Original Research Article

Combining Ability Studies and the Gene Action involved in Sunflower Lines

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A B S T R A C T

5 CMS lines (as female lines) and 8 lines as a testers (used as males) for hybridisation in Line × Tester fashion to study combining ability *i.e* general and specific combining ability and also the gene action involved. All the F_1 hybrid combinations were further evaluated in *kharif* 2018 for combining ability studies for 10 different traits. Testers used showed significant variance for all the traits except for test weight and days to maturity, where as lines exhibited significant variance for all the traits. From the present investigation it was observed that none of the testers showed good gca effect for all the traits studied. But DSR-132 recorded significant gca effect for six traits *viz*, plant height, SPAD at 60 DAS, days to flowering, head diameter, days to maturity and seed yield per ha. Similarly the line (which was used as female parent) CMS 7-1-1A recorded better gca effect for plant height, days to 50 %flowering, seed yield per hectare and oil content None of the hybrid combinations showed significant sca effect for all the traits studied, but the combination 4546 × DSF2 A × DSR-132 recorded high and significant sca effect for the traits *viz*, days to 50 percent flowering, SPAD chlorophyll content at 60 DAS, head diameter, test weight, seed yield per hectare, oil content and oil yield.

Introduction

Sunflower (*Helianthus annuus* L.) is the most important oilseed crop after soybean in the world, belonging to Asteraceae/Compositae family originated from temperate North America and has high content of unsaturated fatty acids and lacks cholesterol, thus there is a high oil benefits from it with a desirable quality. It is a diploid crop with an haploid genome size of about 3000 Mb with diploid chromosome number 2n=34 (Darvishzadeh *et al.,* 2010). Sunflower has been successfully cultivated over a widely scattered geographical area across the world. It is a highly cross pollinated crop, which can be adapted to a various environmental conditions having high yield potential. Due to its photo

insensitiveness it can be grown in all seasons and can be taken in various inter and sequence cropping systems. Due to its moderate requirements and high oil quality, its acerage has been increased in both developing anddeveloped countries.

Production of sunflower can be increased by improving its genetic potential. Moreover, sunflower breeders aim to achieve the highest seed yield and oil content through the expression of heterosis. It hashigh yield potential, wider adaptability, drought resistance, and salt tolerance. For the selection of superior varieties/hybrids, genetic variability is necessary. In an efficient breeding program, selectionof better parents for drought tolerant genotypes and the crosses to develop geneticvariability is necessary for the identification of superior hybrids/varieties.

One of the efficient techniques for the evaluation of large number of inbred lines is line × tester analysis which is mainly used for combining ability tests (Throat *et al*., 2016). The heterotic performance of a hybrid combination mainly depends upon the combining abilities of parents used. Scientists reported that heterotic hybrids have been obtained by crossing inbred CMS female and restorer lines having high GCA (General Combining Ability) and SCA (Specific Combining Ability) values.This higher GCA variance refers to additive gene action depicting breeding value of the particular line, while higher SCA variance indicates the greater role of non-additive gene action, which is of great importance in heterosis breeding (Shabbir*et al.*, 2016).

Materials and Methods

A set of 5 CMS lines viz., CMS 21A, CMS-1030A, 4546 × DSF 2A, CMS 7-1-1 A and CMS-853A were planted in *kharif*2018 at College of agriculture vijayapura. Crossing

was performed using 8 restorer lines in line x tester fashion to generate 40 hybrid combinations in summer 2018.

The 40 hybrids along with four checks (RHA 95C-1, RHA 6D-1, KBSH-53 and cauvery champ) were evaluated in field condition during *kharif* 2018 in randomised block design with two replications atcollege of Agriculture, Vijayapura. Two rows of each hybrid were sown with a spacing of 60 cm × 30 cm and row length of 4 m. All the recommended package of practices were followed to raise a good crop.The observations for 10 different traits were recorded from five randomly tagged plants in each hybrid from both the replication viz., days to 50 per cent flowering, days to maturity, relative chlorophyll content using SPAD chlorophyll meter at 45 DAS, relative chlorophyll content using SPAD chlorophyll meter at 60 DAS, head diameter, seed yield per plant, test weight, seed yield per hectare and oil content to study the combining ability and gene action involved. Line × Tester analysis was carried out for evaluating the hybrids using window stat software as mentioned by Kempthrone (1957).

Results and Discussion

The ANOVA for combing ability from a line × tester design shown large variations among the hybrids. Testers used showed significant variance for all the traits except for test weight and days to maturity, where as lines exhibited significant variance for all the traits (Table 1).

Contribution of testers and the lines was approximately equal for days to 50 % flowering. But contribution of testers used was more for some of the traits like SPAD chlorophyll content at 45 and 60 DAS, days to maturity and oil content. The contribution of lines as compared to testers was more for plant height, head diameter, test weight and

seed yield ha^{-1}. Variance due to Line × Tester was highly significant for all the traits indicating that the testers were highly divergent from lines. The SCA variance was higher than GCA variance for all the traits studied. The ratio of GCA/SCA variance observed to be higher for seed yield/ha and plant height as compared to other traits (Table-1).

Similarly the additive variance and dominance variance is shown in the same Table at F=0 (for cross pollinated plants). The dominance variance was more for some of traits like plant height, SPAD at 60 DAS, days to 50 per cent flowering, head diameter and test weight which indicates that heterosis breeding is a better chance, where as other traits exhibited higher additive variance.

Analysis of variance

Sprague and Tatum (1942) first reported general and specific combining ability to discriminate good as well as poor combiners which help in selecting the desirable parents. The combining ability analysis was performed using Line × Tester combination. The combining abilityanalysis with variances due to GCA indicates relative measure of additive gene action and variance due to SCA represents non-additive gene actions for various traits. Persistence of additive gene action among the inbred lines for the development of OPV's is important. And for hybrid breeding programme, presence of non-additive gene action is very important.

The ANOVA for combing ability exhibitedsignificantvariations among the hybrids. Testers used shown significant variance for all the traits except for test weight and days to maturity, where as lines showed significant variance for all the traits.Contribution of testers and thelines was approximately equal for days to 50 %

flowering. But contribution of testersrecorded more for some of the traits like SPAD chlorophyll content at 45 and 60 DAS, days to maturity and oil content. The contribution of lines as compared to testers was more for plant height, head diameter, test weight and seed yield/ha. Variance due to Line × Tester was highly significant for all the traits indicating that the testers were highly divergent from lines. The SCA variance was higher than GCA variance for all the traits studied. The ratio of GCA/SCA variance recorded higher for seed yield per hectare and plant height as compared to other traits.

The additive variance and dominance variance for different traits is exhibited in the Table 1. The dominance variance recorded more for some of traits like plant height, SPAD at 60 DAS, days to 50 percent flowering, head diameter, test weight and oil yield which indicates that heterosis breeding is a better chance, where as other traits exhibited higher additive variance.Similar results involving additive and dominance gene action was reported by several workers for different traits which are presented below.

General combining ability effects

The general combining ability of the parental lines is important for hybridisation programme, So that we can select best parents for hybrid breeding programme. The importance of combining ability in sunflower reported by Giriraj*et al.,*1987.

The capability of the line to be used as a parent during hybridization depends on *per se* performance, gca effect and the performance of F_1 hybrid derived from it. Thus, the line having good gca for seed yield must also possess good gca for other related traits, as seed yield is associated with many other traits.

Table.1 Analysis of variance for combining ability in sunflower

Source	d.f	SPAD at 45 DAS	SPAD at 60 DAS	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	Test weight (g)	Seed yield (kg/ha)	Oil content (%)	Oil yield (kg ha⁻¹)
Replications	1	2.58	1.74	11.25	37.81	5.10	1.25	0.19	30031.25	0.07	3849.47
Cross	39	17.48*	44.85*	23.42*	33.71*	650.00*	3.31*	0.32*	16352.30*	23.82*	4690.31*
Lines (C)	4	10.92*	18.71*	46.60*	25.51*	2800.01*	18.48*	0.55*	66172.51*	38.99*	16226.53*
Testers (C)	7	27.26*	48.76*	26.27*	47.05	424.41*	1.60*	0.17	9909.42*	33.67*	4020.46*
Line x Tester (C)	28	15.97*	47.61*	19.39*	31.55*	399.25*	1.58*	0.32*	10845.80*	19.19*	3209.74*
Error	39	7.36	7.77	6.48	18.79	34.12	0.29	0.1164	2412.50	4.55	509.02
s² GCA		0.0400	-0.0729	0.1065	0.0572	6.6345	0.0461	0.0000	145.6932	0.1225	39.17
s² SCA		4.3000	19.9220	6.4592	6.3842	182.5660	6.6373	0.1021	4216.6709	7.3212	1350.36
s² GCA/ s²SCA		0.0092	-0.0036	0.0164	0.0089	0.0363	0.0069	0.000	0.0345	0.0167	0.03
F=0 A		0.1597	-0.2915	0.4260	0.2288	26.5378	0.1842	-0.0002	582.7726	0.4898	156.69
F=0 D		0.0798	-0.1458	25.8367	0.1144	730.2640	2.5492	0.4082	291.3863	0.2449	5401.44
F=1 A		17.2146	79.6880	0.2130	25.5370	13.2689	0.0921	-0.0001	16866.6836	29.2848	78.34
F=1 D		4.3036	19.9220	6.4592	6.3842	182.5660	0.6373	0.1021	4216.6709	7.3212	1350.36

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	Percentage contribution of lines, testers and Linex Testers to total variance in sunflower									
	SPAD at 45 DAS	SPAD at 60 DAS	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	Test weight (g)	Seed yield (kg/ha)	Oil content (%)	Oil yield (kg ha^{-1})
Lines	6.41	4.28	20.41	7.76	44.18	57.23	17.84	41.50	16.78	35.48
Testers	27.99	19.52	20.14	25.05	11.72	8.69	10.04	10.88	25.37	15.39
Line x Tester	65.60	76.20	59.46	67.19	44.10	34.08	72.12	47.62	57.85	49.13

* Significance at 5% level

Table.2 General combining ability effects (gca) of parents for seed yield and its component traits in sunflower

SI No.	Sources	SPAD at 45 DAS	SPAD at 60 DAS	DFF	DM	PH (cm)	HD (cm)	TW (g)	Yl/ha (kg)	OC (%)	OY (kg ha^{-1})
Females											
1	CMS 21A	0.48	-0.67	-0.11	-1.14	-0.84	-0.99**	-0.16	-9.55	-1.03	-9.90
2	CMS-1030A	-0.17	-1.02	0.32	1.99	14.9**	-0.29*	0.09	5.39	0.66	3.78
3	4546 × DSF 2A	-0.67	-0.66	2.70**	0.49	-16.39**	-0.68**	-0.24**	-96.86*	-1.66*	-44.35**
4	CMS 7-1-1 A	-0.81	1.17	-1.49*	-0.70	-9.11**	0.23	0.13	81.64**	2.35**	43.99*
5	CMS-853A	1.17	1.18	-1.42*	-0.64	11.23**	1.74**	0.18*	19.39	-0.37	6.49
	SE for lines	0.6785	0.6968	0.6364	1.0836	1.4604	0.1365	0.0853	12.279	0.533	5.64
Males											
1	DSR-13	-1.19	-2.98**	2.13*	-0.06	0.80	-0.54**	0.01	-50.00**	-1.21	-26.03**
2	DSR-19	-0.24	-0.34	0.82	-1.86	-1.08	-0.10	-0.15	11.30	0.76	10.53
3	DSR-23	-2.94**	-2.13*	1.13	0.04	-6.50	-0.22	0.13	29.10	2.56**	24.24**
4	DSR-35	-0.93	0.96	-0.68	3.74**	-2.74	0.03	0.08	7.70	1.61*	11.01
5	DSR-37	1.57	3.73*	-1.77*	2.34	7.66	0.70**	0.15	24.00	1.07	13.73
6	DSR-66	1.19	-0.6	1.63*	-0.66	-6.54**	-0.36*	-0.18	-18.50	-2.85**	-22.02
7	DSR-107	1.96*	-0.82	-1.17	-0.46	-13.16**	0.13	-0.12	-37.00*	-1.76*	-22.74**
8	DSR-132	0.59	2.18*	-2.08*	-3.06*	11.58**	0.36**	0.08	33.40*	-0.18	11.27
	SE for testers	0.8582	0.814	0.8050	1.3707	1.8473	0.1727	0.1079	15.532	0.6745	7.13

DFF- Days to 50% flowering, DM- Days to maturity,PH- Plant height, HD-Head diameter, TW- Test weight, Yl/ha- Seed yield per hectare, OC- Oil content, OY- Oil yield per hectare

Table.3 Specific combining ability (sca) effects for seed yield and its component traits in sunflower

Sl No.	Sources	SPAD at 45 DAS	SPAD at 60 DAS	DFF	DM	PH (cm)	HD (cm)	TW (g)	Yl/ha (kg)	OC (%)	OY (Kg ha^{-1})
1	CMS 21A × DSR-13	0.00	1.16	**4.81 ***	-0.06	0.12	0.35	-0.28	21.25	-1.56	2.49
2	CMS 21A × DSR19	-2.12	-2.64	-1.89	0.74	-6.80	-0.33	-0.07	**-97.5***	-2.92	**-52.6 ***
3	CMS 21A × DSR 23	2.05	0.61	-1.19	-1.16	**-16.59 ***	0.12	-0.08	9.65	-0.21	2.85
4	CMS 21A × DSR 35	0.83	-1.69	-1.39	-1.86	-4.54	-0.41	-0.11	30.05	-0.14	10.09
5	CMS 21A × DSR 37	3.45	1.66	-1.29	**-6.46 ***	-6.34	0.32	0.01	-19.75	2.02	2.47
6	CMS 21A × DSR 66	-4.07 *	-2.91	-1.19	-1.46	**23.85 ***	**1.25 ***	0.41	22.75	1.05	14.80
7	CMS 21A × DSR-107	-1.96	0.20	3.11	**7.34 ***	**18.38 ***	-0.01	0.41	64.25	-0.60	20.75
8	CMS 21A × DSR-132	1.82	3.60	-0.99	2.94	-8.07	**-1.28 ***	-0.29	-30.65	2.36	-0.79
9	CMS-1030A × DSR-13	1.07	1.92	**-6.63 ***	-3.19	-6.72	-0.59	0.16	31.81	2.86	26.81
10	CMS-1030A × DSR-19	-1.15	-1.99	0.68	0.61	-1.34	-0.22	0.03	10.51	0.40	3.94
11	CMS-1030A × DSR-23	**-4.40 ***	**-6.15 ***	**5.88 ***	-0.29	7.48	**-0.93 ***	0.25	-24.79	-2.38	-22.18
12	CMS-1030A × DSR-35	**-4.84 ***	-1.68	-1.82	0.01	**8.32 ***	0.09	-0.03	62.11	1.83	**35.64 ***
13	CMS-1030A × DSR-37	1.94	0.34	0.27	2.41	**34.62 ***	**1.01 ***	0.05	47.81	**-3.28 ***	1.51
14	CMS-1030A × DSR-66	3.16	**4.00 ***	0.88	2.41	**-15.68 ***	0.25	-0.11	-53.69	1.37	-14.97
15	CMS-1030A × DSR-107	1.56	3.41	0.17	**-6.79 ***	**-13.26 ***	0.24	-0.23	58.81	1.80	31.74
16	CMS-1030A × DSR-132	2.67	0.15	0.58	-0.19	**-13.40 ***	0.16	-0.13	**-132.9***	-2.61	**-62.5***
17	4546 × DSF 2A × DSR-13	-1.75	-1.76	-0.50	3.31	**12.27 ***	0.36	0.17	14.56	-0.36	6.29
18	4546 × DSF 2A × DSR-19	-1.20	-2.89	2.80	**-6.89 ***	8.04	0.14	-0.28	-19.74	**-4.01 ***	-27.76
19	4546 × DSF 2A × DSR-23	-2.76	-3.36	-1.50	-0.79	7.57	0.06	-0.45	-18.54	-0.15	-11.14
20	4546 × DSF 2A × DSR-35	2.79	-0.90	-0.20	4.51	4.20	0.45	-0.42	-41.14	**-3.09 ***	-31.43
21	4546 × DSF 2A × DSR-37	0.77	-0.18	0.90	3.91	**-25.99 ***	-0.73	-0.31	**-92.44 ***	0.57	**-35.72 ***

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Sl. No	Sources	SPAD at 45 DAS	SPAD at 60 DAS	DFF	DM	PH (cm)	HD (cm)	TW (g)	Yl/ha (kg)	OC (%)	OY (Kg ha⁻¹)
22	4546 × DSF 2A × DSR-66	1.30	1.29	**4.50 ***	-3.09	-4.40	**-0.90 ***	0.19	15.56	-2.83	-2.70
23	4546 × DSF 2A × DSR-107	-1.20	-0.21	-3.20	-2.29	-1.78	**-1.04 ****	0.09	-44.94	**3.86 ***	-3.18
24	4546 × DSF 2A × DSR-132	2.03	**8.01 ****	-2.80	1.31	0.09	**1.67 ****	**1.01 ****	**186.6****	**6.01 ****	**105.6****
25	CMS 7-1-1 A × DSR-13	-0.45	-2.43	**5.69 ****	0.50	**-10.81 ***	-0.70	0.10	-11.94	-2.07	-16.86
26	CMS 7-1-1 A × DSR-19	2.06	-1.60	-2.01	5.30	-3.73	0.25	-0.29	-2.24	0.65	1.07
27	CMS 7-1-1 A × DSR-23	2.75	-1.83	-3.31	0.90	-5.21	0.25	-0.10	-52.54	-0.86	-25.51
28	CMS 7-1-1 A × DSR-35	1.11	**7.85 ****	2.99	-2.30	**-8.97 ***	**1.26 ****	**0.54 ***	44.86	1.12	26.80
29	CMS 7-1-1 A × DSR-37	-2.56	**5.73 ****	-0.91	3.10	3.63	**0.80 ***	**0.73 ****	34.06	1.29	24.55
30	CMS 7-1-1 A × DSR-66	0.22	-1.76	**-3.81 ***	-4.90	-7.17	**-1.11 ****	-0.47	-18.44	0.04	-9.65
31	CMS 7-1-1 A × DSR-107	-1.37	-2.35	0.99	-1.10	5.95	0.17	-0.22	34.56	1.41	19.16
32	CMS 7-1-1 A × DSR-132	-1.76	-3.61	0.39	-1.50	**26.31 ****	**-0.91 ***	-0.28	-28.34	-1.58	-19.57
33	CMS-853A × DSR-13	1.12	1.11	-3.38	-0.56	5.15	0.59	-0.16	-55.69	1.12	-18.74
34	CMS-853A × DSR-19	2.42	**9.12 ****	0.42	0.24	3.83	0.17	**0.61 ***	**109****	**5.89 ****	**75.42****
35	CMS-853A × DSR-23	2.36	**10.73 ****	0.12	1.34	6.75	0.51	0.39	**86.21 ***	**3.59 ***	**55.97 ****
36	CMS-853A × DSR-35	0.11	-3.58	0.42	-0.36	0.99	**-1.39 ****	0.02	**-95.8****	0.27	**-41.10 ***
37	CMS-853A × DSR-37	-3.59	**-7.55 ****	1.02	-2.96	-5.91	**-1.39 ****	-0.48	30.31	-0.60	7.19
38	CMS-853A × DSR-66	-0.61	-0.62	-0.38	2.04	3.39	0.51	-0.02	33.81	0.37	12.52
39	CMS-853A × DSR-107	2.97	-1.05	-1.08	2.84	**-9.29 ***	0.65	-0.05	**-112.6***	**-6.47****	**-68.47****
40	CMS-853A × DSR-132	**-4.77 ***	**-8.15 ****	2.83	-2.56	-4.93	0.36	-0.30	4.91	**-4.18****	**-22.81**
	SE.m ±	1.91	1.97	1.80	3.06	4.13	0.38	0.24	34.73	1.50	15.59

DFF- Days to 50% flowering, DM- Days to maturity,PH- Plant height, HD-Head diameter, TW- Test weight, Yl/ha- Seed yield per hectare, OC- Oil content, OY- Oil yield per hectare

From the present investigation it was observed that none of the testers showedgood gca effect for all the traits studied. But DSR-132 recordedsignificant gca effect for six traits *viz*, plant height, SPAD at 60 DAS, days to flowering, head diameter, days to maturity and seed yield per ha. Similarly the line (which was used as female parent) CMS 7-1-1A recorded better gca effect for plant height, days to 50 %flowering, seed yield per hectare and oil content. The line CMS 853A exhibited significant gca effect for days to 50 percent flowering, head diameter and test weight indicating that these are the good general combiners among the lines. The results indicate that DSR-132 exhibited significant gca effect of 11.58, 2.18, -2.08, 0.36, -3.06 and 33.40 for plant height, SPAD at 60 DAS, days to 50 % flowering, head diameter, days to maturity and yield per hectare respectively which can be used for further development of open pollinated varities and hybrids.

For earliness, the tester DSR-132 and the line CMS 7-1-1 A found to be good general combiners. These both may serve as desirable parents in combining earliness in the hybrid combination CMS 7-1-1 A ×DSR-132. These results are in accordance with reports of Gangappa*et al.* (1997) and Khan *et al.* (2008).

Among the testers, DSR-23 and among the line CMS-7-1-1A showed maximum gca effect for oil content, which serve as desired parental lines for combining oil content in the hybrid combination CMS 7-1-1 A × DSR-23 which was responsible for exhibiting positive heterosis of 16.58 % and 19.58 % over KBSH-53 and cauvery champ respectively.None of the testers showed good gca effect for both seed yield and oil content, where as the line CMS 7-1-1 A has shown good gca effect for both oil content and yield per hectare (shown in Table 2).

Specific combining ability effects

The estimation of specific combining ability effect helps to detect the best crosses. The best crosses are identified based on specific combining ability effects in desirable direction. The specific combining ability effects of new experimental hybrids presented in **Table 3**.None of the hybrid combinations showed significant sca effect for all the traits studied, but the combination 4546 × DSF2 A × DSR-132 recorded high and significant sca effect for the traits *viz*, days to 50 percent flowering,SPAD chlorophyll content at 60 DAS, head diameter, test weight, seed yield per hectare, oil content and oil yield. The top three hybrid combinations with maximum sca effect are interpreted in the Table 25.

Among 40 crosses, CMS 21A × DSR 23, CMS 1030 A × DSR-66 and CMS 1030 A × DSR-132 recorded significant sca effect for plant height. Since dwarf plants (resistant to lodging) are preferred, these are the best cross identified with significant sca effect for plant height. Similarly for SPAD at 60 DAS, CMS-853A × DSR-19 exhibitedmaximum sca effect. For days to 50 per cent flowering CMS-1030A × DSR-13 showed significant sca effect in the negative direction, indicating earliness of the hybrid which is desirable in crop improvement programme.The cross 4546 × DSF 2A × DSR-132 showed significant maximum sca effect for head diameter ,test weight, seed yield per hectare oil content and oil yield respectively, which is due to superior performance of testerswith better combining ability. These results are in agreement with the reports of Burli and Jadhav (2001), Sharma *et al.* (2003), Halaswamy*et al.* (2004), Reddy and Madhavilatha, (2005), Vishwanath and Goud (2006), Sujatha *et al.* (2009), Keerthi (2010) and Reddy *et al*. (2005).

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