International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

Combining Ability and Gene Action Studies in Diverse CMS Sources in Sunflower (*Helianthus annuus* L.)

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Abstract: ***Ten diverse CMS lines and nine inbred lines were crossed in a line x tester fashion to elucidate the information on the combining ability for seed yield, yield components and oil content and also to know the nature of gene action involved in inheritance of important quantitative traits. A total of 90 crosses were evaluated for 12 different quantitative traits. Among the lines CMS E002-92 and CMS-AGR-6 exhibited significant gca effects for most of the characters studied and were found to be the best combiners. Likewise, inbredsR-27 Br and R-77-2III was the best combiner for seed yield per plant, volume weight, seed filling per cent, kernel per cent, hull per cent, KH ratio and oil content. The estimates of variance components revealed predominance of non-additive gene action for all characters studied.***

Keywords: Sunflower, diverse CMS source, combining ability, line x tester analysis

1. Introduction

Yield is a complex character involving number of components each of which ispolygenically 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. Combining ability studies elucidates the nature and magnitude of gene action involved in the inheritance of character by providing the information on the two components of variance *viz.*, additive genetic and dominance variance, which are important to decide upon the parents and crosses to be selected for eventual success.Combining ability analysis helps in identification of suitable parents for further exploitation in breeding programme for crop improvement. A wide range 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.

2. Material and Methods

The present field study was carried out at Main Agricultural Research Station, Raichurcampus of the University of Agricultural Sciences, Raichur (Karnataka)India, in two seasons. The campus is being geographically situated in the NorthEastern Dry Zone (Zone 2) of Karnataka State at 16°12' N latitude and 77°21' E longitude with an altitude of 389.37 meters above mean sea level. Crossing work was done in *rabi*summer 2007-08 and evaluation of parents and F_1's was taken up in late *rabi* 2008-09, resultant 90 crosses and two check hybrids were sown in a simple Randomized Block Design with two replications for evaluation in line x tester fashion. Each entry was raised with two rows in a plot having 3 m x 0.6 m (1.8 m^2) by adopting a spacing of 60 cm between rows and 30 cm between plants.

The materials used and methods followed during the course of the investigation are presented below. The parent materials for the present study consisted of ten cytoplasmic male sterile lines which include diversified cms linesand nine elite inbred lines were used in the investigation (Table1). The seed materials were obtained from the Principal Scientist and Head (Breeding), All India Co-ordinated Research Project on Sunflower, Main Agricultural Research Station, UAS Raichur, India. The following observations of twelve different quantitative characters were recorded: *viz.*, days to 50 percent flowering, head diameter, plant height, days to maturity, volume weight, Seed filling percentage, 100 seed weight, oil content, seed yield per plant, hull percent, Kernel per cent and KH ratio. The data were analysed by L × T.

3. Results and Discussion

The analysis of variance for parents and crosses (Table2) indicated significant differences for all the characters except seed yield per pant indicating the existing of genetic diversity in the parental material. Mean sum of squares for crosses were also found to be significant for all the traits. The lines, testers and line v/s testers exhibited significant differences among themselves for all characters except head diameter and seed yield per plant in lines and testers and hull percent, kernel percent, KH ratio in lines and lines v/s testers. It could be because of the diverse nature of testers and the significant interaction between lines and testers. The parent v/s hybrid interactions had significant difference for all the characters studied except hull percent and KH ratio. The variance component due to specific combining ability (sca) was greater in magnitude than that of general combining ability (gca) for all characters indicating predominance of non-additive type of gene action which is in agreement with the findings of Singh *et al.* (1999) and Radhika*et al.* (2001).

The general combining ability effects (Table 3) indicated that the line CMS-PHIR-27 was found to possess genes for earliness as evident from its significant negative highest gca effect in desirable direction for days to 50 per cent flowering. The line CMS E 002-92 was recorded the highest gca effect for hull content, kernel content and KH ratio in desirable direction and CMS- AGR-6 were reported the highest positive gca effects for seed yield per plant, seed filling percent. Among the male parents, R-77-2III for head diameter, volume weight, seed filling per cent, oil content and seed yield per plant. R-27Br for hull per cent, kernel per cent and KH ratio produced the highest gca effects in desirable direction. These results were in agreement with those of Govindraju*et al*. (1992) and Ashok *et al*. (2000). Radhika*et al*. (2001) observed that gca for yield was related to gca for one or more yield components which was in conformity with the present study. The parents, which were good general combiners for economic traits, may be extensively used in hybridization programmes. Many workers *viz.*,Halaswamy*et al*. (2004), Reddy and MadhaviLatha (2005), Manivannan*et al*. (2005) and Tavade*et al*. (2009) reported good general combiners for most of the characters under study.

The sca effects (Table 4) showed that no single cross showed maximumsca effects for all characters. The cross A-6 x R-4 indicated the highest sca effect for plant height and seed filling per cent, while A-9 x R-6 for 100 seed weight, hull per cent and kernel per cent reported significant sca effects.Eleven crosses were noticed significant positive sca effects for seed yield per plant. Among these crosses A-6 x R-8 (9.65), A-9 x R-1 (9.44) and A-2 x R-2 (8.02) were indicated the highest positive sca effects. These results were in conformity with the earlier findings of Patil*et al.* (2007) and Tavade*et al.* (2009) In the majority of the crosses high sca effect was due to low x low, high x low and low x high combining parents which further substantiate the operation of non-additive gene action for the characters studied.

Therefore it can be concluded in the present investigation that almost all the characters studied were governed by non-additive gene action. Besides using diverse CMS sources are equally efficient in expressing their fullest potential of yield and yield contributing characters. Thus breeders can safely use these sources to broaden the genetic base of CMS source and sunflower crop can be safeguarded from any eventuality of biotic and abiotic threats in future.

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Table 1: The diverse CMS lines and inbred lines used in the present study

Sl. No	*CMS line designation*	*Origin*	*Abbreviations used*
1	CMS E 002-91	*Helianthus annuus*	A-1
2	CMS E 002-92	*Helianthus annuus*	A-2
3	CMS- AGR-2	*Helianthus argophyllus*	A-3
4	CMS-X	*Helianthus annuus*	A-4
5	CMS- AGR-6	*Helianthus argophyllus*	A-5
6	CMS DV-10	*Helianthusdebilisspp. vertitus*	A-6
7	CMS-PRUN 29	*Helianthus praecox spp. runyonii*	A-7
8	CMS PKUZ	*Helianthusannuus*	A-8
9	CMS PHIR-27	*Helianthus praecox spp. hirsutus*	A-9
10	77A x 72B	*Helianthusannuus*	A-10

Sl.	*Inbreds*	*Abbreviations used*
1	R-393 Br	R-1
2	R-8297	R-2
3	R3-Br	R-3
4	R-127	R-4
5	R-27Br	R-5
6	R-5	R-6
7	R-272	R-7
8	R-77-2III	R-8
9	275Br	R-9

Table 2.ANOVA for parents and crosses for yield and yield components in sunflower

Source	df	Days to 50 per cent flowering	Head diameter (cm)	Plant height (cm)	Days to maturity	Volume weight (g/100ml)	Seed filling per cent	100 seed weight (g)	Oil content (%)	Seed yield/ plant (g)	Hull per cent	Kernel per cent	KH ratio
Replication	1	14.38	98.45	445.10	24.17	0.00	0.32	0.16	2.22	3.84	4.74	10.87	0.12
Parents	18	5.23**	30.79**	416.78**	21.71**	40.69**	21.39**	0.17*	7.73**	8.19	9.72**	6.04*	0.40**
Lines	9	5.67**	2.31	607.13**	14.90*	32.10**	18.24**	0.08	12.37**	6.38	5.51	1.52	0.28
Testers	8	4.43*	3.81	252.25**	22.47**	54.52**	16.59*	0.26**	1.89**	10.88	15.46**	11.75**	0.58**
Lines v/s Testers	1	7.76**	502.93**	19.91	76.92**	7.43**	88.12**	0.24	12.76**	2.97	1.68	0.95	0.01
Crosses	89	25.77**	9.97*	499.77**	24.53**	16.77**	139.52**	0.74**	10.52**	41.14**	19.72**	20.97**	0.78**
Parents v/s Hybrids	1	1445.59**	208.10**	10202.73**	6400.89**	4699.19**	129.58**	1.16**	3.11**	1756.52**	0.05	162.95**	0.00
Error	108	2.11	6.60	93.24	6.18	0.76	6.27	0.09	0.57	8.27	3.23	3.44	0.15
Genetic components													
σ^2gca		0.1643	0.0608	4.5427	0.1380	0.1151	0.2059	-0.0004	0.0775	0.2693	-0.0283	-0.0327	-0.0016
σ^2sca		6.7348	-0.6393	59.3194	4.7238	4.4722	62.8893	0.3763	2.7592	7.7738	9.8597	10.6009	0.4027
σ^2gca / σ^2sca		0.0243	-0.0951	0.0765	0.0292	0.0257	0.0032	-0.0010	0.0280	0.0346	-0.0028	-0.0030	-0.0039

*, ** – Significant at 5% and 1% levels, respectively

Table 3: Estimates of general combining ability (gca) effects of male and female parents for 12 different characters in sunflower

Parents	*Days to 50 per cent flowering*	*Head diameter (cm)*	*Plant height (cm)*	*Days to maturity*	*Volume weight (g/100ml)*	*Seed filling per cent*	*100 seed weight (g)*	*Oil content (%)*	*Seed yield/ plant (g)*	*Hull per cent*	*Kernel per cent*	*KH ratio*
Lines												
CMS E 002-91	1.41**	-0.29	7.13**	1.99**	-0.34	-0.64*	-0.34**	1.16**	0.96	-0.12	0.26	-0.03
CMS E 002-92	-0.14	-1.45*	-12.93**	-0.12	-0.97**	-4.73**	0.22**	0.36**	-2.37**	-1.54**	1.68**	0.32**
CMS- AGR-2	0.41	0.66	-4.15	1.38*	-0.37	1.27**	0.03	-0.62**	-2.37**	-0.75*	0.89**	0.12
CMS- X	-1.76**	-0.47	-1.17	-2.51**	1.16**	4.65**	0.00	0.56**	-1.34	-0.62*	-0.65*	0.04
CMS- AGR-6	-1.87**	-0.30	-10.59**	-1.96**	-0.25	1.68**	-0.09**	-0.77**	3.81**	0.95**	-0.81*	-0.19**
CMS- DV-10	2.80**	1.91**	3.30	-1.12	0.63**	0.26	-0.09**	0.24*	-0.67	0.74*	-0.60	-0.10
CMS- PRUN-29	0.02	0.69	6.13*	1.16	0.50*	-0.87**	0.13**	-0.09	-0.13	-0.17	0.31	0.04
CMS- PKUZ	-0.42	-0.03	7.24**	1.82**	0.21	1.59**	-0.00	0.70**	1.41*	-0.29	0.43	0.07
CMS- PHIR-27	-2.76**	0.07	3.05	-1.40	-1.11**	-1.81**	-0.02	0.40**	2.77**	1.25**	-1.11**	-0.19**
77A x 72B	2.30**	-0.79	1.99	0.77	0.54**	-1.41**	0.15**	-1.94**	-2.08**	0.54	-0.40	-0.07
CD at 5%	0.9789	1.8089	6.6569	1.6952	0.5703	0.6880	0.0803	0.3191	1.9834	0.8733	0.8813	0.1853
CD at 1%	1.3003	2.4027	8.8422	2.2516	0.7575	0.9138	0.1066	0.4238	2.6345	1.1600	1.1706	0.2461
Testers												
R- 393 Br	-1.37**	-1.07	-14.26**	-0.88	1.82**	0.64**	0.29**	0.49**	1.00	-0.54	-0.58	0.04
R- 8297	-2.87**	0.64	-7.16**	-2.78**	-3.65**	3.13**	-0.20**	-0.99**	0.88	1.58**	-1.44**	-0.25**
R- 3Br	0.43	-0.54	14.39**	0.62	-2.25**	-5.54**	-0.06*	-1.27**	-1.58*	0.41	-0.27	-0.08
R-127	-0.82*	-0.59	3.57	-0.83	-1.83**	-6.48**	0.17**	-1.72**	-0.69	-0.48	0.62*	0.06
R- 27Br	-0.17	0.50	-3.16	2.12**	1.47**	0.46	0.06*	1.64**	2.51**	-0.93**	1.08**	0.18**
R-5	-0.07	-1.66**	-11.56**	-2.43**	0.37	0.89**	-0.34**	-2.05**	-4.97**	0.23	-0.09	-0.04
R-272	-0.67*	-0.34	-0.88	0.02	0.29	1.57**	-0.07**	0.34**	-1.67*	-0.49	0.63*	0.08
R-77-2III	4.33**	3.11**	19.87**	2.72**	2.56**	5.12**	0.23**	2.29**	4.15**	0.01	0.13	0.05
275Br	1.18**	-0.04	-0.83	1.42*	1.20**	0.21	-0.07**	1.24**	0.37	0.22	-0.08	-0.04
CD at 5%	0.9287	1.7161	6.3153	1.6082	0.5410	0.6526	0.0762	0.3027	1.8816	0.8285	0.8360	0.1758
CD at 1%	1.2336	2.2794	8.3885	2.1361	0.7187	0.8669	0.1011	0.4021	2.4993	1.1004	1.1105	0.2335

*, ** – Significant at 5% and 1% levels, respectively

Table 4a. Specific combining ability (sca) effects for 12 different characters in sunflower

Hybrid	Days to 50 per cent flowering	Head diameter (cm)	Plant height (cm)	Days to maturity	Volume weight (g/100ml)	Seed filling per cent	100 seed weight (g)	Oil content (%)	Seed yield/ plant (g)	Hull per cent	Kernel per cent	KH ratio
A-1 x R-1	-1.91	2.71	4.14	-2.29	0.60	1.73*	0.38**	0.93**	-0.11	-058	1.71	0.18
A-1 x R-2	-0.41	1.10	3.04	-0.39	2.32**	0.66	-0.08	2.96**	-3.74	-1.36	1.22	0.18
A-1 x R-3	0.29	0.63	-0.01	-3.29	-2.28**	-3.92**	0.08	1.04**	1.79	2.05*	-2.19*	-0.39
A-1 x R-4	-1.96	-0.42	1.32	-2.34	-1.40*	9.38**	-0.05	-1.66**	2.61	1.03	-1.17	-0.19
A-1 x R-5	-2.11*	0.04	12.79	-2.29	-0.65	-1.39	-0.39**	-0.87*	1.84	0.02	-0.16	-0.02
A-1 x R-6	0.29	-1.85	-1.81	3.76*	-1.45*	5.55**	0.31**	0.42	-3.53	-0.13	-0.01	-0.02
A-1 x R-7	2.39*	-1.57	-6.73	1.81	2.28**	-2.43**	-0.56**	-0.52	-2.98	3.25**	-3.39**	-0.63**
A-1 x R-8	-0.11	0.38	-9.23	1.11	0.56	-9.21**	0.69**	-1.57**	4.70*	-2.26*	2.11*	0.44*
A-1 x R-9	3.54**	-1.02	-3.53	3.91*	0.02	-0.38	-0.36**	-0.72*	-0.58	-2.01*	1.87*	0.45*
A-2 x R-1	5.14**	-2.82	-12.30	2.82	0.28	-2.23**	-0.78**	-0.72*	-3.81	4.15**	-3.02**	-0.84**
A-2 x R-2	-2.86**	-2.14	11.35	-2.28	-2.80**	5.34**	0.61**	-1.54**	8.02**	-3.68**	3.53**	0.78**
A-2 x R-3	-0.66	1.30	-3.45	-2.68	-1.45*	-12.67**	-0.58**	1.55**	-0.12	2.79**	-2.93**	-0.65**
A-2 x R-4	5.09**	0.70	-10.38	3.77*	1.23*	0.73	0.45**	-0.05	0.04	0.71	-0.85	-0.17
A-2 x R-5	-4.06**	-0.64	-15.90*	-4.18*	2.88**	8.22**	0.40**	0.08	-2.44	-0.30	0.16	0.07
A-2 x R-6	-1.16	0.32	6.50	0.37	3.93**	-1.21	-0.20*	0.82*	4.22*	-0.35	0.21	0.03
A-2 x R-7	-5.06**	1.34	-8.18	1.42	-2.89**	-0.45	-0.67**	-0.32	-2.96	1.51	-1.65	-0.37
A-2 x R-8	1.94	0.94	19.33**	-0.28	0.04	11.37**	0.28**	2.03**	-0.71	-2.52**	2.38*	0.59**
A-2 x R-9	1.59	0.99	13.03	1.02	-1.20	-9.10**	0.48**	-1.87**	-2.24	-2.32*	2.17*	0.56**
A-3 x R-1	-1.91	-1.34	-7.83	-2.18	-2.02**	9.45**	-0.59**	2.31**	-1.28	-0.62	1.75	0.23
A-3 x R-2	0.59	-1.60	-12.93	3.22	0.70	-10.54**	0.85**	1.29**	0.32	-3.62**	3.48**	0.70**
A-3 x R-3	0.29	1.68	2.02	-0.18	0.05	-5.88**	0.61**	0.38	1.84	-3.12**	2.97**	0.74**
A-3 x R-4	-0.96	2.73	9.10	-2.23	-2.92**	7.28**	-0.37**	-2.77**	-1.25	2.67**	-2.81**	-0.55**
A-3 x R-5	4.39**	-3.21	-7.68	-0.68	-0.91	-6.24**	-0.96**	-1.29**	-3.31	3.53**	-3.67**	-0.74**
A-3 x R-6	2.29*	1.45	4.72	3.87*	1.23*	-2.88**	0.89**	0.35	2.36	-1.85	1.71	0.38
A-3 x R-7	-1.11	-1.07	6.05	-0.58	0.61	2.03**	-0.38**	-2.39**	-1.31	2.89**	-3.03**	-0.61**
A-3 x R-8	-0.11	2.23	-8.95	0.72	1.19	2.59**	-0.33**	2.26**	-1.35	0.34	-0.48	-0.15
A-3 x R-9	-3.46**	-0.87	15.50*	-1.98	2.05**	4.18**	0.27**	-0.14	3.97	-0.23	0.09	-0.01
A-4 x R-1	-0.74	1.95	0.95	1.71	-2.35**	2.30**	-0.36**	-2.22**	2.09	-2.93**	-7.23**	0.33
A-4 x R-2	2.26*	0.83	-10.15	1.11	-2.38**	-5.81**	-0.07	-2.34**	1.86	2.57**	-1.30	-0.51*
A-4 x R-3	-2.04	1.72	3.30	-0.29	-1.23*	1.57*	0.24**	-2.61**	0.51	-1.50	2.77**	0.34

Table 4b: Specific combining ability (sca) effects for 12 different characters in sunflower

Hybrid	Days to 50 per cent flowering	Head diameter (cm)	Plant height (cm)	Days to maturity	Volume weight (g/100ml)	Seed filling per cent	100 seed weight (g)	Oil content (%)	Seed yield/ plant (g)	Hull per cent	Kernel per cent	KH ratio
A-4 x R-4	2.17*	-0.63	7.38	2.66	3.80**	-1.03	-0.44**	0.84*	-0.57	0.50	0.77	-0.06
A-4 x R-5	-1.94	2.83	-9.90	-2.79	-0.60	0.75	0.57**	2.13**	0.79	-1.00	2.27*	0.29
A-4 x R-6	2.46*	-1.96	-0.75	-0.24	-0.55	-0.80	0.62**	1.27**	-2.56	0.58	0.69	-0.11
A-4 x R-7	0.06	-4.04*	6.57	-2.19	0.73	9.30**	-0.45**	-0.12	-1.73	0.59	0.69	-0.09
A-4 x R-8	-0.44	-1.14	2.83	5.11**	1.96**	-0.31	0.55**	2.73**	-3.20	-1.55	2.82**	0.32
A-4 x R-9	-2.29*	0.46	-0.23	-5.09**	0.62	-5.98**	-0.65**	0.33	2.81	2.73**	-1.46	-0.53**
A-5 x R-1	-0.63	-3.48	-4.88	-1.34	0.31	5.26**	0.18*	-0.09	-0.29	-2.99**	4.12**	0.71**
A-5 x R-2	-0.13	2.16	2.52	-0.44	1.53*	3.53**	0.38**	-2.66**	1.73	-2.50**	2.36*	0.35
A-5 x R-3	1.07	0.04	12.47	3.16	0.58	-0.69	-0.07	1.77**	0.93	-0.94	0.80	0.10
A-5 x R-4	-2.18*	0.89	-3.46	-1.89	-1.29*	-19.05**	-0.69**	0.32	1.53	1.14	-1.29	-0.26
A-5 x R-5	3.67**	0.45	-6.48	3.16	-1.93**	2.80**	0.61**	-0.49	1.41	-4.55**	4.41**	1.12**
A-5 x R-6	-1.43	1.71	3.17	-1.79	-0.29	4.54**	-0.69**	-0.60	-2.61	1.04	-1.19	-0.27
A-5 x R-7	-1.33	0.84	7.24	-1.74	-0.26	-4.61**	0.90**	0.66	-2.20	0.77	-0.91	-0.23
A-5 x R-8	1.17	-0.01	1.99	-0.44	3.17**	7.76**	-0.66**	0.86*	-1.09	4.22**	-4.37**	-0.81**
A-5 x R-9	-0.18	-2.61	-12.56	1.36	-1.82**	0.46	0.05	0.26	0.60	3.80**	-3.95**	-0.70**
A-6 x R-1	-2.80**	-0.09	2.73	0.82	3.68**	-8.54**	0.38**	1.00**	-2.83	-2.56**	3.69**	0.52**
A-6 x R-2	1.70	1.40	14.38*	-1.28	0.25	-8.75**	-0.12	0.78*	-2.12	2.11*	-2.25*	-0.50*
A-6 x R-3	-5.60**	-4.02*	5.33	-0.68	2.25**	-0.76	-0.12	0.42	-2.34	0.89	-1.03	-0.26
A-6 x R-4	1.15	-3.22	-17.60*	-0.23	1.28*	15.51**	-0.59**	0.42	-4.07	2.09*	-2.23*	-0.47*
A-6 x R-5	2.00	1.04	-3.37	2.82	0.68	3.75**	0.61**	-0.70*	0.13	-2.17*	2.03*	0.38
A-6 x R-6	2.90**	-0.70	2.28	-1.63	-2.07**	-0.84	0.36**	-0.16	-2.38	-3.95**	3.81**	0.77**

A-6 x R-7	5.50**	4.08*	-4.65	6.92**	-2.74**	3.07**	0.70**	1.15**	6.24**	-4.60**	4.46**	1.06**
A-6 x R-8	0.50	1.78	8.10	-4.28*	-2.46**	0.73	-1.11**	-2.35**	9.65**	8.44**	-8.58**	-1.38**
A-6 x R-9	-5.35**	-0.27	-7.20	-2.48	-0.85	-4.17**	-0.10	-0.55	-2.28	-0.25	0.11	-0.10
A-7 x R-1	-1.02	-0.41	-6.86	-0.96	1.71**	-5.62**	-0.09	1.18**	-1.11	0.63	0.50	-0.13
A-7 x R-2	-0.02	0.13	-5.96	-0.06	1.08	1.80*	0.60**	0.06	1.34	-5.76**	5.62**	1.25**
A-7 x R-3	-3.32**	-0.24	4.24	-2.46	-2.93**	14.34**	-0.94**	-1.26**	2.96	4.84**	-4.98**	-0.89**
A-7 x R-4	-4.07**	-0.24	15.32*	-1.51	-0.74	3.46**	0.48**	0.54	-1.09	-1.51	1.37	0.31
A-7 x R-5	2.78**	-0.08	4.54	3.04	0.36	-1.00	-0.56**	1.18**	0.93	2.44*	-2.58**	-0.57**
A-7 x R-6	2.18*	-0.82	-9.56	-4.41*	1.50*	-2.16**	-0.66**	-1.93**	-2.06	1.84	-1.98*	-0.43*
A-7 x R-7	1.78	0.81	8.77	-0.36	-1.36*	-4.62**	0.62**	0.48	5.79**	-2.12*	1.98*	0.44*
A-7 x R-8	-2.22*	-0.55	-6.48	2.44	-0.64	-5.57**	0.17	-0.87*	-5.19*	-3.09**	2.95**	0.64**

Table 4c: Specific combining ability (sca) effects for 12 different characters in sunflower

Hybrid	Days to 50 per cent flowering	Head diameter (cm)	Plant height (cm)	Days to maturity	Volume weight (g/100ml)	Seed filling per cent	100 seed weight (g)	Oil content (%)	Seed yield/ plant (g)	Hull per cent	Kernel per cent	KH ratio
A-7 x R-9	3.93**	1.40	-4.03	4.24*	1.03	-0.63	0.37**	0.63	-1.56	2.73**	-2.87**	-0.61**
A-8 x R-1	3.92**	1.26	27.03**	0.38	-3.10**	1.71*	-0.36**	-0.26	1.45	5.47**	-4.34**	-0.98**
A-8 x R-2	0.42	-2.41	8.93	-0.22	-1.13	2.31**	-0.96**	3.82**	-0.59	3.07**	-3.21**	-0.65**
A-8 x R-3	2.62*	-1.77	-12.62	2.88	5.03**	6.72**	0.74**	-0.99**	-1.86	-2.89**	2.75**	0.58**
A-8 x R-4	-2.13*	1.63	-4.04	-2.67	0.95	3.09**	0.32**	0.16	4.25*	-2.27*	2.13*	0.54**
A-8 x R-5	-3.28**	-0.41	5.93	0.38	1.81**	10.16**	0.57**	1.64**	0.68	-2.44*	2.30*	0.59**
A-8 x R-6	-3.88**	0.80	-14.42*	0.43	2.05**	-4.05**	-0.78**	0.63	4.75*	2.29*	-2.43*	-0.53**
A-8 x R-7	-0.28	0.92	10.66	2.98	1.04	-16.85**	0.36**	-1.91**	-2.23	-0.21	0.07	-0.02
A-8 x R-8	1.22	-0.68	-11.09	-0.22	-3.28**	-10.18**	0.65**	-2.81**	-6.40**	-0.24	0.10	-0.09
A-8 x R-9	1.37	0.67	-10.39	-3.92*	-3.37**	7.09**	-0.54**	-0.31	-0.06	-2.77**	2.63**	0.57**
A-9 x R-1	-0.74	2.56	0.23	0.60	-1.33*	0.22	0.71**	-0.66	9.44**	-0.64	1.77	0.06
A-9 x R-2	0.76	0.89	2.63	1.00	0.29	2.75**	-0.55**	-0.18	-3.11	5.92**	-6.06**	-0.94**
A-9 x R-3	2.46*	0.13	-13.42	3.60*	-2.51**	8.27**	-0.49**	-3.54**	-4.28*	2.50**	-2.64**	-0.54**
A-9 x R-4	-0.29	-1.22	-5.10	1.05	-0.28	1.43	0.38**	0.86*	-2.25	-4.01**	3.87**	0.86**
A-9 x R-5	0.56	-0.21	-1.37	-2.40	3.18**	-21.71**	-0.51**	-0.21	-4.34*	1.67	-1.81	-0.46*
A-9 x R-6	-1.54	0.05	-4.72	-0.35	-1.23*	3.27**	0.89**	0.33	-0.33	-5.84**	5.70**	1.27**
A-9 x R-7	-0.94	-1.93	-5.40	-3.80*	2.30**	-0.83	-0.88**	2.04**	1.31	1.93*	-2.07*	-0.45*
A-9 x R-8	-3.44**	-1.08	10.85	-4.50*	-0.67	3.91**	0.57**	1.59**	6.02**	-4.45**	4.31**	0.83**
A-9 x R-9	3.21	0.82	16.30*	4.80**	0.24	2.70**	-0.13**	-0.26	2.20	2.93**	-3.07**	-0.62**
A-10 x R-1	0.70	-0.34	-3.22	0.43	2.22**	-4.27**	0.54**	-1.47**	-3.55	0.07	1.06	-0.07
A-10 x R-2	-2.30*	-0.35	-13.82	-0.67	0.14	8.69**	-0.67**	-2.19**	-3.71	3.25**	-3.39**	-0.66**
A-10 x R-3	4.90**	0.53	2.13	-0.07	2.49**	-6.96**	0.54**	3.24**	0.58	-4.61**	4.47**	0.98**
A-10 x R-4	2.65*	-0.22	7.46	3.38	-0.63	-20.79**	0.51**	1.34**	1.07	-0.35	0.21	-0.01
A-10 x R-5	-2.00	0.19	21.43**	2.93	-4.82**	4.65**	-0.33**	-1.47**	4.31*	2.80**	-2.94**	-0.65**
A-10 x R-6	-2.10*	1.00	14.58*	-0.02	-3.13**	-1.43	-0.73**	-1.13**	2.14	6.36**	-6.50**	-1.10**
A-10 x R-7	-1.00	0.63	-14.34*	-4.47*	0.30	15.39**	0.35**	0.93**	0.06	-4.00**	3.86**	0.90**
A-10 x R-8	1.50	-1.87	-7.34	0.33	0.13	-1.10	-0.80**	-1.87**	-2.44	1.10	-1.25	-0.38
A-10 x R-9	-2.35*	0.43	-6.89	-1.87	3.29**	5.82**	0.60**	2.63**	1.54	-4.62**	4.48**	0.99**
CD at 5%	2.9368	5.4267	19.9707	5.0855	1.7109	2.0639	0.2408	0.9572	5.9502	2.6198	2.6438	0.5558
CD at 1%	3.9009	7.2082	26.5267	6.7549	2.2726	2.7414	0.3199	1.2714	7.9035	3.4799	3.5117	0.7383

*, ** – Significant at 5% and 1% levels, respectively