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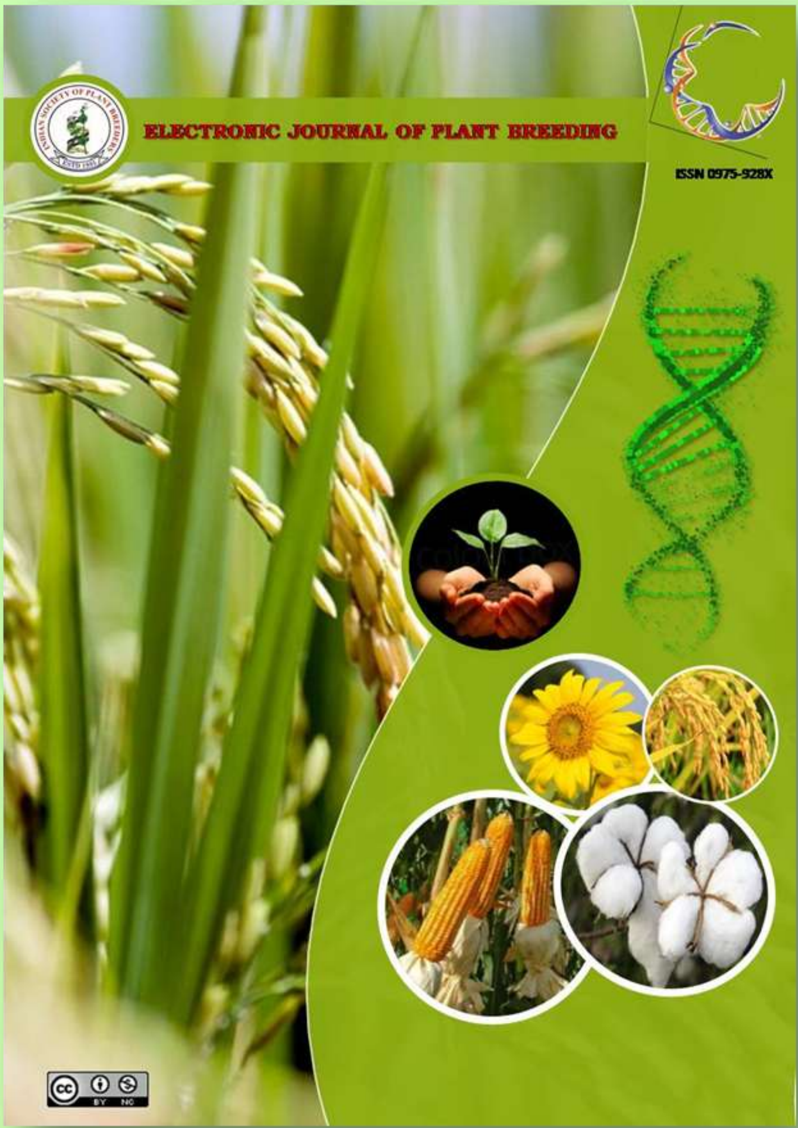

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Research Note

Studies on combining ability of new restorer lines in sunflower (*Helianthus Annuus* L.)

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Abstract
The present investigation was undertaken to assess the combining ability of parents and also to estimate the extent of heterosis for eleven different characters in 40 hybrids which were derived by crossing four CMS lines with ten testers in a line x tester mating design during *kharif* 2015. The resultant hybrids and parents along with standard checks, LSFH-35 and LSFH-171 were evaluated for seed yield and yield contributing traits. CMSPET 89-1A and CMS PET 2-7-1A, were good combiners for seed yield and oil content, respectively. Two restorers RHA138-2, EC 601957 were found to be the best general combiners for yield and other yield contributing traits. The best cross combinations, PET 2-7-1A x EC 601957,CMS 234A x EC 601924, PET 2-7-1A X R-16 and ARM 249A x R 271-1 for seed yield per plant with high significant sca effect and heterosis have been identified.

Keywords
Sunflower, heterosis, combining ability, seed yield, oil content

Sunflower is a cross pollinated crop wherein combining ability analysis is of special significance to identify parental lines and to develop good hybrids/synthetics/ composites. Earlier studies led to the selection of inbreds with high gca and predominance of non-additive gene action for seed yield and its components. The present investigation aims at identification of superior parents (lines and testers) and cross combinations for seed yield and its component characters. Breeding programs can take advantage from such information on combining ability to find the best selection strategy for developing high yielding lines and hybrids (Skoric, 1992). Also, evaluating genotypes for combining ability is important in determining appropriate procedures or genotypes to utilize efficiently in breeding programs for main yield characters in sunflower (Inamullah *et al.*, 2006).Improvement in sunflower emphasizes the urgency of generating heterotic hybrids that is achieved by tapping the excellent combining ability and heterotic vigour available in the genetically divergent inbreds or genotypes. Keeping these points in view, the present investigation was undertaken with the following specific objectives, to choose appropriate parents and hybridization based on combining ability and to study inter-relationship between gca and sca hybrids and non-additive gene action for exploitation of vigour in sunflower.

Experiment material comprised of four lines and ten testers. The testers were crossed with each line and thus forty F_1s were produced. The fourteen parents along with forty F_1s were grown in a randomized block design with three replications at Experiment Farm, Oilseed Research Station, Latur during *kharif* 2015. Each entry was planted in two rows of 3m length with spacing of 60 cm between rows and 30 cm between plants. Observations were recorded on eleven quantitative characters. Data related to days to 50% flowering, days to maturity, plant height (cm), head diameter (cm), seed filling (%), hull content (%), test weight (g), volume weight (g), oil content (%), seed yield per plant (g) and pollen viability (%). The mean of five plants was used for all statistical analysis and data were subjected for analysis of general and specific combining ability analysis as per the procedure of Kempthorne (1957).

The analysis of variances showed highly significant differences among all the characters indicating the existence of sufficient variability and diversity among the parents. The magnitudes of mean sum of squares particularly for plant height, seed yield/plant, seed filling percentage, hull content (%), head diameter(cm), and pollen viability (%) were high and it was less for days to50% flowering, oil content (%),volume weight (g) and test weight (g).

Combining ability analysis helps the breeder in selecting desirable parents for exploitation in breeding programme. Use of general combining ability *i.e.* gca effects of the parents is the important criteria for selection. Generally the parents with high *per se* may not transmit their superiority in their progenies. Hence it is essential to assess the compatibility of parents to express their own high performance to the hybrids involving them.

General and specific combining ability effects helps to pinpoint the good parents and hybrids, respectively. The perusal of gca effects of 14 parents (4 CMS lines and 10 testers) for 11 traits indicated that the CMS PET 2-7-1B was good general combiner for early flowering (-1.442), plant height (-4.775),seed filling (3.667), hull content (-3.596), test weight (0.630), volume weight (1.404) and oil content (1.216) exhibiting significant gca effects in positive direction and CMS PET 89-1B is also found to be good general combiner for seed yield/plant (1.333), exhibiting significant gca effects in positive direction. The CMS ARM 249B was good general combiner for pollen viability (3.939), recording significant gca effects in positive direction. Among the testers, EC-601957 was good general combiner for head diameter (2.248), hull content (-2.337), test weight (1.140), seed yield/plant (6.517) oil content (2.286) and pollen viability (3.386). The restorer line, RHA 138-2 was good general combiner for head diameter (1.740), seed filling (8.983), hull content (-2.963), seed yield/plant (10.183) and oil content (1.044) exhibiting significant gca effects in positive direction. All these testers could be exploited for development of better hybrids and also in conventional breeding programme.

In sunflower, negative SCA effects are considered to be desirable for days to 50% flowering, plant height and hull content. Among 40 crosses, one hybrid for days to 50% flowering, four hybrids for plant height and ten hybrids for hull content exhibited highly significant SCA effects in desirable direction similarly, positive and significant SCA effects were recorded by 12 hybrids for seed yield/plant, 10 hybrids for seed filling (%) and 15 hybrids for test weight, three hybrids for volume weight, three hybrids for head diameter and seven hybrids for oil content. The hybrid, LSH-13 was found with good SCA effects for plant height, head diameter, test weight, volume weight and oil content. The hybrid, LSH-38 recorded good SCA effects for seed yield, head diameter, seed filling and test weight and the hybrid, LSH-28 exhibited superiority for seed yield per plant, test weight, hull content and oil content.

For all the traits under study, 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 epistastic gene interactions. The ideal cross combination to be exploited is one which shows high magnitude of sca in addition to gca in both or at least in one of the parents.

The best four cross combinations, LSH-38 (CMS 234A x EC 601957), LSH-19 (CMS 234A x EC 601924), LSH-31(PET 2-7-1A x R-16) and LSH-44 (ARM 249A x R 271-1) for seed yield per plant with high significant sca effects and significant economic heterosis have been identified. The lines, CMSPET 89-1A and CMS PET 2-7-1A, were found to be good combiners for seed yield and oil content, respectively. Two restorers;RHA138-2 and EC 601957 were found to be best general combiners for seed yield and other yield contributing traits. These lines can be exploited for the development of single cross hybrid as non-additive was observed for most of the traits studied.

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Table 1. Analysis of variance for parents and crosses for eleven characters in sunflower

Characters	Source of variation								
	Rep. MSS 2 (d.f.)	Treatments MSS 53(d.f.)	Parents MSS 13 (d.f.)	CMS Lines MSS 3 (d.f.)	Tester MSS 9 (d.f.)	Crosses MSS 39 (d.f.)	Line x Tester MSS 1 (d.f.)	Parents v/s Crosses MSS 1 (d.f.)	Error MSS 106 (d.f.)
Days to 50% flowering	16.78395	25.55614**	26.27839**	28.75000**	26.55185**	25.43397**	16.40238	20.93126	6.02294
Days to maturity	2.30247	7.18018**	17.46703**	22.88889**	15.26296**	3.75983	21.03810*	6.84462	4.04461
Plant Height (cm)	180.22840	1723.35069**	531.89011**	1320.33333**	305.92593**	951.72970**	200.23810	47305.55666**	87.49255
Head diameter (cm)	2.51654	37.83357**	33.38513**	45.09889**	28.31126**	12.10841**	43.90867**	1098.94436**	3.80271
Seed yield / plant (g)	8.26543	448.66341**	141.21612**	72.75000**	158.24074**	365.78120**	193.39286**	7677.88430**	155.71321
Seed filling (%)	37.15432	340.09143**	624.75641**	29.11111	768.22593**	215.57607**	1120.4667**	1495.54568**	14.05998
100-seed weight (g)	0.28667	4.93769**	9.54293**	12.25639**	8.66537**	3.52191**	9.300060**	0.28502	0.10296
Volume weight(g/100ml)	10.02599	19.28336**	36.68229**	20.98890**	15.58685**	13.86000**	273.62143**	4.60859	3.30253
Hull content (%)	0.20809	70.50612**	77.65705**	20.67078*	102.49726**	69.73237**	25.05395	7.72010	7.05153
Oil content (%)	0.75907	13.18424**	2.22112	1.03778	2.52330	16.13920**	3.05153	40.45734**	1.49002
Pollen viability (%)	1.29167	46.99187**	7.94601	10.30556	7.50666	59.37682**	4.82143	71.57540	20.41928

d. f. = Degree of freedom

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Table 2. Estimates of general combining ability (GCA) effect of lines and testers for eleven characters in sunflower

Parents	Days to 50% Flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	Seed yield / plant (g)	Seed filling (%)	100-seed weight(g)	Volume weight (g/100ml)	Hull content (%)	Oil content (%)	Pollen viability (%)
seniL											
CMS 234 A	-2.075**	-0.083	-4.708**	-0.793	-0.800	-2.133**	-0173**	-1.999**	2.872**	0.249	2.869**
PET 89-1A	0.425	-0.083	-7.742**	0.270	1.333*	3.300**	0.007	0.671*	0.406	-0.494*	-3.188**
PET 2-7-1A	-1.442**	-0.350	-4.775**	-0.030	-0.333	3.667**	0.630**	1.404**	-3.596**	1.216**	-3.621**
ARM 249 A	3.092**	0.517	17.225**	0.553	-0.200	-4.833**	-0.463**	-0.076	0.318	-0.971**	3.939**
sretseT											
R 16	0.975	-0.150	5.708	-0.968	3.433**	5.650**	0.123	0.042	-1.148	-0.564	1.511
RHA 1-1	-2.942*	-0.233	-11.125	0.707	-1.817	-8.683**	0.407**	-0.407	0.645	0.761*	-2.006
RHA 138-2	0.975	1.183*	2.458	1.740**	10.183**	8.983**	-0.077	1.001	-2.963**	1.044**	0.302
R 271-1	-0.608	0.600	30.125**	-0.168	9.100**	-1.100	0.340**	-0.024	1.058	0.536	-1.873
IC294034	-0.108	0.183	-7.125*	-0.910	-6.733**	-2.933**	-0.018	-0.783	0.034	-0.089	-1.264
EC623023	-1.858*	-1.233*	-7.792**	-1.202*	-11.567**	-0.017	-0.735**	-0.457	1.002	0.603	-0.139
EC623016	0.725	0.650	-16.2089**	-0.960	-5.400	-0.183	-0.177	-0.991	-0.123	-3.064**	-1.973
EC601957	-1.275	0.183	-4.208	2.248**	6.517**	1.067	1.140**	0.884	-2.337**	2.286**	3.386*
EC601924	2.892**	0.600	10.125**	0.073	2.433*	1.650	0.032	0.151	4.662**	-1.039**	1.869
6 D-1R	1.225	-0.483	-1.958	-0.560	-6.150**	-4.433**	-1.035	0.584	-0.832	-0.472	0.186

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Table 3. Hybrids of sunflower with significant cross and their sca and gca effect with character

Character	Significant cross	SCA effect	GCA effect	
			Line	Tester
Days to 50% flowering	LSH-12(CMS234A x RHA 1-1)	-1.258	-2.075**	-2.942**
	LSH-14(CMS234A x R 271-1)	-2.592	-2.075**	-0.608
Days to maturity	LSH-12(CMS234A x RHA 1-1)	-1.333	-0.083	-0.233
	LSH-26(CMS PET-89-1A x EC-623023)	-0.667	-0.083	-1.233*
Plant Height (cm)	LSH-17(CMS234A x EC-623016)	-11.458*	-4.708**	-16.208**
	LSH-27(CMS PET-89-1A x EC-623016)	0.242	-7.742**	-16.208**
Head diameter (cm)	LSH-38(CMS PET 2-7-1A x EC-601957)	3.572**	-0.030	2.248**
	LSH-28(CMS PET-89-1A x EC-601957)	2.005	0.270	2.248
Seed yield / plant (g)	LSH-38(CMS PET 2-7-1A x EC-601957)	16.583**	-0.333	6.517**
	LSH-19(CMS234A x EC-601924)	10.867**	-0.200	9.100
Seed filling (%)	LSH-43(CMS ARM 249A x RHA 138-2)	8.417**	-4.833**	8.983**
	LSH-38(CMS PET 2-7-1A x EC-601957)	6.833**	3.667**	1.067
100-seed weight (g)	LSH-32(CMS PET 2-7-1A x RHA 1-1)	1.320**	0.630**	0.407**
	LSH-38(CMS PET 2-7-1A x EC-601957)	0.587**	0.630**	1.140**
Volume weight (g/100ml)	LSH-38(CMS PET 2-7-1A x EC-601957)	1.563	1.404**	0.884
	LSH-28(CMS PET-89-1A x EC-601957)	1.462	0.671*	0.884
Hull content (%)	LSH-310CMS PET 2-7-1A x 6 D-1R)	-6.000**	-3.596**	-0.832
	LSH-37(CMS PET 2-7-1A x EC-623016)	-5.762**	-3.596**	-0.123
Oil content (%)	LSH-12(CMS234Ax RHA 1-1)	2.976**	0.249	0.761*
	LSH-38(CMS PET 2-7-1A x EC-601957)	0.317	1.216**	2.286**
Pollen viability (%)	LSH-11(CMS234A x R-16)	2.789	2.869**	1.511
	LSH-41(CMS ARM 249A x R-16)	1.486	3.939**	1.511

* and ** significance at 5 and 1 per cent level, respectively.

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