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Combining Ability Studies Based on Mori CMS System in Indian Mustard [*Brassica juncea* (L.) Czern. & Coss.]

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Authors' contributions

This work was carried out in collaboration among all authors. Author RRC performed the statistical analysis, managed the analyses of the study and wrote the first draft of the manuscript. Authors RA and RKS designed the study and wrote the protocol. Authors Samita and DK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

An experiment for Line x tester analysis was carried out to estimate combining ability effects of 50 hybrids developed by crossing of 10 *Mori* CMS lines with five restorers in Indian mustard. The F_1 hybrids along with parental genotypes planted at Oilseeds Research Area, Department of Genetics & Plant Breeding, CCS Haryana Agricultural University, Hisar India during 2018-19. Data recorded for 12 characters viz., days to 50% flowering, days to maturity, plant height (cm), number of primary branches per plant, number of secondary branches per plant, main shoot length (cm), numbers of siliquae on main shoot, siliquae length (cm), number of seeds per siliquae, 1000-seed weight (g), oil content (%) and seed yield per plant (g). Analysis of variance revealed sufficient genetic variability present among lines, testers and crosses for most of the traits. There was presence of both additive and non-additive gene actions with preponderance of non-additive gene action in controlling yield and component traits. On the basis of overall performance of parents, line MA-023 and tester MR-38 were found the best general combiners for majority of component traits including seed yield per plant. Other three lines *viz*; MA-8701, MA-8812 and MA-9301 were also observed as

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good general combiners for most of component traits including seed yield per plant. Tester MR-43 and MR-44 were found good general combiner for earliness. On the basis of *per se* performance and specific combining ability, crosses namely MA-9301 x MR-44, MA-8701 x MR-38 and MA-9705 x MR-31 were observed as superior cross combinations for seed yield in desirable direction.

Keywords: Brassica juncea (L.); gene action; GCA; SCA; line x tester; Mori CMS.

1. INTRODUCTION

Indian mustard [*Brassica juncea* (L.) Czern. & Coss.] is an important oilseed crop of Indian sub-continent. Indian mustard is grown under more than 80% of the total rapeseed and mustard area of country [1]. Rapeseed and mustard stands world's second largest vegetable oil crop after soybean and in India first in vegetable oil production and contribute ~23% to the total vegetable oil of the country [2]. It covers an area of 6.93 million ha with a production of 8.70 million tonnes and the average productivity of 1256 kg/ha in India in 2019-20 [3]. Oilseed brassica shares ~23.4% area and ~24.2% production of total oilseeds in the country [2]. In the Indian sub-continent, genetic improvement of yield potential is foremost breeding objective while in European countries and Canada, breeding for quality (Canola type, high oleic and high linoleic etc.) receives greater attention. [4].

In India almost there is stable production during the last decade because of continuous decrease in growing area and low productivity [5]. The India is lag behind in the term of brassica productivity (1.26 tonnes/ha) as compared to world's average productivity (2.04 tonnes/ha). Moreover, there are wider yield gaps when productivity of India is compared with European countries. The development of cultivars with high seed yield and oil content has an important role to fill the gap between oil production and human population. The knowledge of combining ability provides fundamental information regarding the breeding techniques to be employed for crop improvement through different breeding methods. The foremost requirement for any hybrid breeding programme is identification and selection of diverse parents that having good general and specific combining ability with other parents for most of yield contributing traits [6]. Combining ability studies also help in rejecting a large number of germplasm lines in F_1 generation itself and selecting only those having high yield potential with good general and specific combining ability. Selection of parents based on diversity estimates, coupled with combining ability analysis, may be useful in the selection of suitable parents for hybrid development programme. Hybrids offer an opportunity for mobilizing greater amount of genetic variation and heterotic responses. Therefore, the present investigation was carried out to study the combining ability effects in *Mori* based hybrids of Indian mustard.

2. MATERIALS AND METHODS

In this experiment, 10 *Mori* CMS lines *viz*; MA-1-30, MA-023, MA-270, MA-8701, MA-8812, MA-9705, MA-9301, MA-9518, MA-9811 and MA-9702 were crossed with five testers *viz*; MR-9, MR-31, MR-38, MR-43 and MR-44 during Rabi, 2017-18 to develop a total of 50 crosses. These 50 F_1s crosses along with 15 parents and 3 checks *viz*; DMH-1, RH-749 and RH-30 were evaluated in randomized block design with three replications in paired rows of 4-meter length, maintaining crop geometry of 45 x 15 cm during Rabi 2018-19. The recommended agronomical practices were adopted to raise a healthy crop. The observations were recorded for 12 traits *viz*; days to 50% flowering, days to maturity, plant height (cm), number of primary branches per plant, number of secondary branches per plant, main shoot length (cm), numbers of siliquae on main shoot, siliquae length (cm), number of seeds per siliquae, 1000-seed weight (g), oil content (%) and seed yield per plant (g). The oil content was determined through Soxhlet Method of Oil Extraction [7]. The combining ability analysis was carried out as per the method of Kempthorne [8].

3. RESULTS AND DISCUSSION

The data on 50 crosses along with 15 parents were analysed and the total variance was subdivided into three components *viz*; variance due to lines, testers and line x testers. The data on crosses were further analysed to determine the lines and testers GCA effects and line x testers SCA effects variance components for all the traits (Table 1). The mean squares due to crosses were significant for all the traits, due to lines it was found significant for the traits like days to 50% flowering, plant height, main shoot

Table 1. Analysis of variance for combining ability in Indian mustard

Source of variation	d.f.	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches	No. of secondary branches	Main shoot length (cm)	No. of siliquae on main shoot	Silique length (cm)	No. of seeds per siliquae	1000 seed weight (g)	Seed yield (g)/plant	Oil content (%)
Replication	2	9.44*	3.24	7.12	1.15*	2.95	171.28**	26.11	0.02	0.10	0.01	20.03	0.02
Crosses	49	18.15**	11.57**	177.19**	0.84**	6.31**	111.75**	58.87**	0.30**	2.28**	0.39**	35.73**	2.16**
Line	9	47.83**	11.18	346.35**	0.92	8.46	392.29**	103.87*	0.56**	3.14	0.81**	91.41**	1.82
Tester	4	55.21**	21.97	827.35**	0.44	1.86	89.45	112.00*	1.51**	3.89	0.68*	20.56	2.43
Line x Tester	36	6.61**	10.51**	62.66	0.86**	6.26**	44.09*	41.72**	0.11**	1.89**	0.25**	23.50**	2.21**
Error	98	2.29	3.84	66.45	0.25	1.33	26.84	16.39	0.02	0.35	0.01	10.47	0.01
Total	149	7.60	6.37	102.07	0.45	2.99	56.70	30.49	0.11	0.98	0.13	18.90	0.71
Variance													
σ^2L		3.03**	0.49	18.66**	0.04	0.47	24.36**	5.83*	0.04**	0.18	0.05**	5.39**	0.12
σ^2T		1.76**	0.60	25.36**	0.01	0.01	2.08	3.18*	0.05**	0.11	0.02*	0.33	0.08
σ^2GCA		2.18**	0.56**	23.12**	0.02	0.17	9.51**	4.06**	0.04**	0.14**	0.03**	2.02**	0.09
σ^2SCA		1.44**	2.22**	-1.26	0.20**	1.64**	5.75*	8.44**	0.03**	0.51**	0.08**	4.34**	0.73**
σ^2GCA/σ^2SCA		1.51	0.25	-18.34	0.10	0.10	1.65	0.48	1.33	0.27	0.37	0.46	0.12

**, ** Significant at P = 0.05 and P = 0.01, respectively*

Table 2. General combining ability effects of lines and testers for various traits in Indian mustard

S. no.	Parents	Plant height	Days to 50% flowering	Days to maturity	No. of primary branches	No. of secondary branches	Main shoot length	No. of siliquae on the main shoot	Siliquae length	No. of seeds per siliquae	1000 seed weight	Seed yield per plant	Oil content
1.	MR-9	1.61	0.61**	0.84**	0.16*	0.22	-1.64*	-0.57	-0.38**	-0.21*	0.06**	0.79	0.28**
2.	MR-31	3.32**	1.31**	0.97**	-0.06	-0.18	-1.69*	-1.37	0.03	-0.09	0.20**	-0.86	-0.39**
3.	MR-38	4.30**	0.81**	-0.29	0.03	-0.01	0.08	2.56**	0.02	0.24**	-0.20**	0.96*	0.24**
4.	MR-43	-0.42	-2.02**	-0.62*	-0.16*	-0.30	0.89	-2.04**	0.12**	0.47**	-0.04*	-0.30	0.03**
5.	MR-44	-8.82**	-0.72**	-0.89**	0.03	0.27	2.35**	1.42*	0.20**	-0.42**	-0.02	-0.58	-0.16**
6	MA-1-30	-4.94*	-0.82*	0.90	-0.14	-1.04**	-0.46	-0.03	-0.09*	-0.43**	0.11**	-0.79	0.19**
7.	MA-023	-4.28*	-2.48**	0.10	-0.01	0.13	4.48**	3.22**	0.19**	-0.27	0.27**	1.68*	-0.19**
8.	MA-270	-9.62**	-2.22**	-1.56**	-0.01	-0.03	-9.81**	-5.24**	-0.23**	-0.14	-0.38**	-4.51**	0.73**
9.	MA-8701	3.43	1.44**	0.37	0.11	-0.38	-3.95**	1.13	-0.31**	0.26	-0.14**	1.80*	0.25**

S. no.	Parents	Plant height	Days to 50% flowering	Days to maturity	No. of primary branches	No. of secondary branches	Main shoot length	No. of siliquae on the main shoot	Siliquae length	No. of seeds per siliquae	1000 seed weight	Seed yield per plant	Oil content
10.	MA-8812	6.24**	2.11**	-0.29	0.52**	1.23**	-2.70*	0.34	0.25**	0.73**	0.17**	3.18**	-0.12**
11.	MA-9705	2.43	1.64**	1.37**	-0.32*	0.21	4.30**	1.54	0.17**	-0.13	-0.22**	1.02	-0.40**
12.	MA-9301	1.84	-1.22**	-1.02*	0.26*	0.76*	3.37*	-2.23*	0.17**	0.67**	-0.20**	2.27**	-0.09**
13.	MA-9518	3.22	-1.35**	0.37	-0.20	-0.67*	7.81**	3.59**	-0.03	-0.54**	0.15**	-0.24	0.14**
14.	MA-9811	0.46	1.71**	0.10	-0.17	-0.88**	-1.24	-1.42	-0.01	0.25	-0.05*	-1.24	-0.43**
15.	MA-9702	1.20	1.18**	-0.36	-0.03	0.66*	-1.80	-0.90	-0.11**	-0.39*	0.29**	-3.14**	-0.06**

**, ** Significant at P = 0.05 and P = 0.01, respectively*

Table 3. Top 10 crosses with per se performance, GCA effects of parents and SCA effects of crosses

S.No.	Crosses	Seed yield (g)	SCA effects	GCA Effects		σ^2GCA status of parents
				Line	Tester	
1.	MA-9301 x MR-44	34.5	4.83*	2.27**	-0.58	A x H
2.	MA-8701 x MR-38	34.4	3.61	1.80*	0.96*	A x A
3.	MA-8812 x MR-9	33.1	1.08	3.18**	0.79	A x A
4.	MA-023 x MR-38	33.0	2.35	1.68*	0.96*	A x A
5.	MA-9705 x MR-31	32.1	3.95*	1.02	-0.86	A x H
6.	MA-8701 x MR-9	31.9	1.32	1.80*	0.79	A x A
7.	MA-8812 x MR-31	31.8	1.46	3.18**	-0.86	A x H
8.	MA-1-30 x MR-9	31.7	3.65	-0.79	0.79	H x A
9.	MA-023 x MR-9	31.6	1.16	1.68*	0.79	A x A
10.	MA-8812 x MR-44	31.6	0.96	3.18**	-0.58	A x H

**, ** Significant at P = 0.05 and P = 0.01, respectively* length, number of siliquae on main shoot, siliquae length, 1000 seed weight and seed yield per plant, due to testers it was found significant for the traits like days to 50% flowering, plant height, number of siliquae on main shoot, siliquae length and 1000 seed weight and due to line x tester it was found significant for all the traits except for plant height. The significant mean squares due to lines and testers indicated a significant contribution of parents towards GCA variance components for these traits. The significant mean squares due to line x testers indicated a significant contribution of hybrids for specific combining ability variance components. Similar results were also reported by many workers [9,10] in Indian mustard.

Variance due to lines were of higher magnitude than that of testers for the traits like days to 50% flowering, number of primary branches per plant, number of secondary branches per plant, main shoot length, numbers of siliquae on main shoot, number of seeds per siliquae, 1000-seed weight (g), oil content (%) and seed yield per plant (g) indicated that the contribution of lines variance ($\sigma^2 L$) for all these traits was greater than that of testers (Table 1). The estimates of SCA variance were of higher magnitude than GCA variance for most of yield contributing traits which indicated the presence of a non-additive type of gene action for these traits [11].

Besides this, the ratio of σ^2GCA/ σ^2SCA was less than unity for the traits *viz*; days to maturity, number of primary branches, number of secondary branches, number of siliquae on the main shoot, number of seeds per siliquae, 1000 seed weight, seed yield per plant and oil content (Table 1). This indicated that the presence of non-additive gene effects in the inheritance of these traits and improvement in these traits would be possible through use of heterosis breeding.

On the basis of overall performance of parents, line MA-023 and tester MR-38 was found the best general combiner for majority of component traits including seed yield per plant. Other three lines *viz*; MA-8701, MA-8812, and MA-9301 were also found as good general combiners for seed yield and the majority of yield contributing traits *viz*; number of primary branches, number of secondary branches, main shoot length, number of siliquae per plant, siliquae length and number of seeds per siliquae. Lines MA-023 and MA-270 were identified as good general combiners on the basis of their GCA effects for days to 50 per cent flowering, maturity and plant height while two testers namely, MR-43 and MR-44 were found good general combiners for siliquae length, days to 50% flowering and days to maturity. This indicated that these lines and testers may be used for development of early maturity hybrids with reduced height in future breeding programmes. Lines MA-023, MA-8701, MA-8812 and MA-9301 were identified as good general combiner for seed yield per plant. Lines MA-8812 and MA-9301 were found good general combiners for number of primary branches per plant, number of secondary branches per plant, number of seeds per siliquae and siliquae length. Lines MA-023 and MA-9518 were found good general combiner for main shoot length, number of siliquae on main shoot and 1000 seed weight. Parents having high general combining ability effects in desirable direction may be utilized in future crossing programme for development of superior hybrids for seed yield and other desirable traits. These findings are in accordance with the results of [5,9,12,13,14].

For oil content, lines MA-1-30, MA-270, MA-8701 and MA-9518 while, testers MR-9, MR-38 and MR-43 were found good general combiners. Among the five testers, MR-38 was observed as best general combiner because it showed significant GCA effects for number of siliquae on the main shoot, number of seeds per siliquae, seed yield per plant and oil content. Based on the *per se* performance and SCA effects of crosses, top 10 crosses *viz*; MA-9301 x MR-44, MA-8701 x MR-38, MA-8812 x MR-9, MA-023 x MR-38, MA-9705 x MR-31, MA-8701 x MR-9, MA-8812 x MR-31, MA-1-30 x MR-9, MA-023 x MR-9 and MA-8812 x MR-44 were identified (Table 3). High SCA effects resulting from five crosses *viz*; MA-8701 x MR-38, MA-8812 x MR-9, MA-023 x MR-38, MA-8701 x MR-9 and MA-023 x MR-9, where both the parents were good general combiners (i.e., good GCA x good GCA) may be attributed to additive x additive gene action [15,16]. The remaining five crosses *viz*; MA-9301 x MR-44, MA-9705 x MR-31, MA-8812 x MR-31, MA-1-30 x MR-9 and MA-8812 x MR-44 showed the high SCA effects includes good x poor general combiner parents [16] may be attributed to favourable additive effects of the good general combiner parents and epistatic effects of poor general combiners, which fulfils the favourable plant attribute. These parental (poor general combiners) lines would help in exploiting favourable epistatic genetic components of variation to develop hybrids.

Table 4. SCA effects for plant height, number of primary branches per plant, number of secondary branches per plant, main shoot length, number of siliquae on main shoot and siliquae length

S. no	Genotype	Plant height	No. of primary branches	No. of secondary branches	Main shoot length	No. of siliquae on the main shoot	Siliquae length
1.	MA-1-30 x MR-9	6.74	0.27	1.06	0.92	2.93	-0.17
2.	MA-1-30 x MR-31	-0.60	0.88**	2.23**	-0.17	-0.06	0.01
3.	MA-1-30 x MR-38	-2.18	-0.06	-2.63**	-3.31	-1.32	0.08
4.	MA-1-30 x MR-43	0.98	-0.69*	-1.24	2.58	0.90	-0.14
5.	MA-1-30 x MR-44	-4.94	-0.40	0.58	-0.01	-2.45	0.21*
6.	MA-023 x MR-9	-0.88	-0.28	-0.35	0.07	-1.58	-0.06
7.	MA-023 x MR-31	1.34	-0.73*	-2.80**	-0.08	1.41	0.09
8.	MA-023 x MR-38	0.09	1.41**	1.63*	0.94	3.98	-0.20*
9.	MA-023 x MR-43	-2.51	0.07	0.71	1.20	-2.74	0.34**
10.	MA-023 x MR-44	1.96	-0.46	0.81	-2.13	-1.07	-0.17
11.	MA-270 x MR-9	2.55	0.21	-0.35	-3.62	1.01	0.10
12.	MA-270 x MR-31	3.84	-0.66*	-1.21	-4.41	-1.12	-0.07
13.	MA-270 x MR-38	-1.96	-0.52	-0.30	5.20	-2.32	-0.20*
14.	MA-270 x MR-43	-1.27	0.97**	2.35**	-1.60	0.78	0.20*
15.	MA-270 x MR-44	-3.16	0.00	-0.49	4.43	1.65	-0.04
16.	MA-8701 x MR-9	-4.24	-0.11	0.84	-1.65	-1.83	-0.18*
17.	MA-8701 x MR-31	-5.38	-0.22	-1.85**	-6.51*	-2.89	-0.09
18.	MA-8701 x MR-38	1.93	-0.54	1.08	6.34*	6.74**	0.27**
19.	MA-8701 x MR-43	1.36	0.55	0.42	3.87	-0.22	0.04
20.	MA-8701 x MR-44	6.33	0.31	-0.48	-2.05	-1.78	-0.03
21.	MA-8812 x MR-9	-2.88	0.41	1.38*	-2.50	-1.73	0.04
22.	MA-8812 x MR-31	-2.46	0.30	1.19	0.97	-2.80	0.20*
23.	MA-8812 x MR-38	0.32	-0.05	-0.74	-1.83	-0.56	-0.09
24.	MA-8812 x MR-43	4.22	-0.39	-0.91	-1.17	0.26	-0.18*
25.	MA-8812 x MR-44	0.79	-0.26	-0.92	4.53	4.84*	0.03
26.	MA-9705 x MR-9	1.45	-0.44	-1.59*	-1.24	-1.27	0.13
27.	MA-9705 x MR-31	2.18	-0.12	1.71*	2.96	3.59	-0.31**
28.	MA-9705 x MR-38	-5.46	0.32	0.75	-2.48	-5.13*	-0.07
29.	MA-9705 x MR-43	1.66	0.52	-0.86	1.01	2.33	0.26**
30.	MA-9705 x MR-44	0.16	-0.28	-0.00	-0.25	0.47	-0.02
31.	MA-9301 x MR-9	-12.51**	-0.03	-0.68	-3.48	-3.09	-0.07
32.	MA-9301 x MR-31	-1.22	-0.01	1.49*	2.89	3.10	0.11
33.	MA-9301 x MR-38	0.79	0.09	1.33*	2.42	0.84	-0.08
34.	MA-9301 x MR-43	6.52	-0.46	-2.55**	-0.35	3.17	-0.30**
35.	MA-9301 x MR-44	6.42	0.59*	0.41	-1.48	-4.02	0.34**
36.	MA-9518 x MR-9	2.60	-0.09	0.36	3.51	5.57*	-0.06
37.	MA-9518 x MR-31	1.56	-0.10	1.77**	3.12	1.84	0.03
38.	MA-9518 x MR-38	3.41	-0.32	0.59	-6.55*	-3.88	0.03
39.	MA-9518 x MR-43	-9.19	0.27	1.69*	-1.62	-7.68**	-0.12
40.	MA-9518 x MR-44	1.61	0.23	0.31	1.54	4.15	0.12
41.	MA-9811 x MR-9	1.43	-0.12	0.37	4.56	3.92	0.02
42.	MA-9811 x MR-31	2.39	0.23	0.28	1.74	-2.44	0.04
43.	MA-9811 x MR-38	-0.88	0.28	0.18	3.80	2.56	0.04
44.	MA-9811 x MR-43	-0.09	-0.86**	-0.96	-8.24**	-4.50	0.02
45.	MA-9811 x MR-44	-2.85	0.47	0.13	-1.87	0.46	-0.13
46.	MA-9702 x MR-9	5.72	0.17	-1.04	3.43	-3.93	0.24**
47.	MA-9702 x MR-31	-1.65	0.42	0.73	-0.52	-0.63	-0.03
48.	MA-9702 x MR-38	3.93	-0.43	-0.69	-4.53	-0.89	0.20*
49.	MA-9702 x MR-43	-1.67	0.03	1.35*	4.32	7.70**	-0.12
50.	MA-9702 x MR-44	-6.33	-0.20	-0.35	-2.70	-2.25	-0.30**

**, ** Significant at P = 0.05 and P = 0.01, respectively*

Table 5. SCA effects for days to 50% flowering, days to maturity, number of seeds per siliquae, test weight, seed yield and oil content

S. no.	Genotype	Days to 50% flowering	Days to maturity	No. of seeds per siliquae	1000 seed weight	Seed yield per plant	Oil content
1.	MA-1-30 x MR-9	-1.08	2.02	-0.73*	-0.26**	3.65	1.67**
2.	MA-1-30 x MR-31	-0.11	1.22	-0.35	-0.01	2.24	-0.01
3.	MA-1-30 x MR-38	0.38	-3.50**	0.17	0.30**	-1.22	-0.68**
4.	MA-1-30 x MR-43	0.88	1.82	-0.52	-0.15*	-2.38	-0.84**
5.	MA-1-30 x MR-44	-0.08	-1.57	1.44**	0.12*	-2.30	-0.14**
6.	MA-023 x MR-9	0.25	-0.17	1.60**	0.06	1.16	-0.40**
7.	MA-023 x MR-31	1.88*	0.69	0.05	-0.47**	-2.91	0.27**
8.	MA-023 x MR-38	1.38	1.62	-0.42	0.30**	2.35	-0.29**
9.	MA-023 x MR-43	-3.11**	-3.04**	0.28	0.24**	-0.47	-0.39**
10.	MA-023 x MR-44	-0.41	0.89	-1.52**	-0.14*	-0.12	0.81**
11.	MA-270 x MR-9	0.98	1.82	0.48	-0.07	-1.16	-1.20**
12.	MA-270 x MR-31	1.62	-0.64	0.14	0.18**	-0.50	-0.92**
13.	MA-270 x MR-38	1.12	1.29	0.21	-0.13*	-0.83	1.70**
14.	MA-270 x MR-43	-1.04	-1.04	-0.11	0.13*	3.00	1.67**
15.	MA-270 x MR-44	-2.68**	-1.44	-0.72*	-0.11	-0.51	-1.25**
16.	MA-8701 x MR-9	-0.01	2.56*	-0.56	0.18**	1.32	1.20**
17.	MA-8701 x MR-31	-0.38	0.09	-0.59	-0.15*	-2.76	-0.27**
18.	MA-8701 x MR-38	-0.54	1.69	0.37	-0.27**	3.61	-1.18**
19.	MA-8701 x MR-43	-0.38	-2.30*	0.24	0.29**	-0.18	0.45**
20.	MA-8701 x MR-44	1.32	-2.04	0.53	-0.05	-1.99	-0.20**
21.	MA-8812 x MR-9	-1.01	0.56	0.56	-0.30**	1.08	1.09**
22.	MA-8812 x MR-31	-1.04	-0.24	0.77*	0.02	1.46	-0.06
23.	MA-8812 x MR-38	0.78	1.69	-0.23	-0.16**	-1.59	-0.63**
24.	MA-8812 x MR-43	2.28*	0.69	-0.66	0.11	-1.91	-0.56**
25.	MA-8812 x MR-44	-1.01	-2.70*	-0.43	0.32**	0.96	0.17**
26.	MA-9705 x MR-9	-0.54	-4.10**	-0.89*	0.23**	-7.29**	0.01
27.	MA-9705 x MR-31	-0.91	-0.90	-0.52	-0.17**	3.95*	0.05
28.	MA-9705 x MR-38	-0.41	-0.30	0.14	0.03	0.96	-0.18**
29.	MA-9705 x MR-43	0.08	2.02	0.57	-0.22**	0.83	-0.11*
30.	MA-9705 x MR-44	1.78*	3.29**	0.70*	0.12*	1.54	0.22**
31.	MA-9301 x MR-9	-0.34	-1.04	-0.70*	-0.35**	-0.08	-0.63**
32.	MA-9301 x MR-31	0.62	0.49	0.93**	0.37**	1.30	-0.25**
33.	MA-9301 x MR-38	-0.88	-0.91	-0.80*	0.08	-3.72*	1.17**
34.	MA-9301 x MR-43	0.95	0.42	-0.29	-0.17**	-2.34	-0.12*
35.	MA-9301 x MR-44	-0.34	1.03	0.86*	0.07	4.83*	-0.15**
36.	MA-9518 x MR-9	0.78	0.22	0.24	0.12*	-0.26	-1.01**
37.	MA-9518 x MR-31	-2.91**	-0.24	-0.25	0.11	1.82	0.80**
38.	MA-9518 x MR-38	-1.41	-1.64	-0.68*	-0.13*	-3.73*	0.96**
39.	MA-9518 x MR-43	2.75**	0.69	0.25	0.40**	1.10	-0.33**
40.	MA-9518 x MR-44	0.78	0.96	0.44	-0.51**	1.05	-0.42**
41.	MA-9811 x MR-9	0.38	0.16	-0.42	0.10	3.00	-0.26**
42.	MA-9811 x MR-31	1.02	0.69	0.15	0.26**	-1.60	0.31**
43.	MA-9811 x MR-38	-0.48	-0.70	1.04**	-0.33**	1.10	-0.28**
44.	MA-9811 x MR-43	0.02	-0.37	-0.81*	0.04	-0.82	0.24**
45.	MA-9811 x MR-44	-0.94	0.22	0.04	-0.07	-1.68	-0.01
46.	MA-9702 x MR-9	0.58	-2.04	0.43	0.28**	-1.43	-0.46**
47.	MA-9702 x MR-31	0.22	-1.17	-0.33	-0.15*	-3.01	0.08
48.	MA-9702 x MR-38	0.05	0.76	0.20	0.32**	3.06	-0.58**
49.	MA-9702 x MR-43	-2.44**	1.09	1.07**	-0.70**	3.16	-0.01
50.	MA-9702 x MR-44	1.58	1.36	-1.36**	0.24**	-1.78	0.98**

**, ** Significant at P = 0.05 and P = 0.01, respectively*

Out of 50 crosses, two crosses *viz*; MA-9301 x MR-44 and MA-9705 x MR-31 showed significant SCA effects for seed yield (Table 3) as well as other yield contributing characters like number of primary branches, number of secondary branches, number of seeds per siliquae and siliquae length. The estimates of SCA effects presented in Tables 4 & 5. None of the cross combination was found to be a common combiner for all the characters under study. For plant height only one cross, MA-9301 x MR-9 expressed highly significant but negative SCA effects.

Similar negative significant SCA effects were observed in four crosses for days to 50% flowering and in five crosses for days to maturity. High and significant SCA effects were observed for number of primary branches/ plant in four hybrids, number of secondary branches/plant in nine hybrids, main shoot length in only one hybrid, siliquae length in nine hybrids, number of seeds/siliquae in eight hybrids, 1000 seed weight in 15 hybrids and oil content in 16 hybrids.

4. CONCLUSION

Based on the results, the three crosses such as MA-9301 x MR-44, MA-8701 x MR-38 and MA-9705 x MR-31 were found best per se performers and specific combiners among all 50 cross combinations. These hybrids may take for advanced trails and isolation of superior parental lines.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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