International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(1): 1130-1134

Received: 14-11-2018
Accepted: 18-12-2018

PP Kale
M.Sc. Scholar, Department of Agricultural Botany (Genetics and Plant Breeding), Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

ER Vaidya
Associate Professor, Post Graduate Institute, Department of Agricultural Botany, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

Sangita U Fatak
Junior research assistant (Oilseeds Research Unit), Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

SS Nichal
Associate Professor, (Regional Research Centre, Dr. P.D.K.V., Amaravati, Maharashtra, India

Aditi R Rajane
M.Sc. Scholar, Department of Agricultural Botany (Genetics and Plant Breeding), Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

Correspondence
PP Kale
M.Sc. Scholar, Department of Agricultural Botany (Genetics and Plant Breeding), Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

Combining ability analysis for seed yield, its components and oil content in Sunflower (*Helianthus annuus* L.)

PP Kale, ER Vaidya, Sangita U Fatak, SS Nichal and Aditi R Rajane

Abstract
Six Cytoplasmic Male Sterile lines and nine testers and their 54 F_1 (crosses) along with two standard checks DRSH-1 and PDKVSH-952 were evaluated in Randomized Block Design with three replications at the experimental field of Oilseeds Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *kharif* 2017. Among the parents two lines HA-303A and HA-228A and four testers AK-1R, RHA-138-2R, 856R and EC-601951 were found to have best general combining ability for seed yield, its contributing traits and oil content, these parents may be useful to develop better sunflower hybrid with high seed yield and oil content. The highest significant specific combining ability effect for seed yield was recorded by the four crosses *viz.* AKSF-15-1-2A x TSG-187 (8.43) followed by HA-228A x GMU-1116 (7.08), HA-303A x AK-1R (6.86) and AKSF-15-1-2A x RHA-138-2R (6.07). On the basis of mean performance, gca and sca effects of crosses, four crosses viz., HA-303A x AK-1R, HA-303A x RHA-138-2R, HA-303A x EC-512687 and HA-249A x 856R were identified as promising crosses. Thus, these crosses may be tested in preliminary or multilocation hybrid trials for further commercial exploitation.

Keywords: cytoplasmic male sterile, randomized block design, general combining ability

Introduction
Sunflower (*Helianthus annuus* L.) is an important oilseed crop. As regards taxonomic category, sunflower belongs to, division Angiosperm, sub division Tubiflorae, tribe Heliantheae, family Compositeae or Asteraceae sub family Asteroideae, genus Helianthus and species *annuus* (Panero and Funck, 2002) [6]. Combining ability studies helps us to study 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 variance and dominance variance, which is eventually necessary to select parents and crosses. Identification of suitable parents can be also achieved through combining ability studies, such parents can be used in breeding programme for further commercial exploitation. So, the present study was under taken in order to identify the lines possessing good combining ability and also to identify the good specific combiner crosses.

Materials and Methods
The present investigation was carried out at the research farm of Oilseeds Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. During the *rabi* season of 2016-17, all the F_1 were obtained by crossing the six cytoplasmic male sterile lines viz., AKSF-14-2A, AKSF-15-1-2A, AKSF-15-1-3A, HA-228A, HA-249A and HA-303A along with nine restorer lines viz., AK-1R, RHA-138-2R, 856R, EC-601951, PKV-105R, GMU-1116, EC-6022011, EC-512687 and TSG-187. During *kharif* 2017, all the 71 genotypes which comprised of the 54 hybrids, nine restorer lines, six maintainer (B) lines and two standard checks DRSH-1 and PDKVSH-952 were sown in randomized block design (RBD) with three replications. 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. The crop was raised under rainfed condition. The crop stand and the crop growth were satisfactory. All the recommended practices were followed for raising successful crop. The observations for days to 50 per cent flowering and days to maturity were recorded on plot basis and the remaining observations viz., plant height at harvest (cm), head diameter (cm), hundred seed weight (g), volume weight (g/100ml), seed filling percentage, hull content (%),

oil content (%) and seed yield per plant (g) were recorded on plant basis. 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) [10].

Results and Discussion

The analysis of variance for combining ability for the characters studied in a Line x Tester analysis of 54 crosses obtained by crossing six CMS lines with nine testers was carried out and the total variance due to crosses was partitioned into portions attributable to females (lines), males (testers), interactions female x male (Line x Tester) and error sources. The analysis of variance for combining ability is presented in (Table 1). The variance due to crosses was significant for all the characters studied. The variance due to lines (females) were found to be significant for days to 50% flowering, days to maturity, plant height, and oil content. However, the magnitude of variance in females was not significant for head diameter, 100 seed weight, volume weight, seed filling percentage, hull content and seed yield per plant. The variance for testers (males) was highly significant for days to 50 per cent flowering, plant height, seed filling percentage and it was not significant for days to maturity, head diameter, 100 seed weight, volume weight, hull content, oil content and seed yield per plant. Highly significant variation was noticed in males and females interactions for all the characters. Significant variance indicated the presence of substantial amount of genetic variability among the parents and crosses for respective characters.

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	0.57	6.00	205.01	2.38	0.43	18.0	6.57	1.13	0.97	18.40
Crosses	53	18.00**	23.49**	1270.52**	8.40**	2.22**	24.79**	91.50**	97.52**	4.68**	69.67**
Females (lines)	5	92.29**	105.90**	8438.84**	6.14	0.58	48.31	31.02	110.44	21.08**	72.79
Males (testers)	8	24.25**	22.43	1946.49**	8.41	3.32	33.88	197.08*	154.84	2.16	84.42
Females vs Males	40	7.47**	13.40**	239.28**	8.68**	2.20**	20.03**	77.94**	84.44**	3.13**	66.33**
Error	106	1.91	2.18	68.86	1.12	0.24	6.03	3.72	1.54	1.63	6.42

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

Table 2: General combining ability effect 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**
AKSF 14-2-A	2.87**	2.90**	24.51**	-0.38	-0.23**	-1.18*	1.19**	-1.55**	-1.15**	-0.83
HA -249-A	-2.09**	-2.06**	-21.71**	-0.33	0.05	1.16*	-0.71*	-3.20**	0.17	-0.02
AKSF 15-1-3-A	1.20**	1.56**	13.02**	0.83**	0.20*	0.68	1.04**	-0.95**	-0.21	1.36**
AKSF 15-1-2-A	-0.02	-0.28	1.98	-0.21	-0.07	0.31	0.14	-0.88*	-0.65**	-1.29*
HA-303A	-1.72**	-2.09**	-17.80**	0.30	0.01	1.11*	-0.01	1.71**	0.49*	2.50**
HA -228 A	-0.24	-0.05	-0.05	-0.20	0.04	-2.09**	-1.64**	1.77**	1.35**	1.72**
SE (D)±	0.27	0.28	1.77	0.20	0.88	0.48	0.34	0.34	0.24	0.50
CD (5%)	0.55	0.56	3.52	0.41	0.17	0.96	0.68	0.68	0.48	0.99
CD (1%)	0.72	0.74	4.65	0.54	0.23	1.27	0.91	0.90	0.63	1.31

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

Cont…: 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
AK 1R	-1.77**	-1.728**	-3.492	0.59*	0.17	1.15	3.40**	-0.81	-0.27	0.50
RHA138-2R	0.50	0.66	-0.10	0.25	0.21	0.40	3.30**	1.39**	-0.43	1.14
856-R	-0.11	0.049	4.59*	1.32**	0.44**	1.76**	3.98**	-1.52**	-0.47	4.36**
EC-601951	0.16	-0.228	1.66	-0.18	-0.23*	-1.87**	-2.30**	-1.18**	0.58*	-0.59
PKV-105 R	0.94**	0.88*	8.37**	-0.73**	-0.52**	0.26	-3.14**	-1.21**	-0.09	-2.98**
GMU-1116	1.55**	1.77**	11.76**	-0.62*	-0.68**	-1.73**	-3.85**	-2.48**	0.15	-1.52*
EC-6022011	-0.05	-0.34	3.40	0.05	-0.10	0.63	-1.42**	-1.06*	0.27	0.60
EC-512687	0.66	0.43	-1.59	0.08	0.09	-1.59**	2.94**	-0.42	0.17	0.61
TSG-187	-1.88**	-1.50**	-24.62**	-0.76**	0.62**	0.96	-2.91**	7.31**	0.07	-2.13**
SE (D)±	0.34	0.34	2.17	0.25	0.10	0.59	0.42	0.42	0.29	0.61
CD (5%)	0.67	0.69	4.31	0.50	0.21	1.17	0.84	0.84	0.58	1.21
CD (1%)	0.89	0.91	5.70	0.67	0.28	1.55	1.11	1.11	0.78	1.61

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

The information on the general combining ability of parents are presented in (Table 2). Among the lines HA-303A and HA-228A were found as the best general combiners for yield as well as yield related traits and oil content. Among the testers AK-1R, 856R, RHA-138-2R and EC-512687 were good general combiners for yield and most of the yield contributing characters. For oil content EC-601951, EC-6022011 and EC-512687 were good general combiners. Reddy and Madhavilatha (2005) [8], Sawargaonkar and Ghodke (2008) [9], Asif *et al*. (2013) [1], Jondhale *et al.* (2014) [3], Janjal *et al.* (2016) [2], Rathi *et al.* (2016) [7] also reported comparable results in sunflower.

Specific combining ability effects are presented in Table 3. In the present investigation, three types of parental combinations were observed in the crosses. However, majority of the crosses exhibited high sca effects as a result of either high x low or low x high gca parents indicating a genetic interaction of the additive x dominance or dominance x additive interaction.

The cross HA-249A x PKV-105R (-4.90) showed highest negative significant sca effect for days to 50% flowering. For days to maturity the cross HA-249A x PKV-105R (-5.66) and for plant height the cross AKSF-15-1-2A x GMU-1116 (-17.35) has recorded highest significant sca effect in desirable direction. For head diameter cross HA-228A x GMU-1116 (3.33) exhibited highest significant sca effect, for 100 seed weight cross HA-303A x AK-1R (1.23) exhibited highest sca effect for the volume weight AKSF-14-2A x EC-6022011 (5.01) and for seed filling percentage AKSF-15-1-2A x TSG-187 (9.19) showed the maximum positive significant sca effect. For hull content the cross HA-303A x AK-1R (-8.17) recorded significant negative sca effect. These findings are in agreement with earlier reports of Reddy and Madhavilatha (2005) [8] and Sawargoankar and Ghodke (2008) [9].

Out of 54 crosses tested, 4 crosses recorded significant sca effects for oil content, the cross AKSF-14-2A x AK-1R (1.80) was the best specific combiner for oil content, followed by AKSF-15-1-3A x EC-6022011 (1.69), HA-303A x GMU-1116 (1.53) and HA-249A x AK-1R (1.42). Out 54 crosses, 15 crosses recorded significant sca effect for seed yield. The highest significant positive sca effect has recorded by the cross AKSF-15-1-2A x TSG-187 (8.43) followed by HA-228A x GMU-1116 (7.08) and HA-303A x AK-1R (6.86). Earlier workers Machikowa *et al.* (2011) [5], Asif *et al*. (2013) [1], Janjal *et al.* (2016) [2], Rathi *et al.* (2016) [7], Kulkarni and Supriya (2017) [4] and Thorat *et al*. (2018) [11] also reported comparable results for specific combining ability for seed yield and their components.

On the basis of mean seed yield performance, gca and sca effects four crosses were identified as promising crosses (Table 4). The cross HA-303A x AK-1R recorded highly significant sca effects (6.86) with parent high x low gca effect, whereas the cross HA-303A x RHA-138-2R has recorded significant sca effect (5.52) with high x low gca effect of the parent involved. The cross HA-303A x EC-512687 has recorded highly significant sca effect (5.93) with high x low gca effect of the parent involved. The fourth cross HA-249A x 856R showed highly significant sca effect (4.13) having low x high gca interaction.

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	AKSF-14-2A X AK -1R	-1.48	-1.01	1.61	-1.52*	-0.75**	-0.17	-3.06**	1.59	1.80**	-1.58
2	AKSF-14-2A X RHA -138-2R	-0.09	-0.06	-7.99	-1.01	-0.72**	-3.92**	0.99	0.20	-0.52	-0.79
3	AKSF-14-2A X 856 R	1.51	1.21	-1.77	1.36*	0.43	2.71	-0.83	-0.88	-1.46*	0.76
4	AKSF-14-2A X EC-601951	1.24	1.15	-3.77	-0.36	-0.61*	0.68	0.80	2.83**	-0.68	-2.10
5	AKSF-14-2A X PKV-105 R	0.13	-0.62	-3.15	-0.23	-0.15	-0.95	6.68**	0.98	0.69	1.30
6	AKSF-14-2A X GMU -1116	0.51	-0.84	21.32**	-0.06	0.63*	-1.12	-4.13**	-7.392**	-1.23	-2.76
7	AKSF-14-2A X EC -6022011	-0.87	-0.40	-2.91	1.99**	1.08**	5.01**	5.34**	-0.98	1.19	5.01**
8	AKSF-14-2A X EC-512687	-0.59	-0.17	-2.24	-0.43	-0.27	0.24	-5.42**	8.45**	-0.44	0.09
9	AKSF-14-2A X TSG187	-0.37	0.76	-1.08	0.27	0.36	-2.48	-0.36	-4.81**	0.65	0.06
10	HA-249-A X AK -1R	4.48**	7.28**	13.60*	-1.5*	-1.14**	-2.69	-2.12*	-6.10**	1.42*	-6.32**
11	HA-249-A X RHA 138-2R	1.20	1.56	-2.51	-0.002	-0.01	-1.61	-5.20**	4.78**	0.01	-2.03
12	HA-249-A X 856-R	-2.85**	-2.82**	-0.91	1.40*	0.91**	-0.80	5.11**	-2.90**	-0.71	4.13**
13	HA-249-A X EC-601951	-1.13	-1.88*	1.37	0.02	0.59*	3.50*	-0.87	1.41	0.56	3.50*
14	HA-249-A X PKV-105-R	-4.90**	-5.66**	-9.13	2.64**	1.05**	1.86	4.62**	-2.800**	1.14	6.71**
15	HA-249-A X GMU-1116	0.14	0.78	-12.12*	-3.19**	-1.38**	-2.13	-3.41**	6.26**	-1.52*	-5.98**
16	HA-249-A X EC-6022011	0.09	-0.43	-3.08	0.77	-0.20	0.16	7.66**	-3.62**	-1.88**	3.12*
17	HA-249-A X EC- 512687	2.70**	2.78**	10.979*	0.17	0.43	3.55*	-2.05	3.47**	0.32	0.05
18	HA-249-A X TSG-187	0.25	-1.60	1.80	-0.30	-0.25	-1.83	-3.73**	-0.48	0.65	-3.18*
19	AKSF 15-1-3A X AK 1R	-2.48**	-4.67**	-9.39	1.20	1.20**	1.12	4.15**	0.79	-1.40*	4.96**
20	AKSF 15-1-3A X RHA138-2R	0.24	0.26	-8.04	-2.13**	-0.83**	-2.29	-5.21**	1.99	0.75	-4.99**
21	AKSF 15-1-3A X 856-R	0.51	2.54**	-1.81	-0.91	-0.37	-1.99	-0.21	-1.18	0.61	-1.43
22	AKSF 15-1-3A X EC-601951	0.90	-0.17	4.04	1.93**	0.77**	0.81	-0.96	-3.83**	-0.67	4.95**
23	AKSF 15-1-3AX PKV-105 R	2.13*	1.71*	3.99	-0.89	0.06	1.17	0.33	-5.85**	0.29	-0.71
24	AKSF 15-1-3A X GMU-1116	-0.48	0.82	1.87	-1.67**	-0.77**	2.17	-3.79**	6.25**	0.67	-4.48**
25	AKSF 15-1-3A X EC-6022011	0.46	1.26	6.97	1.48*	0.64*	-0.68	1.43	-0.92	1.69*	2.46
26	AKSF 15-1-3A X EC- 512687	-0.25	-0.84	4.24	1.73**	0.28	-0.79	0.60	-5.94**	-0.35	2.21
27	AKSF 15-1-3A X TSG-187	-1.03	-0.90	-1.86	-0.74	-1.010**	0.48	3.66**	8.70**	-1.59*	-2.97
28	AKSF 15-1 -2A X AK 1R	-0.92	-0.49	-9.09	-0.77	-1.07**	-0.50	-8.23**	12.65**	-0.93	-4.97**
29	AKSF 15-1 -2A X RHA138-2R	-0.87	-1.21	9.99	2.40**	0.44	1.57	4.03**	-0.24	-0.03	6.07**
30	AKSF 15-1 -2A X 856-R	0.07	0.39	0.75	-0.73	-0.19	-0.28	-2.99**	5.16**	1.06	-3.10*
31	AKSF 15-1 -2A X EC-601951	-0.20	0.00	0.61	0.99	0.52	0.51	2.67*	-3.99**	0.40	-0.27
32	AKSF 15-1 -2A X PKV-105 R	0.68	0.22	0.70	-0.26	-0.65*	-1.62	-5.10**	-3.14**	-1.77**	-2.52

Cont….Table 3: Specific combining ability 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**
33	AKSF 15-1 -2A X GMU-1116	0.07	-0.32	-17.35**	0.18	0.67*	1.046	5.55**	-3.87**	0.58	1.89
34	AKSF 15-1 -2A X EC-6022011	0.01	-0.54	5.67	-1.20	-0.24	-1.14	-4.32**	2.10*	0.48	-2.40
35	AKSF 15-1 -2A X EC-512687	-0.03	0.00	8.07	-1.74**	0.29	-1.92	-0.80	-6.93**	0.18	-3.11*
36	AKSF 15-1 -2A X TSG-187	1.18	1.95*	0.63	1.13	0.20	2.35	9.19**	-1.74	0.01	8.43**
37	HA-303 A X AK 1R	0.11	-0.01	1.76	1.61*	1.23**	2.02	5.73**	-8.17**	-0.51	6.86**
38	HA-303 A X RHA138-2R	-0.16	-0.40	-1.48	2.23**	1.02**	4.11**	5.28**	-4.93**	0.05	5.52**
39	HA-303 AX 856-R	1.11	0.87	-2.59	-2.41**	-0.71**	-2.41	-7.48**	1.27	-0.22	-4.01**
40	HA-303 A X EC-601951	-1.83*	-0.51	-8.52	-1.49*	-1.22**	-2.77	-0.01	1.02	0.04	-6.45**
41	HA-303 A X PKV-105 R	1.05	1.71*	-1.30	-1.59*	-1.04**	-0.41	-4.42**	9.36**	-0.10	-6.87**
42	HA-303 A X GMU-1116	0.44	-0.17	12.97*	1.42*	-0.07	-1.25	4.656**	1.18	1.53*	4.25**
43	HA-303 A X EC-6022011	-0.27	-0.40	-8.72	-1.94**	-0.62*	-2.77	-8.90**	1.99	-1.00	-4.36**
44	HA-303 A X EC- 512687	-1.3	-1.17	-4.19	2.03**	0.97**	4.61**	6.216**	-5.64**	-0.28	5.93**
45	HA-303 AX TSG-187	0.88	0.09	12.09*	0.14	0.44	-1.11	-1.06	3.89**	0.50	-0.86
46	HA 228-A X AK 1R	0.29	-1.08	1.49	1.01	0.53*	0.23	3.53**	-0.76	-0.36	1.06
47	HA 228-A X RHA138-2R	-0.31	-0.14	10.04	-1.48*	0.09	2.14	0.10	-1.79	-0.26	-3.76*
48	HA 228-A X 856-R	-0.37	-2.19*	6.34	1.27*	-0.07	2.78	6.414**	-1.46	0.72	3.65*
49	HA 228-A X EC-601951	1.01	1.41	6.27	-1.10	-0.06	-2.74	-1.61	2.54*	0.33	0.37
50	HA 228-A X PKV-105 R	0.90	2.63**	8.89	0.34	0.72**	-0.04	-2.10*	1.44	-0.25	2.08
51	HA 228-A X GMU-1116	-0.74	-0.25	-6.69	3.33**	0.92**	1.28	1.13	-2.43*	-0.03	7.08**
52	HA 228-A X EC-6022011	0.57	0.52	2.07	-1.10	-0.66*	-0.57	-1.21	1.43	-0.49	-3.82*
53	HA 228-A X EC- 512687	-0.48	-0.58	-16.86**	-1.77**	-1.72**	-5.68**	1.46	6.59**	0.57	-5.18**
54	HA 228-A X TSG-187	-0.92	-0.30	-11.57*	-0.50	0.24	2.59	-7.70**	-5.55**	-0.22	-1.48
	SE(m)±	0.83	0.85	5.32	0.62	0.26	1.45	1.04	1.03	0.72	1.50
	CD 5%	1.65	1.69	10.56	1.24	0.52	2.88	2.06	2.05	1.44	2.98
	CD 1%	2.18	2.23	13.97	1.64	0.69	3.81	2.73	2.72	1.91	3.94

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

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

Crosses	Mean seed yield/plant	SCA Effect	Oil content (%)	GCA effects of parents for seed yield	Significant GCA effects of parents for other characters
HA-303A x AK-1R	44.30**	6.86**	37.25	2.50** x 0.50 H L	$P_{1 – 1,2.3.6.8.9}$ $P_{2 - 1,2,4,7}$
HA-303A x RHA-138-2R	43.61**	5.52**	37.65	2.50** x 1.14 H L	$P_{1 – 1,2,3,6,8,9}$ $P_{2 – 7}$
HA-303A x EC-512687	43.49**	5.93**	37.92	2.50** x 0.61 H L	$P_{1 – 1,2,3,6,8,9}$ $P_{2 – 7}$
HA-249A x 856R	42.91**	4.13**	36.52	-0.02 x 4.36** L H	$P_{1 – 1,2,3,6,8}$ $P_{2 – 4,5,6,7,8}$

Note:* Significant at 5% level of significance, ** Significant at 1% level of significance
P_1- Line **P_2**- Tester H - High gca effect L - Low gca effect
1) Days to 50% flowering **2)** days to Maturity **3**) Plant height
4) Head diameter **5)** 100 seed weight **6**) Volume weight
7) Seed filling percentage **8)** Hull content **9**) Oil content
Mean seed yield / plant is significant for values of standard heterosis over check PDKVSH-952.

Conclusion

In this study fifty four F1 hybrids obtained from crossing of six cytoplasmic male sterile lines and nine restorers were evaluated using line x tester design as an appropriate method for the determination of general and specific combining abilities. Among the parents, two lines HA-303A and HA-228A and four testers AK-1R, RHA-138-2R, 856R, EC-601951 were found to be best general combiners for most of the yield contributing traits, seed yield and also for oil content.

The highest significant sca effect for seed yield was recorded by the cross AKSF-15-1-2A x TSG-187 (8.43) followed by HA-228A x GMU-1116 (7.08), HA-303A x AK-1R (6.86) and AKSF-15-1-2A x RHA-138-2R (6.07). One combination viz., HA-303A x GMU-1116 recorded highly significant sca effects (1.53 and 4.25) for oil content as well as for seed yield respectively. Thus, on the basis of mean performance, gca and sca effects of crosses, four crosses *viz*., HA-303A x AK-1R, HA-303A x RHA-138-2R, HA-303A x EC-512687 and HA-249A x 856R were identified as promising crosses for high seed yield and oil content, thus these crosses may be tested in preliminary or multilocation hybrid trials for further commercial exploitation.

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