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Combining ability for yield contributing traits and oil content in sunflower (*Helianthus annuus* L.)

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Abstract: *Five lines and ten testers were crossed in a line x tester mating design during* rabi *2014. Parents and their fifty hybrids were evaluated in randomized block design with three replications at Oilseed Research Unit, Dr. PDKV, Akola during* kharif *2015. The objectives of this research was to determine combining ability of female and male lines through line x tester analysis for developing rewarding sunûower hybrids. Considerable and significant genetic differences were observed for the interaction of lines and testers demonstrating the importance of specific combining ability effects. Among the parents, three lines (CMS 137-12A, AKSF-10-1A and AKSF-6-1A) and three testers (RHA 138–2 R, 856 R and AKSF-14 R) were found to be good general combiners for seed yield per plant and most of the yield contributing traits, whereas CMS 137-12A, AKSF-6-1A and 3/147 R were good combiners for oil content. Highly significant specific combining ability effects for seed yield per plant along with most of the yield contributing traits were recorded by AKSF-10-1A x MRHA-1R, PET-89-1A x 298R and PET-89-1A x AK-1R crosses. On the basis of mean performance, specific combining ability effects of crosses and general combining ability effects of the parents, five crosses* viz.*, AKSF-10-1A X MRHA-1R, PET 89-1A X 298R, PET-89-1A x AK-1R, CMS- 607A X AK-1R and CMS 137-12A x MRHA-1R are identified as promising crosses for further commercial exploitation.*

Key words: *General combining ability, Specific combining ability, Line x Tester.*

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the most important oilseed crops in the world. Sunflower is originated in the South-West United States-Mexico area (Heifer [6], 1955; Vranceanu and Stoenescu [14], 1979). Sunflower was introduced for commercial cultivation in India in 1969 from former USSR. Yield is a complex character involving number of components each of which is polygenically controlled and thus susceptible to environmental fluctuations. Thus selection of parents for hybridization is therefore, a complex problem. Hybrids using lines developed based on heterosis are preferred by farmers due to their high yielding performance, quality and uniformity. To develop sunflower hybrids with improved yield potential, the choice of parents through careful and critical evaluation is of paramount importance in order to improve productivity and total production. Knowledge of the nature of inheritance and the way in which parents can transmit favourable alleles for desirable traits to their progeny enhances breeder's ability to select genetically superior parents and practice selection within segregating population. Good combining ability implies to the ability of a parent to produce superior progeny when combined with another parent (Khan *et al.* [8], 2008). General combining ability (GCA) provides an evaluation of the degree of mainly additive gene action, while specific combining ability (SCA) refers to the performance of two particular lines in a specific cross and it thus reflects non-additive types of gene interaction. Common technique has been extensively used in sunflower to classify parental lines in terms of their ability to combine and express hybrid vigour in cross combination. A wide range

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of variability and cytoplasmic male sterility are available in sunflower (*Helianthus annuus* L.). With a view to identify the lines with good combining ability and to identify the good specific crosses for further exploitation, the present investigation was under taken.

MATERIAL AND METHODS

The present field study was carried out at field of Oilseed Research Unit, Dr. PDKV, Akola. Crossing work was done in *rabi* 2014 and evaluation of parents and F_1's was taken in *kharif* 2015, resultant 50 crosses and one check were sown in a simple Randomized Block Design with three replications for evaluation in line x tester fashion. 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 materials used and methods followed during the course of the investigation are presented below. The parent materials for the present study consisted of five cytoplasmic male sterile lines *viz.*, CMS-137-12A, PET89-1A, CMS-607A, AKSF-10-1A and AKSF-6-1A and ten restorer lines *viz.*, AKSF-6R, RHA-138-2R, 856R, AKSF-14R, MRHA-1R, 3/147R, AKSF-12R, AK-1R, 298R and PKV-105R were used in the investigation. The following observations of ten different quantitative characters were recorded: *viz.*, days to 50 percent flowering, days to maturity, plant height, head diameter, 100 seed weight, volume weight, seed filling percentage, hull percent, oil content and seed yield per plant. Oil content of all genotypes were determined by using NMR (nuclear magnetic resonance) machine at Instrumental cell, Oilseed Research Unit, Dr. PDKV, Akola. The analysis of combining ability (GCA and SCA) effect was done by using the Line x Tester analysis method given by Kempthorne (1957).

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 for male x female for all the characters The estimate of general combining ability effects are presented in Table 2, the GCA effects revealed that non of the parent had good general combining ability for all the traits. The similar results were reported by Ragab and Friedt [11] (1992). 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. The lines CMS 137-12A, AKSF-10-1A and AKSF-6-1A were good general combiner for seed yield per plant and most of the yield contributing characters. Among the testers RHA-138-2R, AKSF-14R and 856R were good general combiner for seed yield per plant and most of the yield contributing characters. In sunflower early to medium duration and medium to dwarf heighted hybrids are preferred and in the present study the parents AKSF-6-1A, AK 1R and PKV-105R were found to be good general combiners for earliness and dwarf plant height. Good general combining parents for earliness coupled with medium to dwarf plant height were also reported by Shekar *et al*. [12] (2003), Gejli *et al*. [4] (2011) and Asif *et al.* [2] (2013). For oil content, parents CMS 137-12A, AKSF-6-1A, 3/147R, AKSF-6R and PKV-105R were good general combiner. The lines CMS 137-12A, AKSF-6-1A were good general combiner for seed yield per plant and most of the yield contributing characters coupled with oil content. The above results are in agreement with Phad *et al*. [10] (2002), Patil *et al.* [9] (2007), Deengra *et al.* [3] (2012) and Asif *et al.* [2] (2013).

Specific combining ability of 50 hybrid combinations was studied (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. Significant sca effects for seed yield were recorded in hybrids AKSF-10-1A x MRHA-1R, PET-89-1A X 298R, PET-89-1A X AK-1R, CMS-607A X AK-1R and CMS-137-12A X MRHA-1R. The results are in accordance with Halaswamy *et al.* [5] (2004). The cross CMS-607A x AK-1R show highest negative sca effect for days to 50% flowering. Among the 50 crosses PET-89-1A X AKSF-6R exhibited highest negative SCA effect for days to maturity followed by AKSF-6-1A X RHA138-2R and AKSF-6-1A X856R. The cross CMS-

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	5.626	11.527	52.271	8.832	0.242	3.737	3.207	11.670	0.917	20.915
Crosses	49	15.587**	27.007**	602.291**	20.172**	2.309**	34.524**	41.297**	16.972**	5.554**	183.919**
Females(lines)	4	35.723**	181.693**	1211.996	59.972*	2.526	115.720*	49.110	29.626	15.835**	1144.166**
Males(testers)	9	37.902**	8.786	294.614	12.092	3.568	11.165	19.201	18.659	8.211*	158.120
Females vs Males	36	7.771**	14.374**	611.465**	17.769**	1.971**	31.343**	45.951**	15.143**	3.748**	83.675**
Error	98	0.946	1.615	22.698	2.834	0.143	1.528	5.036	1.892	1.629	5.328

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

Table 2
General combining ability effects of female (line) and male (tester) for yield and yield contributing 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 (%)*	*Seedyield / plant (g)*
Females (lines)										
CMS 137-12A	-1.693**	0.953**	0.803	3.401**	0.080	1.294**	1.053**	-0.686**	1.151**	4.907**
PET 89-1A	0.407*	-1.350**	0.795	-3.760**	0.087	0.201	-2.447**	-0.665*	-0.739**	-5.271**
CMS 607A	1.373**	1.020**	-2.203**	-4.773**	-0.021	0.130	0.053	1.606**	-0.615**	-8.050**
AKSF-10-1A	0.440	1.693**	1.782**	3.064**	0.288**	0.820*	0.020	-0.756**	-0.471	4.697**
AKSF-6-1A	-0.527*	-2.310**	-1.177*	2.068**	-0.231**	-2.445**	1.320**	0.100**	0.674**	3.718**
SE (D)±	0.4764	0.6131	2.3617	0.7938	0.2002	0.6162	1.102	0.6691	0.6019	1.091
CD (5%)	0.1814	0.2334	0.899	0.3022	0.0762	0.2346	0.4195	0.2547	0.2291	0.4153
CD (1%)	0.3599	0.4631	1.7841	0.5997	0.1512	0.4655	0.8325	0.5055	0.4547	0.8242
Males (testers)										
AKSF-6R	0.940**	0.353	0.520	-0.081	0.222*	0.538	0.487*	0.499	0.760*	-4.506**
RHA138-2R	1.540**	-0.713*	1.751**	4.686**	0.685**	0.569*	0.587*	-0.996*	-0.114	5.788**
856R	-0.727**	0.220	-0.499	2.328*	0.042	0.040	-0.780*	-1.522**	-0.718*	2.520**
AKSF-14R	0.940**	0.353	1.453**	4.228**	0.043	0.597*	0.053	-0.066	0.414	4.130**
MRHA -1R	-0.860**	1.487**	-0.573	0.986	-0.999**	-0.892**	0.287	0.972*	-0.546	-2.461**
3/147R	0.007	0.687*	0.340	-3.589**	0.182	0.510	0.687*	1.826**	1.079**	0.053
AKSF-12R	-1.860**	-0.580	-0.289	-7.198**	-0.035	-0.119	-0.480	0.834*	-0.744*	0.089
AK-1R	-2.593**	-0.847*	-1.167*	-4.939**	0.155*	0.610*	-0.947	-0.125	-0.986**	-1.482*
298R	-0.060	-0.113	-0.482	0.053	-0.321*	-1.304**	-0.180	-0.617	0.040	-1.405*
PKV-105R	2.673**	-0.847*	-1.054*	3.527**	0.025	-0.550	0.287	-0.806*	0.813*	-2.726**
SE (D)±	0.673	0.867	3.34	1.122	0.283	0.871	1.558	0.946	0.851	1.542
CD (5%)	0.256	0.330	1.271	0.427	0.107	0.331	0.593	0.360	0.324	0.587
CD (1%)	0.509	0.655	2.523	0.848	0.213	0.658	1.177	0.714	0.643	1.165

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)	Headdiameter (cm)	100 seed weight (g)
		1	2	3	4	5
1	CMS 137-12A X AKSF-6R	-0.307	3.313 **	-10.178 **	1.518	-0.244
2	CMS 137-12A X RHA138-2R	-0.573	0.380	5.389	1.109	-0.323
3	CMS 137-12A X 856R	0.360	1.447	13.039 **	1.259	-0.297
4	CMS 137-12A X AKSF-14R	-0.640	-2.020 **	1.431	2.457 *	0.305
5	CMS 137-12A X MRHA -1R	0.160	-0.487	12.381 **	-0.501	-0.606 *
6	CMS 137-12A X 3/147R	-0.707	-0.687	10.956 **	0.019	0.513 *
7	CMS 137-12A X AKSF-12R	1.160 *	-2.753 **	3.064	-0.268	0.493 *
8	CMS 137-12A X AK-1R	1.227 *	-1.153	-10.819 **	-2.232 *	-0.391
9	CMS 137-12A X 298R	-0.973	1.447	-24.311 **	-2.900 **	0.289
10	CMS 137-12A X PKV-105R	0.293	0.513	-0.952	-0.461	0.263
11	PET 89-1A X AKSF-6R	1.593 **	-4.553 **	11.043 **	1.537	-0.987 **
12	PET 89-1A X RHA138-2R	-1.007	3.180 **	-3.765	-3.042 **	0.187
13	PET 89-1A X 856R	-1.740 **	1.913 *	14.885 **	2.050 *	1.773 **
14	PET 89-1A X AKSF-14R	-2.073 **	-2.220 **	-23.723 **	-2.818 **	-0.597 *
15	PET 89-1A X MRHA -1R	2.060 **	-1.020	-21.398 **	1.099	0.141
16	PET 89-1A X 3/147R	1.193 *	0.780	-1.573	-0.981	-0.133
17	PET 89-1A X AKSF-12R	0.393	2.047 **	4.160	-1.118	0.830 **
18	PET 89-1A X AK-1R	-0.873	-0.353	0.902	-1.491	0.477
19	PET 89-1A X 298R	0.593	-0.420	14.910 **	2.792 **	-1.207 **
20	PET 89-1A X PKV-105R	-0.140	0.647	4.560	1.972 *	-0.483 *
21	CMS- 607A X AKSF-6R	0.727	1.913 *	12.806 **	-1.012	0.361
22	CMS- 607A X RHA138-2R	2.127 **	-1.353	24.248 **	5.131 **	-0.832 **
23	CMS- 607A X 856R	4.060 **	-0.620	-1.978	-2.294 *	-1.919 **
24	CMS- 607A X AKSF-14R	1.060	-0.420	5.289	3.054 **	0.697 **
25	CMS- 607A X MRHA -1R	-1.473 *	-0.887	3.781	0.988	1.326 **
26	CMS- 607A X 3/147R	1.327 *	0.913	-14.728 **	1.588	0.054
27	CMS- 607A X AKSF-12R	-1.807 **	1.180	-9.828 **	0.071	-0.556 *
28	CMS- 607A X AK-1R	-2.740 **	0.113	-5.836 *	-0.194	0.194
29	CMS- 607A X 298R	-2.607 **	-1.287	12.048 **	-0.169	0.321
30	CMS- 607A X PKV-105R	-0.673	0.447	-25.803 **	-7.164 **	0.354
31	AKSF-10-1A X AKSF-6R	-0.907	-0.920	-15.248 **	-1.214	0.919 **
32	AKSF-10-1A X RHA138-2R	0.827	1.813 *	-0.515	-1.221	0.146
33	AKSF-10-1A X 856R	-0.907	0.880	-11.490 **	0.096	-0.094
34	AKSF-10-1A X AKSF-14R	0.760	0.080	2.652	-2.414 *	-1.068 **
35	AKSF-10-1A X MRHA -1R	-0.440	-0.720	-2.148	-0.864	0.530 *
36	AKSF-10-1A X 3/147R	-0.307	-2.920 **	18.260 **	0.698	-0.374
37	AKSF-10-1A X AKSF-12R	-1.440 *	0.013	-0.465	-0.747	0.209
38	AKSF-10-1A X AK-1R	1.293 *	1.947 **	4.443	2.105 *	-0.621 *
39	AKSF-10-1A X 298R	1.093	1.213	-5.965 *	1.321	0.156
40	AKSF-10-1A X PKV-105R	0.027	-1.387	10.477 **	2.240 *	0.199
41	AKSF-6-1A X AKSF-6R	-1.107	0.247	1.577	-0.829	-0.049
42	AKSF-6-1A X RHA138-2R	-1.373 *	-4.020 **	-25.357 **	-1.977 *	0.822 **
43	AKSF-6-1A X 856R	-1.773 **	-3.620 **	-14.457 **	-1.111	0.538 *
44	AKSF-6-1A X AKSF-14R	0.893	4.580 **	14.352 **	-0.279	0.664 **
45	AKSF-6-1A X MRHA -1R	-0.307	3.113 **	7.385 *	-0.723	-1.391 **
46	AKSF-6-1A X 3/147R	-1.507 **	1.913 *	-12.915 **	-1.325	-0.059
47	AKSF-6-1A X AKSF-12R	1.693 **	-0.487	3.068	2.063 *	-0.975 **
48	AKSF-6-1A X AK-1R	1.093	-0.553	11.310 **	1.812	0.341
49	AKSF-6-1A X 298R	1.893 **	-0.953	3.318	-1.044	0.441
50	AKSF-6-1A X PKV-105R	0.493	-0.220	11.718 **	3.412 **	-0.332
	SE(D)±	1.5066	1.9387	7.4684	2.5102	0.633
	CD 5%	0.5735	0.738	2.843	0.9556	0.2409
	CD 1%	1.1382	1.4646	5.6419	1.8963	0.4782

Note: * Significant at 5% level of significance

** Significant at 1% level of significance

contd. table 3

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 137-12A X AKSF-6R	-2.686 **	4.247 **	-1.313	-1.216	-4.006 **
2	CMS 137-12A X RHA138-2R	-3.907 **	3.647 **	2.742 **	-0.026	-0.639
3	CMS 137-12A X 856R	-0.638	-1.420	0.228	1.098	2.491
4	CMS 137-12A X AKSF-14R	-0.235	-2.887 *	-0.124	-0.338	1.539
5	CMS 137-12A X MRHA -1R	4.958 **	-0.687	0.614	-0.054	5.676 **
6	CMS 137-12A X 3/147R	-2.292 **	0.780	-1.260	-0.069	4.362 **
7	CMS 137-12A X AKSF-12R	3.681 **	3.313 *	1.528	0.220	-0.501
8	CMS 137-12A X AK-1R	3.732 **	-1.353	1.014	-0.471	-5.473 **
9	CMS 137-12A X 298R	0.560	-3.220 *	-1.527	0.187	-0.880
10	CMS 137-12A X PKV-105R	-3.171 **	-2.420	-1.902 *	0.670	-2.569
11	PET 89-1A X AKSF-6R	-0.388	4.047 **	2.063 *	-0.036	2.292
12	PET 89-1A X RHA138-2R	2.654 **	4.113 **	-0.706	-0.580	1.919
13	PET 89-1A X 856R	1.846 *	-0.620	0.611	0.915	4.366 **
14	PET 89-1A X AKSF-14R	-5.408 **	1.247	-3.272 **	-0.221	-13.050 **
15	PET 89-1A X MRHA -1R	1.702 *	-0.553	-4.060 **	0.032	-3.329 *
16	PET 89-1A X 3/147R	2.409 **	-4.087 **	-0.107	1.001	-2.600
17	PET 89-1A X AKSF-12R	-7.005 **	-2.553	-0.136	-0.746	-3.509 **
18	PET 89-1A X AK-1R	2.146 **	-1.887	-2.136 **	-0.008	5.825 **
19	PET 89-1A X 298R	2.340 **	-0.087	4.436 **	0.234	6.525 **
20	PET 89-1A X PKV-105R	-0.294	0.380	3.308 **	-0.590	1.562
21	CMS- 607A X AKSF-6R	-0.669	-7.187 **	-2.131 **	-1.914 **	2.151
22	CMS- 607A X RHA138-2R	0.153	-8.453 **	0.013	1.453 *	-1.786
23	CMS- 607A X 856R	-3.151 **	5.147 **	0.927	-1.152	-3.572 **
24	CMS- 607A X AKSF-14R	4.339 **	-1.987	-0.626	0.085	1.879
25	CMS- 607A X MRHA -1R	-2.025 **	3.880 **	2.022 *	0.388	1.926
26	CMS- 607A X 3/147R	3.895 **	4.347 **	2.579 **	1.584 *	4.639 **
27	CMS- 607A X AKSF-12R	0.811	-2.120	-0.147	-1.244	-2.214
28	CMS- 607A X AK-1R	-2.485 **	6.547 **	-2.854 **	1.475 *	5.818 **
29	CMS- 607A X 298R	-1.373	3.013 *	-0.692	0.106	-6.660 **
30	CMS- 607A X PKV-105R	0.506	-3.187 *	0.910	-0.780	-2.182
31	AKSF-10-1A X AKSF-6R	2.367 **	-4.653 **	-2.450 **	1.146	-3.846 **
32	AKSF-10-1A X RHA138-2R	0.886	-2.920 *	-0.828	-0.151	0.734
33	AKSF-10-1A X 856R	-0.812	-1.987	-1.838 *	-1.073	-4.212 **
34	AKSF-10-1A X AKSF-14R	1.671 *	1.880	2.232 **	-0.532	4.062 **
35	AKSF-10-1A X MRHA -1R	0.420	-1.253	0.960	1.444 *	8.439 **
36	AKSF-10-1A X 3/147R	-2.449 **	3.880 **	-1.260	-1.334	-2.348
37	AKSF-10-1A X AKSF-12R	4.867 **	0.080	-0.752	1.969 **	0.616
38	AKSF-10-1A X AK-1R	-4.082 **	2.080	4.621 **	-1.542 *	-5.560 **
39	AKSF-10-1A X 298R	-1.878 *	1.213	-0.564	-0.041	3.210 *
40	AKSF-10-1A X PKV-105R	-0.988	1.680	-0.122	0.116	-1.093
41	AKSF-6-1A X AKSF-6R	1.376	3.547 **	3.831 **	2.021 **	3.409 *
42	AKSF-6-1A X RHA138-2R	0.215	3.613 **	-1.221	-0.695	-0.227
43	AKSF-6-1A X 856R	2.757 **	-1.120	0.073	0.213	0.927
44	AKSF-6-1A X AKSF-14R	-0.366	1.747	1.790 *	1.007	5.571 **
45	AKSF-6-1A X MRHA -1R	-5.054 **	-1.387	0.465	-1.810 *	-12.712 **
46	AKSF-6-1A X 3/147R	-1.563 *	-4.920 **	0.048	-1.181	-4.053 **
47	AKSF-6-1A X AKSF-12R	-2.354 **	1.280	-0.494	-0.199	5.608 **
48	AKSF-6-1A X AK-1R	0.690	-5.387 **	-0.645	0.547	-0.611
49	AKSF-6-1A X 298R	0.352	-0.920	-1.653 *	-0.485	-2.195
50	AKSF-6-1A X PKV-105R	3.948 **	3.547 **	-2.194 **	0.585	4.283 **
	SE(D)±	1.9485	3.4847	2.116	1.9035	3.4501
	CD 5%	0.7418	1.3265	0.8055	0.7246	1.3134
	CD 1%	1.472	2.6325	1.5985	1.438	2.6063

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

Table 4
Mean yield performance, GCA and SCA effects in promising crosses

Crosses	*Mean seed yield/plant*	*SCA Effect*	*GCA Effects*
AKSF-6-1A X AKSF-14R	58.02**	5.51**	3.71** X 4.13** H H
AKSF-10-1A X AKSF-14R	57.49**	4.06 **	4.69** X 4.13** H H
AKSF-10-1A X MRHA-1R	55.28**	8.43**	4.69** X -2.46** H L
CMS-137-12A X 3/147R	53.93**	4.36**	4.90 ** X 0.05 H L

Note: * Significant at 5% level of significance
** Significant at 1% level of significance
L - Low gca effects
H - High gca effects

607A x PKV-105R show highest negative sca effect for plant height followed by AKSF-6-1A X RHA138-2R and CMS137-12A X 298R. Venkanna *et al.* [13] (2005) and Patil *et al.* [9] (2007) also reported maximum sca effect in desirable direction for days to 50% flowering, days to maturity and plant height.

The cross CMS-607A x RHA138-2R exhibited highest positive significant sca effect for head diameter followed by AKSF-6-1A x PKV-105R and CMS-607A x AKSF-14R. The cross PET-89-1A X 856R exhibited maximum significant positive effect for 100 seed weight followed by CMS-607A x MRHA-1R and AKSF-10A x AKSF-6R. Among the crosses CMS-607A x AK-1R recorded maximum significant sca effect for seed filling percentage followed by CMS-607A x 856R and CMS-607A x 3/147R.The cross PET-89-1A X MRHA-1R registered negative significant sca effect for hull content followed by PET-89-1A X AKSF-14R and CMS-607A x AK-1R. Among the crosses six crosses (AKSF-6-1A x AKSF-6R, AKSF-10-1A x AKSF-12R, CMS-607 X 3/147R, CMS-607A X AK-1R, CMS-607A X RHA-138-2R and AKSF-10-1A x MRHA-1R) showed the significant positive sca effect for oil content. Shekar *et al.* [12] (2003), Athoni and Nandini [1] (2012) reported similar results for specific combining ability for seed yield and most of the yield contributing character.

Four promising cross combinations were identified on the basis of mean yield performance, gca and sca effects (Table 4). These crosses are AKSF-6-1A X AKSF-14R, AKSF-10-1A X AKSF-14R, AKSF-10-1A X MRHA-1R and CMS-137-12A X 3/147R. The cross AKSF-6-1A X AKSF-14R was identified as best cross combination, as it has recorded highest value of seed yield per plant (58.02 g), highly significant sca effect (5.51**) for seed yield with both the parents involve in cross have high (good) general combining ability. Similarly, other three identified crosses also recorded highly significant mean yield per plant and significant sca effect with high x high and high x low general combiner parent involve.

Based on the above results, the lines CMS-137-12A, AKSF-10-1A and AKSF-6-1A and the testers RHA-138-2R, 856R and AKSF-14R recorded significant gca effect for yield and most of the yield contributing characters, thus these parents should be included in further hybridization programme. Among the parents CMS-137-12A, AKSF-6-1A, 3/147R, AKSF-6R and PKV-105R were also good general combiner for oil content. On the basis of mean performance and sca effects of crosses, four crosses viz., AKSF-6-1A X AKSF-14R, AKSF-10-1A X AKSF-14R, AKSF-10-1A X MRHA-1R and CMS-137-12A X 3/147R are identified as promising crosses and these crosses need further evaluation for commercial exploitation.

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