



RESEARCH ARTICLE

Gene action and Combining Ability Studies Using line x Tester Analysis in Sunflower (*Helianthus annuus* L.)

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ABSTRACT

The present investigation was aimed to study the combining ability and gene action in parents and hybrids of sunflower for seed yield and components traits. Six female lines were crossed with four male lines by Line x Tester method, to obtain 24 F₁s. Data were recorded on ten characters. Among the female parents CMS-108A, CMS-250A and CMS-207A were good general combiners for seed yield and other contributing traits. Among the male parents, IB-22, EC-178178, EC-601957 were identified as the best general combiners for seed yield and other yield contributing traits. The crosses showing high desirable SCA effect have involved one of the parents of high GCA effect and in turn, had high per se performance. The SCA effect of hybrids viz., CMS-207A x IB-22 and CMS-108A x GP-6-116 were highly significant for seed yield/plant (g) and other component traits in a desirable direction, indicating that the high performance of these crosses is due to non-allelic gene action. Non-additive gene action is predominant for all the studied characters except days to 50% flowering, plant height (cm) and hull content (%).

Keywords: Sunflower; Combining ability; Gene Action; GCA; SCA; Line; Tester.

INTRODUCTION

Sunflower (*Helianthus annuus* L. 2n=34), is an important oilseed crop in the world, belongs to the genus *Helianthus* and the family 'Asteraceae' (Compositae). It is also known as 'Surajmukhi' in Hindi, 'Suryaphul' in Marathi. It is native to southern parts of the USA and Mexico. Sunflower is the second most important oilseed crop globally after soybean because of its wide range of adaptability and high oil (40-50%) and protein content (23%). It can be grown successfully in different parts of the world due to its wide adaptability, photo-insensitive and thermo-insensitive nature. Several biometrical techniques have been developed to generate information on gene action and mode of inheritance of various characters, among which line x tester analysis (Kempthorne, 1957) has been widely used for genetic analysis in a large number of crop plants. It is a very efficient technique for evaluating many inbreds for their combining ability and studying gene action controlling various characters to adopt an appropriate breeding strategy.

MATERIALS AND METHODS

The present investigation for combining ability studies in sunflower (*Helianthus annuus* L.) using

Line x Tester mating design was conducted during *kharif* 2019-2020, at Oilseeds Research Station, Latur. The experimental material for the present study included four CMS lines as female parents and six restorers as male parents, which were crossed by Line x Tester mating design to produce 24 new hybrids, in *Rabi*, 2018-19. The hybrids were evaluated in Randomized Block Design with two replications for combining ability in *Kharif* 2019-20. Observations were recorded on five random but competitive plants for ten characters viz., days to 50 percent flowering, days to maturity, plant height (cm), head diameter (cm), seed filling (%), hull content (%), 100 seed weight (g), seed yield / plant (g), oil content (%) and volume weight (g/100mL). Mean values were subjected to line x tester analysis to estimate general combining ability (GCA) and specific combining ability (SCA) effects and their respective variances as per the method suggested by Kempthorne (1957).

RESULT AND DISCUSSION

The analysis of variance was worked out to assess the variation among the parental lines and crosses for ten characters. The significance was marked by applying F-test. The analysis of variance

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for ten characters consisting of replication mean square, treatment mean square, error mean square and critical differences at 5 % and 1 % is given in table 1. The mean sum of squares due to treatments

were highly significant for all the characters under study. This indicates the existence of sufficient variability for yield and yield contributing characters in the material under study.

Table 1: Analysis of variance for parents and crosses for ten morphological traits in sunflower.

Source of variation	d. f.	Days to 50 % flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	Seed filling (%)	Hull content (%)	100 Seed weight (g)	Seed Yield / plant (g)	Oil content (%)	Volume weight (g/100mL)
Replication	1	6.485	16.014	8.47	2.7	5.292	0.381	0.371	0.044	0.214	29.554
Treatment	35	7.520**	21.399**	620.02**	4.553**	106.94**	37.874	0.696**	120.136**	11.38**	46.584**
Parents	9	7.755*	39.800**	881.27**	3.486**	160.02**	33.662	0.7801**	40.051**	21.98**	11.71
CMS lines	3	8.5	30.791**	728.44**	2.219	120.44**	4.547	1.892**	58.817**	40.16**	9.087
Tester	5	6.933	49.483**	1071.23**	4.920**	160.28**	20.622	0.250**	30.053**	4.492**	10.408
Crosses	23	7.187**	14.716*	263.68**	1.84	12.396**	32.717	0.5815**	231.27**	3.711**	47.793**
Line x Tester	15	9.633	18.408	389.98**	0.119	277.46**	186.20**	0.0891	33.739**	54.91**	26.096
Parents v/s Crosses	1	13.078*	9.512	6464.61**	76.56**	1803.97**	194.41**	2.603**	1186.5**	92.51**	332.64**
Error	35	2.9398	6.59	22.992	1.0875	14.093	21.821	0.0392	1.9188	0.7621	7.825

**and* indicates significant at 1% and 5%, respectively.

Generally, the parents with high *per se* may not transmit their superiority in their progenies. Hence, it is crucial to calculate the combining ability of parents forestimating their performance in the hybrids. Crosses were found to be significant for all traits except head diameter (cm) and hull content (%). The significance of variance due to parents Vs crosses indicated the presence of heterosis in hybrids for all characters except days to maturity. Similar findings were also reported by Halaswamy *et al.* (2004) and RaviRana *et al.* (2004).

The magnitude of specific combining ability variances was larger than general combining ability variances for all the characters except days to 50% flowering, plant height, seed filling (%) and hull content (%). The ratio of (δ_2GCA/δ_2SCA) was less than unity for almost all characters except days to 50% flowering, hull content, and plant height, indicating the predominance of non-additive gene action, which is in agreement with the results of Radhika *et al.* (2001).

Table 2: Estimates of general combining ability effects (GCA) of lines and testers for ten morphological traits.

Characters	Days to 50 % flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	Seed filling (%)	Hull content (g)	100 – Seed weight (g)	Seed Yield plant (g)	Oil content (%)	Volume weight (g/100ml)
CMS 108A	-1.438**	1.354	-14.916**	0.53	1.821	4.290**	-0.112	3.893**	-0.003	3.113**
CMS 250A	1.063*	-2.313**	8.276**	0.519	0.633	-1.552	0.024	-1.639**	-0.274	1.303
CMS 249A	-0.104	1.271	1.556	0.681*	-2.097	-2.71	0.079	-5.453**	1.355**	-1.672*
CMS 207A	0.479	-0.313	5.084**	-0.368	-0.357	-0.207	0.01	3.199**	-1.078**	-2.743**
IB-22 R	-1.188	0.271	-2.541	0.169	-2.14	-0.885	-0.180*	2.548**	0.298**	1.264
EC-601957R	0.313	0.146	-4.083*	-0.232	1.158	1.665	0.037	-1.838**	0.239	-3.516**
EC-198075R	-0.313	-0.854	0.834	-0.075	0.659	-1.198	0.326**	-1.117**	-1.178**	0.359
EC-178178R	0.563	-0.354	-0.878	-0.148	-1.155	1.927	-0.371**	-2.745**	0.589**	-3.599**
GP-6-263R	0.313	0.396	4.959**	0.155	0.779	0.727	-0.148*	-2.962**	0.056	1.066
GP-6-116R	0.313	0.396	1.107	0.13	0.699	-2.235	0.336**	6.714**	-0.004	4.426**

** and * indicates significant at 1% and 5%, respectively.

The parents were classified as good, average, and poor combiners based on the estimates of general combining ability effects. A summarized account of GCA effects of parents for different characters is presented in table 2. None of the parental lines was found to be a good combiner for all the traits studied. General combining ability effects help to

pinpoint the good parent. A perusal of GCA effects of ten parents (4 CMS lines and 6 testers) for 10 characters reveals that the CMS-249A was found to be a good general combiner for head diameter (0.684) and oil content (13.55), CMS-108A for days to 50% flowering (1.438), plant height (14.916), seed yield/plant (3.593) and volume weight (3.113)

exhibiting significant GCA effects in a desirable direction. Similarly CMS-207A showed good general combining ability for seed yield/plant (3.199).

Among the male parents, IB-22R was found to be a good general combiner for seed yield/plant (2.548) and oil content (0.298). EC-198075 was a good general combiner for 100 seed weight (0.326) (Table 2). EC-601957 was found to be a good general combiner for plant height (-4.083). The male parent EC-178178 registered good general combining ability for oil content (0.589) while GP-6-116 was a good general combiner for seed yield/plant

(6.714), 100 seed weight (0.336), and volume weight (4.426). The present results suggest that the parents viz., GP-6-116R, IB-22, and EC-178178R possessed high concentration of favorable genes for the respective traits and may be utilized in crossing programmes to develop the varieties/hybrids with desirable characteristics in sunflower. All these lines and testers can be exploited for the development of better hybrids and also in conventional breeding programmes. Such type of good general combiner for economic traits in sunflower was reported by Patil *et al.* (2012), and Kumar *et al.* (2015).

Table 3: Estimates of specific combining ability (SCA) effects of crosses for ten morphological traits in sunflower.

Sr. No	Characters Crosses	Days to 50 % flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	Seed filling (%)	Hull content (%)	100 Seed weight (g)	Seed Yield / plant (g)	Oil content (%)	Volume weight (g/100ml)
1	CMS-108A x IB-22R	0.688	1.896	-8.209*	-1.378	1.408	2.435	0.076	-4.892**	1.510*	-0.435
2	CMS-108A x EC-601957R	-0.813	-2.479	5.333	0.824	2.141	-1.0115	-0.191	0.394	-0.281	-5.915**
3	CMS-108A x EC-198075R	-1.188	2.021	-1.584	0.166	-0.476	-1.552	0.670**	-0.462	-1.064	0.720
4	CMS-108A x EC-178178R	-0.063	1.521	4.628	-0.840	-1.732	-0.477	0.107	-2.100*	-1.031	3.964
5	CMS-108A x GP-6-263R	-0.313	0.271	-1.209	1.351	0.094	0.373	-0.336*	-0.382	0.353	0.179
6	CMS-108A x GP-6-116R	1.688	-3.229	1.041	-0.124	-1.436	0.235	-0.325*	7.442**	0.513	1.489
7	CMS-250A x IB-22R	-1.313	1.063	20.099**	1.768*	-1.874	-0.073	-0.055	-5.030**	0.507	1.360
8	CMS-250A x EC-601957R	1.188	1.688	-3.358	-1.415	1.428	-2.223	0.788**	2.582*	-0.449	2.690
9	CMS-250A x EC-198075R	0.313	-4.313*	-0.776	-0.873	1.487	7.090*	-0.726**	3.400**	0.058	-0.570
10	CMS-250A x EC-178178R	2.938*	-3.313	-1.913	0.831	0.196	-0.485	-0.196	4.263**	-0.074	-2.031
11	CMS-250A x GP-6-263R	-1.813	1.438	-12.401**	-0.968	-1.128	-3.985	0.533**	1.480	-0.926	0.914
12	CMS-250A x GP-6-116R	-1.313	3.438	-1.651	0.357	-0.108	-0.323	-0.736**	-6.696**	0.884	-2.361
13	CMS-249A x IB-22R	-0.646	-0.521	-6.181	-0.147	1.991	-0.765	0.675**	-2.380*	-1.317*	-3.395
14	CMS-249A x EC-601957R	0.854	1.604	-1.808	0.200	-0.737	0.435	-0.492**	2.836**	-0.739	0.245
15	CMS-249A x EC-198075R	2.979*	2.604	4.444	0.292	-0.768	-1.452	-0.386*	2.160*	1.429*	-1.375
16	CMS-249A x EC-178178R	-1.396	-0.896	-0.843	-0.464	0.151	3.473	-0.134	1.912	0.461	3.474
17	CMS-249A x GP-6-263R	-0.146	-3.146	6.819	-0.203	1.437	-0.627	-0.132	2.855**	0.895	4.539*
18	CMS-249A x GP-6-116R	-1.646	0.354	-2.431	0.322	-2.073	-1.065	0.469**	-7.382**	-0.730	-3.486
19	CMS-207A x IB-22R	1.271	-2.438	-5.709	-0.244	-1.524	-1.598	-0.696**	12.302**	-0.700	2.471
20	CMS-207A x EC-601957R	-1.229	-0.813	-0.167	0.392	-2.832	2.802	-0.104	-5.812**	1.469*	2.981
21	CMS-207A x EC-198075R	-2.104	-0.313	-2.084	0.115	-0.243	-4.085	0.442**	-5.098**	-0.424	1.226
22	CMS-207A x EC-178178R	-1.479	2.688	-1.872	0.473	1.386	-2.510	-0.170	-4.075**	0.644	-5.406
23	CMS-207A x GP-6-263R	2.271	1.38	6.791	-0.180	-0.403	4.240	-0.064	-3.953**	-0.322	-5.631**
24	CMS-207A x GP-6-116R	1.271	-0.563	3.041	-0.555	3.617	1.152	0.592	6.636**	-0.667	4.359*

** and * indicates significant at 1% and 5%, respectively.

In sunflower, negative SCA effects are considered to be desirable for days to 50% flowering, days to maturity, plant height, and hull content. Among 24 crosses, one hybrid for days to maturity, two

hybrids for plant height and one hybrid for hull content registered high negative significant SCA effects. Similarly positive and significant SCA effects were recorded by one hybrid for head diameter,

seven hybrids for 100 seed weight, three hybrids for oil content (%), nine hybrids for seed yield per plant, and two hybrids for volume weight (g/100 mL) (Table 3).

The hybrid CMS-207A x GP-6-116R exhibited a good SCA effect for 100 seed weight, volume

weight, and seed yield/plant. CMS 249 x EC-198075 recorded significant SCA effect for oil content and seed yield/plant. The cross CMS-249A x GP-6-263 registered a good SCA effect for seed yield/plant and volume weight. The hybrid CMS-108A x IB-22 identified good SCA effects for days to 50% flowering, plant height, and seed yield/plant.

Table 4: Estimation of gene action (Var.gca and Var.sca) for ten morphological traits in sunflower.

Characters	Variance gca	Variance sca	Ratio Var.gca/ Var.sca	Gene action
Days to 50 % flowering	0.1422	0.1353	1.0509	Additive
Days to maturity	0.4022	4.09301*	0.0982	Non-additive
Plant height (cm)	55.9036	49.0710	1.1392	Additive
Head diameter (cm)	0.0599	0.3671	0.1631	Non-additive
Seed filling (%)	1.5773**	-3.1805	-0.4959	Non-additive
Hull content (%)	4.7644**	-0.8847	-5.3853	Additive
100 – Seed weight (g)	-0.0286	0.3080**	-0.0928	Non-additive
Seed Yield / plant (g)	9.9669**	36.7071	0.2715	Non-additive
Oil content (%)	0.5424**	0.7328*	0.7401	Non-additive
Volume weight (g/100mL)	5.1184**	11.3085**	0.4526	Non-additive

** and * indicates significant at 1% and 5%, respectively.

Cross CMS-250A x EC-198075 showed good SCA effects for early days to maturity and seed yield/plant. The hybrid CMS-250A x EC-601957 had good SCA effect for 100 seed weight and seed yield/plant. The cross CMS-250A x GP-6-263 was with good SCA effect for plant height and 100-seed weight. The crosses exhibiting higher *per se* performance and significant desirable SCA effects for various traits involved either good x good, good x average, good x poor, average x average, average x good, poor x good and poor x average combining parents.

For all the traits under study, the crosses with significant SCA effects in the desirable direction involved parents with high x high, high x low or low x low GCA effect indicating that the high performance of these crosses was due to additive, dominance, and epistatic gene interaction. The ideal cross combination to be exploited is one whose high magnitude of SCA is present in addition to GCA in both or at least in one of the parents. Therefore, the hybrids CMS-207A x IB-22 and CMS-207A x GP-6-116 for seed yield/plant and CMS-108A x IB-22 and CMS-207A x EC-601957 for oil content could be exploited through heterosis breeding. These results are in agreement with the findings of Chandra *et al.* (2011), Jondhale *et al.* (2012), Qamar *et al.* (2015), and Aleem *et al.* (2015).

The value of estimates of GCA and SCA variances, their ratios, and gene action is presented in table 4. It was observed that the magnitude of specific combining ability variances was larger than general

combining ability variances for all characters except days to 50 % flowering, plant height, seed filling (%), and hull content (%). The ratio of (δ^2GCA/δ^2SCA) was less than unity for all characters (except days to 50 % flowering, plant height, and hull content (%), indicating predominance of non-additive gene action. The ratio of GCA/SCA was less than 1 for days to maturity (0.0982), head diameter (cm) (0.1631), seed filling (%) (0.4959), 100 seed weight (g) (0.0928), oil content (%) (0.7401), seed yield/plant (g) (0.2715) and volume weight (g/100mL) (0.4526) which indicated the presence of non-additive gene action.

CONCLUSION

The crosses showing high desirable SCA effect have involved either one of the parents of high GCA effect and in turn, had high *per se* performance. The SCA effect of hybrids *viz.*, CMS-250A x EC-198075 and CMS-249A x EC-198075 were highly significant for seed yield/plant (g) and other component traits in a desirable direction, indicating the high performance of these crosses is due to non-allelic gene action. The ratio of (δ^2GCA/δ^2SCA) was less than unity for all characters except days to 50 % flowering and plant height, indicating the additive type of gene action and predominance of non-additive gene action for other studied traits. The hybrids *viz.*, CMS-207A x IB-22 and CMS-108A x GP-6-116 recorded a high significant SCA effect for yield and yield components. Most of the crosses exhibiting high SCA effect involved either good x

good or average x good general combiners for the majority of the characters studied. The presence of additive or additive x additive, additive x dominance gene interaction effects would enhance the chance of crop improvement through simple selection. The prevalence of additive and non-additive genetic effects suggests the simultaneous exploitation of these gene actions by adopting selective inter-mating and recurrent selection. The parental lines 108A, 250A, IB-22, and EC-601957 have been identified as good general combiners and could be preferred in a breeding programme, as these parents upon crossing, are expected to give desirable segregants in the succeeding generations.

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