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Selection of best germplasm & crosses based on heterotic response and combining ability parameters in Indian mustard (*Brassica juncea* L. Czern & Coss)

Amit Tomar and Mahak Singh

Abstract
General combining ability effects revealed that the parents namely; Vaibhav, Varuna, Durgamani and Kranti were found good general combiners for seed yield per plant (g). Specific combining ability effects revealed that the crosses namely; Vaibhav x Mathura Rai, Pusa Jai Kisan x Pusa Agrani and KR-5610 x Pusa Agrani were found good specific combiners for seed yield per plant (g). High heterosis over economic parent (Varuna) was observed in the crosses namely; Rohini x Mathura Rai, Maya x RK-9807, Pusa Bahar x Pusa Agrani, KR-5610 x Pusa Agrani and Pusa Jai Kisan x Pusa Agrani for seed yield per plant. The above lines and cross combiners may be utilized to improve particular traits in Indian mustard.

Keywords: Combining ability, correlation, genetic advance and heritability.

1. Introduction
Indian mustard (*Brassica juncea*) is a naturally autogamous species, yet in this crop frequent out-crossing occurs which varies from 5 to 30% depending upon the environmental conditions and random variation of pollinating insects. Cytologically Indian mustard is an amphidiploid (2n=36), derived from interspecific cross of *Brassica campestris* (2n=20) and *Brassica nigra* (2n=16) followed by natural chromosome doubling. These relationships have been confirmed by the artificial synthesis of amphidiploids species by hybridizing basic diploid species and also by analysis of chloroplast and mitochondrial DNA restriction pattern of basic and amphidiploid species. The improved mustard seeds contain 39-44% oil. For International acceptance, erucic acid content should be <2%. Seed quality, Seed yield and other yield related parameters of *Brassica* oil seed crop has been tried to improve by several researchers (Rakow, 1995 and Singh, 2003) [13, 17]. In India the estimated area, production and productivity of Rapeseed-mustard is 6.62 lakh ha, 8.25 million tonnes and 1245 kg/ha, respectively during in rabi 2013-14, (GOI 2013-14) [1]. Rapeseed-mustard plays a major role in the catering edible oil demand of the country. Population of India is increasing rapidly and consequently edible oil demand is also going up day- by-day, hence, it has become necessary to enhance the present production by developing superior varieties of Indian mustard.

2. Materials and Methods
The present investigation comprised twenty lines namely; Varuna, Maya, Urvashi, Basanti, Rohini, Pusa Bold, Kranti, NDR-8501, Pusa Bahar, Pusa Barani, Pusa Jai Kisan, Vaibhav, Durgamani, Ashirwad, KR-5610, B-85, Vardan, Nav-gold, RH-30, RLM-198 used as female and four teters namely; Pusa Agrani, RK-9807, RK-9808 and Mathura Rai used as males of Indian mustard [*Brassica juncea* (L.) Czern & Coss]. 104 treatments (20 lines + 4 testers + 80 F_1's) were shown in three replications at the Oilseed Research Farm of Chandra Shekhar Azad University of Agriculture & Technology, Kanpur during rabi 2010-2011. Each treatment was planted in two rows of 5m length and 45cm apart, plant to plant distance was maintained at 15 cm by thinning. All recommended agronomic practices were adopted for raising a good crop. Data were recorded for six characters namely; number of siliquae per plant, number of seeds per siliqua, 1000-seed weight (g), harvest index (%), oil content (%) and seed yield per plant (g). Mean values of parents and F_1s were used for estimation of heterosis as per Fonseca and Patterson (1968) [2]. Oil content (%) was estimated with the help of NMR method. Line x Tester analysis was analyzed as suggested by O. Kempthorne (1957) [5].

3. Results and Discussion
The analysis of variance for combining ability are given in Table-1. Combining ability analysis revealed that significant differences among the genotypes for all the six characters due

to lines in respect of gca in F_1 generation. The gca analysis was significant for all the six characters except for number of siliquae per plant. The interaction between lines x testers in respect of sca were showed highly significant differences for all the six characters except for 1000-seed weight (g) in F_1 generation. The significant differences with respect of gca and sca showed the importance of both additive and non-additive gene action involved in the expressions of trait's accordingly. Similar finding were also reported by Khulbe *et al*. (2002) [7], Ghose and Gulati (2001) [3], Singh and Sachan (2003) [15] and Sachan *et al*. (2004b) [14]. The results of gca effects are given in Table-2. Among twenty parents the only sixteen parents namely; Varuna, Maya, Urvashi, Basanti, Rohini, Pusa Bold, Kranti, NDR-8501, Pusa Barani, Pusa jai kisan, Durgamani, Ashirwadh, KR-5610, B-85, Nav-gold and RLM-198 were found good general combiners for number of siliquae per plant. The parents viz., Maya, Basanti, Rohini, NDR-8501, Pusa Bahar, Ashirwadh, Vardan, Nav-gold, RH-30 and RLM-198 were found good general combiners for number of seeds per siliqua. All the parents and testers were found good general combiners for 1000-seed weight (g). The parents namely; Maya, Urvashi, Basanti, Pusa Bold, Kranti, Pusa Barani, Durgamani, Ashirwadh, B-85 and RH-30 and the testers namely; Pusa Agrani and RK-9807 were found good general combiners for harvest index. For oil content the parents namely; Varuna, Pusa Barani, Durgamani, Ashirwadh, KR-5610, B-85 and RH-30 and one tester RK-9808 were found good general combiners. For seed yield per plant parents namely; Varuna, Maya, Urvashi, Basanti, Kranti, NDR-8501, Pusabarani, Vaibhav, Durgamani, Ashirwadh and RH-30 and two testers viz; Pusa Agrani and RK-9807 were found good general combiners. Similar finding were also reported by Thakur *et al*. (1989) [24], Singh and Lallu (2004) [19], Singh *et al*. (2008b) [20] and Singh *et al*. (2010) [22]. The results of specific combining ability are presented in Table-3. Specific combining ability revealed tha the interaction effects that may be due to dominance or epistatic components of variation that are non-fixable in nature. The crosses namely; Urvashi x RK-9808, Rohini x Pusa Agrani, NDR-8501 x Pusa Agrani, Pusa Bahar x RK-9807 and B-85 x Pusa Agrani showed positive and significant sca effects for number of siliquae per plant. For number of seeds per siliqua the crosses namely; Pusa Bold x Pusa Agrani, Kranti x RK-9808, NDR-8501 x Pusa Agrani, Pusa Bahar x Pusa Agrani, Ashirwad x RK-9807 showed significant sca effects. The crosses namely; Varuna x Pusa Agrani, Varuna x RK-9808, Urvashi x Pusa Agrani, Urvashi x Pusa Agrani and Basanti x Mathura Rai were found good specific combiners for 1000-seed weight. For Harvest index the best specific crosses namely; Maya x RK-9807, Rohini x Mathura Rai, NDR-8501 x RK-9808, Pusa Bahar x Pusa Agrani, Pusa Jai Kisan x Pusa Agarni. The crosses namely; Varuna x Pusa Agrani, Pusa Bahar x Mathura Rai and Pusa Jai Kisan x RK-9808 showed significant sca effects. For seed yield per plant the crosses namely; Varuna x RK-9807, Maya x RK-9807, Rohini x Mathura Rai, Kranti x Mathura Rai and Pusa Bahar x Pusa Agrani showed significant and positive sca effects. Similar findings were also reported by Khulbe *et al.* (1998a) [6], Ghosh *et al.*(2002) [4], Singh *et al*. (2006) [18], Singh and Dixit (2007) [23], Lohia *et al*. (2008) [8], Nigam *et al*. (2009) [10] and Maurya *et al.* (2012) [9]. Heterosis was calculated in per cent over economic parent for six characters and the results are presented in Table-4. Top five crosses namely; Pusa Bold x Mathura Rai, Rohini x Pusa Agrani, NDR-8501 x Pusa Agrani, Pusa Bahar x RK-9807 and Urvashi x RK-9808 showed positive and significant economic heterosis for number of siliquae per plant. For number of seeds per siliqua the crosses namely; Vaibhav x Pusa Agrani, Maya x RK-9808, Rohini x RK-9808, Pusa Bahar x Pusa Agrani, Kranti x RK-9808 showed significant economic heterosis. Top five crosses namely; Varuna x RK-9807, Pusa Bahar x RK-9807, NDR-8501 x Mathura Rai, Pusa Bahar x Pusa Agrani and Pusa Jai Kisan x Pusa Agrani showed significant economic heterosis for 1000-seed weight. Top five crosses namely; Maya x RK-9807, Rohini x Mathura Rai, NDR-8501 x RK-9808, Pusa Bahar x Pusa Agrani and Pusa Jai Kisan x Pusa Agarni showed significant economic heterosis for harvest index. Top five crosses namely; Kranti x Mathura Rai, Maya x RK-9807, B-85 x Mathura Rai, KR-5610 x RK-9808 and Pusa Bold x Mathura Rai showed significant economic heterosis for oil content. For seed yield per plant the crosses namely; Rohini x Mathura Rai, Maya x RK-9807, Pusa Bahar x Pusa Agrani, KR-5610 x Pusa Agrani and Pusa Jai Kisan x Pusa Agrani showed significant and positive economic heterosis. Similar findings were also reportedob by Singh *et al*. (2009), Priti *et al*. (2010) [12], Vaghela *et al*. (2011) [25], Verma *et al*. (2011) [26], Patel *et al*. (2013) [11] and Singh *et al*. (2013) [16].

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

Sources of variation	d.f.	Number of siliquae per plant	Number of seeds per siliqua	1000-seed weight (g)	Harvast index (%)	Oil content (%)	Seed yield per plant (g)
Line	19	9966.91**	6.40**	1.50**	48.37**	3.70**	31.98**
Tester	3	21.55**	0.20	3.66**	28.32**	1.00**	11.80**
Line x Tester	57	1468.15**	2.00**	0.82	22.23**	1.06**	13.64**
Error	158	320.06	0.72	0.09	2.19	0.47	2.49

*significant at p= 0.05, **significant at p= 0.01.

Table 2: General combining ability analysis for six characters in Indian mustard.

Parents/Lines	Number of siliquae per plant	Number of seeds per siliqua	1000-seed weight (g)	Harvest index (%)	Oil content (%)	Seed yield per plant (g)
Varuna	26.00**	-0.35	0.38**	0.57	1.36**	1.42**
Maya	38.66**	-1.85**	-0.04**	-2.26**	0.18	-2.00**
Urvashi	12.83**	-0.18	-0.09**	-1.93**	0.37*	-2.00**
Basanti	-9.17*	-0.68**	0.34**	2.32**	0.42*	1.42**
Rohini	28.33**	-0.51*	0.29**	0.07	-0.31	0.67
Pusa bold	10.75*	-0.35	-0.18**	1.66**	-0.16	0.59
Kranti	30.00**	0.32	0.51**	4.41**	-0.22	3.75**

NDR-8501	12.08**	-0.68**	-0.07**	-0.01	0.36*	-1.33**
Pusa bahar	-4.42	0.90**	0.28**	0.16	-0.15	-0.50
Pusa barani	18.66**	-0.18	0.57**	-2.43**	0.54**	-1.83**
Pusa jai kisan	17.58**	-0.26	0.26**	-0.51	0.10	-0.50
Vaibhav	-7.84	0.07	-0.07**	0.74*	-0.30	1.09**
Durgamani	-15.84**	-0.10	-0.10**	3.66**	-0.72**	2.67**
Ashirvadh	-61.09**	1.32**	-0.51**	-2.51**	-0.88**	-2.41**
KR-5610	-34.00**	0.07	-0.68**	-0.43	-0.66**	0.17
B-85	-58.25**	0.40	-0.02*	-1.43**	-0.82**	-0.41
Vardan	2.50	0.82**	0.18**	0.49	-0.36*	0.59
Nav-gold	-36.17**	0.52*	-0.61**	0.91*	0.33	0.34
RH-30	0.19	-0.43*	-0.32**	-3.18**	0.53**	-1.83**
RLM-198	28.50**	1.07**	-0.12**	-0.34	0.35	0.90*
Testers						
Pusa agrani	-0.12	-0.03	0.14**	0.84**	0.11	0.62**
RK-9807	-0.15	-0.06	0.14**	-0.79**	0.11	-0.43**
RK-9808	-0.57	0.07	0.10**	0.17	-0.07	-0.13
Mathura rai	0.85	0.02	-0.37**	-0.23	-0.15*	-0.06
S.E.(gi) (±)	4.41	0.21	0.03	0.37	0.17	0.39
S.E.(gi)(±)	1.75	0.08	0.01	0.15	0.07	0.15

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

Table 3: Specific combining ability analysis for six characters in Indian mustard.

Cross combinations	Number of siliquae per plant	Number of seeds per siliqua	1000-seed weight (g)	Harvest index (%)	Oil content (%)	Seed yield per plant (g)
Varuna x Pusa Agrani	19.20*	-0.89	0.73**	-0.37	0.30**	1.83**
Varuna x RK-9807	15.24*	0.81*	-0.90**	2.01**	-0.09	0.79
Varuna x RK-9808	17.99*	0.35	-0.43	-0.62	0.19**	-0.84
Varuna x Mathura Rai	-52.43**	-0.27	0.59*	-1.02	-0.40**	-1.77**
Maya x Pusa Agrani	-0.13	0.61	0.24	-0.95	0.38**	-3.34**
Maya x RK-9807	1.90	-0.02	0.22	3.76**	0.37**	4.29**
Maya x RK-9808	1.99	-1.49**	-0.03	0.46	0.17**	1.99**
Maya x Mathura Rai	-3.76	0.90*	-0.43	-3.27**	-0.92**	-2.94**
Urvashi x Pusa Agrani	-34.96**	0.28	-0.26	-2.62**	0.21**	-3.01**
Urvashi x RK-9807	-33.93**	0.65	0.19	0.76**	0.18**	1.29*
Urvashi x RK-9808	41.42**	-0.82*	0.37	0.80	0.26**	0.33
Urvashi x Mathura Rai	27.07**	-0.10	-0.30	1.06	-0.65**	1.39*
Basanti x Pusa Agrani	-5.96	0.78*	0.03	-0.70	-0.28**	0.08
Basanti x RK-9807	6.40	-0.85*	-0.05	-1.99**	-0.32**	-1.96**
Basanti x RK-9808	7.15	-0.65	-0.23	1.38*	0.13*	0.41
Basanti x Mathura Rai	-7.60	0.73*	0.24	1.31	0.47**	1.48
Rohini x Pusa Agrani	25.87**	-0.05	-0.05	-2.62**	-0.59**	-2.34**
Rohini x RK-9807	1.90	-1.35**	0.17	-0.90	0.04	-0.37
Rohini x RK-9808	-37.35**	1.18**	-0.06	0.13	-0.04	-0.34
Rohini x Mathura Rai	9.57	0.23	-0.06	3.40**	0.59**	3.06**
Pusa Bold x Pusa Agrani	-16.55**	-1.55**	0.54	-0.54	0.54**	0.08
Pusa Bold x RK-9807	-4.51	0.15	0.38	-0.15	-0.10	0.04
Pusa Bold x RK-9808	-1.10	0.68	0.00	0.55	-1.28**	1.08
Pusa Bold x Mathura Rai	22.15**	0.73*	-0.92**	0.15	0.85**	-1.19
Kranti x Pusa Agrani	-16.13*	-0.89*	0.52*	-0.70	-0.36**	-1.34**
Kranti x RK-9807	-10.43	0.15	0.33	1.68*	-0.21**	1.62*
Kranti x RK-9808	8.32	1.35**	-0.42	2.05*	0.22**	2.99**
Kranti x Mathura Rai	18.24*	-0.60	-0.42	-3.02**	0.35**	-3.27**
NDR-8501 x Pusa Agrani	34.12**	0.78*	0.71*	-2.90**	0.11	-0.26
NDR-8501 x RK-9807	-7.85	-0.85*	0.74*	1.46*	0.02	-5.29**
NDR-8501 x RK-9808	-18.76*	-0.32	0.19	-0.94	-0.98**	3.41**
NDR-8501 x Mathura Rai	-7.51	0.40	-1.10**	3.88**	0.85**	2.14**
Pusa Bahar x Pusa Agrani	-2.05	1.20**	0.24	-1.07	0.25**	5.24**
Pusa Bahar x RK-9807	31.32**	-0.44	-0.79**	0.30	-0.36**	-0.79
Pusa Bahar x RK-9808	-20.93**	-0.90*	-0.92**	-3.10**	-0.32**	-0.76
Pusa Bahar x Mathura Rai	-8.35	0.15	1.46**	-0.45	0.42**	-3.69**
Pusa Barani x Pusa Agrani	13.87	0.95*	0.01	-0.40	-0.26**	-0.17
Pusa Barani x RK-9807	-25.43**	0.31	0.01	-0.70	0.03	0.13
Pusa Barani x RK-9808	-4.01	-0.15	0.15	1.56*	-0.22**	-1.17
Pusa Barani x Mathura Rai	15.57*	-1.10**	-0.28	4.21**	0.45**	1.25*
Pusa Jai kisan x Pusa Agrani	-2.05	0.36	0.11	-0.74	0.03	5.91**
Pusa Jai kisan x RK-9807	11.65	0.86*	0.03	-1.37*	-0.37**	-0.46
Pusa Jai kisan x RK-9808	18.40*	-0.07	-0.68*	-2.10**	-0.32**	-1.76**

Pusa Jai kisan x Mathura Rai	-28.01**	-0.35	1.16**	-3.04**	0.65**	-3.69**
Vaibhav x PusaAgrani	-0.63	-0.97**	-0.50	-1.32*	0.21**	-4.34**
Vaibhav x RK-9807	8.07	0.73*	-0.04	1.38*	0.34**	-1.38*
Vaibhav x RK-9808	21.82**	0.26	-0.01	2.98**	0.10	0.99
Vaibhav x Mathura Rai	-29.26**	-0.02	-0.29	0.71	-0.66**	4.73**
Durgamani x Pusa Agrani	-3.36	0.02	0.34	0.10	0.06	0.74
Durgamani x RK-9807	2.74	-0.77*	-0.07	-0.54	0.29**	0.04
Durgamani x RK-9808	-14.18	0.10	0.13	-0.27	0.32**	-0.92
Durgamani x Mathura Rai	15.07*	0.48	0.45	2.46**	-0.67**	0.14
Ashirwadh x Pusa Agrani	17.95*	0.11	-0.86**	1.18	-0.69**	2.91**
Ashirwadh x RK-9807	11.32	1.15**	-0.86**	-2.45**	0.07	1.21
Ashirwadh x RK-9808	-12.96	-0.32	0.53	-1.19	0.61**	-1.76**
Ashirwadh x Mathura Rai	-16.35*	-0.94*	1.10**	4.21**	0.02	-2.36**
KR-5610 x Pusa Agrani	-17.13*	-0.30	0.01	-2.74**	-0.13*	5.49**
KR-5610 x RK-9807	-2.43	-0.60	0.26	-0.70	-0.40**	-3.21**
KR-5610 x RK-9808	13.99	-0.26	-0.57	-0.77	0.65**	-1.51*
KR-5610 x Mathura Rai	5.57	0.65	0.30	-3.20**	-0.13*	-0.77
B-85 x Pusa Agrani	27.45**	0.03	0.22	2.51**	-0.77**	-5.17**
B-85 x RK-9807	-28.85**	0.73*	0.46	-0.12	0.06	3.46**
B-85 x RK-9808	-26.10**	-0.40	-0.03	0.81	0.13*	0.49
B-85 x Mathura Rai	27.49**	-0.35	-0.64*	-0.20	0.58**	1.23
Vardan x Pusa Agrani	-33.96**	0.28	-0.69*	-0.49	0.06	-0.76
Vardan x RK-9807	-0.26	0.65	0.65*	-0.21	-0.12*	-0.46
Vardan x RK-9808	27.49**	-0.15	0.30	0.81	-0.18**	-0.09
Vardan x Mathura Rai	6.74	-0.77*	-0.25	0.71	0.24**	1.31*
Nav-gold x Pusa Agrani	-9.30	-0.80*	-1.02**	1.43*	0.14*	0.83
Nav-gold x RK-9807	0.74	-0.10	0.45	-1.87**	0.04	1.79**
Nav-gold x RK-9808	-11.85	1.10	0.07	-0.27	-0.05	-1.84**
Nav-gold x Mathura Rai	20.40**	-0.19	0.50	-1.79**	-0.14*	-0.77
RH-30 x Pusa Agrani	-8.71	0.86*	0.15	0.26	0.49**	-0.76
RH-30 x RK-9807	24.65**	-0.44	-0.27	-0.70	0.29**	-0.12
RH-30 x RK-9808	-10.60	-0.90*	-0.03	2.23**	0.38**	-1.09
RH-30 x Mathura Rai	-5.35	0.48	0.15	-1.37*	-1.17**	1.98**
RLM-198 x Pusa Agrani	12.70	-0.97**	0.09	-0.99	0.30**	-1.59*
RLM-198 x RK-9807	-2.26	0.06	-0.65*	0.71	0.21**	-0.62
RLM-198 x RK-9808	-1.18	0.93*	0.21	1.65*	0.22**	0.41
RLM-198 x Mathura Rai	-9.26	-0.02	0.34	0.81	-0.73**	1.81**
S.E (s_{ij}) (±)	3.42	0.46	0.02	1.18	0.27	0.86

*,**significant at 5 and 1% levels, respectively.

Table 4: Top best economic cross combinations for six characters in Indian mustard (*Brassica juncea* (L.) Czern & Coss).

Characters	Economic crosses	Heterosis over economic-parent	sca effects
Number of siliquae per plant	Pusa Bold x Mathura Rai	1.51**	22.15**
	Rohini x Pusa Agrani	2.38**	25.87**
	Pusa Bahar x RK-9807	0.78**	31.32**
	NDR-8501 x Pusa Agrani	0.16**	34.12**
	Urvashi x RK-9808	7.28**	41.42**
Number of seeds per siliqua	Vaibhav x Pusa Agrani	14.55**	-0.97**
	Maya x RK-9808	8.96**	-1.49**
	Rohini x RK-9808	19.14**	1.18**
	Pusa Bahar x Pusa Agrani	23.36**	1.20**
	Kranti x RK-9808	2.01**	1.35**
1000-seed weight (g)	Varuna x RK-9807	3.36**	0.73**
	Pusa Bahar x RK-9807	3.61**	-0.79**
	NDR-8501 x Mathura Rai	2.30**	-1.10**
	Ashirvadh x Mathura Rai	3.23**	1.10**
	Pusa Jai Kisan x RK-9808	4.58**	-0.92**
Harvest index (%)	Varuna x RK-9807	3.06**	2.01**
	Rohini x Mathura Rai	67.34**	3.40**
	Maya x RK-9807	23.76**	3.76**
	Pusa Bahar x Pusa Agrani	23.36**	-1.07**
	Pusa Jai Kisan x Agrani	38.43**	-0.74**
Oil content (%)	Kranti x Mathura Rai	4.78**	0.35**
	Maya x RK-9807	2.14**	-0.07**
	B-85 x Mathura Rai	1.15**	0.58**
	KR-5610 x RK-9808	1.73**	0.65**
	Pusa Bold x Mathura Rai	1.70**	0.85**

Seed yield per plant (g)	Rohini x Mathura Rai	18.56**	3.06**
	Maya x RK-9807	25.44**	4.29**
	Pusa Bahar x Pusa Agrani	11.96**	5.24**
	KR-5610 x Pusa Agrani	12.50**	5.49**
	Pusa Jai Kisan x Pusa Agrani	69.31**	5.91**

*,**significant at 5 and 1% levels, respectively.

4. References

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