Biological Forum – An International Journal 14(2a): 255-260(2022)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Combining Ability Assessment in Sunflower through Line × Tester Analysis

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(Received 24 April 2022, Accepted 23 June, 2022)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Sixty hybrids were tested using line × tester design involving five cytoplasmic male sterile lines and twelve restorer lines using Randomized block design with three replications at the field of Oilseeds Research Unit, Dr. PDKV, Akola. The hybrids and parents were evaluated during *kharif* 2017 to estimate the combining ability effects. Among the parents HA228A, HA208A, HA303A, AKSFI-16-1, AKSFI-16-2, AKSFI-16-4, AKSFI-16-4, AKSFI-16-5 and AKSFI-16-12 were found to be best general combiner for seed yield and most of the yield contributing traits. The parents HA303A, AKSFI-16-1, AKSFI-16-2, AKSFI-16-4, AKSFI-16-5 and AKSFI-16-12 were also good general combiner for oil content. On the basis of mean performance and sca effects of crosses, three crosses *viz.*, HA228A × AKSFI-16-4, HA208A × AKSFI-16-2 and HA303A × AKSFI-16-12 were identified as promising crosses.

Keywords: General combining ability, Specific combining ability, line × tester analysis and randomized block design.

INTRODUCTION

Sunflower is one of the most important oilseed crop grown for edible purposes in the world. Per capita consumption and requirements for edible oil is increasing. So the local production of hybrid seed with increased seed and oil yield is one of basic step to achieve the goal**.** Compared to other oilseed crop, sunflower possesses several advantages. As for example, short duration (90-110 days) and high yield potential with higher % of edible oil, having tolerance to drought and salt (Ahmad *et al.,* 2012) with wider adaptability to different soil and climatic conditions (Sunil and Khan 2013). Oil of sunflower is light in taste, appearance and more essential vitamin E then, other vegetable oil. The sunflower consists of monounsaturated and polyunsaturated fats. It is used like, foods, cosmetics, industries, and for the treatment of Cholesterol and atherosclerosis. (Madhavi *et al.*, 2010). Low yielding genotypes and hybrids of sunflower are the major constraints of sunflower productivity. To conquer this constraint breeders have attention towards production of hybrids through heterosis breeding, which become possible due to discovery of cytoplasmic male sterility by Leclerq (1969) and fertility restoration system by Kinman (1970).

In plant breeding general combining ability (GCA) and specific combing ability (SCA) are important techniques to identify best lines for the production of hybrid. Combining ability analysis provides the information for selection of desirable parents and cross combination for exploitation. In this analysis, total variance is partitioned into GCA and SCA effect to verify the parents in terms of combining ability to combine in hybrid combination.

MATERIAL AND METHODS

Present research was conducted at Oilseeds Research Unit, Dr. PDKV, Akola. The parental material for the study consisted of five CMS lines *viz.*, HA2228A, HA249A, HA302A, HA208A and HA303A and twelve restorer lines *viz.*, AKSFI-16-1, AKSFI-16-2 AKSFI-16-3, AKSFI-16-4, AKSFI-16-5, AKSFI-16-6, AKSFI-16-7, AKSFI-16-8, AKSFI-16-9, AKSFI-16-10, AKSFI-16-11 and AKSFI-16-12. Crossing work was done in *rabi* 2016 and evaluation was done in *kharif* 2017, resultant 60 crosses and two checks (PDKVSH-952 and DRSH-1) were sown in RBD design with three replications for evaluation in line × 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 data was recorded on plant basis and plot basis, from each genotype in each replication on 5 randomly selected plants and their average value was computed for ten quantitative traits *viz.*, days to 50% flowering, days to maturity, plant height at harvest (cm), head diameter (cm), hundred seed weight (g), volume weight (g/100ml), seed filling percentage, hull content (%), seed yield per plant (g) and oil content (%). Oil content of all genotypes was determined by using Bench top Pulse Nuclear magnetic Resonance (NMR) Spectrometer (Model MQC OXFORD). Heterosis was calculated over mid parent, better parent and standard checks (PDKVSH-952 and DRSH-1) for seed yield, its components and oil content. The significance of GCA and SCA effects was determined at the 0.05 and 0.01 level using the t-test (Singh and Choudhary 1977).

RESULTS AND DISCUSSION

Analysis of variance for combining ability of seventeen parents and sixty crosses (obtained by crossing 5 lines with 12 testers) was carried out and the total variance due to crosses was partitioned into portions attributable to crosses, females (lines), males (testers), lines × testers and error sources (Table 1). The components of variances attributable to lines and testers were used as a measure of general combining ability effects and the variances due to interaction between lines and testers was used as a measure of specific combining ability effects.

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	3.01	5.19	22.97	3.02	0.07	0.55	26.94	0.09	1.49	37.08
Crosses	59	8.23**	17.86**	605.55**	7.99**	1.04**	29.92**	495.44**	369.67**	6.07**	190.13**
Females (lines)	4	29.79*	53.79*	1411.67**	5.40	2.81**	64.10*	690.48	164.36	12.76**	398.04**
Males (testers)	11	4.60	18.76	1689.48**	24.12**	2.85**	62.34**	1305.50**	1063.47**	19.60**	503.75**
Females Vs Males	44	7.18**	14.36**	261.30**	4.19**	0.43**	18.71**	275.19**	214.88**	2.08**	92.83**
Error	118	1.55	1.77	37.32	1.00	0.08	1.67	17.49	0.03	0.49	13.68

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

Table 1a: General Combining ability of parents.

Females (lines)	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
HA228A	-1.18**	-0.51*	3.22**	0.52**	0.43**	1.99**	4.87**	-3.53**	0.01	3.65**
HA249A	-0.71**	-1.23**	-8.15**	-0.34	0.11*	-0.98**	-2.86**	2.23**	-0.81**	-4.40**
HA302A	0.27	-0.87**	-5.28**	-0.43*	-0.46**	-1.56**	-5.84**	0.15	0.51**	-2.48**
HA208A	0.66**	1.24**	5.23**	0.12	0.09	0.08	0.60	0.31	-0.34**	1.86**
HA303A	0.96**	1.38**	4.98**	0.13	-0.17**	0.47*	3.22**	0.84	0.64**	1.37*
SE (D)±	0.20	0.24	0.99	0.17	0.05	0.21	0.63	0.03	0.13	0.56
CD (5%)	0.40	0.47	1.97	0.34	0.10	0.42	1.25	0.06	0.25	1.10
CD (1%)	0.53	0.62	2.60	0.45	0.14	0.55	1.65	0.08	0.33	1.46

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

The variances due to lines were significant for days to 50% flowering, days to maturity, plant height, 100 seed weight, volume weight, oil content and seed yield, whereas, the variances due to males were significant for plant height, head diameter, 100 seed weight, volume weight, seed filling percentage, hull content, oil content and seed yield per plant. The variances due to crosses were highly significant for all the characters studied such as days to 50% flowering, days to maturity, plant height, head diameter, 100 seed weight, volume weight, seed filling percentage, hull content, oil content and seed yield. The variances due to lines × testers were also highly significant all the traits studied. Significant variance indicated the presence of substantial amount of genetic variability among the parents and crosses for respective characters.

The estimates of general combining ability effects of female and male parents are presented in Table 2. In sunflower positive gca effects are desirable for all the characters except days to 50 per cent flowering, days to maturity, plant height and hull content. In sunflower early to medium duration hybrids or genotypes are preferred and in the present study among the lines, two lines *viz.*, HA228A (-1.18) and HA249A (-0.71) recorded significant negative gca effects and among the testers, two testers *viz.*, AKSFI-16-2 (-0.64) and AKSFI-16-12 (-1.04) recorded significant negative gca effects for 50% flowering. For days to maturity line HA249A (-1.23) ranks top in the list followed by HA302A (-0.87) and HA228A (-0.51). Among twelve restorers, five *viz*. AKSFI-16-5, (-1.43), AKSFI-16-7 (-1.23), AKSFI-16-2 (-1.17), AKSFI-16-4 (-1.17) and AKSFI-16-3 (-0.83) showed significant negative GCA. The lines, HA249A (-8.15) and HA302A (-5.28) and testers AKSFI-16-1 (-19.65) and AKSFI-16-2 (-20.59) recorded significant negative gca effects for the dwarfness.

Table 2: General combining ability effect of parents.

Males (testers)	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
AKSFI-16-1	0.02	0.10	-19.65**	0.97**	0.36**	3.27**	10.69**	-3.95**	1.59**	7.73**
AKSFI-16-2	-0.64*	-1.17**	-20.59**	1.35**	0.09	2.27**	6.98**	-2.98**	0.77**	4.27**
AKSFI-16-3	-0.31	-0.83*	-0.80	-0.82**	0.18*	-1.06**	0.23	1.65**	-0.48*	-1.40
AKSFI-16-4	0.16	-1.17**	7.63**	2.19**	0.51**	2.54**	11.90**	-8.69**	1.01**	8.90**
AKSFI-16-5	-0.18	-1.43**	-2.05	0.85**	-0.22**	-0.21	-0.54	-10.55**	0.55**	3.04**
AKSFI-16-6	1.02**	1.30**	0.27	-1.46**	-0.37**	-2.03**	-13.79**	8.84**	-0.41*	-8.31**
AKSFI-16-7	-0.31	-1.23**	13.57**	0.15	0.16	-0.86**	-1.10	-8.35**	0.93**	0.95
AKSFI-16-8	0.36	0.30	4.19**	-0.71**	-0.31**	-1.54**	-0.39	7.65**	-1.55**	-3.93**
AKSFI-16-9	0.62	1.50**	-0.76	-1.15**	-0.39**	-1.36**	-9.48**	9.65**	-1.09**	-7.48**
AKSFI-16-10	0.22	1.03**	7.82**	-1.45**	-0.40**	-1.29**	-4.22**	3.71**	-1.50**	-5.08**
AKSFI-16-11	0.09	1.23**	10.11**	-1.12**	-0.49**	-2.26**	-13.42**	12.65**	-1.09**	-3.40**
AKSFI-16-12	-1.04**	0.367	0.26	1.19**	0.89**	2.52**	13.15**	-9.62**	1.26**	4.70**
SE (D)±	0.32	0.37	1.54	0.27	0.08	0.33	0.98	0.05	0.19	0.86
CD (5%)	0.63	0.73	3.05	0.53	0.16	0.65	1.94	0.10	0.39	1.71
CD (1%)	0.83	0.97	4.03	0.70	0.21	0.86	2.56	0.13	0.51	2.26

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

Hull content is an important character in deciding the ideal hybrid or genotype. Out of five lines tested, HA228A (-3.53) exhibited significant negative gca effects for hull content. Among males AKSFI-16-1 (-3.95), AKSFI-16-2 (-2.98), AKSFI-16-4 (-8.69) and AKSFI-16-12 (-9.62) showed significant gca effects in negative direction.

The characters like head diameter, 100 seed weight, volume weight and seed filling percentage are yield contributing characters and increase in these characters ultimately result in increased seed yield. The highest gca effect for head diameter was registered by line HA228A (0.52). Among males AKSFI-16-4 (2.19) showed maximum positive gca effect followed by AKSFI-16-2 (1.35) and AKSFI-16-12 (1.19). For 100 seed weight, among lines tested, HA228A (0.43) and HA249A (0.11) exhibited significant positive gca effect and out of the twelve testers AKSFI-16-1 (0.36), AKSFI-16-3 (0.18), AKSFI-16-4 (0.51) and AKSFI-16-12 (0.89) recorded significant positive gca effects. Highest significant GCA effect for volume weight was exhibited by AKSFI-16-1(3.27) followed by AKSFI-16-4 (2.54), AKSFI-16-12 (2.52), AKSFI-16-2 (2.27), HA228A (1.99) and HA303A (0.47). Out of five lines tested, HA228A (4.87) and HA303A (3.22) exhibited significant positive gca effects for seed filling. Among males AKSFI-16-1 (10.69), AKSFI-16-2 (6.98), AKSFI-16-4 (11.90) and AKSFI-16-12 (13.15) were significantly superior in positive direction, thus these parents were good general combiners for seed filling percentage.

The main use of sunflower is for edible oil purpose, thus the improvement in oil content is the major objective of sunflower improvement programme. In the present study, out of five lines tested, two lines viz., HA302A (0.51) and HA303A (0.64) exhibited significant positive gca effects for oil content and among males AKSFI-16-1 (1.59) showed maximum significant positive gca effect followed by AKSFI-16-12 (1.26), AKSFI-16-4 (1.01), AKSFI-16-2 (0.77) and AKSFI-16-5 (0.55). Thus, these parents were good general combiners for oil content.

Improvement in seed yield is a prime objective of any breeding programme. Out of five lines tested, three lines HA228A (3.65), HA208A (1.86) and HA303A (1.37) exhibited significant positive gca effects for seed yield per plant. Among males AKSFI-16-4 (8.90) showed maximum significant positive gca effect followed by AKSFI-16-1 (7.73), AKSFI-16-12 (4.70), AKSFI-16-2 (4.27) and AKSFI-16-5 (3.04). So they can be considered as good general combiners for seed yield per plant. These findings are in agreement with earlier reports of Uttam *et al*. (2005); Reddy and Madhavilatha (2005); Venkanna *et al.* (2005); Sawargoankar and Ghodke (2008); Misal (2009); Satishcandra *et al.* (2011); Patil *et al.* (2012); Saleem *et al.* (2014); Qamar *et al.* (2015); Sapkale *et al.* (2016); Kulkarni and Supriya (2017).

The estimates of specific combining ability effects of the 60 crosses are presented in 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.

In sunflower early maturity is desirable. Among 60 hybrids, 7 hybrids recorded significant negative sca effect for days to 50% flowering which is considered to be desirable since earliness is desirable, the cross HA303A × AKSFI-16-12 (-3.76) shows highest significant negative sca effect, followed by HA228A × AKSFI-16-7(-3.69), HA228A × AKSFI-16-2 (-2.36), HA302A × AKSFI-16-4 (-2.27) and HA228A × AKSFI-16-3 (-2.02). Out of sixty crosses ten crosses registered negative significant SCA effects for days to maturity. Highest positive SCA effect was exhibited by HA208A × AKSFI-16-10 (4.49) followed by HA302A × AKSFI-16-7 (3.87) and HA249A × AKSFI-16-4 (3.17). The sca effects ranged from -18.37 (HA228A × AKSFI-16-10) to 17.01 (HA302A × AKSFI-16-2) for plant height. Cross HA228A × AKSFI-16-10 (-18.37) exhibit highest significant negative sca effect followed by HA249A × AKSFI-16-2 (-17.98) and HA303A × AKSFI-16-3 (-17.11).

Table 3: Specific combining ability effects of crosses.

Sr. No.	Crosses	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	100 seed weight (g)	Volume weight (g/100ml)	Seed filling (%)	Hull content (%)	Oil content (%)	Seed yield per plant (g)
		1	2	3	4	5	6	7	8	9	10
1	HA228A X AKSFI-16-1	-1.02	0.51	9.17**	-0.49	0.02	-0.79	-7.66**	-0.63**	0.43	-4.70*
2	HA228A × AKSFI-16-2	-2.36**	-1.56	-15.48**	0.69	-0.21	-3.04**	3.09	-1.61**	0.69	-1.33
3	HA228A × AKSFI-16-3	-2.02**	-3.56**	-1.26	2.81**	1.12**	5.29**	14.03**	-5.23**	0.84	7.99**
4	HA228A × AKSFI-16-4	0.18	0.11	5.69	0.05	0.32*	0.94	9.78**	0.11	0.58	4.66*
5	HA228A × AKSFI-16-5	0.18	2.71**	-1.53	0.78	-0.14	-0.31	6.12**	-8.03**	-0.53	3.01
6	HA228A × AKSFI-16-6	0.64	-0.02	-3.08	0.68	0.01	1.26	-0.63	17.57**	0.25	-0.05
7	HA228A × AKSFI-16-7	-3.69**	-2.16**	2.02	0.18	0.22	2.59**	10.28**	-0.23*	0.27	5.69**
8	HA228A × AKSFI-16-8	1.98**	2.31**	-2.20	0.18	-0.73**	-0.73	-16.74**	-1.23**	-0.42	-11.87**
9	HA228A × AKSFI-16-9	1.38	0.44	9.44**	0.36	-0.31	-0.91	0.39	-8.23**	-0.49	6.44**
10	HA228A × AKSFI-16-10	1.11	0.91	-18.37**	-3.34**	-0.46*	-2.73**	6.55**	12.71**	-1.05*	-7.39**
11	HA228A × AKSFI-16-11	1.58*	-0.29	6.48	-0.12	0.12	-1.21	-14.95**	-11.23**	-0.49	1.07
12	HA228A × AKSFI-16-12	2.04**	0.58	9.13**	-1.76**	-0.01	-0.29	-10.21**	6.03**	-0.08	-3.53
13	HA249A × AKSFI-16-1	-0.49	-1.43	2.87	0.46	-0.16	0.43	-1.35	1.13**	-0.46	2.45
14	HA249A × AKSFI-16-2	0.17	0.17	-17.98**	0.96	0.60**	4.43**	5.25*	3.03**	0.66	6.23**
15	HA249A × AKSFI-16-3	0.84	-1.17	14.56**	0.97	0.02	-1.74*	11.36**	-4.47**	1.07*	5.83**
16	HA249A × AKSFI-16-4	0.71	3.17**	6.791	-1.36*	0.18	-4.59**	0.57	5.87**	-0.56	-5.65**
17	HA249A × AKSFI-16-5	0.04	-0.23	-10.99**	-1.37*	-0.08	1.66*	-17.25**	-2.27**	-0.14	-8.23**
18	HA249A × AKSFI-16-6	0.17	-0.63	11.36**	-0.10	0.07	0.98	-6.34**	-0.68**	-0.05	2.17
19	HA249A × AKSFI-16-7	0.17	-0.43	-0.48	0.29	-0.21	-0.94	-13.36**	5.53**	-0.50	-5.02*
20	HA249A × AKSFI-16-8	-1.16	-0.30	0.16	1.22*	0.25	4.49**	18.34**	-10.47**	0.05	14.92**
21	HA249A × AKSFI-16-9	0.57	1.17	1.12	-0.20	0.33	0.06	-6.31**	-2.47**	0.79	-0.75
22	HA249A × AKSFI-16-10	-1.03	-0.37	4.51	1.31*	-0.23	-0.01	8.96**	3.47**	0.66	1.54
23	HA249A × AKSFI-16-11	0.11	0.43	-11.02**	-0.51	-0.31	-0.45	2.77	-5.47**	-0.68	-7.25**
24	HA249A × AKSFI-16-12	-0.09	-0.37	-0.90	-1.67**	-0.45*	-4.32**	-2.64	6.80**	-0.84	-6.25**
25	HA302A × AKSFI-16-1	-0.47	1.87*	-8.60*	-0.48	-0.02	-1.39	7.01**	-3.55**	0.62	0.74
26	HA302A × AKSFI-16-2	1.20	1.14	17.01**	-1.49*	-0.50**	-1.15	-11.22**	6.48**	-1.77**	-7.60**
27	HA302A × AKSFI-16-3	0.87	3.47**	4.09	-1.15	-0.34	-1.23	5.42*	1.85**	-1.51**	-0.82
28	HA302A × AKSFI-16-4	-2.27**	-5.19**	4.85	1.20*	0.08	0.33	1.00	1.19**	0.58	1.12
29	HA302A × AKSFI-16-5	-0.60	-4.93**	2.68	-0.41	0.31	-2.75**	-8.72**	4.05**	0.68	0.09
30	HA302A × AKSFI-16-6	-0.80	1.34	-2.35	0.24	0.05	-1.85*	4.80*	-5.34**	-1.58**	2.91
31	HA302A × AKSFI-16-7	1.53*	3.87**	-2.21	-0.08	-0.07	-0.76	5.20*	1.85**	0.60	-3.28
32	HA302A × AKSFI-16-8	0.20	-0.66	-3.97	-0.35	-0.02	-0.09	-8.60**	-4.15**	-0.16	1.36
33	HA302A × AKSFI-16-9	-0.07	0.81	-7.55*	-0.40	0.15	2.40**	0.01	8.85**	0.19	-4.82*
34	HA302A ×AKSFI-16-10	-1.00	-2.73**	1.73	1.24*	0.25	3.33**	-3.34	-20.21**	0.95*	3.04
35	HA302A × AKSFI-16-11	0.47	0.07	-1.31	0.60	0.16	2.38**	5.09*	15.85**	0.71	2.80
36	HA302A × AKSFI-16-12	0.93	0.94	-4.37	1.09	-0.05	0.77	3.35	-6.88**	0.68	4.46*
37	HA208A × AKSFI-16-1	0.14	-2.24**	-0.38	0.20	0.13	0.53	1.85	2.28**	0.09	2.39
38	HA208A × AKSFI-16-2	-0.19	-1.97*	5.44	1.32*	0.23	2.36**	6.77**	-3.69**	0.79	4.96*
39	HA208A × AKSFI-16-3	-0.19	0.03	-0.29	-0.91	-0.27	-3.80**	-13.93**	1.68**	-0.51	-2.14
40	HA208A × AKSFI-16-4	-0.99	0.36	-13.19**	0.31	0.14	5.10**	-2.00	-7.97**	-0.47	2.09
41	HA208A × AKSFI-16-5	-0.32	0.96	0.83	-0.01	0.04	0.18	13.76**	3.88**	-0.33	-0.15
42	HA208A × AKSFI-16-6	-0.19	-1.11	-1.16	-0.15	0.03	-0.67	-0.24	-5.51**	-0.18	-4.63*
43	HA208A × AKSFI-16-7	-0.52	-1.91*	0.21	-0.95	-0.01	-0.09	-6.33**	-8.31**	-0.51	-0.19
44	HA208A × AKSFI-16-8	0.14	0.23	4.12	-0.88	0.21	-2.39**	3.12	20.68**	0.90*	-2.25
45	HA208A × AKSFI-16-9	-0.46	0.03	-4.79	-0.34	-0.12	-0.84	-5.89**	-6.31**	0.25	0.26
46	HA208A × AKSFI-16-10	2.61**	4.49**	14.95**	0.37	-0.02	0.76	-4.54*	-0.37**	0.55	-1.99
47	HA208A × AKSFI-16-11	-0.92	0.96	-9.13**	0.50	-0.02	-1.27	4.19	10.68**	0.44	1.06
48	HA208A × AKSFI-16-12	0.88	0.16	3.38	0.55	-0.32	0.11	3.23	-7.05**	-1.01*	0.60
49	HA303A × AKSFI-16-1	1.84*	1.29	-3.06	0.32	0.04	1.23	0.14	0.76**	-0.68	-0.88
50	HA303A × AKSFI-16-2	1.17	2.22**	11.02**	-1.47*	-0.11	-2.60**	-3.89	-4.21**	-0.38	-2.25
51	HA303A × AKSFI-16-3	0.51	1.22	-17.11**	-1.72**	-0.53**	1.48*	-16.89**	6.16**	0.10	-10.87**
52	HA303A × AKSFI-16-4	2.37**	1.56	-4.14	-0.19	-0.78**	-1.78*	-9.35**	0.80**	-0.13	-2.22
53	HA303A × AKSFI-16-5	0.71	1.49	9.01*	1.02	-0.13	1.22	6.10**	2.36**	0.32	5.28**
54	HA303A × AKSFI-16-6	0.17	0.42	-4.78	-0.67	-0.15	0.28	2.41	-6.03**	1.56**	-0.40
55	HA303A × AKSFI-16-7	2.51**	0.62	0.46	0.56	0.07	-0.80	4.20	1.16**	0.14	2.80
56	HA303A × AKSFI-16-8	-1.16	-1.58	1.90	-0.16	0.29	-1.29	3.89	-4.84**	-0.37	-2.16
57	HA303A × AKSFI-16-9	-1.43*	-2.44**	1.79	0.59	-0.05	-0.72	11.82**	8.16**	-0.73	-1.14
58	HA303A × AKSFI-16-10	-1.69*	-2.31**	-2.82	0.41	0.47*	-1.37	-7.63**	4.40**	-1.11*	4.79*
59	HA303A × AKSFI-16-11	-1.23	-1.18	14.98**	-0.47	0.05	0.60	2.90	-9.84**	0.02	2.32
60	HA303A × AKSFI-16-12	-3.76**	-1.31	-7.24*	1.79**	0.84**	3.73**	6.32**	1.10**	1.25**	4.71*
	SE(D)±	0.70	0.82	3.44	0.60	0.18	0.73	2.19	0.11	0.44	1.93
	CD 5%	1.39	1.63	6.82	1.18	0.36	1.45	4.34	0.22	0.86	3.83
	CD 1%	1.84	2.15	9.01	1.56	0.48	1.92	5.73	0.29	1.14	5.06

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

For yield contributing traits like head diameter, hundred seed weight, volume weight and seed filling percentage, positive significant *sca* effects are desirable. A total of seven hybrids recorded significant positive sca effects for head diameter. Among crosses, HA228A × AKSFI-16-3 (2.81) exhibited maximum significant positive sca effect, followed by HA303A × AKSFI-16-12 (1.79) and HA208A × AKSFI-16-2 (1.32). Five hybrids recorded significant positive sca effects for 100 seed weight. Among crosses, HA228A × AKSFI-16-3 (1.12) exhibited maximum significant positive sca effect, followed by HA303A × AKSFI-16-12 (0.84) and HA249A × AKSFI-16-2 (0.60).Out of 60 crosses, twelve crosses exhibited significant positive sca effect for volume weight. And for seed filling percentage, out of 60 hybrids, 19 hybrids exhibited significant positive sca effect.

Out of 60 crosses, 30 crosses showed significant and negative sca effects, which is desirable for the hull content. The highest negative significant sca effect was recorded by the cross HA302A × AKSFI-16-10 followed by HA228A × AKSFI-16-11 (-11.23), HA249A × AKSFI-16-8 (-10.47) and HA303A × AKSFI-16-11 (-9.84).

For oil content positive sca is desirable. Out of 60 tested hybrids, five only hybrids recorded significant positive sca effects andcross HA303A × AKSFI-16-6 (1.56) was recorded as the best specific cross combination for oil content, followed by HA303A × AKSFI-16-12(1.25) and HA249A × AKSFI-16-3 (1.07), HA302A × AKSFI-16-10(0.95) and HA208A × AKSFI-16-8 (0.90)

A total of 12 hybrids exhibited positive sca effects for seed yield per plant, of which seven crosses recorded highly significant positive SCA effect for seed yield per plant. Cross HA249A × AKSFI-16-8 (14.92) recorded highest significant SCA effect followed by HA228A × AKSFI-16-3 (7.99), HA228A × AKSFI-16-9 (6.44), HA249A x AKSFI-16-2 (6.23), HA249A × AKSFI-16-3 (5.83), HA303A × AKSFI-16-10 (4.79) and HA303A × AKSFI-16-12 (4.71). Venkanna *et al.* (2005) also reported sca effects in desirable direction for days to 50% flowering, days to maturity, 100 seed weight, seed yield per plant, head diameter and plant height. Patil *et al.* (2007) reported maximum sca effects in desirable direction for plant height, percentage of filled seed per head, seed yield per plant, 100 seed weight and oil yield. Chavan *et al*. (2009) reported similar result for specific combining ability for seed yield, oil content per cent and head diameter. Also, Khan *et al*. (2009); Gejli *et al*. (2011), Athoni and Nandini (2012); Asif *et al*. (2013); Rizwana *et al.* (2015) reported similar result for specific combining ability for seed yield and their components.

Table 4: Mean yield performance, gca and sca effects of promising crosses.

Crosses	Mean seed yield /plant	Meanoil content (%)	SCA Effect	GCA Effects	Significant GCA Effects of parents for other characters
HA228A × AKSFI-16-4	54.73**	38.46	4.66*	3.65** x 8.90** H H	P1-1,2,4,5,6,7,8 P2-2,4,5,6,7,8,9
HA208A × AKSFI-16-2	48.60*	38.09	4.96*	1.86** x 4.27** H H	P1-1,2 P2-1,2,3,4,6,7,8,9
HA303A×AKSFI-16-12	48.30*	40.03**	4.71*	1.37* x 4.70** H H	P1-6,7,9 P2-1,4,5,6,7,8,9

Note : * Significant at 5% level of significance
** Significant at 1% level of significance
P_1 - Line, P_2 - Tester
1) Days to 50% Flowering, **2)** days to Maturity, **3**) Plant hight, **4**) Head diameter **5)** 100 seed weight (g)
6) Volume weight 7) Seed filling percentage **8)** Hull content (%) **9**) Oil content.
L - Low gca effects
H - High gca effecs

CONCLUSION

On the basis of mean seed yield performance, gca and sca effects three crosses were identified as promising crosses (Table 4). The cross HA228A × AKSFI-16-4 recorded highest seed yield (54.73 g), highest standard heterosis (27.91%) and significant sca effect (4.66) with parents having high × high gca effect. The second cross HA208A × AKSFI-16-2 exhibits the mean seed yield per plant (48.60 g), standard heterosis (13.59%) and significant sca effect (4.96) with high × high gca effect. The third cross HA303A × AKSFI-16-12 exhibits the mean seed yield per plant (48.30 g), standard heterosis (12.88%) and significant sca effect (4.71) with high × high gca effect. The crosses HA228A × AKSFI-16-4 and HA208A × AKSFI-16-2 were identified as promising crosses for seed yield, whereas cross HA303A × AKSFI-16-12 was identified as promising cross for seed yield coupled with oil content. The current study focus that the evaluated parental materials possess enough genetic diversity which could be used in the future sunflower varietal development program. Inheritance of all the characters governed by additive gene effect was confirmed by the greater ratio of GCA than SCA. The parents with good general combining ability in this study could be used to develop potential hybrid, synthetic and composite sunflower variety with higher commercial yield. Thus, these parents and crosses need further evaluation in preliminary or multilocation hybrid trials for further commercial exploitation.

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How to cite this article: Aditi R. Rajane, Satish S. Nichal, Sangita U. Fhatak, E.R. Vaidya, Pallavi R. Sasane and S.H. Karvar (2022). Combining Ability Assessment in Sunflower through Line × Tester Analysis. *Biological Forum – An International Journal*, *14*(2a): 255-260.