	-3.98**
{ND-2A x (R-296 x 15 NB-7)}	-1.53	-0.04	12.03*	-2.52**	-3.68	-4.10**	-0.46**	-3.31**	-3.81**	0.62	0.70	4.72**
{ND-2A x (R-348 x R-274)}	1.57	0.18	-4.65	-0.54	-2.74	-0.92	0.08	1.40	-1.12	-1.34**	-15.82**	2.57
{ND-2A x (RHA-6D-1 x R-272-4)}	4.91*	4.29	-10.37	2.77**	4.07*	3.62*	0.35**	2.20	2.82**	-0.25	2.69	-7.61**
{ND-2A x (15 NB-7 x HRA-5)}	-1.75	-2.04	7.08	-2.89**	-3.81*	-7.05**	-0.61**	-4.96**	-2.89**	0.61	7.31*	-2.83
{ND-2A x (15 NB-7 x R-356)}	-4.19*	-3.15	5.52	1.69**	2.80	6.52**	0.81**	4.94**	1.09	-0.72	33.32**	2.07
CD at 5%	1.48	2.03	2.03	0.43	1.42	1.17	0.08	0.73	0.76	0.37	2.70	-2.73
CD at 1%	2.77	3.80	3.80	0.804	2.66	2.195	0.15	1.38	1.43	0.69	5.06	1.10

*Significant at 5% level and **significant at 1% level

Table 4a: Estimates of heterosis (%) over better parent (BP) and standard heterosis (SH) over respective check in sunflower

	DFF		DPM		PH		HD		SF		SYPP	
	BP	SH	BP	SH	BP	SH	BP	SH	BP	SH	BP	SH
(CMS-17A x HAM-183)	2.41	-0.78	0.85	0.00	37.42**	-0.31	35.79**	1.98	13.65**	-1.31	58.82**	17.15**
(CMS-17A x IB-19)	6.83**	3.50	2.54	1.68	17.11**	-4.25	36.32**	2.38	4.81*	-8.99**	45.31**	7.19
(CMS-17A x IB2M)	-4.02	-7.00**	-3.95	-4.76*	8.55*	-10.78**	-5.55	-29.07**	-14.33**	-25.61**	11.34*	-17.87**

(CMS-17A x PISF-110-8-1)	-3.61	-6.61**	0.28	-0.56	62.93**	-4.49	5.87	-20.49**	-6.63**	-18.92**	17.30**	-13.48**
(CMS-17A x 3376-R)	-2.39	-4.67*	-1.97	-2.24	62.43***	7.56*	48.29**	11.37**	7.65**	0.76	78.22**	31.46**
{CMS-17A x (IB-19 x R-274)}	-2.81	-5.84*	0.00	-0.84	35.91**	-5.62	44.90**	8.82**	11.31**	-3.34	61.63**	19.23**
{CMS-17A x (KOP-I x RHA-856)}	6.83**	3.50	4.80*	3.92	62.10**	-5.84	16.52**	-12.50**	-5.30*	-13.75**	28.88**	-4.93
{CMS-17A x (KOP-I x 15 NB-7)}	5.62*	2.33	3.39	2.52	18.84**	-10.48**	31.58**	-1.19	12.35**	-2.17	50.91**	11.32**
{CMS-17A x (P-356 x R-274)}	-1.61	-4.67*	-1.41	-2.24	40.01**	-18.67**	-2.01	-26.41**	3.26	-10.34**	12.67*	-16.89**
{CMS-17A x (R-296 x 15 NB-7)}	1.20	-1.95	0.00	-0.84	24.18**	-14.52**	42.87**	7.30*	14.27**	-0.78	49.94**	10.60*
{CMS-17A x (R-348 x R-274)}	-2.81	-5.84*	-1.41	-2.24	24.57**	-8.35*	32.56**	-0.45	12.09**	-2.67	36.42**	0.63
{CMS-17A x (RHA-6D-1 x R-272-4)}	7.23**	3.89	3.93	3.64	33.31**	-2.90	39.61**	4.84	12.39**	0.29	69.91**	25.34**
{CMS-17A x (15 NB-7 x HRA-5)}	4.74*	3.11	3.63	3.92	26.65**	-6.72	45.21**	9.05**	-0.52	-2.55	55.21**	14.49**
{CMS-17A x (15 NB-7 x R-356)}	-3.98	-6.23**	-4.18	-3.64	42.35**	-15.63**	-2.76	-26.97**	-1.17	-14.18**	6.33	-21.56**
(CMS-234A x HAM-183)	4.12	-1.56	2.01	-0.56	40.03**	7.31*	7.37	-18.70**	8.16**	-5.73**	23.26**	-9.52*
(CMS-234A x IB-19)	-2.43	-6.23**	-1.70	-3.08	19.44**	-2.35	-1.27	-25.24**	-12.50**	-23.73**	-2.94	-28.75**
(CMS-234A x IB2M)	6.45**	2.72	5.22*	1.68	4.47	-14.13**	-13.89**	-34.80**	-12.27**	-23.54**	-12.48*	-35.76**
(CMS-234A x PISF-110-8-1)	2.82	-0.78	3.68	2.52	28.49**	-1.53	23.23**	-6.69*	10.12**	-4.02	34.52**	-1.26
(CMS-234A x 3376-R)	0.40	-1.95	-0.84	-1.12	24.49**	-4.60	36.45**	3.32	2.23	-4.31*	48.71**	9.16*
{CMS-234A x (IB-19 x R-274)}	7.63**	-1.17	4.69	0.00	32.52**	1.55	8.61*	-17.76**	1.72	-11.34**	15.06**	-15.54**
{CMS-234A x (KOP-I x RHA-856)}	2.87	-2.33	1.72	-0.56	30.81**	0.25	37.86**	4.39	4.26	-5.05*	49.20**	9.52*
{CMS-234A x (KOP-I x 15 NB-7)}	1.63	-3.11	1.73	-1.40	31.93**	1.10	25.84**	-4.71	3.26	-10.00**	36.23**	0.00
{CMS-234A x (P-356 x R-274)}	-8.68**	-14.01**	-2.33	-5.88*	25.00**	-4.21	-2.36	-26.07**	-21.15**	-31.27**	11.75*	-17.97**
{CMS-234A x (R-296 x 15 NB-7)}	-0.81	-5.06*	-0.57	-2.24	21.80**	-6.66	21.41**	-8.07*	6.77**	-6.94**	30.72**	-4.04
{CMS-234A x (R-348 x R-274)}	1.64	-3.50	4.07	0.28	24.68**	-4.45	39.38**	5.54	10.10**	-4.04	49.69**	9.88*
{CMS-234A x (RHA-6D-1 x R-272-4)}	-6.58**	-11.67**	-6.74**	-7.00**	10.13*	-15.60**	3.73	-21.45**	-4.49	-14.77**	8.94	-20.04**
{CMS-234A x (15 NB-7 x HRA-5)}	-2.37	-3.89	-2.23	-1.96	32.04**	1.18	-0.97	-25.01**	-16.72**	-18.43**	3.79	-23.81**
{CMS-234A x (15 NB-7 x R-356)}	3.98	1.56	0.00	0.56	5.28	-19.32**	-29.67**	-46.75**	-16.95**	-27.61**	-16.89**	-38.99**
(ND-2A x HAM-183)	-2.47	-7.78**	-2.01	-4.48	25.68**	-8.82*	6.90	-7.75*	-0.63	-9.62**	13.11**	-2.34
(ND-2A x IB-19)	-0.81	-4.67*	-1.42	-2.80	13.61**	-7.11*	-19.77**	-30.76**	-16.35**	-23.92**	-21.44**	-32.17**
(ND-2A x IB2M)	2.82	-0.78	3.46	0.56	8.90*	-10.50**	-14.70**	-26.39**	-11.15**	-19.20**	-12.49*	-24.44**
(ND-2A x PISF-110-8-1)	-0.81	-4.28	-0.28	-1.40	64.88**	-3.35	-2.40	-15.78**	-4.87*	-13.49**	15.40**	-0.36
(ND-2A x 3376-R)	-2.39	-4.67*	-0.56	-0.84	54.38**	2.23	-2.95	-16.25**	-6.55**	-12.54**	1.14	-12.67**
{ND-2A x (IB-19 x R-274)}	1.65	-4.28	0.00	-2.80	49.56**	3.86	12.25**	-3.13	3.82	-5.58**	18.52**	2.34
{ND-2A x (KOP-I x RHA-856)}	4.92*	-0.39	2.29	0.00	45.00**	-17.14**	-2.05	-15.48**	-5.09*	-13.56**	12.90**	-2.52
{ND-2A x (KOP-I x 15 NB-7)}	4.08	-0.78	4.32	1.40	39.29**	4.92	11.01**	-4.20	4.53*	-4.93*	17.38**	1.35
{ND-2A x (P-356 x R-274)}	3.72	-2.33	2.88	0.00	88.16**	6.45	-1.07	-14.63**	-5.00*	-13.60**	2.08	-11.86**
{ND-2A x (R-296 x 15 NB-7)}	-2.85	-7.00**	-0.57	-2.24	48.25**	2.04	-16.03**	-27.54**	-3.57	-12.30**	-7.60	-20.22**
{ND-2A x (R-348 x R-274)}	2.46	-2.72	1.44	-1.40	23.54**	-9.11**	6.82	-7.82*	-1.30	-10.24**	9.57*	-5.39
{ND-2A x (RHA-6D-1 x R-272-4)}	9.88**	3.89	3.37	3.08	13.66**	-17.22**	26.91**	9.52**	6.92**	-2.76	27.89**	10.42*
{ND-2A x (15 NB-7 x HRA-5)}	-2.77	-4.28	-2.51	-2.24	42.98**	5.31	-28.44**	-38.25**	-17.47**	-19.16**	-30.59**	-40.07
{ND-2A x (15 NB-7 x R-356)}	-8.37**	-10.51**	-6.69**	-6.16**	50.45**	-10.83**	-16.84**	-28.24**	-10.41**	-18.52**	3.33	-10.78*

*Significant at 5% level and **significant at 1% level

Table 4b: Estimates of heterosis (%) over better parent (BP) and standard heterosis (SH) over respective check in sunflower

	TW		VW		HC		OC		BYPP		HI	
	BP	SH	BP	SH	BP	SH	BP	SH	BP	SH	BP	SH
(CMS-17A x HAM-183)	37.50**	20.88**	20.00**	3.79	38.73**	-0.14	-2.58	-4.36**	50.91**	14.25**	4.19	-6.94
(CMS-17A x IB-19)	30.88**	15.06**	14.01**	-1.40	23.10**	-11.38**	6.45**	-2.50	16.24**	20.82**	-9.18*	-19.61**
(CMS-17A x IB2M)	-9.56**	-20.49**	-2.45	-15.63**	23.50**	-11.10**	-9.69**	-10.26**	32.83**	0.56	-16.47**	-26.06**
(CMS-17A x PISF-110-8-1)	13.60**	-0.13	21.21**	4.83	-2.19	-8.04**	-0.88	4.97**	11.36**	-15.69**	5.06	-7.00
(CMS-17A x 3376-R)	48.16**	30.25**	9.95**	-4.91	17.76**	4.87	6.22**	-2.72	45.01**	9.78**	22.54**	8.47*
{CMS-17A x (IB-19 x R-274)}	35.07**	18.75**	17.53**	1.64	14.49**	-6.16*	9.11**	-0.07	38.28**	4.68	16.44**	3.07
{CMS-17A x (KOP-I x RHA-856)}	12.50**	-1.10	3.55	-10.45**	12.85**	-18.77**	-6.15**	-12.31**	55.68**	17.86**	-17.47**	-26.95**
{CMS-17A x (KOP-I x 15 NB-7)}	17.65**	3.43	10.24**	-4.66	25.14**	-2.54	-2.54	-4.72**	37.61**	4.17	9.37*	-3.19
{CMS-17A x (P-356 x R-274)}	0.74	-11.44**	-7.45*	-19.96**	6.17	-23.57**	2.96	-5.70**	82.96**	38.51**	-38.85**	-45.87**
{CMS-17A x (R-296 x 15 NB-7)}	35.15**	18.81**	18.28**	2.29	-7.48*	-9.48**	-6.73**	-14.58**	19.67**	13.47**	-0.08	-11.55**
{CMS-17A x (R-348 x R-274)}	19.85**	5.37*	2.18	-11.63**	30.29**	-6.21*	0.96	-7.53**	47.12**	11.38**	-7.62	-18.23**
{CMS-17A x (RHA-6D-1 x R-272-4)}	41.91**	24.76**	21.55**	7.11**	37.22**	3.58	2.52	3.07*	13.30**	-14.23**	49.41**	32.25**
{CMS-17A x (15 NB-7 x HRA-5)}	34.56**	18.29**	20.92**	4.58	5.19	3.04	-6.78**	-4.00**	56.39**	18.39**	-1.06	-12.42**
{CMS-17A x (15 NB-7 x R-356)}	-0.15	-12.22**	-21.46**	-32.08**	13.02**	-18.65**	-3.06*	1.43	12.87**	-14.55**	-6.15	-16.93**
(CMS-234A x HAM-183)	7.62**	-11.44**	11.72**	-1.88	12.13**	-4.19	5.48**	6.10**	26.44**	-3.43	-5.03	-15.18**
(CMS-234A x IB-19)	10.93**	-12.73**	-12.69**	-23.32**	19.10**	1.77	2.07	2.67	12.08**	16.49**	-36.37**	-44.67**
(CMS-234A x IB2M)	-13.25**	-30.19**	-15.66**	-25.92**	-8.32*	-21.66**	-5.31**	-4.75**	-36.25**	-51.31**	37.29**	19.40**
(CMS-234A x PISF-110-8-1)	38.10**	7.30**	-17.24**	-27.31**	-9.27**	-14.70**	6.94**	13.25**	15.67**	-11.65**	16.37**	1.19
(CMS-234A x 3376-R)	33.94**	4.07	6.82*	-6.18*	20.38**	7.21*	1.06	1.65	-6.52	-28.60**	59.52**	38.71**
{CMS-234A x (IB-19 x R-274)}	29.37**	0.52	10.18**	-3.23	3.69	-11.40**	-1.27	-0.69	1.12	-22.76**	13.72**	-1.11
{CMS-234A x (KOP-I x RHA-856)}	54.74**	20.23**	-4.41	-16.05**	-8.81**	-22.08**	-4.21**	-3.64*	15.84**	-11.52**	29.17**	12.32**
{CMS-234A x (KOP-I x 15 NB-7)}	26.04**	-2.07	5.43	-7.41**	1.37	-13.38**	-4.15**	-3.59*	12.15**	-14.34**	21.72**	5.84
{CMS-234A x (P-356 x R-274)}	1.75	-20.94**	-1.73	-13.69**	-25.97**	-36.74**	2.98*	3.59*	-12.41**	-33.10**	27.84**	11.16**
{CMS-234A x (R-296 x 15 NB-7)}	28.47**	4.72*	-9.76**	-20.74**	0.79	-1.39	-21.01**	-20.55**	-15.06**	-19.47**	23.88**	7.72
{CMS-234A x (R-348 x R-274)}	31.45**	2.13	13.51**	-0.30	10.53**	-5.56	-1.44	-0.86	16.07**	-11.35**	29.33**	12.46**
{CMS-234A x (RHA-6D-1 x R-272-4)}	6.49*	-17.26**	-8.37**	-19.26**	-6.67*	-20.25**	4.33**	4.95**	14.34**	-12.67**	-4.43	-16.90**
{CMS-234A x (15 NB-7 x HRA-5)}	5.66*	-17.91**	-7.25*	-18.54**	-9.56**	-11.41**	1.83	4.86**	-4.50	-27.06**	8.90	-5.31
{CMS-234A x (15 NB-7 x R-356)}	-20.13**	-37.94**	-29.13**	-37.76**	-8.12*	-21.49**	5.36**	10.24**	-23.48**	-41.56**	8.79	-5.40

(ND-2A x HAM-183)	13.90**	-6.27**	31.03**	4.81	-17.28**	-16.47**	-7.47**	-9.16**	1.37	-0.53	-0.10	-10.78**
(ND-2A x IB-19)	-2.83	-22.43**	-24.71**	-39.78**	7.41**	8.47**	7.73**	0.65	-24.41**	-21.43**	-3.95	-22.86**
(ND-2A x IB2M)	-4.42	-23.08**	-4.26	-23.42**	-4.66	-3.72	1.43	0.79	-3.67	-5.47	-17.25**	-28.03**
(ND-2A x PISF-110-8-1)	1.21	-19.20**	15.02**	-8.00**	-8.44**	-7.54**	0.76	6.70**	19.21**	16.97**	-6.04	-22.83**
(ND-2A x 3376-R)	15.38**	-7.89**	21.31**	-2.97	3.69	4.72	7.15**	0.11	-0.85	-2.71	1.29	-18.66**
{ND-2A x (IB-19 x R-274)}	25.51**	0.19	2.21	-18.24**	-15.54**	-14.71**	7.64**	0.56	-12.79**	-14.42**	31.98**	9.03*
{ND-2A x (KOP-I x RHA-856)}	31.82**	5.24*	9.91**	-12.08**	-25.64**	-24.90**	4.72**	-2.16	-6.90*	-8.64**	18.49**	-3.07
{ND-2A x (KOP-I x 15 NB-7)}	36.84**	9.24**	19.06**	-4.77	-16.19**	-15.36**	2.18	-0.11	-13.75**	-15.37**	35.17**	8.55*
{ND-2A x (P-356 x R-274)}	22.27**	-2.39	14.95**	-8.05**	-17.23**	-16.41**	0.98	-5.66**	3.99	2.04	-2.37	-21.59**
{ND-2A x (R-296 x 15 NB-7)}	11.82**	-8.86**	-6.65*	-25.33**	-22.59**	-21.82**	-9.02**	-15.01**	2.25	0.33	-10.54*	-28.15**
{ND-2A x (R-348 x R-274)}	23.89**	-1.10	21.03**	-3.19	-12.08**	-11.21**	-3.88*	-10.20**	-17.55**	-19.09**	32.14**	6.12
{ND-2A x (RHA-6D-1 x R-272-4)}	33.60**	6.66**	13.37**	-0.10	1.61	2.62	2.20	2.76	-5.64	-7.41*	27.51**	7.97*
{ND-2A x (15 NB-7 x HRA-5)}	-6.07*	-25.02**	-14.64**	-29.69**	-17.58**	-16.77**	-0.01	2.97*	10.04**	7.97*	-37.44**	-49.76**
{ND-2A x (15 NB-7 x R-356)}	14.49**	-8.60**	2.52	-17.99**	-17.07**	-16.25**	-2.00	2.54	21.85**	19.57**	-16.22**	-32.72**

*Significant at 5% level and **significant at 1% level

Table 5: Crosses exhibited maximum SCA effects, their mean performance and GCA Effects of parents of twelve characters in sunflower

Character	Desirable crosses	SCA effects	Mean	GCA effects	
				Line	Tester
DFF	CMS-234A x (RHA-6D-1 x R-272-4)	-8.39	75.67	Average	Low
	CMS-17A x IB-2M	-5.51	79.67	Low	Low
	CMS-234A x (P-356 x R-274)	-5.50	73.67	Average	High
DPM	CMS-234A x (RHA-6D-1 x R-272-4)	-7.75	110.67	Average	Low
	CMS-17A x IB-2M	-5.65	113.33	Low	Low
PH (cm)	CMS-17A x (P-356 x R-274)	-18.37	132.73	High	Average
	ND-2A x (KOP-I x RHA-856)	-17.30	135.23	Low	Average
HD (cm)	CMS-17A x (15 NB-7 x HRA-5)	3.50	19.28	High	Low
	CMS-234A x (KOP-I x RHA-856)	2.78	18.46	Low	High
	ND-2A x (RHA-6D-1 x R-272-4)	2.77	19.37	Low	High
SF (%)	CMS-234A x PISF-110-8-1	9.41	86.34	Low	Low
	CMS-234A x (KOP-I x RHA-856)	7.27	85.41	Low	Average
SYPP (g)	ND-2A x (15 NB-7 x R-356)	6.52	33.10	Low	Low
	CMS-17A x (RHA-6D-1 x R-272-4)	5.50	46.50	High	High
	CMS-234A x (KOP-I x RHA-856)	5.46	40.63	Low	High
TW (g)	CMS-234A x (KOP-I x RHA-856)	0.90	5.40	Low	High
	CMS-234A x PISF-110-8-1	0.86	5.53	Low	Low
VW (g/100ml)	CMS-17A x IB-19	5.23	36.97	High	Low
	ND-2A x (15 NB-7 x R-356)	4.94	37.49	Low	Low
HC (%)	CMS-234A x R-296 x 15 NB-7)	4.29	35.89	Low	Low
	ND-2A x (P-356 x R-274)	3.49	30.42	Low	Low
OC (%)	CMS-234A x HAM-183	2.04	36.58	High	Low
	ND-2A x IB-2M	1.94	34.70	Low	Low
BYPP (g)	ND-2A x (15 NB-7 x R-356)	33.32	132.10	Average	High
	CMS-234A x IB-19	28.30	128.70	Low	High
HI (%)	CMS-17A x (RHA-6D-1 x R-272-4)	10.09	47.22	Low	High
	CMS-234A x IB-2M	7.96	44.29	High	Low

GCA: General combining ability, SCA: Specific combining ability

Table 6: Best five hybrids identified on the basis of *per se* performance, economic heterosis and SCA effects for seed yield per plant

S. No.	Crosses	*Per se* performance	Economic heterosis (%)	SCA effects
1	CMS-17A x (RHA-6D-1 x R-272-4)	46.50**	25.34**	5.50**
2	CMS-234A x (R-348 x R-274)	40.77**	9.88*	5.22**
3	CMS-234A x (KOP-I x RHA-856)	40.63**	9.52**	5.46**
4	ND-2A x (RHA-6D-1 x R-272-4)	40.97**	10.42**	3.62*
5	CMS-17A x 3376-R	48.77**	31.46**	2.60

*, ** Significant at 5% level and 1% level of significance, respectively.

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References

1. Ashok S, Mohamad Sheriff N, Narayanan SL. Combining ability studies in sunflower (*Helianthus annuus* L.). Crop Research. 2000; 20(3):457-462.
2. Chandra BS, Ranganatha ARG, Sudheer Kumar S. Heterosis studies for seed yield and its components in sunflower hybrids over locations. Madras Agricultural Journal. 2013; 100(1-3):23-29.
3. Dhootmal RR. Heterosis and combining ability in sunflower (*Helianthus annuus* L.) Ph.D. *Thesis.* Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India, 2017.
4. Dudhe MY, Moon MK, Lande SS. Evaluation of restorer lines for heterosis studies on sunflower. Journal Oilseeds Research. 2009; 26:140.142.

5. Dutta A, Ghosh PD, Sadhukha R, Hossain M, Hossain F. Combining ability and heterosis for yield and its components characters in sunflower (*Helianthus annuus* L.). Journal of Oilseeds Research. 2011; 28(1):33-39.
6. Habib H, Mehdi SS, Rashid A, Iqbal S, Anjum MA. Heterosis Studies in sunflower (*Helianthus annuus* L) crosses for agronomic trait and oil yield under Faisalabad condition. Pakistan Journal of Agrilcultural Sciences. 2005; 43:3-4.
7. Hallauer AR, Miranda JB. Quantitative genetics in maize breeding. Iowa State University Press, Ames, 1986, 267-294.
8. Heiser CB. Taxonomy of Helianthus and Origin of Domesticated Sunflower. Carter, Jack F. (ed.). Sunflower Science and Technology, 1978, 31.
9. Kang SA, Khan FA, Ahsan MZ, Chatha WS, Saeed F. Estimation of combining ability for the development of hybrid genotypes in sunflower (*Helianthus annuus* L.). J Biol. Agric. Healthc. 2013; 3:68-74.
10. Karasu A, Mehmet OZ, Sincik M, Goksoy AT, Turn ZM. Combining ability and heterosis for yield and yield components in sunflower. Not Bot Hort Agrobot Cluj. 2010; 38:259-264.
11. Kempthorne O. Introduction to genetic statistics. *John Wiley and Sons Inc*, New York, 1957.
12. Kinman ML. New development in the USDA and state Experiment Station, Sunflower breeding programme. Proceeding of the Fourth International Sunflower Confefernce, Memphis, Tennessa, 1970, 181-183.
13. Kulkarni VV, Supriya SM. Heterosis and combining ability studies for yield and yield components traits in sunflower (*Helianthus annuus* L.). International Journal of Current Microbiology Applied Sciences. 2017; 6(9):3346-3357.
14. Leclercq P. Une sterilite cytoplasmique chez tournesol. Annales del Amelioration des Plantes. 1969; 19:99-106.
15. Longanathan P, Gopalan A. Combining ability in sunflower (*Helianthus annuus* L.). Research on Crops. 2006; 7(1):213-217.
16. Madhavilatha K, Reddy AVV, Devasenamma V. Hybrid vigour and combining ability in sunflower (*Helianthus annuus* L.). hybrids involving CMS lines. Journal of Oilseeds Research. 2005; 22(2):309-312.
17. Neelima S, Parameshwarappa KG. Heterosis and combining ability for seed yield, oil content and other quantitative traits in Sunflower (*Helianthus annuus* L.). Journal of Oilseeds Research. 2009; 26(2):94-97.
18. Parameshwari C, Muralidharan V, Subbalaksmi B, Manivannan M. Genetic analysis of yield and important traits in sunflower (*Helianthus annuus* L.) hybrids. Journal of Oilseeds Research. 2004; 21(1):168-170.
19. Patil Rudragouda, Vikas Kulkarni V, Mallikarjun Kenganal, Shankergoud I, Diwan JR. Combining ability studies in restorer lines of sunflower (*Helianthus annuus* L.). Journal of Applied and Natural Science. 2017; 9(1):603-608.
20. Patil R, Shaker Goud I, Vikas Kulkarni, Banakar C. combining ability and gene action studies for seed yield and its components in Sunflower (*Helianthus annuus* L.). Electronic Journal of Plant Breeding. 2012; 3(3):861-867
21. Radhika P, Jagadeshwar K, Khan KA. Heterosis and combining ability through line x tester analysis in sunflower (*Helianthus annuus* L.). Journal of Research, Acharya N. G. Ranga Agricultural University, 2001; 29(2-3):35-43.
22. Rathi SR, Nichal SS, Vaidhya ER, Wandhare MR, Janjal SM. Heterosis for yield, its component and oil contents in sunflower (*Helianthus annuus* L.). International Journal of Tropical Agriculture. 2016; 34(7):1063-1072.
23. Reddy A, Madhavi Latha K. Combining ability for yield and yield components in sunflower. Journal of Research, Acharya N. G. Ranga Agricultural University, 2005; 33(2):12-17.
24. Sawargaonkar SL, Ghodke MK. Heterosis in relation to combining ability studies in restorer lines of Sunflower. Helia. 2008; 31:95-100.
25. Sharma S, Bajaj RK, Kaur N, Seghal SK. Combining ability studies in sunflower (*Helianthus annuus* L.). Crop Improvement. 2003; 30(1):69-73.
26. Sher AK, Habib A, Ayub K, Muhammad S, Shah MK, Bashir A. Using line × tester analysis for earliness and plant height traits in sunflower (*Helianthus annuus* L.). Recent Res. Sci. Technol. 2009; 1:202-206.
27. Singh UK, Dhiraj Kumar. Combining ability study in sunflower. Journal of Genetics, Genomics and Plant Breeding. 2018; 2(2):1-6.
28. Sujatha M, Reddy AV. Heterosis and combining ability for seed yield and other yield contributing characters in sunflower (*Helianthus annuus* L.). Journal Oilseeds Research. 2009; 26(1):21-31.
29. Tavade SN, Lande SS, Patil SP. Combining ability studies in restorer lines of sunflower (*Helianthus annuus* L.). Karnataka Journal Agricultural Sciences. 2009; 22(1):32-35.
30. Vikas Kulkarni, Shankegoud I, Govindappa MR. Evaluation and characterization of sunflower germplasm accessions for quantitative characters. Electronic Journal of Plant Breeding. 2015; 6(1):257-263.