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Heterosis and combining ability analysis in seed yield and its component traits in Indian mustard (*Brassica juncea* L. Czern & Coss.)

Swati Mandal and Sonali Kar

Abstract
The present investigation was carried out with the set of seven varieties of Indian mustard and twenty-one F1s obtained through partial diallel crossing, with the objective to explore hybrid vigour and find out best heterotic crosses. The seven parents and twenty- one F1s and two checks were grown in two line for the eleven quantitative characters. The analysis of variance showed highly significant difference among the genotypes (parents and crosses) for all the characters. NPJ – 112, DRMRIJ-12-40, DRMRIJ-31 and LES-39, DRMRIJ-12-48 parents have significant general combining ability, while TN-3 X NPJ- 112, DRMRIJ-31 X TN-3, DRMRMIB-35 X DRMRIJ-12-48 and DRMRIJ-12-48 X LES-39 have strong hybrid SCA results. The significant positive relative heterosis was recorded in TN-3 X NPJ-112 (13.75. The significant positive heterobeltiosis was recorded in DRMRIJ-31 X TN-3 (9.24). The highest significant positive standard heterosis over check parent (Varuna) was recorded in TN-3 X NPJ-112 (17.07), with respect to seed yield per plant.

Keywords: Mustard, GCA, SCA, heterosis value

Introduction
Indian mustard is one of the most important edible oil with lowest amount of saturated fats of the country and it occupies considerably large acreage among the brassica group oil seed, leafy vegetable rich in minerals, antioxidant and tasteful condiment crop. (Akabri *et al*. 2015) [1]. Indian mustard has a wide range of uses, including in food preparation, medicine, phytoremediation, and agronomic procedures like mulching. The oil cake is utilised as manure and feed. Mustard oil is used in the tanning industry to soften leather. Sinigrin, myrosin, erucic, oleic, and palmitric acid are a few of the glucosinolates and fatty acids found in the seeds.
Globally, India accounts 6.69 mha of total acreage and 674 (MT) of total production. Rapeseed mustard 674 (MT) is the third most important annual oilseed crop in India, next to soybean 1007 (MT) and groundnut 1676 (MT) (Anonymous 2021) [2]. In Chhattisgarh during 2020-21, the production of 517 (kg/ha) has been recorded (Anonymous 2021) [2]. In India mustard seed production is estimated at 861.826 (MT) in 2021-22. The area under coverage has been pegged at 87.44 lakh hectares while the productivity of 1349 Kg/ha has been recorded (Anonymous 2022) [1].
In India heterosis was first reported in brown sarson (*Brassica napus*) by Singh and Mehta (Singh *et al*., 1954) [9]. In general, hybridization between genetically distinct groups exploits higher levels of heterosis than within groups. Exploitation of high level of heterosis in plants necessitates large and usable heterosis, effective pollination control mechanism and profitability of seed production (Chand *et al*., 2018) [5]. Therefore, it is crucial to improve genetic gain, heterosis, rapeseed, and mustard (Chand *et al*., 2020) [4]. Primary goal of *Brassica* breeding is to meet the demands of the producer, miller, and consumer by raising yield, quality and lowering the cost of production. Singh *et al*. (2003) [10] reported significant heterosis over standard variety was seen for biological yield (61.4%), seed yield (56.0%), and seed/siliqua (17.8%); however, over better parents, biological (76.3%), seed yield (50.0%), primary branches, and seed/silique were all significantly higher than standard variety in Indian mustard. Ranjeet and Shweta (2007) [8] reported heterobilities for seed yield ranged from - 21.4 to 19.6%, and standard heterosis from - 23.6 to 29.6%. All the characters under study showed a significant desired heterosis over their best parent in Indian mustard [*Brassica juncea* (L.) Czern & Coss.].

Combining ability can determine the capacity of individual towards the transmission of superior performance to its offspring. Combining ability plays an important role in parental selection and is useful for figuring out the nature of gene action. It examines the importance of parental lines for recombinants and for producing superior hybrids. Combining ability studies highlighted the predominance effects of GCA on yield and most of the yield components indicating the importance of additive gene action (Wos *et al*. 1999) [11]. While Pandey *et al*. (1999) [7] review evidence for the presence of significant SCA effects for yield and yield components indicating importance of non- additive gene action. Gupta *et al*. (2011) [6] reported significant GCA and SCA varience were for all characters, in eight parents with GCA varience being higher for days to 50% flowering, days to maturity, plant height, and weight of 1000 seeds, and SCA varience being higher for seed yield and the remaining parameters.

Keeping these points in view, the present investigation was undertaken to determine general combining ability and specific combining ability of parental lines and better parent heterosis of different cross combinations in *Brassica juncea*.

Materials and Method

The experiment was carried out during *rabi* season of 2022 at the Instructional cum Research Farm, Shaheed Gundadhoor College of Agriculture and Research Station, Kumhrawand, Jagdalpur, Chhattisgarh. The crosses were attempted during *rabi* season 2021 followed by evaluating those twenty one crosses with their seven parents along with two checks (Varuna & C.G. Sarson) were obtained from DRMR, Bharatpur., (Rajasthan). The materials were sown in two line with row length 3 meter. The distance between plant to plant is 10 cm and row to row 30 cm is maintained. All the interculture operations and plant protection measures were carried out to raise healthy plants. Data were taken from five randomly selected plants from both lines of thirty characters *viz*, Days to 50% flowering, Plant height (cm), Number of primary branches per plant, Number of secondary branches per plant, Days to maturity, Siliqua length (cm), Number of siliqua per plant, Number of seed per siliqua, Test weight (g), Harvest Index (%), Seed yield per plant (g).

Table 1: Analysis of variance for seed yield and its attributing traits in Indian mustard genotypes.

Source of variation	df	Days to 50 % flowering	Plant height	No. of Primary Branches	No. of secondary Branches	Days to maturity	Siliqua Length	No of Siliqua per plant	No of seed per siliqua	Test weight	Harvest Index	Seed yield per plant
Replication	2	1.79	42.11	0.00	0.03	30.90	0.013	13.10	0.126	0.018	1.10	0.18
Treatment	29	21.79**	230.17**	1.61**	4.57**	85.10**	1.086**	4061.17* *	2.264**	0.360**	38.06**	1.66**
Error	58	3.14	35.36	0.05	0.10	16.61	0.051	105.94	0.334	0.025	1.08	0.15
Total	89	9.19	98.99	0.56	1.56	39.24	0.387	1392.64	0.958	0.134	13.13	0.64

Table 2: Estimation of general combining ability (GCA) effects of parents for different traits in Indian mustard

S. No	Parents	Days to 50% flowering	Plant height	No. of Primary Branches	No. of secondary Branches	Days to maturity	Siliqua Length	No of Siliqua per plant	No of seed per siliqua	Test weight	Harvest Index	Seed yield per plant
1	DRMRMIB-35	-0.52	-1.88	0.11 **	0.55 **	1.57 *	0.02	3.30	-0.11	0.09 **	0.59 **	-0.25 **
2	DRMRIJ-12-48	-0.67 *	3.68 **	0.24 **	0.09	-0.87	-0.23 **	-14.30 **	-0.35 **	0.08 **	0.81 **	-0.08
3	DRMRIJ-12-40	0.22	0.92	0.14 **	-0.78 **	1.46 *	-0.05	2.34	-0.26 *	-0.24 **	-0.30	0.24 **
4	DRMRIJ-31	-0.11	-3.06 **	-0.09 *	-0.49 **	-0.43	0.22 **	9.81 **	0.05	-0.03	1.25 **	0.18 *
5	LES-39	0.67 *	-3.52 **	-0.38 **	0.11	-1.54 *	-0.01	24.81 **	-0.11	0.10 **	0.97 **	-0.35 **
6	TN – 3	0.33	1.36	0.07	0.29 **	-0.43	-0.02	-17.63 **	0.43 **	0.09 **	-2.55 **	-0.05
7	NPJ – 112	-0.44	2.50 *	-0.08 *	0.24 **	0.24	0.07	-8.32 **	0.36 **	-0.08 **	-0.77 **	0.31 **
	SE (gca)	0.32	1.03	0.04	0.06	0.70	0.04	1.86	0.10	0.03	0.19	0.07
	SE (sii)	0.49	1.58	0.06	0.09	1.08	0.06	2.83	0.16	0.04	0.29	0.11
	SE (gi-gj)	-0.52	-1.88	0.11 **	0.55 **	1.57 *	0.02	3.30	-0.11	0.09 **	0.59 **	-0.25 **

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

Table 3: Estimation of specific combining ability (SCA) effects of crosses for different traits in Indian mustard

No	Hybrids	Days to 50% flowering	Plant height	No. of Primary Branches	No. of secondary Branches	Days to maturity	Siliqua Length	No. of Siliqua per plant	No of seed per siliqua	Test weight	Harvest Index	Seed yield per plant
1	DRMRMIB-35 X DRMRIJ-12-48	0.42	-9.11 **	-0.89 **	-1.17 **	0.44	0.35 **	-42.16 **	0.64 **	0.14 **	-2.02 **	0.71 **
2	DRMRMIB-35 X DRMRIJ-12-40	0.53	-1.36	-0.39 **	0.70 **	-0.89	0.57 **	37.79 **	0.55 **	-0.01	-1.47 **	0.25 **
3	DRMRMIB-35 X DRMRIJ-31	-0.14	-0.38	0.24 **	1.41 **	0.00	0.40 **	4.73	-0.16	-0.30 **	1.79 **	-1.02 **
4	DRMRMIB-35 X LES-39	1.08 *	10.49 **	0.93 **	-0.19 *	0.11	0.03	-0.67	-0.01	-0.15 **	-1.55 **	-0.53 **
5	DRMRMIB-35 X TN-3	3.42 **	4.20 **	-0.22 **	-0.57 **	2.00 *	0.48 **	34.57 **	1.06 **	0.26 **	1.75 **	-0.85 **
6	DRMRMIB-35 X NPJ-112	3.19 **	-3.13 *	1.03 **	-0.12	4.33 **	0.03	-1.94	-0.47 **	-0.18 **	5.08 **	-0.27 **
7	DRMRIJ-12-48 X DRMRIJ-12-40	1.19 **	19.69 **	0.08	-0.83 **	-0.44	0.42 **	19.79 **	0.19	-0.30 **	-0.97 **	-1.16 **
8	DRMRIJ-12-48 X DRMRIJ-31	-0.47	0.27	0.41 **	0.68 **	-0.56	0.07	-12.87 **	-2.11 **	0.39 **	-5.20 **	0.28 **
9	DRMRIJ-12-48 X LES-39	2.75 **	-3.47 *	0.60 **	0.88 **	-1.45	0.42 **	0.93	0.04	0.66 **	6.97 **	0.18
10	DRMRIJ-12-48 X TN-3	3.08 **	10.84 **	-0.86 **	0.10	3.45 **	0.31 **	18.97 **	0.31 *	0.07	-1.04 **	0.21 *
11	DRMRIJ-12-48 X NPJ-112	-1.14 **	-0.89	-0.90 **	-1.06 **	4.78 **	0.46 **	9.26 **	-0.43 **	-0.77 **	-2.02 **	0.32 **
12	DRMRIJ-12-40 X DRMRIJ-31	2.64 **	-10.98 **	-0.59 **	-1.06 **	6.11 **	0.22 **	-17.51 **	0.39 **	-0.37 **	2.64 **	0.44 **
13	DRMRIJ-12-40 X LES-39	-2.14 **	-9.11 **	-0.40 **	-0.46 **	3.22 **	0.00	-67.32 **	-0.05	0.21 **	-0.35	-0.76 **

14	DRMRIJ-12-40 X TN-3	1.19 **	-7.20 **	0.54 **	0.37 **	0.11	-0.19 **	-42.07 **	-1.38 **	-0.02	-2.71 **	0.54 **
15	DRMRIJ-12-40 X NPJ-112	3.97 **	15.27 **	0.40 **	2.01 **	-0.56	-0.09	-36.58 **	0.48 **	0.09 *	-5.90 **	-0.13
16	DRMRIJ-31 X LES-39	2.19 **	2.07	0.13 *	1.46 **	0.11	-0.29 **	11.02 **	-1.36 **	0.20 **	-1.54 **	0.30 **
17	DRMRIJ-31 X TN-3	1.53 **	-6.42 **	-1.32 **	0.28 **	0.00	0.38 **	-17.54 **	0.11	-0.04	-0.01	0.74 **
18	DRMRIJ-31 X NPJ-113	-1.70 **	13.44 **	0.64 **	0.72 **	-3.67 **	0.38 **	6.15 *	1.37 **	0.34 **	1.00 **	-0.03
19	LES-39 X TN-3	2.75 **	1.44	-0.83 **	-1.12 **	-0.89	0.77 **	-32.94 **	0.46 **	0.26 **	2.06 **	-0.84 **
20	LES-39 X NPJ-112	2.53 **	-1.69	-0.48 **	0.12	0.44	0.22 **	53.35 **	0.13	-0.24 **	3.97 **	-0.96 **
21	TN-3 X NPJ-112	-2.14 **	1.22	0.07	1.14 **	1.33	-0.07	7.59 **	-0.41 **	0.16 **	1.81 **	1.07 **
	SE sii	0.927	3.004	0.116	0.167	2.049	0.120	5.395	0.299	0.082	0.550	0.202
	SE (sij)	0.422	1.366	0.053	0.076	0.932	0.054	2.454	0.136	0.037	0.250	0.092
	SE(sij-ik)	1.377	4.462	0.171	0.248	3.044	0.178	8.015	0.444	0.121	0.817	0.301

Table 4: Estimation of heterosis, heterobeltiosis and standard heterosis over check parents for yield and yield attributing characters in Indian mustard

S. N	Hybrids	Days to 50 % flowering						Plant height			No. of Primary Branches		
				cc				cc				cc	
		BP	MP	Varuna	CG sarson	BP	MP	Varuna-	C.G. Sarson	BP	MP	Varuna-	C.G Sarson
1	DRMRMIB-35 X DRMRIJ-12-48	10.00**	10.00 **	-2.22	-4.35	-3.87	-2.99	1.58	-2.87	-27.27 **	-18.64 **	14.29 **	-2.04
2	DRMRMIB-35 X DRMRIJ-12-40	9.76 **	11.12 **	0.01	-2.17	-0.65	0.26	4.99	0.39	-10.40 **	-5.48	23.81 **	6.12
3	DRMRMIB-35 X DRMRIJ-31	4.76	7.32 *	-2.22	-4.35	-0.79	-0.46	2.95	-1.56	3.70	5.66	33.33 **	14.29 **
4	DRMRMIB-35 X LES-39	12.20 **	13.58 **	2.22	0.00	6.05	7.03 *	10.04 **	5.22	15.38 **	22.45 **	42.86 **	22.45 **
5	DRMRMIB-35 X TN-3	20.00 **	20.00 **	6.67 *	4.35	1.91	3.49	9.08 **	4.30	-22.06 **	-11.67 **	26.19 **	8.16 *
6	DRMRMIB-35 X NPJ-112	14.62 **	16.04 **	4.44	2.17	1.05	2.06	4.85	0.26	23.08 **	28.00 **	52.38 **	30.61 **
7	DRMRIJ-12-48 X DRMRIJ-12-40	9.76 **	11.11 **	0.00	-2.17	16.52 **	16.52 **	23.13 **	17.73 **	-12.12 **	-6.48 *	38.10 **	18.37 **
8	DRMRIJ-12-48 X DRMRIJ-31	2.38	4.88	-4.44	-6.52 *	1.42	2.68	7.17 *	2.48	-10.61 **	-1.67	40.48 **	20.41 **
9	DRMRIJ-12-48 X LES-39	14.63 **	16.05 **	4.44	2.17	-1.29	0.52	4.31	-0.26	-12.12 **	3.57	38.10 **	18.37 **
10	DRMRIJ-12-48 X TN-3	17.50 **	17.50 **	4.44	2.17	9.68 **	10.38 **	17.40 **	12.26 **	-29.41 **	-28.36 **	14.29 **	-2.04
11	DRMRIJ-12-48 X NPJ-112	2.43	3.70	-6.67 *	-8.70 **	4.26	6.24 *	10.17 **	5.35	-30.30 **	-19.30 **	9.52 *	-6.12
12	DRMRIJ-12-40 X DRMRIJ-31	11.91 **	13.26 **	4.45	2.18	-7.61 *	-6.47 *	-2.37	-6.65 *	-17.29 **	-14.31 **	14.29 **	-2.04
13	DRMRIJ-12-40 X LES-39	4.88	4.88	-4.44	-6.52 *	-6.71 *	-4.99	-1.42	-5.73	-19.01 **	-9.64 **	11.90 **	-4.08
14	DRMRIJ-12-40 X TN-3	12.20 **	13.58 **	2.22	2.10	-3.57	-2.95	3.22	-1.30	-10.29 **	-3.20	45.24 **	24.49 **
15	DRMRIJ-12-40 X NPJ-112	17.06 **	17.07 **	6.67 *	4.35	12.90 **	15.06 **	19.31 **	14.08 **	-0.06	9.40 **	38.10 **	18.37 **
16	DRMRIJ-31 X LES-39	11.90 **	13.25 **	4.44	2.17	0.40	1.00	3.49	-1.04	-7.41 *	0.00	19.05 **	2.04
17	DRMRIJ-31 X TN-3	9.52 **	12.20 **	2.22	0.00	-5.60	-3.83	-3.83	-3.39	-41.18 **	-34.43 **	-4.76	-18.37 **
18	DRMRIJ-31 X NPJ-113	0.00	1.20	-6.67 *	-8.70 **	11.90 **	12.65 **	15.35 **	10.30 **	7.47 *	13.79 **	38.17 **	18.44 **
19	LES-39 X TN-3	17.07 **	18.52 **	6.67 *	4.35	-0.89	1.57	6.08	1.43	-38.24 **	-26.32 **	0.00	-14.29 **
20	LES-39 X NPJ-112	14.62 **	14.63 **	4.44	2.17	2.81	2.88	4.72	0.13	-8.33 *	-6.38	4.76	-10.20 **
21	TN-3 X NPJ-112	2.43	3.70	-6.67 *	-8.70 **	2.80	5.42 *	10.04 **	5.22	-20.59 **	-6.90 *	28.57 **	10.20 **
	SE	1.46	1.26	1.46	1.46	4.73	4.10	4.73	4.73	0.18	0.16	0.18	0.18
	CD at 5%	3.00	2.60	3.00	3.00	9.72	8.42	9.72	9.72	0.37	0.32	0.37	0.37
	CD at 1%	3.73	3.23	3.73	3.73	12.08	10.46	12.08	12.08	0.46	0.40	0.46	0.46

*, ** significant at 5% and 1% level, respectively, MP= Mid parent, BP= Better parent, CC= Commercial check

SN	Hybrids	No. of secondary Branches		CC		Days to maturity		CC		Siliqua Length		CC	
		BP	MP	Varuna-	C.G Sarson	BP	MP	Varuna	CG Sarson	BP	MP	Varuna-	C.G Sarson
1	DRMRMIB-35 X DRMRIJ-12-48	-17.05 **	-16.14 **	44.36 **	-9.30 **	0.95	3.41	-17.19 **	-6.19 *	23.18 **	32.20 **	23.18 **	48.09 **
2	DRMRMIB-35 X DRMRIJ-12-40	-6.42 *	11.37 **	62.86 **	2.33	1.90	2.39	-16.40 **	-5.31	23.83 **	27.91 **	32.27 **	59.02 **
3	DRMRMIB-35 X DRMRIJ-31	4.25	30.68 **	81.43 **	13.99 **	0.95	1.92	-17.19 **	-6.19 *	15.18 **	24.11 **	34.55 **	61.75 **
4	DRMRMIB-35 X LES-39	-6.42 *	-0.02	62.86 **	2.33	0.00	1.94	-17.97 **	-7.08 *	13.68 **	17.18 **	20.91 **	45.36 **
5	DRMRMIB-35 X TN-3	-8.54 **	-5.51 *	59.16 **	0.00	2.85	4.85	-15.63 **	-4.42	30.91 **	30.91 **	30.91 **	57.38 **
6	DRMRMIB-35 X NPJ-112	-4.25	7.16 **	66.63 **	4.69	5.71	7.24 **	-13.28 **	-1.77	9.31 *	15.63 **	22.73 **	47.54 **
7	DRMRIJ-12-48 X DRMRIJ-12-40	-26.09 **	-12.82 **	25.85 **	-20.93 **	0.96	2.94	-17.97 **	-7.08 *	15.32 **	27.53 **	23.18 **	48.09 **
8	DRMRIJ-12-48 X DRMRIJ-31	-6.49 *	16.26 **	59.22 **	0.04	0.00	1.48	-19.53 **	-8.85 **	3.89	19.46 **	21.36 **	45.90 **
9	DRMRIJ-12-48 X LES-39	2.21	8.08 **	74.03 **	9.34 **	0.00	0.50	-21.09 **	-10.62 **	16.67 **	28.77 **	24.09 **	49.18 **
10	DRMRIJ-12-48 X TN-3	-4.35	-2.22	62.86 **	2.33	5.94	6.47 *	-16.40 **	-5.31	21.36 **	30.24 **	21.36 **	45.90 **
11	DRMRIJ-12-48 X NPJ-112	-17.39 **	-8.43 **	40.65 **	-11.63 **	6.86 *	7.92 **	-14.84 **	-3.54	12.96 **	27.69 **	26.82 **	52.46 **
12	DRMRIJ-12-40 X DRMRIJ-31	-6.25	2.10	11.04 *	-30.23 **	7.69 *	8.21 **	-12.50 **	-0.88	10.12 **	15.04 **	28.64 **	54.64 **
13	DRMRIJ-12-40 X LES-39	-12.20 **	-1.37	33.25 **	-16.28 **	3.85	5.36	-15.63 **	-4.42	11.06 **	11.30 **	18.64 **	42.62 **
14	DRMRIJ-12-40 X TN-3	-6.78 *	7.94 **	51.82 **	-4.61	1.92	3.41	-17.19 **	-6.19 *	6.81	10.33 **	14.09 **	37.16 **
15	DRMRIJ-12-40 X NPJ-112	32.48 **	42.08 **	81.43 **	13.99**	1.92	2.91	-17.19 **	-6.19 *	5.26	7.88 *	18.18 **	42.08 **
16	DRMRIJ-31 X LES-39	14.63 **	36.23 **	73.97 **	9.30 **	0.00	0.98	-19.53 **	-8.85 **	1.17	5.91	18.18 **	42.08 **
17	DRMRIJ-31 X TN-3	-4.55	16.67 **	55.46 **	-2.33	0.97	1.96	-18.75 **	-7.96 **	14.01 **	22.85 **	33.18 **	60.11 **
18	DRMRIJ-31 X NPJ-113	18.92 **	35.38 **	62.86 **	2.33	-1.94	-1.46	-21.09 **	-10.62 **	15.56 **	17.86 **	35.00 **	62.30 **
19	LES-39 X TN-3	-13.64 **	-10.59 **	40.65 **	-11.63 **	0.99	0.99	-20.31 **	-9.73 **	28.63 **	32.60 **	36.82 **	64.48 **
20	LES-39 X NPJ-112	7.32 *	12.82 **	62.86 **	2.33	1.96	2.46	-18.75 **	-7.96 **	12.55 **	15.59 **	26.36 **	51.91 **
21	TN-3 X NPJ-112	13.64 **	23.46 **	85.07 **	16.28 **	3.92	4.43	-17.19 **	-6.19 *	6.48	12.63 **	19.55 **	43.72 **
	SE	0.26	0.23	0.26	0.26	3.23	2.80	3.23	3.23	0.19	0.16	0.19	0.19
	CD at 5%	0.54	0.47	0.54	0.54	6.63	5.74	6.63	6.63	0.39	0.34	0.39	0.39
	CD at 1%	0.67	0.58	0.67	0.67	8.24	7.14	8.24	8.24	0.48	0.42	0.48	0.48

SN	Hybrids	Harvest Index				Seed yield per plant			
		BP	MP	CC		BP	MP	CC	
				Varuna-	C.G Sarson			Varuna-	C.G Sarson
1	DRMRMIB-35 X DRMRIJ-12-48	-15.18 **	-8.23 **	8.66 *	13.54 **	0.31	4.53	6.72	-5.00
2	DRMRMIB-35 X DRMRIJ-12-40	-17.17 **	-10.34 **	6.21	10.99 **	-6.38 *	-3.88	5.07	-6.47 *
3	DRMRMIB-35 X DRMRIJ-31	1.66	8.95 **	27.56 **	33.30 **	-15.01 **	-13.44 **	-9.58 **	-19.51 **
4	DRMRMIB-35 X LES-39	2.57	7.44 *	11.50 **	16.51 **	-17.54 **	-16.45 **	-9.91 **	-19.80 **
5	DRMRMIB-35 X TN-3	1.63	14.28 **	10.47 **	15.45 **	-15.63 **	-11.56 **	-10.24 **	-20.10 **
6	DRMRMIB-35 X NPJ-112	22.50 **	30.21 **	33.16 **	39.15 **	-8.37 *	-7.15 *	0.11	-10.88 **
7	DRMRIJ-12-48 X DRMRIJ-12-40	-14.68 **	-14.63 **	9.41 *	14.33 **	-18.55 **	-12.95 **	-8.59 *	-18.63 **
8	DRMRIJ-12-48 X DRMRIJ-31	-23.87 **	-23.09 **	-2.49	1.90	3.97	6.43 *	6.61	-5.10
9	DRMRIJ-12-48 X LES-39	17.33 **	32.45 **	50.29 **	57.05 **	-8.67 **	-3.62	-0.22	-11.18 **
10	DRMRIJ-12-48 X TN-3	-22.66 **	-6.86 *	-0.93	3.53	5.63	6.29 *	3.30	-8.04 *
11	DRMRIJ-12-48 X NPJ-112	-19.89 **	-8.34 **	2.62	7.24	-0.71	4.79	8.48 *	-3.43
12	DRMRIJ-12-40 X DRMRIJ-31	-0.66	0.42	27.39 **	33.12 **	-0.29	4.21	11.89 **	-0.39
13	DRMRIJ-12-40 X LES-39	-11.98 **	-0.59	12.87 **	17.95 **	-17.27 **	-16.16 **	-7.16 *	-17.35 **
14	DRMRIJ-12-40 X TN-3	-32.36 **	-18.52 **	-13.27 **	-9.37 *	-1.57	5.80 *	10.46 **	-1.67
15	DRMRIJ-12-40 X NPJ-112	-37.24 **	-28.17 **	-19.53 **	-15.91 **	-4.61	-3.33	7.05 *	-4.71
16	DRMRIJ-31 X LES-39	-8.77 **	2.06	14.47 **	19.62 **	-4.94	-1.92	3.85	-7.55 *
17	DRMRIJ-31 X TN-3	-15.85 **	0.51	5.59	10.34 *	9.24 **	12.50 **	12.00 **	-0.29
18	DRMRIJ-31 X NPJ-113	-5.98	6.62 *	17.98 **	23.28 **	-1.61	1.51	7.49 *	-4.31
19	LES-39 X TN-3	14.91 **	23.80 **	13.58 **	18.69 **	-18.75 **	-13.75 **	-11.23 **	-20.98 **
20	LES-39 X NPJ-112	31.48 **	33.52 **	29.96 **	35.81 **	-16.33 **	-16.33 **	-8.59 *	-18.63 **
21	TN-3 X NPJ-112	9.26 *	16.04 **	4.70	9.42 *	7.16 *	13.75 **	17.07 **	4.22
	SE	0.87	0.75	0.87	0.87	0.32	0.28	0.32	0.32
	CD at 5%	1.78	1.54	1.78	1.78	0.65	0.57	0.65	0.65
	CD at 1%	2.21	1.92	2.21	2.21	0.81	0.70	0.81	0.81

Result and Discussion

The results of partial diallel analysis for assessment of combining ability and heterosis are discussed under the following sub-heads:

Analysis of variance

Table 1 presenting the analysis of variance for seed yield and its components in Indian mustard indicated that the mean sum of squares for all genotypes were highly significant for all the characters. The presence of highly significant variation revealed that all the character had high variability. High variability among all the characters were observed due to the diversity present in the experimental material used in the study.

Combining ability analysis for GCA and SCA effects

Variation in general combining ability (GCA) and specific combining ability (SCA) effects was estimated eleven traits to identify the best parent as well as crosses. The results of the general combining ability effects for parents and specific combining ability (SCA) for crosses are presented in Table 2 & Table 3. High positive values of (GCA) effects would be of interest in most of traits under investigation for days to 50 % flowering, plant height, no. of primary branch plant, no. of secondary branches per plant days to maturity, siliqua length, no. of siliqua per plant, no. of seed per siliqua, test weight, harvest index, seed yield per plant. High negative values for days to flowering and plant height and days to maturity would be useful from the breeder's point of view.

Out of 21 crosses, four cross combinations showed positive significant SCA effect for seed yield per plant (g) trait. Maximum SCA effect was reported by TN-3 X NPJ-112, DRMRIJ-31 X TN-3, DRMRMIB-35 X DRMRIJ-12-48 and DRMRIJ-12-48 X LES-39. For seed yield per plant.

Heterosis

Heterosis measured as mean superiority of F1s over their better parents or mid parent or the best commercial variety and thus, it is rated to be an important parameter in such studies. The results of the heterosis analysis for crosses are presented in Table 4. The significant positive relative heterosis was recorded in TN-3 X NPJ-112 (13.75), DRMRIJ-31 X TN-3 (12.50), DRMRIJ-12-48 X DRMRIJ- 31 (6.43), DRMRIJ-12-48 X TN-3 (6.29).

The significant positive heterobeltiosis was recorded in DRMRIJ-31 X TN-3 (9.24), TN-3 X NPJ-112 (7.16). The highest significant positive standard heterosis over check parent (Varuna) TN-3 X NPJ-112 (17.07), DRMRIJ-31 X TN-3 (12.00), DRMRIJ-12-40 X DRMRIJ-31 (11.89) with respect to seed yield per plant.

Conclusion

Combining capability revealed that individual's influence through interaction. The above experiment showed that NPJ – 112, DRMRIJ-12-40, DRMRIJ-31 and LES-39, DRMRIJ-12-48 parents have significant general combining capacity, while TN-3 X NPJ-112, DRMRIJ-31 X TN-3, DRMRMIB-35 X DRMRIJ-12-48 and DRMRIJ-12-48 X LES-39 have strong hybrid SCA results.

Sufficiently high magnitude of relative heterosis for no. of secondary branches per plant, siliqua length, no. of seed per siliqua, test weight, harvest index and seed yield per plant similarly high magnitude of heterobeltiosis recorded for no. of branches per plant, siliqua length and harvest index and high magnitude of standard heterosis recorded for no. of primary branches per plant, no. of secondary branches per plant, days to maturity, siliqua length, harvest index and seed yield per plant.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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