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Genetics of seed yield in Indian mustard [*Brassica juncea* (L.) Czern. & Coss.] under late sown environment

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Abstract
An experiment consisting twenty one single crosses derived from 7 x7 diallel cross and seven parents of Indian mustard was conducted at Oilseed research Farm of C. S. Azad Univ. of Ag. & Tech., Kanpur during Rabi 2015-16. Each parent and F_1^s was sown in two rows of 5 meter long spaced at 45x10 cm between rows and plants respectively during the month of December in three replications. The data were recorded on 5 randomly selected plants for days to 50% flowering, days to maturity, plant height (cm), number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, number of seeds per siliqua, 1000-seed weight (g), biological yield per plant (g), harvest index (%), oil content (%) and seed yield per plant (g). The analysis of variance showed highly significant differences among parents and crosses revealing sufficient quantity of variations in the genetic materials used in study. The Analysis of Variance for Combining Ability revealed highly significant differences both for GCA and SCA for all the characters except harvest index for GCA and days to maturity and harvest index based on SCA. Higher the value for variances due to SCA as compared with corresponding variances due to GCA for all the characters except days to maturity & 1000 seed weight indicated the preponderance role of non -additive gene action for controlling the characters. Parents Kranti, RLM-198, RGN-291 and Vardan were noted as good general combiner for majority of the characters. It showed the consistency of fixable additive and/or additive X additive gene action. The crosses selected on the basis of *per se* performance and desirable significant SCA effects for seed yield per plant and associated characters showed that cross combinations namely; Kranti x NRCHB-101, Kranti x Ashirvad, NRCHB-101 x RLM-198, NRCHB-101 x RGN-291, RLM-198 x Ashirvad, RGN-291 xAshirvad, RH-30 x Ashirvad and Vardan x Ashirvad were the best specific combiners for seed yield per plant. A perusal of these crosses showed that the parents involved in these combinations had high x low and Low x Low GCA status. Kranti x NRCHB-101, Kranti x Ashirvad, NRCHB-101 x RLM-198, NRCHB-101 x RGN-291, NRCHB-101 x RH-30 and RH-30 x Ashirvad also showed positive and significant economic heterosis for seed yield per plant. All these crosses can be further exploited for yield and its attributes through appropriate selection procedures for harvesting of the desirable transgressive segregates in advanced generations.

Keywords: *Brassica juncea*, Indian mustard, gene action, combining ability, heterosis, yield components

Introduction
Rapeseed-mustardis cultivated all over India and worldwide, belongs to family Cruciferae (*Brassicaceae*) the Indian colza. It has 38 to 42 % oil and 24% protein and has prime position as cooking media in north india. Rapeseed-mustard ranked third after soybean (*Glycine max*) and palm (*Elaeis guineensis* Jacq.) oil in the world. Rapeseed-mustard (*Brassica spp.*) contributes 28.6% in the total production of oilseeds in country. *Brassica juncea* is an important oilseed crop of the Indian subcontinent and contributes more than 80% of the total rapeseed-mustard production of the country. It is the second important oilseed crop at national level and contributes nearly 27% of edible oil pool of the country (Singh *et al.*, 2013) [13]. There are six species in Genus *Brassica* (*B. nigra, B. oleracea, B. campestirs, B. carinata, B. juncea, and B. napus). B. nigra, B. oleracea, B.campestirs,* are primary and diploid with 2n=16, 18 and 20chromosomes and *B. carinata, B. juncea, and B. napus* are tetraploid with chromosome numbers 2n=34, 36 and 38. All these crops are grown under diverse agro-climatic conditions.
Productivity of Indian mustard is very low in India as compared with Germany, France and UK. Therefore; it is need to increase the seed yield of mustard for getting self sufficiency in edible oils. Improvement of seed yield and oil quality in seed is required for stabilize high production and productivity. This can be improved through effective utilization of diverse germplasms. Several Researchers like Rakow, (1995) [9]; Singh, (2003) [14]; Saini, (2015) [11]

and Kumar, (2017) [7] had tried to improve seed quality, yield and other parameters of Brassica. Hybridization play very important role in increasing the production and productivity of any crop. Heterosis breeding on the other hand is a very effective option to break the yield barriers which is realized as increased vigor, size, fruitfulness, development speed, resistance to disease and insect pests or climatic vigor's, manifested by cross-bred organisms as compared with corresponding inbreds (Shull, 1952; Jinks and Jones, 1958) [12, 2].

Comprehensive analysis of the combining ability involved in the inheritance of quantitative traits and in the phenomenon of heterosis is necessary for evaluation of various breeding procedures (Allard, 1960) [2]. Combining ability analysis is one of the powerful tools to test the value of parental lines to produce superior hybrids and valuable recombinants (Singh *et al.*, 2013) [13].

Significant positive heterosis for seed yield and component traits in Indian mustard were also reported earlier by many workers (Ram *et al.*, 1976; Banga and Labana, 1984; Hirve and Tiwari, 1992; Verma, 2000; Aher *et al*., 2009; Verma *et al.*, 2011) [10, 3, 6, 16, 15, 1] using different sets of materials. In respect to all the aspects there is much more scope of improvement in Indian mustard by genetic manipulation. Hence this investigation was conducted to adjudge general combining ability and specific combining ability of parental genotypes and extent of heterosis in Indian mustard.

Materials and Methods

The material for the present investigation was consisted seven varieties/genotypes (Table-1) of Indian mustard, [*Brassica juncea*(L.) Czern&Coss] selected on the basis of variability for various characters available in genetic material maintained in the section of Oilseeds, Department of Genetics and Plant Breeding, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur-(UP).

Seven genetically diverse genotypes of Indian mustard namely,Kranti, NRCHB-101, RLM-198, RGN-291, RH-30, Vardan and Ashirvad using in a diallel set (excluding reciprocals) were crossed in all the possible combinations to produce 21 crosses during *Rabi* 2014-15.

The final experiment consisting 7 parents and their 21 F_1's were laid out in Randomized Block Design with three replications in the month of December at Oilseed Research Farm, Kalyanpur, Kanpur during *Rabi* 2015-16. All the recommended package of practices were adopted to raise a good crop except sowing time.

The observations were recorded on five randomly selected plants for following characters: days to 50% flowering, days to maturity, plant height (cm), number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, number of seeds per siliqua, 1000-seed weight (g), biological yield per plant (g), harvest index (%), oil content (%) and seed yield per plant (g). Oil content was estimated in per cent using Nuclear Magnetic Resonance (NMR) Oxford 4000 Analyzer. The combining ability analysis was carried out by the procedures of Griffing's (1956 b) [5] Method 2, Model 1 and economic heterosis in per cent as increase or decrease over superior and economic parent the 'Kranti'.

Results and Discussion

The analysis of variance for combining ability is presented in Table-1. The mean sum of square due to gca were highly significant for all the characters except harvest index. The mean sum of square due to sca was also highly significant for all the characters except days to maturity and harvest index.

The estimated variance of general combining ability (σ^2 gca) were higher than variance of specific combining ability (σ^2 sca) for all the characters except days to 50% flowering, plant height, number of primary branches per plant, number of secondary branches per plant, number of silique per plant, number of seeds per siliqua, biological yield per plant, harvest index, oil content and seed yield per plant. Similar findings were also reported earlier by Arifullah *et al*. (2012), Singh *et al*. (2013) [13] and Dholu *et al.* (2014).

The promising combiners based on high *per se* performance and significant gca effects for earliness were RH-30, Vardan, and Ashirvad; RH-30, Vardan and Kranti for days to maturity; Kranti for plant height; NRCHB-101 and RGN-291 for number of primary branches per plent; Kranti and NRCHB-101 for number of secondary branches per plant; Kranti, RLM-198 and RGN-291 for number of siliquae per plant; Kranti and RGN-291 for number of seeds per siliqua; Kranti, RLM-198, Vardan and Ashirvad for 1000-seed weight; Kranti and Ashirvad for biological yield per plant; Kranti, RGN-291 and Vardan for oil content and Kranti for seed yield per plant. Kranti, RLM-198, RGN-291 and Vardan were the good general combiner for number of characters (Table-2).

The parents discussed above had significant and desirable general combining ability effects and had fixable component as additive and/or additive x additive interaction. These could be successfully used for improving particular character which is on target. These parental lines can be utilized for producing the inter-matting population in order to get desirable recombinants for better selection.

None of the cross combination was found as good specific combiner for all the characters under study. However, the good specific cross combinations selected on the basis of significant sca effect and high *per se* performance where NRCHB-101 x RGN-291, RLM-198 x RH-30 and RH-30 x Ashirvad for early flowering; NRCHB-101 x RGN-291, RLM-198 x RH-30 and Vardan x Ashirvad for days to maturity; Kranti x RH-30, NRCHB-101 x Vardan and RH-30 x Ashirvad for plant height; Kranti x NRCHB-101, Kranti x RLM-198, NRCHB-101 x RLM-198, RLM-198 x RH-30, RGN-291 x Vardan and RH-30 x Ashirvad for number of primary branches per plant; Kranti x NRCHB-101, Kranti x RH-30, Kranti x Vardan, NRCHCB-101 x RLM-198, NRCHB-101 x Ashirvad and RH-30 x Ashirvad for number of secondary branches per plant; NRCHB-101 x RGN-291, NRCHB-101 x Vardan, RLM-198 x RH-30, RLM-198 x Vardan, RGN-291 x RH-30, RGN-291 x Vardan, RH-30 x Ashirvad and Vardan x Ashirvad for number of siliquae per plant; Kranti x RH-30, RLM-198 x Vardan, RGN-291 x RH-30 and Vardan x Ashirvad for number of seeds per siliqua; Kranti x NRCHB-101, Kranti x RH-30, Kranti x Ashirvad and RLM-198 x Ashirvad for 1000-eed weight; Kranti x NRCHB-101, NRCHB-101 x RLM-198, RGN-291 x Ashirvad, RH-30 x Ashirvad and Vardan x Ashirvad for biological yield per plant; Kranti x NRCHB-101, Kranti x Vardan, NRCHB-101 x RH-30 and RLM-198 x Vardan for harvest index; Kranti x RGN-291, Kranti x RH-30, NRCHB-291 x RGN-291, NRCHB-101 x Ashirvad and RGN-291 x Vardan for oil content and Kranti x Ashirvad, NRCHB-101 x RGN-291 and RH-30 x Ashirvad for seed yield per plant (Table-3).

The crosses namely, Kranti x NRCHB-101, Kranti x Ashirvad, NRCHB-101 x RLM-198, NRCHB-101 x RGN-

291, RLM-198 x Ashirvad, RGN-291 x Ashirvad, RH-30 x Ashirvad and Vardan x Ashirvad were best specific combiners for seed yield per plant.

An examination of these desirable crosses showed all the shorts of possible combination between the parents of high and low gca effect i.e. high x high, high x low and low x low. Poor inbreed though lacked the additive effect for the good inbred yet they were highly responsive to heterozygosity in the way of non-additive effects (Darrah and Halauer, 1972) [4]. Crosses involving high x high showed the consistency due to involvement of additive and/or additive x additive genes (Lahghum, 1961) [8].

The crosses showed high x law gca status are more important in selection breeding programme as they can produced transgressive segregants in advanced generations if additive effects of one parent and complementary effect of other parents works on same directions Lahghum, 1961 [8] was in view that.

Top ranking desirable Cross combinations namely, RLM-198 x Ashirvad for days to flowering; Kranti x RLM-198, Kranti x RH-30, RLM-198 x RH-30, RH-30 x Ashirvad and Vardan x Ashirvad for number of primary branches per plant; Kranti x NRCHB-101, Kranti x RH-30, NRCHB-101 x RLM-198, NRCHB-101 x Ashirvad and RH-30 x Ashirvad for number of secondary branches per plant; RGN-291 x RH-30 for number of siliquae per plant; Kranti x NRCHB-101, Kranti x Ashirvad, NRCHB-101 x Vardan, RLM-198 x Ashirvad and Vardan x Ashirvad for 1000-seed weight; Kranti x NRCHB-101, Kranti x Ashirvad, RGN-291 x Ashirvad, RH-30 x Ashirvad and Vardan x Ashirvad for biological yield per plant; Kranti x RGN-291, Kranti x RH-30, NRCHB-101 x RGN-291, NRCHB-101 x Ashirvad and RGN-291 x Vardan for oil content and Kranti x NRCHB-101, Kranti x Ashirvad, NRCHB-101 x RLM-198, NRCHB-101 x RGN-291, NRCHB-101 x RH-30 and RH-30 x Ashirvad for higher seed yield. Five best economic crosses for seed yield per plant namely, Kranti x NRCHB-101, Kranti x Ashirvad, NRCHB-101 x RLM-198, NRCHB-101 x RGN-291, NRCHB-101 x RH-30 and RH-30 x Ashirvad shown positive and significant economic heterosis for seed yield per plant along with significant sca effect, *per se* performance and higher magnitude of gca effect of parents. All these crosses can further exploited for yield and its related attributes in terms of varieties.

The true heterosis is depend upon the mean of the parent. Obviously, there is very possibility of getting a cross with high *per se* performance. Contrary to this, there could be some crosses with poor *per se* performance but showed high heterotic response. It means that the choice of the best cross combinations on the basis of high heterosis would not necessarily to be the one which could give the highest *per se* performance also. The heterotic effect revealed the predominance role of non -additive gene action for seed yield per plant as well as yield contributing traits like number of secondary branches per plant, number of siliquae per plant, number of seeds per siliqua, 1000-seed weight and oil content etc. Which reflected that heterosis breeding feasible for improving the yield in Indian mustard otherwise these heterotic combinations may further subjected for obtaining desirable transgressive segregates after evaluation in advanced generations in late sown environments which is a demand for late harvested rice based cropping systems.

Table 1: ANOVA for combining ability and related statistics of 12 characters in a 7 x 7 parental diallel cross in mustard

Sources of variances	d.f.	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches per plant	No. of secondary branches per plant	No. of siliquae per plant	No. of seeds per siliqua	1000-seed weigh (g)	Biological yield per plant (g)	Harvest index (%)	Oil content (%)	Seed yield per plant (g)
GCA	6	4.04**	4.40**	4.43*	2.86**	1.77**	164.33**	2.37**	0.80**	5.47**	0.17	0.50**	0.37*
SCA	21	2.9**	1.21	4.47**	2.75**	1.60**	11.61**	1.06**	0.04**	28.37**	0.17	1.11**	1.75**
Error	54	0.91	0.85	1.44	0.40	0.24	17.61	0.48	0.00	1.36	0.15	0.03	0.14
σ^2gca		0.34	0.39	0.33	0.27	0.17	16.30	0.20	9.99	0.45	0.00	0.05	0.02
σ^2sca		2.01	0.36	3.03	2.35	1.36	93.99	0.57	0.03	27.00	0.01	1.08	1.60
GPR		0.25	0.68	0.17	0.18	0.20	0.25	0.42	0.30	0.03	0.16	0.08	0.03

*, ** significant at 5 and 1 per cent level, respectively.
GCA = General combining ability, SCA = Specific combining ability, GPR = General Predictability Ratio

Table 2: Estimates of gca effects for 7 parents along with their mean performance for 12 characters in F_1's of a diallel cross in Indian mustard.

Parents	Days to 50% flowering		Days to maturity		Plant height (cm)		No. of primary branches per plant		No. of secondary branches per plant		No. of siliquae per plant	
	gca effect	Mean	gca effect	Mean	gca effect	Mean	gca effect	Mean	gca effect	Mean	gca effect	Mean
Kranti	-0.35	73.00	-0.78**	120.33	-1.32**	174.49	0.25	8.66	0.51**	17.66	4.30**	336.66
NRCHB-101	-0.28	73.66	-0.01	122.66	0.91*	179.04	-0.59**	7.33	0.55**	18.00	-0.36	328.66
RLM-198	-1.16**	72.33	-0.52	122.00	-0.00	175.72	0.07	8.33	0.03	16.33	3.04*	329.04
RGN-291	0.06	73.33	-0.41	121.33	0.40	176.34	-0.81**	7.66	-0.70**	16.00	5.08**	330.33
RH-30	0.42	75.00	0.54	123.66	-0.02	177.79	0.85**	9.66	-0.00	17.33	-4.80**	313.00
Vardan	0.75*	74.66	1.24**	124.00	0.34	178.54	0.29	9.00	-0.33	17.00	-5.39**	310.00
Ashirvad	0.60*	75.66	-0.04	122.33	-0.31	175.27	-0.07	8.00	-0.04	15.66	-1.87	324.66
$\overline{X}$		73.95		122.33		176.74		8.33		16.85		324.61
SE (g_i) ±	0.29		0.28		0.37		0.19		0.15		1.29	
SE ($g_i - g_j$) ±	0.45		0.43		0.56		0.29		0.23		1.97	

Parents	No. of seeds per siliqua		1000-seed weight (g)		Biological yield per plant (g)		Harvest index (%)		Oil content (%)		Seed yield per plant (g)	
	gca effect	Mean	gca effect	Mean	gca effect	Mean	gca effect	Mean	gca effect	Mean	gca effect	Mean
Kranti	0.43*	13.00	0.07**	4.07	0.73*	40.26	0.18	24.34	0.25**	39.27	0.30*	9.80
NRCHB-101	-0.82**	11.66	-0.02	4.04	-0.01	42.91	0.00	23.77	0.00	37.86	0.05	10.20
RLM-198	-0.26	12.00	0.05**	4.16	-0.72*	37.27	-0.00	23.83	-0.13**	38.23	-0.17	8.90
RGN-291	0.66	13.33	-0.18**	3.65	-0.17	39.26	-0.10	23.43	0.15**	39.51	-0.14	9.20
RH-30	-0.22	12.33	-0.04**	3.84	0.28	43.35	0.02	23.99	-0.19**	38.42	0.00	10.40
Vardan	0.36	13.66	0.04**	4.23	-1.16*	39.42	0.12	24.35	0.28**	39.17	-0.25*	9.60
Ashirvad	-0.15	12.66	0.08**	4.24	1.05**	39.16	-0.23	24.00	-0.19**	39.30	0.20	9.40
$\overline{X}_p$		12.66		4.03		40.23		23.95		38.82		9.64
SE (g_i) ±	0.21		0.01		0.36		0.12		0.05		0.11	
SE ($g_i - g_j$) ±	0.32		0.02		0.55		0.18		0.08		0.18	

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

Table 3: Estimate of sca effects and mean performance for 12 characters of 21 F_1's derived from a 7 x 7 parental diallel cross in Indian mustard**.**

Hybrid combinations	Days to 50 % flowering		Days to maturity		Plant height (cm)		No. of primary branches per plant		No. of secondary branches per plant		No. of siliquae per plant	
	sca effect	Mean	sca effect	Mean	sca effect	Mean	sca effect	Mean	sca effect	Mean	sca effect	Mean
Kranti x NRCHB-101	-1.72	70.33	-1.29	119.66	0.06	177.66	1.66**	12.00	1.80**	21.00	2.9	341.66
Karnti x RLM-198	-0.50	70.66	-0.11	120.33	0.39	177.10	1.66**	12.66	-0.00	18.66	0.49	342.66
Kranti x RGN-291	0.64	73.00	0.44	121.00	1.30	178.42	-0.77	9.33	0.06	18.00	2.12	346.33
Kranti x RH-30	-0.42	72.33	-0.18	121.33	-2.68*	174.01	0.88	12.66	1.02*	19.66	3.67	338.00
Kranti x Vardan	1.57	74.66	2.11**	124.33	-0.86	176.19	0.77	12.00	1.02*	19.33	-1.06	32.66
Kranti x Ashirvad	-1.61	71.33	-1.25	119.66	3.57**	179.98	0.81	11.66	-0.93*	17.66	5.41	342.66
NRCHB-101 x RLM-198	-0.90	70.33	-0.22	121.00	0.40	179.34	0.51**	10.66	1.62**	20.33	2.15	339.66
NRCHB-101 x RGN-291	-2.09*	70.33	-1.33	120.00	-1.62	177.72	1.07	10.33	0.02	18.00	8.78*	348.33
NRCHB-101 x RH-30	-0.50	72.33	0.03	122.33	3.50**	182.43	0.40	11.33	-1.01*	17.66	-9.65*	320.00
NRCHB-101 x Vardan	2.50**	75.66	1.33	124.33	-2.52*	176.77	-0.03	10.33	-1.00*	17.33	13.60**	342.66
NRCHB-101 x Ashirvad	-0.35	72.66	-0.37	121.33	1.79	180.43	0.66	10.66	1.02*	19.66	-6.91	325.66
RLM-198 x RGN-291	1.46	73.00	0.85	121.66	-0.36	178.06	0.07	10.00	0.87	18.33	1.04	344.66
RLM-198 x RH-30	-2.27**	69.66	-1.77*	120.00	0.62	178.63	1.40**	13.00	0.50	18.66	13.60**	325.66
RLM-198 x Vardan	-1.27	71.00	-0.81	121.66	1.73	180.11	0.96	12.00	-0.15	17.66	7.86*	344.00
RLM-198 x Ashirvad	-0.46	71.66	-0.51	120.66	1.79	179.51	0.33	11.00	0.88	19.00	-1.32	346.66
RGN-291 x RH-30	-0.79	72.33	-0.22	121.66	1.51	179.93	0.96	11.66	-0.08	17.33	14.23**	340.33
RGN-291 x Vardan	0.53	74.00	-0.25	122.33	3.57**	182.36	1.18*	11.33	-0.08	17.00	10.82**	334.66
RGN-291 x Ashirvad	-0.98	72.33	-0.29	121.00	0.61	178.75	0.22	10.00	0.62	18.00	-7.69	349.33
RH-30 x Vardan	-1.53	72.33	-1.22	122.33	-0.27	178.08	0.18	12.00	-0.45	17.33	-11.95**	345.33
RH-30 x Ashirvad	2.61**	76.33	1.74*	124.00	-2.29*	175.41	1.55*	13.00	1.58**	19.66	14.52**	330.33
Vardan x Ashirvad	-2.72**	71.33	-0.63			176.85		12.33		19.33	8.78*	312.66
$\overline{X}$		72.26		121.57		178.46		11.42		18.55		338.22
SE (s_{ij}) ±	0.85		0.82		1.07		0.56		0.44		3.76	
SE ($s_{ij} - s_{ik}$) ±	1.27		1.23		1.60		0.84		0.65		5.59	

Hybrid combinations	No. of seeds per siliqua		1000-seed weight (g)		Biological yield per plant (g)		Harvest index (%)		Oil content (%)		Seed yield per plant (g)	
	sca effect	Mean	sca effect	Mean	sca effect	Mean	sca effect	Mean	sca effect	Mean	sca effect	Mean
Kranti x NRCHB-101	0.58	13.66	0.20**	4.54	4.50**	52.00	0.30	24.66	-0.03	40.12	1.35**	13.00
Karnti x RLM-198	0.69	14.33	0.01	4.42	4.54**	51.33	-0.29	24.06	-0.46**	39.37	0.92*	12.35
Kranti x RGN-291	0.10	14.66	0.14**	4.32	-0.17	47.17	0.26	24.52	0.70**	41.01	0.11	11.57
Kranti x RH-30	1.32*	15.00	0.14**	4.46	1.45	49.26	0.29	24.68	1.36**	41.32	0.56	12.16
Kranti x Vardan	-0.93	13.33	0.04	4.45	2.06	48.41	-0.26	24.22	0.48**	40.92	0.38	11.73
Kranti x Ashirvad	0.91	14.66	0.17**	4.62	3.56**	52.13	0.11	24.24	0.20	40.17	0.84*	12.64
NRCHB-101 x RLM-198	-0.04	12.33	-0.10*	4.21	5.57**	51.61	0.13	24.31	0.93**	40.53	1.37**	12.55
NRCHB-101 x RGN-	1.36*	14.66	0.07	4.15	4.57**	51.16	0.74	24.81	1.48**	41.54	1.57**	12.78

291												
NRCHB-101 x RH-30	-0.08	12.33	0.22**	4.44	-3.92**	43.13	-0.54	23.65	-0.02	39.69	-1.00**	10.35
NRCHB-101 x Vardan	-1.67*	11.33	-0.10*	4.20	0.40	46.00	-0.14	24.15	0.29	40.48	-0.13	10.96
NRCHB101xAshirvad	0.17	12.66	0.11	4.46	-3.47**	44.34	0.34	24.29	1.43**	41.15	-0.73*	10.82
RLM-198 x RGN-291	0.47	14.33	0.28**	4.44	-0.73	45.14	0.33	24.39	-0.57**	39.16	0.07	11.05
RLM-198 x RH-30	-0.63	12.33	0.18**	4.47	1.77	48.11	0.01	24.21	1.49**	40.89	0.52	11.65
RLM-198 x Vardan	1.43*	15.00	-0.03	4.34	0.82	45.71	0.70	25.00	1.07**	40.94	0.38	11.25
RLM-198 x Ashirvad	-0.04	13.00	0.11*	4.54	4.12**	51.23	-0.22	23.71	-0.39*	39.00	0.82*	12.15
RGN-291 x RH-30	1.10	15.00	-0.05	4.00	4.64**	51.54	0.40	24.49	-0.71**	39.14	0.34	11.50
RGN-291 x Vardan	0.17	14.66	0.10*	4.25	1.61	47.06	0.07	24.26	0.81**	41.15	0.51	11.42
RGN-291 x Ashirvad	-0.30	13.66	-0.02	4.16	4.41**	52.08	-0.76*	23.06	-0.36*	39.49	1.00**	12.36
RH-30 x Vardan	0.73	14.33	0.19**	4.47	-0.81	45.09	0.06	24.39	0.21	40.20	-0.04	11.00
RH-30 x Ashirvad	-1.08	12.00	-0.01	4.31	4.87**	53.00	0.24	24.21	-0.14	39.37	1.40**	12.91
Vardan x Ashirvad	1.32*	15.00	0.04	4.46	5.97**	52.64	-0.29	23.76	-0.30	39.69	1.28**	12.53
$\bar{X}$		13.73		4.37		48.96		24.24		40.25		11.84
SE (s_{ij}) ±	0.62		0.04		1.04		0.35		0.15		0.34	
SE ($s_{ij} - s_{ik}$) ±	0.92		0.06		1.55		0.53		0.23		0.51	

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

Table 4: Estimate of heterosis over economic parent for 12 characters in 21 F_1's derived from a 7 x 7 diallel cross in Indian mustardEP= Kranti

Hybrid combinations	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches per plant	No. of secondary branches per plant	No. of siliquae per plant
	EH	EH	EH	EH	EH	EH
Kranti x NRCHB-101	-3.65	-0.55	1.83	38.46**	18.87**	1.49
Karnti x RLM-198	-3.20	0.00	1.49	46.15**	5.66	1.78
Kranti x RGN-291	0.00	0.55	2.25*	7.69	1.89	2.87
Kranti x RH-30	-0.91	0.83	-0.28	46.15**	11.32**	0.40
Kranti x Vardan	2.28	3.32**	0.97	38.46**	9.44*	-1.19
Kranti x Ashirvad	-2.28	-0.55	3.14**	34.62**	0.00	1.78
NRCHB-101 x RLM-198	-3.65	0.55	2.78**	23.08*	15.10**	0.89
NRCHB-101 x RGN-291	-3.65	-0.28	1.85	19.23	1.89	3.47
NRCHB-101 x RH-30	-0.91	1.66	4.55**	30.77**	0.00	-4.95**
NRCHB-101 x Vardan	3.65	3.32**	1.30	19.23	-1.88	1.78
NRCHB-101 x Ashirvad	-0.46	0.83	3.40**	23.08*	11.32**	-3.27
RLM-198 x RGN-291	0.00	1.11	2.05*	15.38	3.78	2.18
RLM-198 x RH-30	-4.57*	-0.28	2.37*	50.00**	5.66	2.97
RLM-198 x Vardan	-2.74	1.11	3.22**	38.46**	0.00	1.09
RLM-198 x Ashirvad	-1.83	0.28	2.88**	26.92*	7.55	-0.59
RGN-291 x RH-30	-0.91	1.11	3.12**	34.62**	-1.88	3.76*
RGN-291 x Vardan	1.37	1.66	4.51**	30.77**	-3.77	2.57
RGN-291 x Ashirvad	-0.91	0.55	2.44*	15.38	1.89	-1.88
RH-30 x Vardan	-0.91	1.66	2.06*	38.46**	-1.88	-7.13**
RH-30 x Ashirvad	4.57*	3.05**	0.52	50.00**	11.32**	1.78
Vardan x Ashirvad	-2.28	1.66	1.35	42.31**	9.44**	-0.10
SE(EP)=	1.35	1.30	1.69	0.89	0.69	5.93

Hybrid combinations	No. of seeds per siliqua	1000-seed weight (g)	Biological yield per plant (g)	Harvest index (%)	Oil content (%)	Seed yield per plant (g)
	EH	EH	EH	EH	EH	EH
Kranti x NRCHB-101	5.13	11.71**	29.16**	1.34	2.18**	32.65**
Karnti x RLM-198	10.26	8.76**	27.50**	-1.15	0.25	26.02**
Kranti x RGN-291	12.82	6.22**	17.16**	0.74	4.43**	18.06**
Kranti x RH-30	15.38	9.58**	22.35**	1.40	5.22**	24.08**
Kranti x Vardan	2.56	9.34**	20.25**	-0.49	4.20**	19.69**
Kranti x Ashirvad	12.82	13.51**	29.48**	-0.41	2.29**	28.98**
NRCHB-101 x RLM-198	-5.13	3.60**	28.19**	-0.12	3.21**	28.06**
NRCHB-101 x RGN-291	12.82	2.05	27.09**	1.93	5.78**	30.41**
NRCHB-101 x RH-30	-5.13	9.17**	7.13	-2.81	1.08	5.61
NRCHB-101 x Vardan	-12.82	3.36	14.26**	-0.77	3.08**	11.84*
NRCHB-101 x Ashirvad	-2.56	9.58**	10.14*	-0.21	4.80**	10.41
RLM-198 x RGN-291	10.26	9.25	12.14**	0.23	-0.27	12.76*
RLM-198 x RH-30	-5.13	9.91**	19.50**	-0.53	4.13**	18.88**
RLM-198 x Vardan	15.38	6.80**	13.54**	2.71	4.25**	14.80*
RLM-198 x Ashirvad	0.00	11.55**	27.25**	-2.59	-0.69	23.98**
RGN-291 x RH-30	15.38	-1.72	28.03**	0.62	-0.32	17.35**
RGN-291 x Vardan	12.82	4.50**	16.89**	-0.33	4.79**	16.53**
RGN-291 x Ashirvad	5.13	2.29	29.36**	-5.24*	0.58	26.12**
RH-30 x Vardan	10.26	9.91	12.00**	0.21	2.39**	12.24**

RH-30 x Ashirvad	-7.69	5.90**	31.64**	-0.53	0.25	31.73**
Vardan x Ashirvad	15.38	9.58**	30.77**	-2.36	1.07	27.86**
SE(EP)=	0.98	0.85	1.65	0.56	0.24	0.54

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

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