INTERNATIONAL JOURNAL OF RESEARCHES IN BIOSCIENCES, AGRICULTURE AND TECHNOLOGY
© VISHWASHANTI MULTIPURPOSE SOCIETY (Global Peace Multipurpose Society) R. No. MH-659/13(N)
www.vmsindia.org

General and Specific Combining Ability in Sunflower (*Helianthus annuus* L.)

S. S. Nichal, G. S.Sahane, N. V. Kayande, R. D. Ratnaparkhi and E. R. Vaidya
Post Graduate Institute, Department of Agricultural Botany,
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola -444 104 (M.S)
Email id: - nichal_satish@rediffmail.com

ABSTRACT
The experimental material was developed by crossing newly developed five lines and nine testers in Line x Tester fashion during *summer* 2015. Parents and their forty five hybrids were evaluated in randomized block design with three replications at Oilseed Research Unit, Dr. PDKV, Akola during *kharif* 2016 to estimate the combining ability effects. Among the parents AKSF-14-2A, EC-601951R and IR-1-1R were found to be best general combiners for most of the yield contributing traits, seed yield and oil content. The line MS-400A and tester P-146R 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. The highest significant specific combining ability (sca) effect for seed yield was recorded by the cross AKSF-14-1A x P-146R followed by CMS-2A x R-16, AKSF-14-2A x AKSF-14R, AKSF-10-1-1A x P-146R and AKSF-14-1A x EC-601951R. On the basis of mean performance, specific combining ability effects of crosses and general combining ability effects of the parents, three crosses *viz.*, AKSF-14-1A X EC-601951R, AKSF-14-2A X IR-1-1R and AKSF-14-2A X AKSF-14R are identified as promising crosses for seed yield and the cross MS-400A X EC-601951R is identified as most promising cross for seed as well as oil content.
Key words: Sunflower, General 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, due to which the area and production of sunflower is decreasing in past few years. To conquer this constraint breeders have centre of 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.

Material and Methods

The experimental material consist of five CMS lines *viz* CMS-2A, AKSF-14-2A, AKSF-14-1A, AKSF-10-1-1A, MS-400A and nine testers *viz.*, IR-1-1R, EC-601951R, AKSF-14R, 856R, AKSF-12R, P-146R, 272R, R-16, BC-3-1R and their 45 F_1's. The five CMS lines were crossed with the nine restorers/testers in Line x Tester fashion during *summer* 2015 and obtained sufficient crossed seeds. The 45 F_1 crosses along with their 14 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* 2016. 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 (%).The oil content (%) was determined by using Bench top Pulse Nuclear Magnetic Resonance (NMR) Spectrometer (Model MQC OXFORD). The samples of 5-10 grams size were taken for determination of oil content. 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).

Result and Discussion

The analysis of variance carried out for the seed yield, its component and oil content is presented in Table 1. The variance due to crosses was significant for all the characters expect for days to maturity. The mean squares due to lines (females) were found to be significant for days to 50% flowering, 100 seed weight and plant height. However, the magnitude of variance in females was non-significant for days to maturity, head diameter, volume weight, seed filling percentage, hull content, oil content and seed yield per plant. The mean squares for testers (males) was significant for days to maturity, head diameter and hull content and it was non-significant for days to 50% flowering, plant height, 100 seed weight, volume weight, seed filling percentage, oil content and seed yield per plant. Highly significant variation was noticed in males and females interactions for all the characters expect for days to maturity.

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% flowering, days to maturity, plant height and hull content, for which negative gca effects are desirable.

In sunflower early to medium duration hybrids or genotypes are preferred and in the present study among the lines AKSF-10-1-1A (-0.95 & -0.15), CMS-2A (-0.84 & -0.56) and among testers 856R (-1.23 & -0.66), P-146R (-1.77 & -1.33) and AKSF-12R (-0.97 & -1.06) were found to be good general combiners for earliness in flowering and maturity, respectively. The lines AKSF-10-1-1A (-11.38), AKSF-14-1A (-4.42) and tester BC-3-1R (-17.70) and IR-1-1R (-2.70) 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. Low hull content ultimately results in high seed weight and seed yield. Among the parents, BC-3-1R (-3.94) showed maximum negative gca effect, followed by EC-601951R (-3.55), IR-1-1R (-2.71), 272R (-1.85) and MS-400A (-2.49) 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.,* MS-400A (0.85) and AKSF-14-2A (0.47) recorded positive significant gca effects for oil content, whereas among the testers, three tester *viz.*, EC-601951R (1.12), AKSF-12R (0.76), and P-146R (0.62) recorded positive significant gca effects. Hence, line MS-400A, AKSF-14-2A and testers EC-601951R, AKSF-12R and P-146R 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 EC-601951R (2.87), IR-1-1R (1.52), 272R (0.57) and AKSF-14-2A (0.55) registered significant gca effect in desirable direction and were good combiners for head diameter. For hundred seed weight, lines, MS-400A (2.27) and CMS-2A (0.42) and AKSF-14-2A (0.34) exhibited positive significant gca effects and testers, IR-1-1R (0.65), R-16 (0.42), AKSF-12R (0.34) and EC-601951R (0.32) recorded positive significant gca effects. Among the parents, lines MS-400A (2.27) and AKSF-14-2A (1.93) and tester EC-601951R (3.34), IR-1-1R (2.60) were good general combiners for volume weight. The female AKSF-14-2A (1.69) exhibited positive significant gca effects for seed filling. Among males EC-601951R (3.34) showed maximum significant positive gca effect followed by AKSF-12R (1.85) 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-14-2A (4.34) and CMS-2A (1.99) recorded positive significant gca effects. Among testers, EC-601951R (8.83) followed by IR-1-1R (5.41) and AKSF-14R (1.83) recorded positive significant gca effects. Thus among the parents AKSF-14-2A, CMS-2A, EC-601951R IR-1-1R 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 45 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 45 crosses, the cross CMS-2A x IR-1-1R (-2.75) noted highest significant negative sca effect for days to 50% flowering, followed by AKSF-10-1-1A X BC-3-1R (-2.37), MS-400A X P-146R (-2.23). The cross AKSF-10-1-1A X BC-3-1R (-4.17) registered highest negative sca effect for days to maturity.

For the plant height, the cross AKSF-10-1-1A x EC-601951R (-18.66) recorded highest significant negative sca effect, followed by MS-400A x BC-3-1R (-18.63) and AKSF-14-1A x 856R (-18.27). The cross AKSF-14-2A x BC-3-1R (4.53) exhibited highest positive significant sca effect for head diameter.

For 100 seed weigh, the cross, AKSF-14-1A x P-146R (1.80) exhibited maximum significant positive sca effect, followed by CMS-2A x R-16 (1.21), MS-400A x AKSF-14R (0.87) and AKSF-14-1A x EC-601951R (0.86). The maximum positive significant sca effect for volume weight was marked by AKSF-14-1A x P-146R (7.43), which was best specific cross combination for the volume weight.

The highest significant sca effect for seed filling percentage was recorded by CMS-2A x AKSF-12R (8.14) followed by AKSF-14-2A x AKSF- 14R (6.43) and CMS-2A x 272R (5.48). The highest negative significant sca effect for hull content recorded by the cross MS-400A x 856R (-7.75) followed by CMS-2A x R-16 (-6.09), AKSF-14-2A x AKSF-14R (-5.70) and AKSF-10-1-1A x P-146R (-5.37). The cross AKSF-14-2A x P-146R (3.15) was the best specific cross combination for oil content, followed by AKSF-10-1-1A x IR-1-1R (2.96), MS-400A x BC-3-1R (2.54) and AKSF-14-2A x 272R (2.45).

Out 45 crosses, 19 crosses recorded significant positive sca effects for seed yield. The cross AKSF-14-1A x P-146R (11.03) recorded the highest significant positive sca effect for seed yield followed by CMS-2A x R-16 (10.84), AKSF-14-2A x AKSF-14R (10.59), AKSF-10-1-1A x P-146R (10.45) and AKSF-14-1A x EC-601951R (10.30).

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, heterosis, gca and sca effects for seed yield, six crosses were identified as promising crosses (Table 4.). The cross AKSF-14-1A X EC-601951R recorded highest seed yield (50.93 g), highest standard heterosis (47.21%) and highly significant sca effect (10.30) and low x high gca effects of parents, whereas the cross AKSF-14-2A X IR-1-1R has recorded second highest mean seed yield per plant (49.10 g), standard heterosis (41.91%) and highly significant sca effect (7.44) with high x high gca effect of the parent involve. The cross AKSF-14-2A X AKSF-14R showed high mean seed yield per plant (48.67 g), standard heterosis (40.66%) along with highly significant sca effect (10.59) and having high x high gca interaction of parents. The cross AKSF-14-1A X IR-1-1R, MS-400A X EC-601951R and CMS-2A X R-16 which were on 4th, 5th and 6th position also exhibits the high mean seed yield, significant standard heterosis and significant sca effect for seed yield.

Out of these six promising crosses, the cross MS-400A X EC-601951R which rank 5th for seed yield have also recorded the high oil content (39.20%), highly significant standard heterosis as well as sca effects for oil content. Thus, the cross MS-400A X EC-601951R have been identified as most promising cross for seed yield as well as for oil content, whereas the top three crosses *viz.*, AKSF-14-1A X EC-601951R, AKSF-14-2A X IR-1-1R and AKSF-14-2A X AKSF-14R were identified as promising crosses for seed yield. Thus, these crosses need further evaluation in preliminary or multilocation hybrid trials for further commercial exploitation.

Conclusion

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-14-1A X EC-601951R (50.93 g) followed by AKSF-14-2A X IR-1-1R (49.10 g) and AKSF-14-2A X AKSF-14R (48.76 g) these crosses were also found to be promising for most of the yield contributing characters. The cross *viz.*, MS-400A X EC-601951R exhibited high mean performance for oil content along with seed yield.

Among the parents line AKSF-14-2A and tester EC-601951R 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.*, AKSF-14-1A x IR-1-1R, CMS-2A x R-16, MS-400A X EC-601951R 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.*, AKSF-14-1A X EC-601951R, AKSF-14-2A X IR-1-1R and AKSF-14-2A X AKSF-14R are identified as promising crosses for seed yield and the cross MS-400A X EC-601951R is identified as most promising cross for seed as well as oil content and thus, these crosses needs further evaluation in preliminary or multilocation hybrid trials for further commercial exploitation.

Table 1., Analysis of variance for combining ability

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)
		1	2	3	4	5	6	7	8	9	10
Replications	2	0.45	13.43	24.32	0.41	0.04	1.52	9.61	0.81	3.19	24.30
Crosses	44	12.79**	9.31	797.80**	19.74**	2.64**	78.21**	52.35**	80.26**	9.55**	224.87**
Females (lines)	4	29.45*	9.84	2087.29*	7.75	9.10*	178.23	28.62	77.45	10.53	413.02
Males (testers)	8	18.15	17.79*	1096.25	40.28*	3.55	67.65	51.08	176.79*	10.57	332.83
Females vs Males	32	9.36**	7.12	562.00**	16.11**	1.61**	68.35**	55.64**	56.47**	9.17**	174.36**
Error	88	1.94	8.55	13.72	1.11	0.25	5.88	6.56	6.18	1.00	10.10

Note: *Significant at 5% level of significance
** Significant at 1% level of significance

Table 2. General Combining ability effects of parents

	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)
	1	2	3	4	5	6	7	8	9	10
Females (lines)										
CMS-2A	-0.84**	-0.56	6.67**	-0.12	0.42**	1.04	0.25	1.29*	-0.45*	1.99**
AKSF-14-2A	0.23	-0.41	10.63**	0.55**	0.34**	1.93**	1.69**	-0.33	0.47*	4.34**
AKSF-14-1A	-0.06	0.17	-4.42**	-0.02	-0.56**	-1.48**	-0.63	1.83**	-0.39	-0.10
AKSF-10-1-1A	-0.95**	-0.15	-11.38**	-0.81**	-0.70**	-3.76**	-0.52	-0.29	-0.48*	-6.19**
MS-400A	1.63**	0.95	-1.49	0.40	0.49**	2.27**	-0.78	-2.49**	0.85**	-0.04
SE (D)±	0.70	1.42	2.30	0.55	0.26	1.45	1.31	1.36	0.53	1.47
CD (5%)	0.26	0.54	0.87	0.21	0.10	0.55	0.49	0.51	0.20	0.55
CD (1%)	0.53	1.07	1.74	0.41	0.20	1.10	0.99	1.03	0.40	1.11
Males (testers)										
IR-1-1R	0.16	0.67	-2.70*	1.52**	0.65**	2.60**	0.32	-2.71**	0.31	5.41**
EC-601951R	0.43	-0.73	12.38**	2.87**	0.32*	3.34**	3.11**	-3.55**	1.12**	8.83**
AKSF-14R	1.16**	0.47	10.10**	-0.12	0.05	-1.34	-2.54**	3.19**	-0.61*	1.83*
856R	-1.23**	-0.66	-1.90	0.02	-0.88**	-2.53**	0.05	3.17**	-0.93**	-2.61**
AKSF-12R	-0.97**	-1.06	-1.61	-0.64*	0.34*	0.94	1.85**	0.92	0.76**	-3.83**
P-146R	-1.17**	-1.33	0.88	-1.76**	-0.32*	1.09	-0.62	-0.98	0.62*	0.10
272R	-0.90*	-0.13	1.13	0.57*	-0.35*	-2.27**	0.52	-1.85**	-0.27	-4.97**
R-16	1.63**	0.61	-0.57	0.18	0.42**	-0.22	-2.61**	5.76**	-1.35**	-0.24
BC-3-1R	0.89*	2.14**	-17.70**	-2.63**	-0.23	-1.61*	-0.08	-3.94**	0.35	-4.52**
SE (D)±	0.94	1.90	3.09	0.74	0.35	1.95	1.76	1.83	0.71	1.97
CD (5%)	0.36	0.72	1.17	0.28	0.13	0.74	0.66	0.69	0.27	0.75
CD (1%)	0.71	1.44	2.33	0.55	0.26	1.47	1.32	1.38	0.54	1.49

Note: *Significant at 5% level of significance
** Significant at 1% level of significance

Table 3., Specific combining ability effects of crosses

Sr. No.	Crosses	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	100 seed weight (g)
		1	2	3	4	5
1	CMS-2A X IR-1-1R	-2.75**	0.03	-12.71**	-3.61**	-0.15
2	CMS-2A X EC-601951R	-2.02*	-0.90	-6.83*	-0.39	-0.28
3	CMS-2A X AKSF-14R	-1.75*	-1.10	-7.75**	-0.66	-0.92**
4	CMS-2A X 856R	-0.02	-2.63	8.648**	1.76**	0.05
5	CMS-2A X AKSF-12R	-1.28	-0.23	7.16**	-0.90	0.42
6	CMS-2A X P-146R	2.24**	2.36	11.60**	2.55**	-0.60*
7	CMS-2A X 272R	2.31**	1.83	-15.41**	-0.16	-0.38
8	CMS-2A X R-16	-0.22	0.43	10.31**	0.90	1.21**
9	CMS-2A X BC-3-1R	3.51**	0.23	4.98	0.51	0.65*
10	AKSF-14-2A X IR-1-1R	-0.49	-0.78	-0.47	1.51*	0.18
11	AKSF-14-2A X EC-601951R	0.57	0.61	8.21**	-1.67**	-0.01
12	AKSF-14-2A X AKSF-14R	2.50**	1.74	7.19**	1.09	0.52
13	AKSF-14-2A X 856R	-0.09	1.21	-2.90	-1.41*	-0.10
14	AKSF-14-2A X AKSF-12R	-0.69	-1.05	-5.99*	-2.31**	-0.733*
15	AKSF-14-2A X P-146R	-0.83	-1.11	-16.22**	-0.26	-0.667*
16	AKSF-14-2A X 272R	-0.76	-2.31	-11.16**	-0.47	0.29
17	AKSF-14-2A X R-16	0.70	-0.71	6.15 *	-1.00	-0.38
18	AKSF-14-2A X BC-3-1R	-0.89	2.41	15.19**	4.53**	0.90**
19	AKSF-14-1A X IR-1-1R	1.80*	-0.71	9.15**	0.95	-0.57
20	AKSF-14-1A X EC-601951R	0.53	0.35	11.97**	4.17**	0.86**
21	AKSF-14-1A X AKSF-14R	-0.53	-0.51	1.75	-1.16	0.02
22	AKSF-14-1A X 856R	-0.80	-0.71	-18.27**	-2.33**	-0.53
23	AKSF-14-1A X AKSF-12R	1.60	1.35	0.26	2.86**	0.007
24	AKSF-14-1A X P-146R	0.80	-1.71	11.67**	-1.68**	1.80**
25	AKSF-14-1A X 272R	-0.46	-0.24	10.22**	-1.79**	0.26
26	AKSF-14-1A X R-16	-1.33	0.02	-16.57**	1.37*	-0.83**
27	AKSF-14-1A X BC-3-1R	-1.60	2.15	-10.20**	-2.38**	-1.02**
28	AKSF-10-1-1A X IR-1-1R	1.68*	0.95	-12.18**	-2.05**	0.20
29	AKSF-10-1-1A XEC-601951R	-0.24	-0.31	-18.66**	-1.47*	-0.23
30	AKSF-10-1-1A X AKSF-14R	0.02	0.15	14.91**	1.75**	-0.49
31	AKSF-10-1-1A X 856R	1.42	1.95	1.41	0.25	-0.12
32	AKSF-10-1-1A X AKSF-12R	1.82*	0.35	-1.87	0.01	0.54
33	AKSF-10-1-1A X P-146R	0.02	0.28	10.73**	0.27	0.04
34	AKSF-10-1-1A X 272-R	-0.24	1.42	14.58**	4.09**	0.60*
35	AKSF-10-1-1A X R-16	-2.11*	-0.64	-17.58**	-2.97**	0.36
36	AKSF-10-1-1A X BC-3-1R	-2.37**	-4.17*	8.65**	0.10	-0.91**
37	MS-400A X IR-1-1R	-0.23	0.51	16.22**	3.19**	0.33
38	MS-400A X EC-601951R	1.16	0.24	5.30*	-0.62	-0.32
39	MS-400A X AKSF-14R	-0.23	-0.28	-16.11**	-1.02	0.87**
40	MS-400A X 856R	-0.50	0.17	11.12**	1.73**	0.71*
41	MS-400A X AKSF-12R	-1.43	-0.42	0.43	0.33	-0.24
42	MS-400A X P-146R	-2.23**	0.17	-17.79**	-0.87	-0.58
43	MS-400A X 272R	-0.83	-0.68	1.76	-1.65**	-0.78*
44	MS-400A X R-16	2.96**	0.91	17.68**	1.70**	-0.36
45	MS-400A X BC-3-1R	1.36	-0.62	-18.63**	-2.77**	0.38
	SE(D)±	2.12	4.26	6.91	1.65	0.79
	CD 5%	0.80	1.62	2.62	0.62	0.30
	CD 1%	1.60	3.22	5.22	1.25	0.60

Note: * Significant at 5% level of significance
** Significant at 1% level of significance

Cont........Table 3.,Specific combining ability effects of crosses

Sr. No.	Crosses	Volume weight (g/100ml)	Seed filling (%)	Hull content (%)	Oil content (%)	Seed yield per plant (g)
		6	7	8	9	10
1	CMS-2A X IR-1-1R	-3.13	-2.65	0.94	-1.61**	-8.87**
2	CMS-2A X EC-601951R	2.14	-2.11	-2.05	0.17	-9.63**
3	CMS-2A X AKSF-14R	0.54	-5.45**	-0.99	-0.21	-2.23
4	CMS-2A X 856R	7.32**	3.28*	6.58**	0.64	7.31**
5	CMS-2A X AKSF-12R	2.52	8.14**	1.34	-0.22	6.77**
6	CMS-2A X P-146R	-8.92**	-9.71**	3.44*	-0.85	-3.83*
7	CMS-2A X 272R	-5.03**	5.48**	-3.35*	-0.65	-3.25
8	CMS-2A X R-16	3.12	4.28**	-6.098**	2.22**	10.84**
9	CMS-2A X BC-3-1R	1.44	-1.25	0.17	0.51	2.89
10	AKSF-14-2A X IR-1-1R	0.67	-0.43	1.41	-1.13	7.44**
11	AKSF-14-2A X EC-601951R	-5.34**	2.77	-0.32	-0.38	-3.408*
12	AKSF-14-2A X AKSF-14R	1.61	6.43**	-5.70**	-0.13	10.59**
13	AKSF-14-2A X 856R	1.27	-4.83**	1.25	-1.61**	-7.59**
14	AKSF-14-2A X AKSF-12R	-3.00	-4.63**	2.67	-1.25*	-3.17
15	AKSF-14-2A X P-146R	2.95	1.83	-4.72**	3.15**	-6.57**
16	AKSF-14-2A X 272R	4.91**	-3.29*	6.91**	2.45**	-1.16
17	AKSF-14-2A X R-16	-4.36*	0.50	-1.16	-1.20	-5.16**
18	AKSF-14-2A X BC-3-1R	1.28	1.63	-0.32	0.12	9.05**
19	AKSF-14-1A X IR-1-1R	1.12	1.23	0.40	1.37*	7.95**
20	AKSF-14-1A X EC-601951R	1.57	-1.56	2.90	-0.90	10.30**
21	AKSF-14-1A X AKSF-14R	-7.39**	3.43*	-2.54	1.37*	-6.96**
22	AKSF-14-1A X 856R	-8.77**	-1.83	-4.95**	-2.50**	-6.51**
23	AKSF-14-1A X AKSF-12R	0.68	-1.63	5.59**	-0.24	-4.79**
24	AKSF-14-1A X P-146R	7.43**	1.17	0.26	0.52	11.03**
25	AKSF-14-1A X 272R	3.46*	-1.96	-1.82	0.92	4.71**
26	AKSF-14-1A X R-16	-0.08	-1.16	-0.04	0.97	-9.45**
27	AKSF-14-1A X BC-3-1R	1.97	2.30	0.19	-1.50*	-6.27**
28	AKSF-10-1-1A X IR-1-1R	2.94	3.16*	-0.67	2.96**	-7.35**
29	AKSF-10-1-1A X EC-601951R	2.86	3.65*	-2.20	-0.65	-1.34
30	AKSF-10-1-1A X AKSF-14R	3.82*	-5.67**	4.85**	0.92	-3.70*
31	AKSF-10-1-1A X 856R	-4.45**	1.39	4.87**	2.44**	-1.26
32	AKSF-10-1-1A X AKSF-12R	1.93	2.59	-4.54**	0.58	4.39*
33	AKSF-10-1-1A X P-146R	4.05*	2.05	-5.37**	-1.52*	10.45**
34	AKSF-10-1-1A X 272-R	-7.38**	2.25	-0.60	-2.48**	-2.06
35	AKSF-10-1-1A X R-16	-2.19	-4.60**	5.78**	-0.57	5.13**
36	AKSF-10-1-1A X BC-3-1R	-1.57	-4.80**	-2.11	-1.68**	-4.24*
37	MS-400A X IR-1-1R	-1.59	-1.28	-2.09	-1.58*	0.83
38	MS-400A X EC-601951R	-1.24	-2.74	1.67	1.76**	4.07*
39	MS-400A X AKSF-14R	1.41	1.25	4.39**	-1.95**	2.31
40	MS-400A X 856R	4.63**	1.98	-7.75**	1.03	8.05**
41	MS-400A X AKSF-12R	-2.13	-4.48**	-5.069**	1.13	-3.19
42	MS-400A X P-146R	-5.51**	4.65**	6.39**	-1.29*	-11.09**
43	MS-400A X 272R	4.04*	-2.48	-1.12	-0.23	1.78
44	MS-400A X R-16	3.52*	0.98	1.52	-1.41*	-1.35
45	MS-400A X BC-3-1R	-3.11	2.11	2.06	2.54**	-1.43
	SE(D)±	4.37	3.93	4.09	1.60	4.42
	CD 5%	1.66	1.49	1.55	0.61	1.67
	CD 1%	3.30	2.97	3.09	1.21	3.33

Note: * Significant at 5% level of significance
** Significant at 1% level of significance

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 (g)	SCA effect	GCA effects of parents		
AKSF-14-1A X EC-601951R	50.93**	10.30**	-0.10 X 8.83** L H	35.27	P1 :1,3, P2:,4,5,6,7,8,9
AKSF-14-2A X IR-1-1R	49.10**	7.44**	4.34** X 5.41** H H	35.10	P1 :4,5,6,7,9 P2:3,4,5,6,8
AKSF-14-2A X AKSF-14R	48.67**	10.59**	4.34** X 1.83** H H	35.17	P1 : 4,5,6,7,9 P2:2
AKSF-14-1A X IR-1-1R	45.17**	7.95**	-0.10 x 5.41 ** L H	35.27	P1: 1, 3 P2: 3, 4, 5, 6, 8
MS-400A X EC-601951R	44.77**	4.07*	-0.04 x 8.83** L H	39.20**	P1: 5,6,8,9 P2: 4, 5, 6, 7, 8, 9
CMS-2A X R-16	44.50**	10.84**	1.99** x 0.24 H L	35.87	P1: 1, 5,9 P2: 5

Note : * Significant at 5% level of significance,

** Significant at 1% level of significance

P_1- Line, **P_2**- Tester

H - High gca effect

L - Low gca effect

1) Days to 50% flowering, **2)** Days maturity **3**) Plant height, **4**) Head diameter, **5)** 100 seed weight, **6**) Volume weight, **7**) Seed filling percentage, **8)** Hull content, **9**) Oil content.

REFERENCES

Asif, M., Y.G. Shadakshari, S.J. Naik, S. Venkatesha, K.T. Vijayakumar and K.V. Basavaprabhu, 2013. Combining ability studies for seed yield and it's contributing traits in sunflower (*Helianthus annuus* L.). *International Journal of Plant Sciences,* 8(1):19-24.

Chavan, M.H., M.K. Ghodke, S.L. Savargaonkar, R.C. Mahajan and P.K. Jagtap, 2009. Combining ability studies in restorer lines of sunflower. *J. Oilseeds Res.,* (26):1

Deengra, S.N., N. Kumar, V. Kumar and R.P.S. Dhaka, 2012. combining ability studies in sunflower (*Helianthus annuus* L.). *Prog. Agric.*, 12(1):154-157.

Gejli, K., S. Goud and K.M. Boraiah, 2011. Studies on the combining ability of dwarf restorer lines in sunflower (*Helianthus annuus* L.). *Helia*, 54:89-98.

Heifer, C.B. 1955. Origin and development of cultivated sunflower. *Ann. Bio. Teach.,* (17):161-167.

Kinman, M.L., 1970. New developments in USDA and state experiment station sunflower breeding programme. *In: Proceedings of 4th International Sunflower Conference,* Memphis, Tennessee, USA, pp. 181-183.

Leclercq P., 1969. Une sterilite male cytoplasmique chez le tournesol. *Annales del Ameloation des Plantes*, 19 : 99-106.

Patil Y.S., R.D. Ratnaparkhi, B. D. Gite, P.A. Kahate and S. P. Patil, 2007. Combining ability studies in sunflower (*Helianthus annuus* L). *PKV Res. J.,* 31(2):16-20.

Singh, R.B. and B.D. Chaudhary, 1977.Biometrical methods in quantitativegenetic analysis. *Line x Tester analysis, Kalyani Publishers,* New Delhi. (10).

Venkanna, V., D. Lokanadha Reddy and A.R.G. Ranganatha, 2005. Combining ability for seed yield and yield components of new inbreds in sunflower. *J. Oilseeds Res.,* 22 (2):394-395.

Vranceanu, A.V. and F.M. Stoenescu, 1979. Expression of heterosis in single, three-way and double cross sunflower hybrids. *Analcae Institutulai de Ceretari Pentu Ceeale Plante Fundulea*, 44:29-36.