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Research Article

Combining ability for seed yield, its components and oil content in sunflower (*Helianthus annuus* L.)

A.U. Ingle, S.S. Nichal*, V.L. Gawande, E.R. Vaidya and B.S. Kharat
Department of Agricultural Botany, Post Graduate Institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S)
E-mail: nichal_satish@rediffmail.com

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Abstract
The experimental material was developed by crossing newly developed seven lines and eight testers in Line x Tester fashion. Parents and their 56 hybrids were evaluated in randomized block design with three replications at Oilseed Research Unit, Dr. PDKV, Akola during *kharif* 2014 to estimate the combining ability effects. Among the parents CMS-243A, RHA-138-2R and AKSF-14R were found to be best general combiners for most of the yield contributing traits, seed yield and oil content. Line CMS-234A and AKSF-8R were also found to be good general combiner for oil content, thus these parents should be included in future hybridization programme for improvement in seed yield as well as oil content in sunflower. On the basis of mean performance, specific combining ability effects of crosses and general combining ability effects of the parents, three crosses *viz.*, CMS-243A x AKSF-8R, CMS-234A x RHA-138-2R and CMS-234A x AKSF-6R were identified as promising crosses for seed yield and as well as oil content.

Key words
Sunflower**, g**eneral combining ability, specific combining ability, line x tester

Introduction

Sunflower (*Helianthus annuus* L.) is one of the most important oilseed crop in the world. Sunflower is originated in the South-West United States-Mexico area (Heifer, 1955; Vranceanu and Stoenescu, 1979). Sunflower was introduced for commercial cultivation in India in 1969 from former USSR. Low yielding genotypes and hybrids of sunflower are the major constraints of sunflower productivity. To conquer this constraint breeders have attention towards production of hybrids through heterosis breeding, which become possible due to discovery of cytoplasmic male sterility by Leclercq (1969) and fertility restoration system by Kinman (1970).

In order to exploit heterosis, it is necessary to identify the best combiner and superior parental lines. Combining ability analysis provides the information for selection of the desirable parents and cross combinations for exploitation. Thus, present investigation is undertaken to study the combining ability effects of parents and cross combinations for selecting superior parental lines and hybrids for yield, yield contributing characters and oil content.

Materials and methods

The experimental material consist of seven CMS lines *viz.*, CMS-243A, CMS-17A, AKSF-10-1A, AKSF-12A, CMS-234A, CMS-10A, CMS-850A and eight testers *viz.*, AKSF-6R, AKSF-14R, RHA-138-2R, 856R, AKSF-8R, PKV-105R, 189/1R, AKSF-12R and their 56 F_1's. The seven CMS lines were crossed with the eight restorers/testers in Line x Tester fashion during *rabi* 2013-14 and obtained sufficient crossed seeds. The 56 F_1 crosses along with their 15 parents were evaluated in Randomized Block Design (RBD) with three replications at the farm of Oilseeds Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra State, India) during *kharif* 2014. Each entry was sown in one row of 4.5 m length in each replication. The inter and intra-row spacing was 60 cm and 30 cm, respectively. All the standard agronomic and plant protection measures were used. The data was recorded on plant basis, from each genotype in each replication on 5 randomly selected plants and their average value was computed for ten quantitative traits *viz.*, days to 50% flowering, days to maturity, plant height at harvest (cm), head diameter (cm), hundred seed weight (g), volume weight (g/100ml), seed filling percentage, hull content (%), seed yield per plant (g) and oil content (%). Oil content of all genotypes was determined by using Bench top Pulse Nuclear magnetic Resonance (NMR) Spectrometer (Model MQC OXFORD). Analysis of variance for combining ability was done according to the line x tester method. The significance of GCA and SCA effects was determined at the 0.05 and 0.01 level using the t-test (Singh and Choudhary, 1977).

Results and discussion

The analysis of variance carried out for the seed yield, its component and oil content is presented in table 1. From the analysis of variance for combining ability, it is quite evident that significant differences existed among lines except for volume weight and hull content. Mean sum of squares due to testers were significant for most of characters except head diameter, 100 seed weight, hull content and seed filling percentage, justifying the selection of parents for combining ability analysis. The crosses between these lines and testers differed significantly from each other for all the characters indicating that lines and testers complement each other for combining ability. The variance due to interaction between females and males was significant for the characters. This indicates the presence of substantial amount of genetic variability among the parents and crosses for all the characters under study.

The information on the general combining ability of parents for yield and its component characters is very much essential as it facilitates the selection of best parents in breeding programmes. The importance of combining ability in selection of parents for hybridization has been emphasized by many workers in sunflower (Deengra *et al.*, 2012).

The estimates of general combining ability effects of female and male parents are presented in table 2. In sunflower positive *gca* effects are desirable for all the characters except days to 50 per cent flowering, days to maturity, plant height and hull content. In sunflower early to medium duration hybrids or genotypes are preferred and in the present study among the lines CMS-17A (-0.71 & -1.36), AKSF-12A (-0.75 & -0.66) and among testers 856R (-1.09 & -1.54), 189/1R (-1.14 & -1.07) and RHA-138-2R (-0.52 & -0.69) were found to be good general combiners for earliness in flowering and maturity, respectively. The lines CMS-10A (-17.88), AKSF-10-1A (-7.55), CMS-17A (-6.37), CMS-850A (-2.57) and tester AKSF-8R (-1.45) were good general combiners for dwarfness. Gejli *et al.* (2011), Deengra *et al.* (2012) and Asif *et al.* (2013) also assessed the general combining ability for earliness and dwarfness in sunflower.

Hull content is an important character in deciding the ideal hybrid or genotype. Among the parents, AKSF-12A (-1.71) showed maximum negative *gca* effect, followed by AKSF-10-1A (-1.31), CMS-234A (-1.23), AKSF-8R (-1.11), AKSF-12R (-0.58) and AKSF-6R (-0.49) and were good combiners for low hull content.

The main use of sunflower is for edible oil purpose, thus the improvement in oil content is the major objective of sunflower improvement programme. In the present study, among lines tested, only two line, *viz.*, CMS-243A (1.23) and CMS-234A (0.48) recorded positive significant gca effects for oil content, whereas among the testers, five tester *viz*., AKSF-8R (0.89), PKV-105R (0.61), AKSF-14R (0.59), 856R (0.50) and RHA-138-2R (0.45) recorded positive significant *gca* effects. Hence, line CMS-243A, CMS-234A and testers AKSF-8R, PKV-105R, AKSF-14R, 856R and RHA-138-2R were found to be good general combiners for oil content. Venkanna *et al*. (2005), Patil *et al*. (2007) and Asif *et al*. (2013) also reported the good general combiners for oil content in sunflower.

The characters like head diameter, 100 seed weight, volume weight and seed filling percentage are yield contributing characters and increase in these characters ultimately result in increased seed yield. The parent CMS-243A (2.03), AKSF-10-1A (1.02), CMS-850A (0.32), PKV-105R (13.33), RHA-138-2R (6.80), AKSF-6R (4.66) and AKSF-14R (3.49) were good combiners for head diameter. For hundred seed weight, lines, CMS-17A (0.63) and CMS-243A (0.51) exhibited positive significant *gca* effects and testers, 856R (0.55), RHA-138-2R (0.49), AKSF-6R (0.27) and AKSF-14R (0.17) recorded positive significant *gca* effects. Among the parents, lines CMS-243A (1.72) and CMS-234A (1.43) and tester AKSF-14R (3.23), 856R (3.10), AKSF-6R (1.19) and RHA-138-2R (1.11) were good general combiners for volume weight. The female AKSF-10-1A (1.89), CMS-243A (1.76) and CMS-17A (1.55) exhibited positive significant *gca* effects for seed filling. Among males AKSF-8R (1.23) showed maximum significant positive *gca* effect followed by RHA-138-2R (1.19) and were good general combiners for seed filling percentage.

Improvement in seed yield is a prime objective of any breeding programme. For seed yield per plant, among the lines tested, AKSF-12A (0.93) and CMS-243A (7.22) recorded positive significant gca effects. Among testers, RHA-138-2R (9.66) followed by AKSF-6R (7.06) and AKSF-14R (3.21) recorded positive significant *gca* effects. Thus among the parents CMS-243A, AKSF-12A, RHA-138-2R, AKSF-6R and AKSF-14R were good general combiners for seed yield performance. Many workers *viz.*, Venkanna *et al*. (2005), Patil *et al*. (2007), Deengra *et al*. (2012) and Asif *et al*. (2013) also reported best general combiner for yield and various yield contributing characters like head diameter, 100 seed weight seed filling percentage and hull content.

The estimates of specific combining ability effects of the 56 crosses are presented in table 3. In sunflower, positive *sca* effects are desirable for all the traits studied except for days to 50 % flowering, days to maturity, plant height and hull content for which negative *sca* effects are desirable.

Among the 56 crosses, 16 crosses noted the significant negative *sca* effect for days to 50 per cent flowering, 12 crosses registered significant negative *sca* effect for days to maturity whereas for plant height, 25 crosses recorded significant negative *sca* effect. Significant negative sca effects are desirable for these characters. For yield contributing traits like head diameter, hundred seed weight, volume weight and seed filling percentage,

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positive significant *sca* effects are desirable. Thus among the 56 crosses, 21 crosses exhibited positive significant *sca* effect for head diameter, 18 crosses exhibited significant positive *sca* effect for hundred seed weight. For the character volume weight and seed filling percentage 11 and 15 crosses respectively marked significant positive *sca* effects. The desirable negative significant *sca* effect for hull content recorded by 21 crosses, whereas desirable positive significant *sca* effects for oil content was recorded by 14 cross combinations. Out 56 crosses, 24 crosses recorded significant positive *sca* effects for seed yield. Patil *et al.* (2007) and Asif *et al.* (2013) also reported sca effects in desirable for seed yield per plant. Venkanna *et al.* (2005) also reported *sca* effects in desirable direction for days to 50% flowering, days to maturity, 100 seed weight, seed yield per plant, head diameter and plant height. Chavan *et al.* (2009) reported similar results for specific combining ability for seed yield, oil content per cent, head diameter, 100 seed weight and plant height.

On the basis of mean seed yield performance, *gca* and *sca* effects, five crosses were identified as promising crosses (Table 4). The cross AKSF-12A x RHA-138-2R recorded highest seed yield (64.42 g) and significant *sca* effects (6.68%) with parents having high x high gca effects, whereas the cross CMS-850A x RHA-138-2R has recorded second highest mean seed yield per plant (63.59 g) and significant *sca* effect (7.12%) with low x high *gca* effect of the parent involve. The cross CMS-234A x AKSF-6R recorded high mean seed yield per plant (63.16 g) along with highly significant *sca* effect (10.19%) and parents having low x high gca interaction. The fourth cross CMS-243A x AKSF-8R has given the 62.69 g seed yield per plant along with significant *sca* effect (5.47%) and having high x low *gca* effects of parents. The fifth cross CMS-234A x RHA-138-2R exhibited the high mean seed yield per plant (62.66 g) and significant sca effect (7.09%) with low x high *gca* effects of the parents involved. Out of these five promising crosses, three crosses *viz.*, CMS-243A x AKSF-8R, CMS-234A x RHA-138-2R and CMS-234A x AKSF-6R has also noted the high oil content and significant *sca* effects for oil content. Thus, these three crosses *viz.*, CMS-243A x AKSF-8R, CMS-234A x RHA-138-2R and CMS-234A x AKSF-6R have been identified as promising crosses for seed yield and as well as oil content and these crosses should be further tested in preliminary or multilocation hybrid trials for further commercial exploitation.

In this study cytoplasmic male sterile lines and restorer were used as parents and line x tester analysis was used as an appropriate method for the determination of general and specific combining abilities.

The highest seed yield recorded by the cross AKSF-12A x RHA-138-2R (64.42 g) followed by CMS-850A x RHA138-2R (63.59 g). These crosses were also found to be promising for most of the yield contributing characters. Three crosses *viz.*, CMS-243A x AKSF-8R (40.54%), CMS-234A x RHA138-2R (40.29%) and CMS-234A x AKSF-6R (39.52%) exhibited high mean performance for oil content along with seed yield.

Among the parents CMS-243A, RHA-138-2R and AKSF-14R were found to be best general combiners for most of the yield contributing traits, seed yield and also for oil content, thus these parents should be included in future hybridization programme for improvement in seed yield as well as oil content in sunflower. Three combinations *viz.*, CMS-234A x RHA-138-2R, CMS-234A x AKSF-6R and CMS-243A x AKSF-8R recorded highly significant sca effects for oil content as well as for seed yield.

Considering the mean performance of crosses, *gca* effects of parents and *sca* effects of crosses, three crosses *viz.* CMS-243A x AKSF-8R, CMS-234A x RHA-138-2R and CMS-234A x AKSF-6R are identified as promising crosses for seed yield as well as oil content and thus, these crosses needs further evaluation in preliminary or multi-location hybrid trials for further commercial exploitation.

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Table 1. Analysis of variance for combining ability for different traits in sunflower

Sources of variation	d.f.	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	100 seed weight (g)	Volume weight (g/100ml)	Seed filling percentage	Hull content (%)	Oil content (%)	Seed yield /plant (g)
Replications	2	1.35	7.04	2.87	1.33	0.56	6.57	9.56	3.42	1.02	13.76
Crosses	55	17.31**	18.04**	1301.50**	19.77**	2.87**	43.39**	35.99**	41.16**	8.94**	310.78**
Females (lines)	6	26.81*	32.02*	4241.70**	52.19**	5.39*	40.05	93.58*	54.51	19.41*	360.29*
Males (testers)	7	46.66**	48.46**	1828.54*	18.01	4.71	172.18**	18.36	16.78	17.46*	864.93**
Females vs Males	42	11.06**	10.97**	793.65**	15.41**	2.20*	22.41**	30.70**	43.32**	6.03**	211.35**
Error	110	0.45	2.30	8.91	0.45	0.19	2.21	3.13	1.23	0.33	13.88

*, ** significant at 5 and 1 per cent level, respectively

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Table 2. General combining ability effects of parents for different traits in sunflower

Traits	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	100 seed weight (g)	Volume weight (g/100ml)	Seed filling percentage	Hull Content (%)	Oil content (%)	Seed yield /plant (g)
Females (lines)										
CMS -243A	2.04 **	2.22**	23.59**	2.03**	0.51**	1.72**	1.76**	0.67**	1.23**	7.22**
CMS-17A	-0.71 **	-1.36**	-6.37**	0.14	0.63**	0.12	1.55**	1.40**	0.18	-1.08*
AKSF10- 1A	0.54 **	0.01	-7.55**	1.02**	0.12	-0.57	1.89**	-1.31**	-0.24*	0.39
AKSF- 12A	-0.75 **	-0.66*	2.08*	-0.69**	-0.38**	0.02	0.68	-1.71*	-0.01	0.93*
CMS-234A	-0.71 **	-0.53	8.70**	-0.14	-0.16	1.43**	-2.36**	-1.23**	0.48**	-1.26**
CMS-10A	-0.75 **	-0.32	-17.88**	-2.69**	-0.01	-2.06**	-0.74*	2.25**	-1.74**	-5.84**
CMS-850A	0.33 *	0.64*	-2.57**	0.32*	-0.72**	-0.66	-2.78**	-0.07	0.11	-0.35
SE (D)±	0.14	0.31	0.61	0.14	0.09	0.30	0.36	0.23	0.12	0.43
CD (5%)	0.27	0.61	1.21	0.27	0.18	0.60	0.72	0.45	0.23	0.86
CD (1%)	0.36	0.81	1.60	0.36	0.23	0.80	0.95	0.59	0.31	1.13
Males (testers)										
AKSF-6R	0.29*	0.08	0.91	4.66**	0.27**	1.19**	-0.10**	-0.49*	-0.28*	7.06**
AKSF-14R	3.44**	3.32**	0.30	3.49**	0.17**	3.23**	-0.77**	0.82**	0.59**	3.21**
RHA-138-2R	-0.52**	-0.69*	0.79	6.80**	0.50**	1.11**	1.19**	-0.47	0.45**	9.66**
856-R	-1.09**	-1.54**	0.66	-1.43**	0.55**	3.10**	0.09	1.70**	0.50**	-1.30**
AKSF-8R	-0.52**	-0.59	-1.45*	-2.74**	-0.16	0.60	1.23**	-1.11**	0.89**	-1.02*
PKV-105R	0.29*	0.84*	0.54	13.33**	-0.34**	-1.11**	0.52	0.01	0.61**	-1.65**
189/1R	-1.14**	-1.07**	-1.13	-6.99**	-0.11	-4.43**	-1.05**	0.12	-1.31**	-6.95**
AKSF-12R	-0.76**	-0.35	-0.63	-17.12**	-0.88**	-3.68**	-1.10**	-0.58*	-1.44**	-9.00**
SE (D)±	0.15	0.33	0.65	0.15	0.10	0.32	0.39	0.24	0.13	0.46
CD (5%)	0.29	0.66	1.29	0.29	0.19	0.64	0.77	0.48	0.25	0.92
CD (1%)	0.38	0.87	1.71	0.38	0.25	0.85	1.01	0.64	0.33	1.21

*, ** significant at 5 and 1 per cent level, respectively

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Table 3. Specific combining ability effects of crosses for different traits in sunflower

S.No.	Crosses	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	100 seed weight (g)	Volume weight (g/100ml)	Seed filling (%)	Hull content (%)	Oil content (%)	Seed yield per plant (g)
1	CMS-243A X AKSF-6R	1.63**	-0.08	-14.46**	1.56**	0.31	2.82**	3.14**	2.12**	0.22	-8.58**
2	CMS-243A X AKSF-14R	2.15**	0.35	13.31**	-0.84*	0.54*	4.52**	-3.86**	2.12**	0.62	2.62*
3	CMS-243A X RHA138-2R	-0.90*	0.35	13.80**	0.75	-1.11**	-1.70	-1.48	-5.62**	0.13	-2.95*
4	CMS-243A X 856R	-2.99**	-2.79**	-3.51*	0.91*	0.29	-1.04	2.29*	5.27**	-1.60**	5.48**
5	CMS-243A X AKSF-8R	-0.57	-0.08	6.88**	-0.58	-0.44	1.08	0.48	-2.34**	0.73*	9.34**
6	CMS-243A X PKV-105R	0.29	1.49	-5.07**	3.22**	0.95**	-3.63**	-2.48*	0.03	-0.57	-14.81**
7	CMS-243A X 189/1R	-1.28**	-1.27	-5.82**	-3.94**	0.27	-1.24	-0.91	2.54**	0.82*	11.88**
8	CMS-243A X AKSF-12R	1.67**	2.02*	-5.14**	2.86**	-0.81**	-0.82	2.81**	-4.12**	-0.35	-2.98*
9	CMS-17A X AKSF-6R	-0.96*	-1.16	-2.83	-0.11	-0.03	0.55	1.69	-0.36	-2.06**	2.15
10	CMS-17A X AKSF-14R	2.57**	2.94**	12.14**	-3.60**	0.88**	1.14	-1.98	-1.23	-0.66	6.79**
11	CMS-17A X RHA138-2R	-1.82**	-2.73**	-37.38**	-2.94**	-0.37	-3.25**	-3.60**	3.53**	1.32**	-15.24**
12	CMS-17A X 856R	-0.91*	-1.88*	-14.68**	-2.57**	-1.29**	-2.23*	0.16	-3.13**	0.34	10.17**
13	CMS-17A X AKSF-8R	2.52**	1.84*	-10.57**	4.42**	0.68**	0.85	1.02	4.70**	-1.55**	-12.75**
14	CMS-17A X PKV-105R	-2.96**	-1.92*	36.36**	0.21	0.87**	0.31	3.07**	-2.08**	1.09**	7.33**
15	CMS-17A X 189/1R	1.47**	2.65**	16.35**	1.74**	0.94**	5.57**	4.97**	-2.17**	2.16**	4.75**
16	CMS-17A X AKSF-12R	0.09	0.27	0.61	0.76	-1.68**	-2.92**	-5.32**	0.74	-0.65	-3.21*
17	AKSF10-1A X AKSF-6R	1.46**	0.46	3.48*	-3.04**	0.53*	-1.72*	0.02	-2.04**	0.37	-3.75**
18	AKSF10-1A X AKSF-14R	1.98**	1.56	-0.68	-1.63**	-1.20**	-2.43**	4.35**	-1.52*	-0.52	-6.22**
19	AKSF10-1A X RHA138-2R	-0.40	0.56	7.14**	-1.43**	0.97**	-1.90*	3.73**	-3.40**	-0.96**	3.26**
20	AKSF10-1A X 856R	2.51**	2.42**	5.37**	4.48**	-0.21	-2.11*	-4.84**	-3.06**	-0.61	5.87**
21	AKSF10-1A X AKSF-8R	-3.40**	-1.87*	-18.25**	1.00*	0.052	2.98**	0.02	4.60**	-0.22	-1.22
22	AKSF10-1A X PKV-105R	-0.21	-0.63	-0.47	-0.03	-0.85**	-0.14	-2.94**	0.11	-0.47	3.67**
23	AKSF10-1A X 189/1R	0.89*	0.94	-9.80**	-0.11	0.22	0.69	-4.70**	2.47**	0.86*	-2.96*
24	AKSF10-1A X AKSF-12R	-2.83**	-3.44**	13.20**	-1.95**	0.48	4.63**	4.35**	2.85**	1.55**	1.35
25	AKSF-12A X AKSF-6R	-1.92**	-2.20*	5.19**	0.65	0.57*	-1.40	-2.11*	-4.98**	1.89**	2.37
26	AKSF-12A X AKSF-14R	0.94*	0.23	5.30**	3.10**	-0.15	0.56	-0.77	-0.97	-0.54	-4.99**
27	AKSF-12A X RHA138-2R	-0.44	0.23	19.12**	1.14**	-0.34	1.23	-0.39	2.49**	-1.38**	6.68**
28	AKSF-12A X 856R	-1.54**	-2.25*	-28.92**	-2.31**	-0.35	2.18*	-0.96	1.84**	0.65	-15.43**
29	AKSF-12A X AKSF-8R	3.23**	3.80**	17.46**	-1.25**	0.76**	0.23	2.89**	-1.78**	-0.19	14.24**
30	AKSF-12A X PKV-105R	1.08**	0.70	3.72*	-0.48	0.08	2.01*	-2.39*	0.05	1.30**	2.96*

*, ** significant at 5 and 1 per cent level, respectively

Table 3. Contd.,

S.No.	Crosses	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	100 seed weight (g)	Volume weight (g/100ml)	Seed filling (%)	Hull content (%)	Oil content (%)	Seed yield per plant (g)
31	AKSF-12A X 189/1R	-1.49**	-0.73	-14.36**	1.10**	-1.04**	-3.65**	0.18	2.42**	-1.44**	-6.67**
32	AKSF-12A X AKSF-12R	0.13	0.23	-7.49**	3.18**	0.47	-1.16	3.56**	0.94	-0.29	0.86
33	CMS-234A X AKSF-6R	-0.29	1.34	14.97**	-1.43**	-0.21	0.79	-2.39*	3.15**	1.63**	10.19**
34	CMS-234A X AKSF-14R	-2.10**	-0.57	-14.46**	2.57**	0.71**	0.96	-1.39	6.20**	1.31**	-3.91**
35	CMS-234A X RHA138-2R	0.19	-0.57	7.22**	-1.41**	0.81**	3.68**	1.98	0.69	1.67**	7.09**
36	CMS-234A X 856R	0.42	0.29	-6.08**	-0.34	0.49	0.95	1.41	-2.98**	-0.88**	-13.51**
37	CMS-234A X AKSF-8R	0.52	-0.33	-3.97*	-1.30**	-1.467**	-5.31**	1.60	-0.23	-2.53**	-2.65*
38	CMS-234A X PKV-105R	2.04**	1.24	-5.51**	-0.08	-0.75**	-1.89*	0.98	1.90**	-1.72**	-10.79**
39	CMS-234A X 189/1R	-0.86*	-1.19	9.35**	-1.18**	-0.01	-1.43	-0.11	-4.32**	0.03	3.37**
40	CMS-234A X AKSF-12R	0.09	-0.23	-1.52	-1.83**	0.43	2.26**	-2.07*	-4.42**	0.48	10.20**
41	CMS-10A X AKSF-6R	0.75	1.13	-6.78**	1.44**	-1.14**	1.06	-1.02	-6.07**	0.55	-6.15**
42	CMS-10A X AKSF-14R	-2.73**	-1.77*	-18.01**	-1.19**	-1.15**	-5.68**	0.64	-5.20**	-1.64**	0.41
43	CMS-10A X RHA138-2R	2.23**	2.56**	-22.93**	1.67**	-0.10	-0.39	4.36**	-0.17	-0.61	-5.97**
44	CMS-10A X 856R	0.46	1.75*	35.64**	1.40**	0.83**	1.19	0.45	3.45**	1.62**	4.70**
45	CMS-10A X AKSF-8R	0.23	-0.54	20.15**	-1.70**	1.32**	-0.32	-6.36**	-1.39*	2.58**	0.11
46	CMS-10A X PKV-105R	-1.58**	-2.30**	-9.46**	-0.03	0.55*	3.98**	0.36 ``	3.63**	0.12	11.36**
47	CMS-10A X 189/1R	-0.16	-1.06	-5.60**	0.25	-1.02**	-1.04	3.93**	-0.98	-2.76**	-3.25**
48	CMS-10A X AKSF-12R	0.80*	0.23	6.99**	-1.93**	0.72**	1.22	-2.36*	6.73**	0.15	-1.20
49	CMS-850A X AKSF-6R	-0.67	0.51	0.43	0.93*	-0.03	-2.09*	0.69	8.89**	-2.61**	3.75**
50	CMS-850A X AKSF-14R	-2.81**	-2.73**	2.40	1.60**	0.37	0.93	3.02**	0.60	1.43**	5.31**
51	CMS-850A X RHA138-2R	1.14**	-0.40	13.02**	2.23**	0.14	2.34**	-4.60**	2.49**	-0.18	7.12**
52	CMS-850A X 856R	2.05**	2.46**	12.19**	-1.57**	0.25	1.06	1.49	-1.39*	0.49	2.74*
53	CMS-850A X AKSF-8R	-2.52**	-2.83**	-11.70**	-0.59	-0.91**	0.50	0.35	-3.57**	1.18**	-7.07**
54	CMS-850A X PKV-105R	1.333**	1.41	-19.58**	-2.80**	-0.85**	-0.64	3.39**	-3.64**	0.25	0.28
55	CMS-850A X 189/1R	1.43**	0.65	9.88**	2.15**	0.65*	1.10	-3.36**	0.04	0.34	-7.12**
56	CMS-850A X AKSF-12R	0.05	0.94	-6.65**	1.56**	0.39	-3.20**	-0.98	-2.71**	-0.89**	-5.02**
	SE(D)±	0.88	0.88	1.72	0.39	0.25	0.86	1.02	0.64	0.33	1.22
	CD 5%	1.74	1.74	3.42	0.77	0.49	1.71	2.02	1.27	0.66	2.42
	CD 1%	2.30	2.30	4.52	1.01	0.66	2.25	2.68	1.68	0.87	3.20

*, ** significant at 5 and 1 per cent level, respectively

Table 4. Mean performance, *gca* and *sca* effects for yield and oil content in promising crosses

Crosses	Seed yield/plant			Oil content		Significant *gca* effects of parents for other characters
	Mean seed yield /plant	*sca* effect	*gca* effects of parents	Oil content (%)	*sca* effect	
AKSF-12A x RHA138-2R	64.42**	6.680 **	0.927 * x 9.659 ** H H	36.75	-1.380**	$P_{1-1, 2, 8.}$ $P_{2-1, 2, 4, 5, 6, 7, 8, 9,}$
CMS-850A x RHA138-2R	63.59**	7.123 **	-0.350 **x 9.659 ** L H	38.07	-0.176	$P_{1-3, 4,}$ $P_{2-1, 2, 4, 5, 6, 7, 8, 9}$
CMS-234A x AKSF-6R	63.16**	10.199 **	-1.255 ** x 7.061 ** L H	39.52**	1.634**	$P_{1-1, 6, 9}$ $P_{2-4,5, 6, 8,}$
CMS-243A x AKSF-8R	62.69**	5.479 **	7.217** x -1.020 ** H L	40.54**	0.733*	$P_{1-4, 5, 6, 7, 9}$ $P_{2-1, 2, 3, 6, 7, 8, 9}$
CMS -234A x RHA138-2R	62.66**	7.095 **	-1.255 ** x 9.659 ** L H	40.29**	1.674**	$P_{1-1, 6, 9}$ $P_{2-1, 2, 4, 5, 6, 7, 8, 9}$

*, ** significant at 5 and 1 per cent level, respectively

1 - Days to 50% flowering 2 - Days to maturity 3 -Plant height (cm) 4 – Head diameter (cm) 5 - 100 seed weight (g) 6 - Volume weight (g/100ml)

6 - Seed filling (%) 7 - Hull content (%) 8 - Oil content (%) 9 - Seed yield per plant (g)