IJPS INTERNATIONAL JOURNAL OF PLANT SCIENCES
Volume **8** | Issue 1 | January, 2013 | 19-24

RESEARCH ARTICLE

Combining ability studies for seed yield and it's contributing traits in sunflower (*Helianthus annuus* L.)

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SUMMARY

A Line × tester analysis of 45 hybrids in sunflower using three CMS lines and 15 testers was carried out to study the combining ability for seed yield and its contributing traits in sunflower (*Helianthus annuus* L.). The result revealed that, variance due to SCA was greater than GCA for all the traits except stem diameter and 100-seed weight, which indicated preponderance of non-additive gene action for all traits, while additive gene action for stem diameter and 100-seed weight. Line CMS 54A was a good general combiner for early flowering, early maturity, plant height, test weight, seed yield and oil yield, while CMS 56A was a good general combiner for hull content and oil content. The testers RHA 93 and RHA 115R transmitted allele with additive effects for seed and oil yield. RHA 6D-5-3-5 was good general combiner for early flowering and early maturity, while RHA 95C-1 was good general combiner for oil content. In lines CMS 54A and CMS 57A and in testers GKVK-1, GKVK-2, RHA 95C-1, RHA 6D-5-3-5, RHA-272-II, RHA 275, RHA-298, RHA-115R and RHA-115R possessed favorable alleles for most of the traits. Among hybrids CMS 57A × RHA 93 was identified as the best specific combiner for seed yield, oil yield, volume weight, head and stem diameter. CMS 56A × RHA 6D-5-3-5 was the best specific combination for early flowering and early maturity. While CMS 54A × RHA 6D-5-3-5 was the best specific combiner for economic trait oil content and oil yield.

Key Words : Sunflower, Line × tester, Combining ability

How to cite this article : Asif, M., Shadakshari, Y.G., Naik, S.J. Satheesh, Venkatesha, K.T., Vijay Kumar, K.V. and Basavaprabhu, N.M. (2013). Combining ability studies for seed yield and it's contributing traits in sunflower (*Helianthus annuus* L.). *Internat. J. Plant Sci.*, **8** (1) : 19-24.

Article chronicle : Received : 07.07.2012; **Revised :** 04.08.2012; **Accepted :** 06.10.2012

In India, the farmers have accepted sunflower hybrid technology, thus making sunflower the second most important oilseed crop at present. The hybrids have proved to be more vigorous, uniform, self fertile and also relatively resistant to diseases and insect pests. Further, the development of sunflower hybrids with high oil content opened new era in sunflower improvement, leading to rapid development of sunflower as an oilseed crop throughout the world. A landmark in sunflower breeding was the discovery of cytoplasmic male sterility by Leclercq (1969) and identification of the genes for fertility restoration by Kinman (1970), which shifted the interest from population breeding to heterosis breeding.

The information on the combining ability status of the parental lines will give an indication as to how well they combine with a given genotype to produce potential and productive hybrid. In this direction the concept of general combining ability *(gca)* and specific combining ability *(sca)* helps the breeders to decide upon the choice of parents for hybridization and to isolate promising genotype from the

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population. One of the techniques, which is widely used to extract information about the potentiality of the parental lines and gene action governing the inheritance of traits, is line x tester (L x T) analysis. The L x T analysis permits estimation of the magnitude of additive and non-additive components along with other genetic properties of parental lines. The estimates of *gca* and *sca* effects and their variances are the effective genetic parameters of direct utility while deciding the breeding programme. Hence, in the present study, results on general combining ability of 18 parents and specific combining ability in 45 F_1 hybrids are presented and discussed.

MATERIALS AND METHODS

Three CMS lines *viz.*, CMS 54A, CMS 56A, and CMS 57A and 15 restorer lines *viz.*, GKVK-1, GKVK-2, GKVK-3, RHA 95 C-1, RHA 95 C-2, RHA 6D-1, RHA 6D-5-3-5, RHA 272-II, LTRR-822, LTRR-83-273, SOF-138-2, RHA-275, RHA-298, RHA-115 R, and RHA-93 were planted during *Kharif*, 2010 at the Zonal Agricultural Research Station, UAS, GKVK, Bangalore and crossing was performed in line x tester fashion to produce 45 hybrids. During *Rabi*, 2010-11 the 45 hybrids along with their parents and two standard checks *viz.*, KBSH-1and KBSH-44 were evaluated in a Randomized Block Design with two replications. Observations were recorded on five randomly selected plants in each hybrid combination per replication for eleven quantitative characters. Data obtained were subjected to line x tester analysis (Kempthorne, 1957) to estimate general and specific combining ability effects and their respective variances.

RESULTS AND DISCUSSION

The analysis of variance (Table 1) for 11 characters revealed significant differences between the genotypes, indicating wide diversity in the material. The mean sum of squares due to hybrids was highly significant, indicating the diverse performance of different cross combinations. The parents versus hybrids mean sum of squares were highly significant for all traits, revealing the presence of heterosis due to the significant difference in the mean performance of hybrids and parents.

The mean sum of squares due to crosses was partitioned into lines, testers, and interaction. The lines were found to be significant for all the traits except for head diameter. The testers also showed significant mean sum of squares for all the traits. The interaction mean sum of squares were found to be significant for days to 50 per cent flowering, plant height (cm), days to maturity, seed yield (kg/ha),volume weight (g/100cc), hull content(%), oil content (%) and oil yield (kg/ha). Significance of variance due to lines, testers and line × tester interaction was also reported by Giriraj *et al.* (1987), Mohan Rao (2001), Devi *et al.* (2005) Pavani *et al.* (2006), Gangappa *et al.* (2007), Shankar *et al.* (2007) and Parameshwarappa *et al.* (2008)

Table 1: Analysis of variance for seed yield and yield attributing traits in sunflower

Source of variation	d.f	Mean sum of squares										
		Days to 50% flowering	Plant height (cm)	Head diameter (cm)	Stem diameter (cm)	Days to maturity	Seed yield (kg/ha)	100 Seed weight (g)	Volume weight (g/100cc)	Hull content (%)	Oil content (%)	Oil yield (kg/ha)
Replication	1	0.96	3.84	0.08	0.04	0.13	29931.46	0.17	7.39	15.90	1.38	1288.96
Genotypes (P+C)	62	15.69**	1927.35**	11.18**	0.30**	16.23**	506975.19**	1.79**	49.87**	33.11**	12.15**	68367.42**
Parents	17	22.50**	752.96**	8.58**	0.23**	23.71**	14572.20	1.55**	10.26**	22.04**	9.05**	1636.65
Crosses	44	7.37**	367.42**	1.40	0.08**	7.16**	151720.44**	0.59**	27.26**	19.04**	5.01**	20262.23**
P Vs C	1	266.06	90529.11**	485.34**	11.32**	288.58**	24509035.21**	58.64**	1718.41**	840.07**	379.13**	3319418.72**
Lines	2	41.11**	4301.54**	0.10	0.42**	44.54**	534517.41**	4.06**	20.80*	42.85**	41.19**	34809.68**
Testers	14	11.57**	300.67**	2.24**	0.13**	9.08**	203930.73**	0.74**	56.25**	21.87**	6.63**	28611.06**
Line × Tester	28	2.86**	119.78**	1.07	0.03	3.52**	98272.65**	0.26	13.22**	15.93**	1.62	15048.71**
Error	62	0.56	1.14	0.89	0.03	0.74	20300.85	0.25	5.60	7.46**	1.35	3065.69**

* and ** Indicate significance of value at P=0.05 and 0.01, respectively, P = Parents C = crosses

The variance due to *sca* was greater than *gca* for all the traits except stem diameter and hundred seed weight (Table 2) which indicated preponderance of non-additive gene action for all the traits while additive gene action for stem diameter and hundred seed weight. The findings of Pavani *et al.* (2006), Parameshwarappa *et al.* (2008) and Sujatha *et al.* (2009) would substantially support the present results of predominance of non-additive gene action for days to fifty per cent flowering, plant height, head diameter, days to maturity, seed yield, volume weight, oil content and oil yield.

A perusal of *gca* effects of 18 parents (3 lines and 15 testers) for 11 traits indicated that the line CMS 54A was a good general combiner for early flowering, early maturity, plant height, test weight, seed yield and oil yield. Whereas CMS

Table 2: Variance due to general and specific combining ability effects for seed yield and its attributes in sunflower

Characters	σ^2GCA	σ^2SCA	σ^2SCA/σ^2GCA	V_A	V_D
Days to 50% flowering	0.09	1.15	2.77	0.17	1.15
Plant height (cm)	4.73	59.35	12.50	9.46	59.35
Head diameter (cm)	0.01	0.12	12.00	0.01	0.12
Stem diameter (cm)	0.001	- 0.002	-2.00	0.00	-0.002
Days to maturity	0.07	1.36	19.40	0.14	1.36
Seed yield (kg/ha)	1020.70	35180.24	34.45	2041.41	35180.24
100 Seed weight (g)	0.01	0.00	0.00	0.01	0.00
Volume weight (g/100cc)	0.27	3.77	13.96	0.54	3.77
Hull content(%)	0.06	2.98	49.67	0.12	2.98
Oil content (%)	0.06	0.36	6.00	0.13	0.36
Oil yield (kg/ha)	99.56	5391.80	54.16	199.13	5391.80

Table 3: Estimates of general combining ability effects of lines and testers for seed yield and its attributes in sunflower

Females	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}
CMS-54A	-1.22 **	-4.07 **	0.04	-0.13 **	-1.26 **	150.89 **	0.41 **	-0.28	1.33 *	-1.35 **	37.74 **
CMS-56A	1.11 **	13.48 **	-0.07	0.10 **	1.18 **	-102.68**	-0.11	-0.65	-0.97	0.69 **	-28.46 *
CMS-57A	0.11	-9.41 **	0.03	0.03	0.08	-48.21	-0.30 **	0.94 *	-0.36	0.67 **	-9.29
S.E.±	0.1371	0.1906	0.167	0.0329	0.1634	30.5026	0.0933	0.435	0.5765	0.173	11.9235
Males											
GKVK-1	0.14	-9.03 **	-0.31	-0.05	-0.49	-186.48**	-0.39	0.43	-1.07	1.40 **	-53.96 *
GKVK-2	-2.19 **	0.74	-0.27	-0.15 *	-1.49 **	-111.64	0.44 *	1.69	-1.14	0.87 *	-30.96
GKVK-3	1.81 **	6.70 **	-0.14	0.15 *	1.68 **	86.19	-0.17	1.89	-0.86	-0.58	23.71
RHA 95 C-1	0.48	7.35 **	0.66	0.07	0.34	104.52	0.13	4.38 **	-1.03	1.71 **	58.21 *
RHA 95 C-2	0.64 *	-1.23 **	-0.21	-0.02	0.68	-287.48**	0.07	-0.57	-2.56	0.38	-99.62 **
RHA 6D-1	2.14 **	5.50 **	0.26	0.17 *	2.01 **	-207.31**	-0.35	-0.94	-0.14	-0.03	-74.79 **
RHA 6D-5-3-5	-2.52 **	-5.86 **	-0.37	-0.06	-2.16 **	-28.31	0.28	-2.44 *	0.63	-1.01 *	-21.62
RHA 272-II	-0.86 **	-10.15 **	0.06	-0.07	-0.66	-166.48 *	0.52 *	-1.48	-0.45	-0.45	-63.62 *
LTRR-822	-0.86 **	-10.38 **	-0.67	-0.17 *	-0.82 *	-63.14	0.06	-6.86 **	3.06 *	-2.11 **	-48.12
LTRR-83-273	0.48	-0.36	-0.64	-0.14	0.18	-162.14 *	-0.50 *	-1.9	0.12	-1.14 **	-69.29 *
SOF-138-2	1.14 **	3.27 **	-0.49	0.01	1.01 **	105.02	-0.15	-0.56	5.08 **	-0.68	29.88
RHA-275	-0.86 **	-1.40 **	-0.14	-0.05	-0.99 **	214.02 **	-0.57 **	-2.23 *	0.05	0.13	77.38 **
RHA-298	-0.86 **	5.72 **	0.03	0.01	-0.82 *	262.52 **	0.25	2.90 **	0.67	-0.16	93.38 **
RHA-115 R	1.64 **	13.40 **	1.73 **	0.38 **	1.68 **	181.86 *	0.43 *	5.63 **	-1.97	1.33 **	82.88 **
RHA-93	-0.36	-4.30 **	0.49	-0.07	-0.16	258.86 **	-0.06	0.05	-0.36	0.33	96.54 **
S.E.±	0.3066	0.4261	0.3734	0.0736	0.3653	68.2058	0.2086	0.9726	1.289	0.3869	26.6618

* and ** Indicate significance of value at P=0.05 and 0.01, respectively, X_1: Days to 50% flowering, X_2: Plant height (cm), X_3: Head diameter (cm), X_4: Stem diameter (cm), X_5: Days to maturity, X_6: Seed yield (kg/ha), X_7: 100 Seed weight (g), X_8: Volume weight (g/100cc), X_9: Hull content (%), X_{10}: Oil content (%), X_{11}: Oil yield (kg/ha) NOTE: Bold figure indicate maximum and minimum value.

Table 4: Estimates of specific combining ability effects of single cross hybrids for seed yield and its attributes in sunflower

HYBRIDS	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}
CMS-54A × GKVK-1	-0.61	3.42 **	0.23	0.10	0.59	56.28	0.04	1.7	-0.76	-0.19	19.09
CMS 54A × GKVK-2	-1.78 **	-0.90	-0.81	-0.18	-2.41 **	165.44	0.2	-0.91	1.45	0.53	69.59
CMS-54A × GKVK-3	1.72 **	6.13 **	1.16	0.15	1.42 *	250.11 *	-0.06	0.85	1.7	1.01	98.92 *
CMS-54A × RHA 95 C-1	-0.44	7.23 **	-0.34	-0.01	-0.74	32.78	0.06	-3.92 *	1.65	-0.40	8.92
CMS-54A × RHA 95 C-2	0.89	3.87 **	-0.07	0.04	0.92	-178.22	-0.34	-0.57	2.02	-0.20	-60.74
CMS-54A × RHA 6D-1	0.39	-3.82 **	-1.04	-0.17	0.59	-46.39	-0.4	-1.71	0.42	0.15	-14.58
CMS-54A × RHA 6D-5-3-5	2.06 **	8.15 **	0.39	0.06	2.26 **	196.61	-0.03	1.66	-0.81	1.63 *	87.76
CMS-54A × RHA 272-II	0.39	5.33 **	-0.24	-0.05	0.26	-108.72	0.55	0.97	1.83	0.36	-32.74
CMS-54A × LTRR-822	0.89	5.27 **	0.09	0.04	0.92	-30.06	-0.15	0.84	-0.04	-0.44	-17.24
CMS-54A × LTRR-83-273	-0.44	-5.80 **	0.06	-0.15	-1.08	-179.56	-0.42	-2.72	-1.22	-2.03 **	-82.08
CMS-54A × SOF-138-2	-1.61 **	-9.18 **	-0.29	-0.09	-1.41 *	14.78	0.7	1.74	-5.34 *	-0.22	-3.24
CMS-54A × RHA-275	-0.61	-6.17 **	0.26	0.03	-0.41	-13.22	0.11	-0.44	0.11	-0.6	-16.74
CMS-54A × RHA-298	0.39	-11.98 **	0.29	0.01	0.42	-282.22 *	-0.17	0.94	-1.34	-0.56	-111.24 *
CMS-54A × RHA-115 R	-0.61	1.28	-0.11	0.13	-0.58	135.44	-0.35	2.26	0.57	0.94	62.26
CMS-54A × RHA-93	-0.61	-2.82 **	0.43	0.06	-0.74	-13.06	0.26	-0.71	-0.23	0.00	-7.91
CMS-56A × GKVK-1	-0.44	-2.43 **	0.53	0.03	0.16	311.34 *	0.03	-0.81	1.99	1.00	127.79 **
CMS-56A × GKVK-2	0.89	0.16	0.50	0.1	0.16	-152.49	-0.37	-3.50 *	-1.94	-1.00	-67.21
CMS-56A × GKVK-3	-1.11 *	-8.81 **	-1.03	-0.14	-1.01	-440.32 **	-0.11	0.00	0.35	-0.86	-165.38 **
CMS-56A × RHA 95 C-1	0.22	-7.96 **	0.47	0.03	0.32	22.34	-0.01	1.72	-3.17	0.06	8.12
CMS-56A × RHA 95 C-2	-0.94	-3.58 **	0.43	0.02	-1.01	69.84	0.46	0.92	-3.13	-0.09	20.96
CMS-56A × RHA 6D-1	-0.44	12.24 **	0.17	-0.01	-0.34	285.68 *	-0.17	6.36 **	-3.28	0.31	106.12 *
CMS-56A × RHA 6D-5-3-5	-2.78 **	-8.54 **	0.70	0.02	-3.18 **	44.18	0.27	0.05	1.71	-1.00	4.46
CMS-56A × RHA 272-II	0.56	4.84 **	-0.23	0.08	0.32	82.34	-0.56	0.08	-0.84	0.73	34.46
CMS-56A × LTRR-822	-0.44	-3.98 **	0.20	0.09	-0.51	-8.99	0.46	-0.83	-1.43	-0.23	-3.04
CMS-56A × LTRR-83-273	0.22	3.51 **	0.37	0.09	0.49	4.51	0.32	1.39	-1.18	0.61	5.62
CMS-56A × SOF-138-2	0.56	3.87 **	-0.08	-0.05	0.66	-40.66	-0.44	0.34	8.50 **	0.32	-10.54
CMS-56A × RHA-275	1.56 **	6.59 **	0.17	0.02	1.66 *	51.34	-0.02	0.41	-0.09	-0.05	19.46
CMS-56A × RHA-298	0.56	11.12 **	0.10	0.02	0.49	220.84	0.13	-1.06	3.56	0.96	94.46 *
CMS-56A × RHA-115 R	1.06	2.74 **	-0.90	-0.09	0.99	-102.49	0.3	-3.44 *	-0.42	-0.76	-47.54
CMS-56A × RHA-93	0.56	-9.76 **	-1.37 *	-0.21	0.82	-347.49 *	-0.31	-1.63	-0.62	-0.01	-127.71 **
CMS-57A × GKVK-1	1.06	-0.99	-0.76	-0.13	-0.74	-367.62 **	-0.07	-0.9	-1.23	-0.81	-146.88 **
CMS-57A × GKVK-2	0.89	0.75	0.31	0.08	2.26 **	-12.96	0.17	4.41 *	0.49	0.47	-2.38

Table 4: Contd....

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CMS-57A × GKVK-3	-0.61	2.68 **	-0.12	-0.01	-0.41	190.21	0.16	-0.86	-2.05	-0.15	66.46
CMS-57A × RHA 95 C-1	0.22	0.73	-0.12	-0.02	0.42	-55.12	-0.05	2.21	1.52	0.33	-17.04
CMS-57A × RHA 95 C-2	0.06	-0.29	-0.36	-0.06	0.09	108.38	-0.12	-0.34	1.11	0.29	39.79
CMS-57A × RHA 6D-1	0.06	-8.42 **	0.88	0.18	-0.24	-239.29 *	0.58	-4.65 **	2.86	-0.46	-91.54
CMS-57A × RHA 6D-5-3-5	0.72	0.4	-1.09	-0.08	0.92	-240.79 *	-0.24	-1.72	-0.89	-0.63	-92.21
CMS-57A × RHA 272-II	-0.94	-10.17 **	0.48	-0.03	-0.58	26.38	0.01	-1.05	-0.99	-1.10	-1.71
CMS-57A × LTRR-822	-0.44	-1.29	-0.29	-0.13	-0.41	39.04	-0.31	0.00	1.48	0.66	20.29
CMS-57A × LTRR-83-273	0.22	2.30 **	-0.42	0.06	0.59	175.04	0.10	1.33	2.4	1.42 *	76.46
CMS-57A × SOF-138-2	1.06	5.31 **	0.38	0.14	0.76	25.88	-0.26	-2.08	-3.16	-0.09	13.79
CMS-57A × RHA-275	-0.94	-0.42	-0.42	-0.05	-1.24	-38.12	-0.09	0.02	-0.01	0.65	-2.71
CMS-57A × RHA-298	-0.94	0.86	-0.39	-0.03	-0.91	61.38	0.03	0.11	-2.23	-0.4	16.79
CMS-57A × RHA-115 R	-0.44	-4.02 **	1.01	-0.04	-0.41	-32.96	0.05	1.18	-0.15	-0.18	-14.71
CMS-57A × RHA-93	0.06	12.58 **	0.94	0.15	-0.08	360.54 *	0.05	2.34	0.86	0.01	135.62 **
S.E.±	0.5311	0.738	0.6468	0.1275	0.6327	118.1359	0.3613	1.6846	2.2327	0.6702	46.1796

and ** Indicate significance of value at P=0.05 and 0.01, respectively, X_1: Days to 50% flowering, X_2: Plant height (cm), X_3: Head diameter (cm), X_4: Stem diameter (cm), X_5: Days to maturity, X_6: Seed yield (kg/ha), X_7: 100 Seed weight (g), X_8: Volume weight (g/100cc), X_9: Hull content (%), X_{10}: Oil content (%), X_{11}: Oil yield (kg/ha) NOTE: Bold figure indicate maximum and minimum value

56A was a good general combiner for hull content and oil content. Among the testers, RHA 6D-5-3-5 was a good general combiner for early flowering and early maturity. RHA 95C-1was a good general combiner for oil content and RHA 115R was good general combiner for head and stem diameter. Whereas RHA 93 was good general combiner for seed yield and oil yield (Table 3).

It can be concluded that in lines CMS 54A and CMS 57A and in testers GKVK-1, GKVK-2, RHA 95C-1, RHA 6D-5-3-5, RHA-272-II, RHA 275, RHA-298, RHA-115R and RHA-115R possessed favorable alleles for most of the traits hence use of these parents in future breeding programmes is advised. The parents which were good general combiners for economic traits may be extensively used in hybridization programme.

The *sca* effects showed that no single cross showed maximum *sca* effects for all the characters. The cross CMS 57A x RHA 93, was identified as the best specific combination for most important economic characters, *viz.,* seed yield, oil yield, volume weight, head and stem diameter. CMS 56A x RHA 6D-5-3-5, was best specific combination for early flowering and early maturity. CMS 54A x RHA 6D-5-3-5 was best specific combination for oil content. Whereas CMS 56A x RHA 6D-1 was the best specific combination for volume weight and hull content (Table 4). The crosses with significant *sca* effects in the desirable direction involved parents with high x high or high x low or low x low *gca* effects, indicating high performance of these crosses due to additive, dominance and epistasis gene interaction. The ideal cross combination to be exploited is one, where high magnitude of *sca* is present in addition to high *gca* in both or atleast in one of the parents. Identification of heterotic crosses involving high × low cross combination as revealed in the present study were reported by kadkol *et al.*(1984) and Limbore *et al.*(1997). In addition, crosses with high *sca* effects involving parents with high x high *gca* effects were also reported by, low x low by Kadkol *et al.* (1984), Giriraj *et al.* (1987) and Limbore *et al.* (1997).

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