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Combining Ability for Seed yield, its Components and Oil Content in Sunflower (*Helianthus annuus* L.)

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Abstract: *The experimental material was developed by crossing newly developed seven lines and eight testers in Line x Tester fashion during* rabi *2013. Parents and their fifty six 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. The highest significant sca effect for seed yield was recorded by the cross AKSF-12A x AKSF-8R followed by CMS-10A x PKV-105R and CMS-234A x AKSF-6R. 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.*

Keywords: 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 center 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.

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

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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 NMR (nuclear magnetic resonance) machine. 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% 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 CMS-17A (-0.708 & -1.363), AKSF-12A (-0.750 & -0.655) and among testers 856R (-1.089 & -1.542), 189/1R (-1.137 & -1.065) and RHA-138-2R (-0.518 & -0.685) were found to be good general

Table 1
Analysis of variance for combining ability

Sources of variation	*d.f.*	*Days to 50% flowering* 1	*Days to maturity* 2	*plant height (cm)* 3	*Head diameter (cm)* 4	*100 seed weight (g)* 5	*Volume weight (g/ 100ml)* 6	*Seed filling percentage* 7	*Hull content (%)* 8	*Oil content (%)* 9	*Seed yield/ plant (g)* 10
Replications	2	1.350	7.035	2.873	1.334	0.561	6.5746	9.563	3.417	1.017	13.760
Crosses	55	17.310**	18.039**	1301.5**	19.765**	2.867**	43.392**	35.985**	41.162**	8.941**	310.784**
Females(lines)	6	26.805*	32.023*	4241.7**	52.191**	5.394*	40.050	93.579*	54.508	19.414*	360.293*
Males(testers)	7	46.659**	48.461**	1828.54*	18.0110	4.709	172.184**	18.359	16.784	17.458*	864.927**
Females vs Males	42	11.061**	10.971**	793.653**	15.409**	2.199*	22.405**	30.695**	43.318**	6.025**	211.354**
Error	110	0.448	2.301	8.91	0.448	0.190	2.209	3.130	1.233	0.332	13.884

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 1	*Days to maturity* 2	*plant height (cm)* 3	*Head diameter (cm)* 4	*100 seed weight (g)* 5	*Volume weight (g/ 100ml)* 6	*Seed filling percentage* 7	*Hull content (%)* 8	*Oil content (%)* 9	*Seed yield/ plant (g)* 10
Females (lines)										
CMS -243A	2.042 **	2.220 **	23.590 **	2.033 **	0.513 **	1.718 **	1.762 **	0.666 **	1.227 **	7.217 **
CMS-17A	-0.708 **	-1.363 **	-6.366 **	0.141	0.627 **	0.116	1.554 **	1.398 **	0.181	-1.083 *
AKSF10- 1A	0.542 **	0.012	-7.550 **	1.023 **	0.117	-0.569	1.887 **	-1.307 **	-0.243 *	0.385
AKSF- 12A	-0.750 **	-0.655 *	2.075 *	-0.690 **	-0.376 **	0.022	0.679	-1.713 *	-0.010	0.927 *
CMS-234A	-0.708 **	-0.530	8.700 **	-0.136	-0.157	1.430 **	-2.363 **	-1.226 **	0.477 **	-1.255 **
CMS-10A	-0.750 **	-0.321	-17.883 **	-2.693 **	-0.009	-2.061 **	-0.738 *	2.254 **	-1.738 **	-5.840 **
CMS-850A	0.333 *	0.637 *	-2.566 **	0.323 *	-0.715 **	-0.656	-2.780 **	-0.072	0.106	-0.350
SE (D)±	0.136	0.309	0.609	0.136	0.089	0.303	0.361	0.226	0.117	0.432
CD (5%)	0.270	0.613	1.207	0.271	0.176	0.601	0.715	0.449	0.233	0.857
CD (1%)	0.357	0.811	1.597	0.358	0.233	0.795	0.946	0.594	0.308	1.133
Males (testers)										
AKSF-6R	0.292 *	0.077	0.914	4.659 **	0.265**	1.186 **	-0.101 **	-0.485 *	-0.283 *	7.061 **
AKSF-14R	3.435 **	3.315 **	0.297	3.487 **	0.168**	3.226 **	-0.768 **	0.821 **	0.589 **	3.208 **
RHA-138-2R	-0.518 **	-0.685 *	0.789	6.802 **	0.499 **	1.113 **	1.185 **	-0.473	0.448 **	9.659 **
856-R	-1.089 **	-1.542 **	0.662	-1.427 **	0.551 **	3.096 **	0.089	1.696 **	0.501 **	-1.304 **
AKSF-8R	-0.518 **	-0.589	-1.447 *	-2.741 **	-0.156	0.599	1.232 **	-1.111 **	0.889 **	-1.020 *
PKV-105R	0.292 *	0.839 *	0.543	13.334 **	-0.343 **	-1.109 **	0.518	0.01	0.605 **	-1.646 **
189/1R	-1.137 **	-1.065 **	-1.127	-6.991 **	-0.108	-4.429 **	-1.054 **	0.121	-1.307 **	-6.954 **
AKSF-12R	-0.756 **	-0.351	-0.630	-17.122 **	-0.875 **	-3.681 **	-1.101 **	-0.580 *	-1.441 **	-9.004 **
SE (D)±	0.146	0.331	0.651	0.146	0.095	0.324	0.386	0.242	0.125	0.462
CD (5%)	0.289	0.656	1.291	0.289	0.188	0.642	0.765	0.480	0.249	0.916
CD (1%)	0.382	0.867	1.708	0.383	0.249	0.850	1.012	0.635	0.329	1.212

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

** Significant at 1% level of significance

combiners for earliness in flowering and maturity, respectively. The lines CMS-10A (-17.883), AKSF-10-1A (-7.550), CMS-17A (-6.366), CMS-850A (-2.566) and tester AKSF-8R (-1.447) 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, AKSF-12A (-1.713) showed maximum negative gca effect, followed by AKSF-10-1A (-1.307), CMS-234A (-1.226), AKSF-8R (-1.111), AKSF-12R (-0.580) and AKSF-6R (-0.485) 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 (1.227) and CMS-234A (0.477) recorded positive significant gca effects for oil content, where as among the testers, five tester *viz.*, AKSF-8R (0.889), PKV-105R (0.605), AKSF-14R (0.589), 856R (0.501) and RHA-138-2R (0.448) 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 (2.033), AKSF-10-1A (1.023), CMS-850A (0.323), PKV-105R (13.334), RHA-138-2R (6.802), AKSF-6R (4.659) and AKSF-14R (3.487) were good combiners for head diameter. For hundred seed weight, lines, CMS-17A (0.627) and CMS-243A (0.513) exhibited positive significant gca effects and testers, 856R (0.551), RHA-138-2R (0.499), AKSF-6R (0.265) and AKSF-14R (0.168) recorded positive significant gca effects. Among the parents, lines CMS-243A (1.718) and CMS-234A (1.430) and tester AKSF-14R (3.226), 856R (3.096), AKSF-6R (1.186) and RHA-138-2R (1.113) were good general combiners for volume weight. The female AKSF-10-1A (1.887), CMS-243A (1.762) and CMS-17A (1.554) exhibited positive significant gca effects for seed filling. Among males AKSF-8R (1.232) showed maximum significant positive gca effect followed by RHA-138-2R (1.185) 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 (0.927) and CMS-243A (7.217) recorded positive significant gca effects. Among testers, RHA-138-2R (9.659) followed by AKSF-6R (7.061) and AKSF-14R (3.208) 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.

Table 3
Specific combining ability effects of crosses

Sr.No.	*Crosses*	*Days to 50% flowering* 1	*Days to maturity* 2	*Plant height (cm)* 3	*Headdiameter (cm)* 4	*100 seed weight (g)* 5
1	CMS-243A X AKSF-6R	1.625 **	-0.077	-14.457 **	1.564 **	0.305
2	CMS-243A X AKSF-14R	2.149 **	0.351	13.314 **	-0.842 *	0.542 *
3	CMS-243A X RHA138-2R	-0.899 *	0.351	13.800 **	0.746	-1.106 **
4	CMS-243A X 856R	-2.994 **	-2.792 **	-3.505 *	0.910 *	0.289
5	CMS-243A X AKSF-8R	-0.565	-0.077	6.876 **	-0.575	-0.441
6	CMS-243A X PKV-105R	0.292	1.494	-5.066 **	3.221 **	0.949 **
7	CMS-243A X 189/1R	-1.280 **	-1.268	-5.821 **	-3.943 **	0.274
8	CMS-243A X AKSF-12R	1.673 **	2.018 *	-5.143 **	2.858 **	-0.812 **
9	CMS-17A X AKSF-6R	-0.958 *	-1.161	-2.834	-0.105	-0.026
10	CMS-17A X AKSF-14R	2.565 **	2.935 **	12.138 **	-3.604 **	0.881 **
11	CMS-17A X RHA138-2R	-1.815 **	-2.732 **	-37.377 **	-2.937 **	-0.374
12	CMS-17A X 856R	-0.911 *	-1.875 *	-14.681 **	-2.568 **	-1.289 **
13	CMS-17A X AKSF-8R	2.518 **	1.839 *	-10.567 **	4.416 **	0.684 **
14	CMS-17A X PKV-105R	-2.958 **	-1.923 *	36.358 **	0.205	0.871 **
15	CMS-17A X 189/1R	1.470 **	2.649 **	16.349 **	1.735 **	0.936 **

(*contd....Table 3*)

Sr.No.	*Crosses*	*Days to 50% flowering* 1	*Days to maturity* 2	*Plant height (cm)* 3	*Headdiameter (cm)* 4	*100 seed weight (g)* 5
16	CMS-17A X AKSF-12R	0.089	0.268	0.614	0.756	-1.683 **
17	AKSF10-1A X AKSF-6R	1.458 **	0.464	3.484 *	-3.040 **	0.531 *
18	AKSF10-1A X AKSF-14R	1.982 **	1.560	-0.678	-1.628 **	-1.199 **
19	AKSF10-1A X RHA138-2R	-0.399	0.560	7.141 **	-1.431 **	0.973 **
20	AKSF10-1A X 856R	2.506 **	2.417 **	5.370 **	4.477 **	-0.209
21	AKSF10-1A X AKSF-8R	-3.399 **	-1.869 *	-18.250**	1.001 *	0.052
22	AKSF10-1A X PKV-105R	-0.208	-0.631	-0.465	-0.029	-0.845 **
23	AKSF10-1A X 189/1R	0.887 *	0.940	-9.800 **	-0.106	0.217
24	AKSF10-1A X AKSF-12R	-2.827 **	-3.440 **	13.198 **	-1.951 **	0.481
25	AKSF-12A X AKSF-6R	-1.917 **	-2.202 *	5.191 **	0.647	0.574 *
26	AKSF-12A X AKSF-14R	0.940 *	0.226	5.296 **	3.101 **	-0.149
27	AKSF-12A X RHA138-2R	-0.44	0.226	19.115 **	1.135 **	-0.34
28	AKSF-12A X 856R	-1.536 **	-2.250 *	-28.923 **	-2.310 **	-0.352
29	AKSF-12A X AKSF-8R	3.226 **	3.798 **	17.458 **	-1.246 **	0.755 **
30	AKSF-12A X PKV-105R	1.083**	0.702	3.716 *	-0.476	0.075
31	AKSF-12A X 189/1R	-1.488 **	-0.726	-14.359**	1.100 **	-1.037 **
32	AKSF-12A X AKSF-12R	0.131	0.226	-7.494 **	3.175 **	0.474
33	CMS-234A X AKSF-6R	-0.292	1.339	14.966 **	-1.428 **	-0.212
34	CMS-234A X AKSF-14R	-2.101 **	-0.565	-14.462 **	2.567 **	0.711 **
35	CMS-234A X RHA138-2R	0.185	-0.565	7.223 **	-1.412 **	0.807 **
36	CMS-234A X 856R	0.423	0.292	-6.081 **	-0.338	0.488
37	CMS-234A X AKSF-8R	0.518	-0.327	-3.967 *	-1.300 **	-1.465 **
38	CMS-234A X PKV-105R	2.042 **	1.244	-5.509 **	-0.084	-0.745 **
39	CMS-234A X 189/1R	-0.863 *	-1.185	9.349 **	-1.181 **	-0.013
40	CMS-234A X AKSF-12R	0.089	-0.232	-1.519	-1.828 **	0.428
41	CMS-10A X AKSF-6R	0.750	1.131	-6.784 **	1.436 **	-1.137 **
42	CMS-10A X AKSF-14R	-2.726 **	-1.774 *	-18.012 **	-1.190 **	-1.153 **
43	CMS-10A X RHA138-2R	2.226 **	2.560 **	-22.927 **	1.671 **	-0.101
44	CMS-10A X 856R	0.464	1.750 *	35.635 **	1.399 **	0.827 **
45	CMS-10A X AKSF-8R	0.226	-0.536	20.150 **	-1.703 **	1.321 **
46	CMS-10A X PKV-105R	-1.583 **	-2.298 **	-9.459 **	-0.034	0.547 *
47	CMS-10A X 189/1R	-0.155	-1.060	-5.601 **	0.249	-1.024 **
48	CMS-10A X AKSF-12R	0.798 *	0.226	6.997 **	-1.931 **	0.720 **
49	CMS-850A X AKSF-6R	-0.667	0.506	0.433	0.927 *	-0.034
50	CMS-850A X AKSF-14R	-2.810 **	-2.732 **	2.404	1.595 **	0.367
51	CMS-850A X RHA138-2R	1.143 **	-0.399	13.023 **	2.228 **	0.139
52	CMS-850A X 856R	2.048 **	2.458 **	12.185 **	-1.570 **	0.247
53	CMS-850A X AKSF-8R	-2.52**	-2.827 **	-11.700 **	-0.592	-0.906 **
54	CMS-850A X PKV-105R	1.333 **	1.411	-19.576 **	-2.803 **	-0.853 **
55	CMS-850A X 189/1R	1.429 **	0.649	9.883 **	2.147 **	0.646 *
56	CMS-850A X AKSF-12R	0.048	0.935	-6.653 **	1.564 **	0.393
	SE(D)±	0.8759	0.8759	1.724	0.3868	0.2521
	CD 5%	1.7357	1.7357	3.4165	0.7665	0.4995
	CD 1%	2.2959	2.2959	4.519	1.0139	0.6607

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)* 1	*Seed filling (%)* 2	*Hull content (%)* 3	*Oil content (%)* 4	*Seed yield per plant (g)* 5
1	CMS-243A X AKSF-6R	2.815 **	3.143 **	2.119 **	0.221	-8.579 **
2	CMS-243A X AKSF-14R	4.522 **	-3.857 **	2.119 **	0.616	2.617 *
3	CMS-243A X RHA138-2R	-1.699	-1.476	-5.623 **	0.134	-2.947 *
4	CMS-243A X 856R	-1.035	2.286 *	5.274 **	-1.602 **	5.479 **
5	CMS-243A X AKSF-8R	1.079	0.476	-2.339 **	0.733 *	9.339 **
6	CMS-243A X PKV-105R	-3.626 **	-2.476 *	0.027	-0.574	-14.809 **
7	CMS-243A X 189/1R	-1.24	-0.905	2.539 **	0.819 *	11.879 **
8	CMS-243A X AKSF-12R	-0.815	2.810 **	-4.117 **	-0.347	-2.978 *
9	CMS-17A X AKSF-6R	0.547	1.685	-0.359	-2.056 **	2.151
10	CMS-17A X AKSF-14R	1.137	-1.982	-1.229	-0.658	6.787 **
11	CMS-17A X RHA138-2R	-3.253 **	-3.601 **	3.525 **	1.320 **	-15.240 **
12	CMS-17A X 856R	-2.233 *	0.161	-3.127 **	0.344	10.169 **
13	CMS-17A X AKSF-8R	0.848	1.018	4.699 **	-1.548 **	-12.745 **
14	CMS-17A X PKV-105R	0.312	3.065 **	-2.078 **	1.089 **	7.334 **
15	CMS-17A X 189/1R	5.565 **	4.970 **	-2.169 **	2.161 **	4.749 **
16	CMS-17A X AKSF-12R	-2.922 **	-5.315 **	0.738	-0.651	-3.205 *
17	AKSF10-1A X AKSF-6R	-1.715 *	0.018	-2.041 **	0.374	-3.747 **
18	AKSF10-1A X AKSF-14R	-2.431 **	4.351 **	-1.521 *	-0.515	-6.217 **
19	AKSF10-1A X RHA138-2R	-1.895 *	3.732 **	-3.404 **	-0.964 **	3.262 **
20	AKSF10-1A X 856R	-2.112 *	-4.839 **	-3.063 **	-0.613	5.865 **
21	AKSF10-1A X AKSF-8R	2.979 **	0.018	4.604 **	-0.218	-1.222
22	AKSF10-1A X PKV-105R	-0.143	-2.935 **	0.106	-0.465	3.674 **
23	AKSF10-1A X 189/1R	0.690	-4.696 **	2.472 **	0.855 *	-2.959 *
24	AKSF10-1A X AKSF-12R	4.626 **	4.351 **	2.846 **	1.545 **	1.345
25	AKSF-12A X AKSF-6R	-1.398	-2.107 *	-4.982 **	1.894 **	2.374
26	AKSF-12A X AKSF-14R	0.562	-0.774	-0.969	-0.537	-4.996 **
27	AKSF-12A X RHA138-2R	1.225	-0.393	2.486 **	-1.380 **	6.680 **
28	AKSF-12A X 856R	2.181 *	-0.964	1.836 **	0.647	-15.434 **
29	AKSF-12A X AKSF-8R	0.229	2.893 **	-1.777 **	-0.194	14.239 **
30	AKSF-12A X PKV-105R	2.010 *	-2.393 *	0.052	1.299 **	2.955 *
31	AKSF-12A X 189/1R	-3.647 **	0.179	2.418 **	-1.438 **	-6.674 **
32	AKSF-12A X AKSF-12R	-1.161	3.560 **	0.936	-0.291	0.856
33	CMS-234A X AKSF-6R	0.787	-2.399 *	3.148 **	1.634 **	10.199 **
34	CMS-234A X AKSF-14R	0.960	-1.399	6.201 **	1.306 **	-3.911 **
35	CMS-234A X RHA138-2R	3.680 **	1.982	0.696	1.674 **	7.095 **
36	CMS-234A X 856R	0.953	1.411	-2.980 **	-0.876 **	-13.513 **
37	CMS-234A X AKSF-8R	-5.312**	1.601	-0.234	-2.530 **	-2.653 *
38	CMS-234A X PKV-105R	-1.894 *	0.982	1.902 **	-1.717 **	-10.794 **
39	CMS-234A X 189/1R	-1.431	-0.113	-4.315 **	0.025	3.374 **
40	CMS-234A X AKSF-12R	2.258 **	-2.065 *	-4.418 **	0.483	10.201 **
41	CMS-10A X AKSF-6R	1.058	-1.024	-6.072 **	0.545	-6.152 **

(*contd....Table 3*)

Sr.No.	*Crosses*	*Volume weight (g/100ml)* 1	*Seed filling (%)* 2	*Hull content (%)* 3	*Oil content (%)* 4	*Seed yield per plant (g)* 5
42	CMS-10A X AKSF-14R	-5.682 **	0.643	-5.202 **	-1.640 **	0.408
43	CMS-10A X RHA138-2R	-0.399	4.357 **	-0.168	-0.609	-5.973 **
44	CMS-10A X 856R	1.187	0.452	3.453 **	1.615 **	4.700 **
45	CMS-10A X AKSF-8R	-0.322	-6.357 **	-1.387 *	2.580 **	0.113
46	CMS-10A X PKV-105R	3.980 **	0.357 “	3.632 **	0.117	11.359 **
47	CMS-10A X 189/1R	-1.037	3.929 **	-0.982	-2.764 **	-3.250 **
48	CMS-10A X AKSF-12R	1.215	-2.357 *	6.726 **	0.154	-1.204
49	CMS-850A X AKSF-6R	-2.094 *	0.685	8.188 **	-2.612 **	3.754 **
50	CMS-850A X AKSF-14R	0.933	3.018 **	0.601	1.427 **	5.311 **
51	CMS-850A X RHA138-2R	2.342 **	-4.601 **	2.488 **	-0.176	7.123 **
52	CMS-850A X 856R	1.059	1.494	-1.394 *	0.485	2.735 *
53	CMS-850A X AKSF-8R	0.500	0.351	-3.567 **	1.177 **	-7.071 **
54	CMS-850A X PKV-105R	-0.639	3.399 **	-3.642 **	0.250	0.281
55	CMS-850A X 189/1R	1.101	-3.363 **	0.037	0.342	-7.118 **
56	CMS-850A X AKSF-12R	-3.200 **	-0.982	-2.712 **	-0.893 **	-5.015 **
	SE(D)±	0.8582	1.0215	0.6411	0.3329	1.2235
	CD 5%	1.7008	2.0243	1.2706	0.6597	2.4247
	CD 1%	2.2497	2.6776	1.6806	0.8726	3.2071

Note: * Significant at 5% level of significance

** Significant at 1% level of significance

Among the 56 crosses, the cross AKSF-10-1A x AKSF-8R (-3.399) noted highest negative sca effect for days to 50% flowering, followed by CMS-243A x 856R (-2.994) and CMS-17A x PKV-105R (-2.958). The cross AKSF-10-1A x ASKSF-12R (-3.440) registered highest negative sca effect for days to maturity, followed by CMS-850A x AKSF-8R (-2.827) and CMS-243A x 856R (-2.792).

For the plant height the cross CMS17A x RHA138-2R (37.377) recorded highest negative sca effect, followed by AKSF-12A x 856R (-28.923) and CMS-10A x RHA-138-2R (-22.927). The cross AKSF-10-1A x 856R (4.477) exhibited highest positive significant sca effect for head diameter.

The cross, AKSF-10-1A x RHA-138-2R (0.973) exhibited maximum significant positive sca effect for hundred seed weight, followed by CMS-243A x PKV-105R (0.949), CMS-234A x RHA-138-2R (0.807) and AKSF-12A x AKSF-8R (0.755). The maximum positive significant sca effect for volume weight was marked by CMS-17A x 189/1R (5.565), which was best specific cross combination for the volume weight.

The highest significant sca effect for seed filling percentage was recorded by CMS-17A x 189/1R (4.970) followed by AKSF-10-1A x AKSF-12R (4.351) and AKSF-12A x AKSF-12R (3.560). The highest negative significant sca effect for hull content recorded by the cross CMS-10A x AKSF-6R (-6.072) followed by CMS-243A x RHA-138-2R (-5.623), CMS-10A x AKSF-14R (-5.207) and AKSF-12A x AKSF-6R (-4.982). The cross CMS-10A x AKSF-8R (2.580) was the best specific cross combination for oil content, followed by CMS-17A x 189/1R (2.161) and AKSF-12A x AKSF-6R (1.894).

Out 56 crosses, 24 crosses recorded significant positive sca effects for seed yield. The cross AKSF-12A x 856R (14.234) recorded the highest significant positive sca effect for seed yield followed by CMS-243A x 189/1R (11.879), CMS-10A x PKV-105R (11.359), CMS-234A x AKSF-12R (10.202) and CMS-234A x AKSF-6R (10.199).

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, where as 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.

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-12A x RHA-138-2R (64.42g) followed by CMS-850A x RHA138-2R (63.59g). These crosses were also found to be promising for most of the yield

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

Crosses	*Seed yield/plant*			*Oil content*		
	Mean seed GCA effects yield / plant	*SCA effect*	*GC A effects of parents*	*Oil content (%)*	*SCA effect*	*Significant GCA effects of parents for other characters*
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**	$P_{1-1,6,9}$ $P_{2-1,2,4,5,6,7,8,9}$

Note : * Significant at 5% level of significance,

** Significant at 1% level of significance

P_1- Line, **P_2**- Tester **1**) Days to 50% flowering, **2)** Days maturity

3) Plant height, **4**) Head diameter, **5)** 100 seed

H - High gca effect weight, **6**) Volume weight, **7**) Seed filling L - Low gca effect percentage, **8)** Hull content, **9**) Oil content.

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 multilocation hybrid trials for further commercial exploitation.

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