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Combining ability (gca and sca) and heterotic response analysis in Indian Mustard (*Brassica juncea* L. Czern and Coss) under Bundelkhand region

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ABSTRACT

Combining ability analysis revealed that good general combiners were Urvashi x KMR-15-2, Pusa Agrani x Pusa Bahar, RH-749 x Pusa Bahar, RH-749 x Durgamani and KMR-15-2 x Pusa Bahar were best specific combiners for seed yield per plant. In hybrid high heterosis over better and mid parent Urvashi x KMR-15-2, Pusa Agrani x Durgamani, RH-749 x KMR-15-2, KMR-15-2 x Pusa Bahar and KMR-15-2 x Durgamani and Urvashi x KMR-15-2, Pusa Agrani x Pusa Bahar, RH-749 x Pusa Bahar, KMR-15-2 x Pusa Bahar and KMR-15-2 x Durgamani, respectively and high x high general combiners with significant sca effects for seed yield per plant. The parents namely, Urvashi, KMR-15-2, Pusa Agrani, Pusa Bahar, RH-749, Pusa Bahar, RH-749, Durgamani, KMR-15-2 and Pusa Bahar were good general combiners for number of traits and hence, may be used further in hybridization programme. Developmental attributes likes days to flowering, days to maturity, number of siliquae per plant and oil content, 1000-seed weight, seed yield per plant should be given maximum frequency for getting higher productivity in Indian mustard.

KEYWORDS

Combining Ability (Gca and Sca), Diallel Analysis, Heterosis, Indian Mustard, Seed Yield

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Indian mustard [*Brassica juncea* (L.) Czern and Coss], which is cultivated under the genus *Brassica* is cultivated all over India and it is throughout the world belongs to family Cruciferae (Brassicaceae). It has 38 to 42 % oil and 24% protein. India is one of the major producers in the global oilseeds/vegetable oil economy. There is a severe shortage of edible oil in the country. The per capita availability of edible oil is only 11 (g)/day as against the normal requirement of 30 (g)/day. Thus the availability of energy through oil is word limited. Insufficient fat consumption reflects the poor living standards of the people. Even at this minimum level of consumption the country imports substantial quantities of edible oil.

Historically the *brassicas* are one of the earliest domesticated crop plants by man. Rapeseed-mustard is the third important oilseed crop in the world after soybean (*Glycine max*) and palm (*Elaeis guineensis* Jacq.) oil. Among the seven edible oilseed (groundnut, rapeseed-mustard, sesame, linseed, sunflower, safflower and niger) cultivated in India, rapeseed mustard (*Brassica spp*.) contributes 28.6% in the total production of oilseeds. The edible oil industry is one of the most vibrant sectors of the Indian agriculture economy. The county ranks first in the world in the production of castor, safflower, sesame and niger; second in groundnut; third in rapeseed-mustard and linseed and fourth in soybean.

Rapeseed and mustard oil is used primarily for edible purposes and is the principle cooking oil in the mustard growing area of the country. Known for its great taste and subtle flavor, this vegetable oil is the world's second leading source of protein meal. Besides seeds, it is used as condiments. The meal cake left after oil extraction forms important cattle feed and may also be used as organic manure.

Important oil seed crop grown in cool season sub tropics, higher elevations and winter crops. Rapeseed oil was produced in the 19th century as a source of a lubricant for steam engines. The oil and protein content varies from 37 to 49% and 22-28%, respectively. The seed and oil are used as condiment in the preparation of pickles and for flavouring curries and vegetables. Rapeseed-mustard oil has high level of antioxidant, which retards growth of free radicals mainly responsible for disease like cancer and ageing. Glucosinolates present in seed meal has shown anticancer properties. *Brassica* species are very rich in phenolic compounds and glucosinolates. *Brassicas* are rich source of vitamins, minerals and contains many medicinal properties. They provide high amounts of vitamin C, soluble fiber and contain multiple nutrients with potent anti-cancer properties. Oil is used in Northern India for cooking and frying purposes. It is also used in preparation of hair oil and medicines. It has industrial importance in soap making and in mixtures with mineral oils for lubrication and grease for various machines. Tender leaves of young plants are used as green vegetable and are good source of sulphur and other minerals in diet.

The estimated area, production and yield of rapeseed-mustard in the world was 36.68 million hectares (mha), 72.42 million tonnes (mt) and 1974 kg / ha, respectively, during 2017-18. Globally, India account for 19.8 % and 9.8% of the total acreage and production (USDA 2016-17). During the last seven years, there has been a considerable increase in productivity from 1840 kg/ha in 2010-11 to 1974 kg/ha in 2017-18 and production has also increased from 61.64 m t in 2010-11 to 72.42 m t in 2017-18.

Materials and Methods

The present experiment consisting of seven genetically diverse genotype namely, Urvashi, PM-27, Pusa Agrani, RH-749, KMR-15-2, Pusa Bahar and Durgamani using in a diallel set (excluding their reciprocals) were crossed with each other in all the possible combinations to produce sufficient F_0 seed of 21 crosses laid out in randomized block design with three replications at Oilseed Research Farm, Kalyanpur, Kanpur during *rabi* 2017-19. F_0 seeds of different crosses were grown to produce F_1 seeds. The plants for recording detailed observations were taken randomly after 30 days of sowing. In each replication, the number of plants in each parent was five, in each F_1's was ten.

The observations were recorded on the following ten qualitative and quantitative traits, *viz*., days to 50% flowering, days to maturity, plant height (cm), length of main raceme (cm), number of siliquae per plant, number of primary branches per plant, number of secondary branches per plant, oil content (%), test weight (g) and seed yield per plant (g). Oil content was estimated in per cent using Nuclear Magnetic Resonance (NMR) Oxford 4000 Analyzer. The analysis of variance for the experimental design is based on the method suggested by (Panse and Sukhatma, 1967). Testing the validity of the hypothesis *i.e*., the assumptions regarding diallel analysis as proposed by (Hayman, 1954a). The combining ability analysis was carried out by the procedure suggested by (Griffing's, 1956 b) method 2, model 1.

Results and Discussion

The analysis of variance for combining ability was done and the results are presented in table 1 and 2. The mean sum of square due to gca were highly significant for all the characters. The mean sum of square due to gca was highly significant for all the characters except days to 50% flowering. The estimated variance of general combining ability (σ^2gca) were higher than variance of specific combining ability (σ^2sca) for all the characters. The results for combining ability are presented in table 3 and 4. The parents namely, Urvashi, PM-27, Pusa Agrani, Durgamani, KMR-15-2 and RH-749 were best general combiners for days to 50% flowering, days to maturity, plant height (cm), length of main raceme (cm), number of siliquae per plant, number of primary branches per plant, number of secondary branches per plant, oil content (%), test weight (g) and seed yield per plant (g). Similar finding were also observed by (Chauhan *et al.* 2011 and Singh *et al.* 2011).

Table 1. Analysis of variance for combing ability

Sourced of variation	D. F.	Days of 50% flowering	Days to 50 % maturity	Plant height (cm)	Main raceme length in (cm)	No. of siliquae per plant	No of primary branch per plant	No of secondary branch per plant	Oil content (%)	1000 seed weight (g)	Seed yield per plant (g)
GCA	6	21.34**	10.88**	87.40**	65.15**	125.62**	0.91**	4.99**	4.69**	0.56**	3.01**
SCA	21	1.04	1.13*	11.03**	8.80**	20.56**	0.20**	0.57**	0.60**	0.16**	0.53**
EROR	54	1.37	0.76	2.08	0.65	3.12	0.06	0.19	0.05	0.01	0.09

*, ** significant at 5% and 1% level, respectively

Table 2. General combining ability effects and variances analysis for parents

Parents	Days of 50% flowering	Days to 50 % maturity	Plant height (cm)	Main raceme length in (cm)	No. of siliquae per plant	No of primary branch per plant	No of secondary branch per plant	Oil content (%)	1000 seed weight (g)	Seed yield per plant (g)
Urvashi	-1.10**	-1.86**	4.37**	-1.55**	1.43**	0.52**	0.29*	0.17*	-0.04	0.08
PM-27	-1.44**	-0.42	-3.26**	-1.45**	-3.81**	-0.35**	-0.53**	-0.11	-0.05*	-0.46**
Pusa Agrani	-1.10**	-0.38	-2.08**	-3.66**	-4.52**	-0.30**	-0.29*	-0.33**	-0.16**	-0.09
RH-749	0.92*	1.34**	3.29**	0.48	2.66**	0.15*	-0.02	0.21*	0.37**	0.14
KMRI15-2	1.01**	-0.42	-0.40	4.83**	5.82**	0.18*	1.53**	1.42**	0.32**	1.18**
Pusa Bahar	-0.95*	0.92**	1.43**	-0.05	-2.29**	-0.27**	-0.67**	-0.71**	-0.25**	-0.51**
Durgamani	2.64**	0.81**	-3.36**	1.40**	0.72	0.07	-0.31*	-0.65**	-0.21**	-0.34**
SE (gi)	0.36	0.27	0.44	0.25	0.55	0.07	0.14	0.07	0.02	0.09
SE (gi-gj)	0.55	0.41	0.68	0.38	0.83	0.11	0.21	0.11	0.04	0.14

*, ** significant at 5% and 1% level, respectively

Table 3. Specific combining ability and their effects analysis in hybrids

S. N.	Parents	Days of 50% flowering	Days to 50 % maturity	Plant height (cm)	Main raceme length in (cm)	No. of siliquae per plant	No of primary branch per plant	No of secondary branch per plant	Oil content (%)	1000 seed weight (g)	Seed yield per plant (g)
1	Urvasi X PM-27	0.05	-1.19	3.11**	-1.09	2.49	0.47*	0.84*	-0.03	-0.09	0.43
2	Urvasi X Pusa Agrani	0.04	1.44	3.77**	-0.21	2.99	0.33	0.15	0.24	0.04	0.11
3	Urvasi X RH-749	0.69	0.38	-1.39	1.18	-1.37	0.02	-0.07	-0.27	-0.08	-0.09
4	Urvasi X KMR15-2	-0.07	-0.19	0.76	4.30**	2.85	0.02	0.18	0.60**	0.56**	0.74**
5	Urvasi X Pusa Bahar	-1.11	0.14	-0.09	0.76	3.11	0.35	0.55	0.57**	0.25**	-0.34
6	Urvasi X Durgamani	-0.36	-0.41	3.54**	1.39	-0.77	0.12	0.22	0.55**	0.19*	-0.02
7	PM-27 X Pusa Agrani	0.38	-0.67	-0.53	1.29	-4.46**	-0.18	0.15	0.09	-0.05	-0.43
8	PM-27 X RH-749	-0.63	0.61	4.24**	0.70	3.56**	0.37	0.41	0.07	-0.26**	-0.31
9	PM-27 X KMR15-2	-0.73	-0.30	2.22	2.77**	5.46**	0.58**	0.92**	0.48*	0.10	0.46
10	PM-27 X Pusa Bahar	-0.43	0.03	3.41**	0.57	-1.52	0.13	-0.41	0.29	0.27**	0.05
11	PM-27 X Durgamani	0.31	-1.86**	-2.58*	0.93	1.44	0.47*	0.02	0.41	0.31**	-0.02
12	Pusa Agrani X RH-749	-0.64	-1.10	2.81*	2.96**	3.91**	0.36	0.05	0.55**	0.68**	0.00
13	Pusa Agrani X KMR15-2	-0.40	-1.67*	0.22	3.42**	5.58**	0.27	0.55	0.51**	0.17*	0.13
14	Pusa Agrani X Pusa Bahar	-0.11	-1.01	1.94	2.68**	-1.41	0.00	0.60	0.21	0.11	0.65**
15	PusaAgrani X Durgamani	-2.70**	-0.90	-0.96	3.08**	2.91**	0.27	0.29	0.27	-0.08	0.51*
16	RH-749 X KMR15-2	-0.08	-0.39	0.66	0.27	-1.22	-0.11	0.13	-0.04	0.07	0.32
17	RH-749 X Pusa Bahar	0.88	-0.06	-1.67	-0.51	5.08**	0.22	0.16	0.68**	0.36**	0.68**
18	RH-749 X Durgamani	-0.38	0.72	3.28**	-0.17	-0.17	0.15	0.04	0.65**	0.40**	0.63**
19	KMR15-2 X Pusa Bahar	1.78	0.03	-0.32	0.82	4.21**	0.19	0.94**	0.86**	0.20*	1.27**
20	KMR15-2 X Durgamani	0.52	0.47	2.44*	0.20	2.00	-0.13	0.71	0.86**	0.23*	0.52*
21	Pusa Bahar X Durgamani	-0.51	0.81	2.60*	-0.01	2.29	0.25	0.21	-0.48*	-0.10	0.24
	SE (sij)	1.05	0.78	1.29	0.73	1.59	0.21	0.39	0.21	0.07	0.26
	SE (sij-sik)	1.56	1.16	1.92	1.08	2.36	0.31	0.59	0.31	0.10	0.39

*, ** significant at 5 and 1 per cent level, respectively

Table 4. Heterosis over BP and MP of hybrids

S. N.	Parents	Days of 50% Flowering		Days to 50 % Maturity		Plant Height (cm)		Main Raceme Length in (cm)		No. of Siliquae Per Plant	
		BP	MP	BP	MP	BP	MP	BP	MP	BP	MP
1	Urvasi X PM-27	-0.19	-0.54	0.26	-1.53	0.17	4.29*	1.62	2.08	0.64	2.24
2	Urvasi X Pusa Agrani	-0.44	-1.32	2.33	0.38	1.12	4.26*	0.99	5.74**	0.57	2.63
3	Urvasi X RH-749	3.10*	0.60	2.85*	0.35	1.23	1.56	1.51	4.40**	0.76	1.14
4	Urvasi X KMR15-2	2.21	0.00	1.04	-0.51	0.44	2.46	4.00**	9.78**	2.61	3.29
5	Urvasi X Pusa Bahar	-1.33	-1.55	2.33	0.13	0.94	1.98	1.59	3.92**	1.35	2.85
6	Urvasi X Durgamani	3.98**	-1.67	1.81	-0.51	0.35	4.31*	1.27	4.89**	1.06	1.17
7	PM-27 X Pusa Agrani	0.25	-0.97	-1.75	-1.87	1.05	2.08	1.93	7.18**	-0.58	-0.12
8	PM-27 X RH-749	1.59	-1.22	0.50	-0.15	0.86	4.68**	1.08	3.51**	0.66	2.63
9	PM-27 X KMR15-2	1.59	-0.96	-1.01	-1.25	1.26	3.39	2.49	7.72**	1.74	4.03
10	PM-27 X Pusa Bahar	-0.64	-0.76	-0.25	-0.62	0.87	3.98	1.49	3.35**	0.98	1.09
11	PM-27 X Durgamani	5.16**	-0.93	-1.75	-2.24	0.94	1.10	0.87	4.03**	0.26	1.74
12	Pusa Agrani X RH-749	-0.43	-1.97	-1.00	-1.52	0.73	3.52	1.15	8.77**	0.54	2.98
13	Pusa Agrani X KMR15-2	0.00	-1.29	-2.01	-2.38*	0.82	1.91	0.86	11.18**	1.55	4.31
14	Pusa Agrani X Pusa Bahar	0.00	-1.10	-1.25	-1.49	0.72	2.81	1.37	8.46**	0.77	1.35
15	Pusa Agrani X Durgamani	-0.87	-5.39**	-1.25	-1.61	0.76	1.62	0.81	9.15**	0.51	2.47
16	RH-749 X KMR15-2	0.42	0.17	0.25	-0.65	0.48	2.18	1.90	4.66**	1.67	1.97
17	RH-749 X Pusa Bahar	4.00	1.25	0.25	-0.03	0.22	0.93	1.30	1.86	1.67	3.55
18	RH-749 X Durgamani	1.60	-1.47	0.50	0.34	0.31	3.95	1.78	2.52**	0.93	1.41
19	KMR15-2 X Pusa Bahar	5.33**	2.82*	0.25	-0.37	0.41	1.40	1.92	5.24**	1.83	4.01
20	KMR15-2 X Durgamani	3.39*	0.00	0.50	-0.25	1.33	3.29	2.79	4.82**	2.09	2.88
21	Pusa Bahar X Durgamani	4.44**	-1.47	0.50	0.37	0.40	3.33	1.37	2.68**	1.05	2.43
	SE	1.48	1.19	1.33	1.07	2.64	1.92	1.59	1.15	3.55	2.57
	CD at 5%	3.14	2.52	2.82	2.27	5.60	4.07	3.37	2.44	7.53	5.45

*, ** significant at 5 and 1 per cent level, respectively

contd……

Table 4. Heterosis over BP and MP of hybrids *contd……*

S. N.	Parents	No of Primary Branch Per Plant		No of Secondary Branch Per Plant		Oil Content in %		1000 Seed Weight (g)		Seed Yield Per Plant in (g)	
		BP	MP	BP	MP	BP	MP	BP	MP	BP	MP
1	Urvasi X PM-27	2.66**	14.50**	5.27**	10.29**	1.30**	1.78**	1.24**	4.22**	1.83**	4.21**
2	Urvasi X Pusa Agrani	1.72**	10.28**	2.80**	6.04**	1.39**	2.81**	7.82**	10.74**	2.11**	3.41**
3	Urvasi X RH-749	3.10**	6.35**	3.05**	3.20**	1.28**	1.38**	2.04**	8.93**	2.25**	2.54**
4	Urvasi X KMR15-2	3.45**	5.76**	3.31**	7.89**	2.36**	4.45**	17.08**	23.09**	7.75**	10.51**
5	Urvasi X Pusa Bahar	2.24**	10.72**	2.89**	8.83**	1.29**	3.85**	10.45**	17.31**	-3.15**	3.19**
6	Urvasi X Durgamani	3.34**	7.88**	3.09**	5.98**	1.39**	3.87**	9.94**	14.72**	-0.20	4.03**
7	PM-27 X Pusa Agrani	3.59**	6.86**	4.74**	6.43**	1.30**	2.24**	-0.41**	5.21**	-1.88**	-0.84
8	PM-27 X RH-749	4.22**	13.00**	1.46	6.15**	1.42**	2.00**	-1.72**	2.02**	-1.72**	0.30
9	PM-27 X KMR15-2	4.94**	14.73**	2.90**	12.33**	1.42**	3.98**	7.78**	10.14**	3.09**	8.14**
10	PM-27 X Pusa Bahar	7.49**	11.02**	2.54**	3.58**	0.86*	2.93**	4.34**	13.88**	0.54	4.78**
11	PM-27 X Durgamani	7.08**	14.77**	3.15**	5.18**	1.31**	3.31**	6.00**	13.72**	1.19	3.12**
12	Pusa Agrani X RH-749	4.63**	10.15**	0.82	3.86**	2.05**	3.59**	14.30**	25.09**	2.33**	3.34**
13	Pusa Agrani X KMR15-2	2.13**	8.44**	2.26**	10.01**	0.94*	4.43**	6.99**	15.36**	3.31**	7.28**
14	Pusa Agrani X Pusa Bahar	6.47**	6.60**	6.51**	9.30**	1.97**	3.12**	10.65**	14.54**	4.38**	9.88**
15	Pusa Agrani X Durgamani	5.38**	9.64**	6.08**	6.45**	2.29**	3.36**	7.10**	8.86**	4.60**	7.71**
16	RH-749 X KMR15-2	2.78**	3.71**	1.48	6.12**	0.94*	2.90*	11.62**	13.43**	5.70**	8.71**
17	RH-749 X Pusa Bahar	3.45**	8.79**	-0.66	4.94**	1.47**	4.13***	6.39**	20.12**	3.85**	10.35**
18	RH-749 X Durgamani	6.28**	7.60**	0.66	3.34**	1.53**	4.12**	7.92**	19.86**	4.59**	8.73**
19	KMR15-2 X Pusa Bahar	1.55**	7.71**	2.31**	12.72**	0.89*	5.50**	5.80**	17.77**	7.35**	17.11*
20	KMR15-2 X Durgamani	1.80**	4.00**	2.95**	10.38*	1.04**	5.58**	7.12**	17.26**	4.13**	11.21**
21	Pusa Bahar X Durgamani	5.42**	9.55**	3.44**	6.51**	1.51**	1.59**	8.13**	10.15**	6.45**	8.90**
	SE	0.42	0.32	0.75	0.55	0.29	0.27	0.10	0.09	0.57	0.41
	CD at 5%	0.89	0.68	1.59	1.17	0.61	0.57	0.21	0.19	1.21	0.87

*, ** significant at 5 and 1 per cent level, respectively

The crosses namely, Urvashi x KMR-15-2, Pusa Agrani x Pusa Bahar, RH-749 x Pusa Bahar, RH-749 x Durgamani, KMR-15-2 x Pusa Bahar, Pusa Agrani x Durgamani, PM-27 x Durgamani, Pusa Agrani x KMR-15-2, Urvashi x Durgamani, Urvashi x Pusa Agrani, Pusa Bahar x Durgamani, Pusa Agrani x RH-749 and PM-27 x KMR-15-2 were best specific combiners for days to 50% flowering, days to maturity, plant height (cm), length of main raceme (cm), number of siliquae per plant, number of primary branches per plant, number of secondary branches per plant, oil content (%), test weight (g) and seed yield per plant (g). These findings were also similar to (Arifullah *et al.,* 2012, Dond *et al.,* 2012, Khosepatil *et al.,* 2012 and Singh *et al.,* 2012).

Table 5 revealed that high heterosis over better and mid parent Urvashi x KMR-15-2, Pusa Agrani x Durgamani, RH-749 x KMR-15-2, KMR-15-2 x Pusa Bahar and KMR-15-2 x Durgamani and Urvashi x KMR-15-2, Pusa Agrani x Pusa Bahar, RH-749 x Pusa Bahar, KMR-15-2 x Pusa Bahar and KMR-15-2 x Durgamani, respectively and high x high general combiners with significant sca effects. In F_1's hybrid, high heterosis over economic parent (>10%) was found in RH-749 x Pusa Bahar, high x high general combiners with significant sca effect for days to 50% flowering, days to maturity, plant height (cm), length of main raceme (cm), number of siliquae per plant, number of primary branches per plant, number of secondary branches per plant, oil content (%), test weight (g) and seed yield per plant (g). Similar findings were also observed by (Lal *et al.,* 2013, Frasat *et al.*, 2013, Priyamedha *et al.,* 2013, Singh *et al.,* 2013 and Shekhawat *et al.,* 2014).

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