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Heterobeltiosis and standard heterosis for seed yield and important traits in *Brassica juncea*

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Abstract

Genetic study was carried out to estimate heterobeltiosis (better parent heterosis) and standard heterosis for isolation of superior cross combinations of Indian mustard [*Brassica juncea* (L.) Czern. & Coss.]. Thirty six F_1 crosses along with thirteen *B. juncea* parental genotypes planted at the Directorate of Rapeseed-Mustard Research (DRMR), Bharatpur, experimental farm during 2011-12 were evaluated for twelve characters, including seed yield / plant (g), plant height (cm), point to first branch (cm), number of primary branches, main shoot length (cm), point to first siliqua (cm), number of siliquae on main shoot, siliqua length (cm), number of seeds per siliqua, 1000-seed weight (g), days to maturity and percent oil content. Analysis of variance revealed considerable genetic variability among parents and F_1 crosses for all the traits. Five crosses *viz.*, DRMR 2486 × Ashirwad, DRMR 2243 × NRCHB 101, DRMR 2269 × NRCHB 101, DRMR 2341 × NRCDR 2, and DRMR 2613 × NRCDR 2 possessed high heterosis and higher *per se* performance over better parent and standard check. In many crosses, highly significant heterosis was observed for point to first branch, number of primary branches, main shoot length, point to first siliqua and number of seeds / siliqua. The high yielding cross combinations from this study can be utilized in future breeding programmes for development of high yielding genotypes.

Key words: *Heterobeltiosis, Indian mustard, yield parameters*

Introduction

Rapeseed-mustard crops in India include Toria (*Brassica rapa* L. var. Toria), Brown Sarson (*B. rapa* L. var. Brown Sarson), Yellow Sarson (*B. rapa* L. var. Yellow Sarson), Indian mustard [*B. juncea* (L.) Czern & Coss.], Black mustard (*B. nigra*) and Taramira (*Eruca satva / vesicara* Mill.) species. These along with non-traditional species like Gobhi Sarson (*B. napus* L.) and Karan rai (*B. carinata* A. Braun) have been recorded to be grown since ancient time. Indian mustard occupies more than 80% of the total rapeseed-mustard cultivated area, contributes nearly 27% of edible oil pool in India, and accounts for >13% of the global edible oil production. In Northern India, mustard oil is mainly utilized for human consumption (Vaghela *et al.*, 2011). During the last decade, the yield of mustard in India almost static is hovering averaged between 1-1.2 tonnes/ha, which is much below the world's average of 1.98 tonnes/ha. There is a much wider yield gaps when productivity of mustard in India is compared with 4.3 tonnes/ha in Germany, 3.8 tonnes/ha in France and 3.4 tonnes/ha in UK (Yadava *et al.*, 2012). Higher yield, therefore, can be achieved if superior germplasm lines are effectively utilized in developing high-yielding genotypes. Seed yield a very complex trait, possesses many components which finally result in a highly plastic yield structure (Diepenbrock, 2000). Grafius (1959) suggested that there might not be any specific genes for yield *per se*. Since, heterosis has an important role in all plant breeding programmes; it would be very helpful to know the relationship between heterosis for seed yield and its components (Azizinia, 2011). Selection of desirable heterotic crosses at an early stage is very important in developing high-yielding genotypes. Effective utilization of heterosis to develop high-yielding hybrids, therefore, has been the major objective of Brassica oilseed breeding in recent years (Wang, 2005). The main objective of the present study, therefore, was to isolate superior cross combination(s) by estimating heterobeltiosis (better parent heterosis) and standard heterosis in F_1 crosses of Indian mustard [*B. juncea* (L.) Czern & Coss.].

Materials and Methods

The study was conducted at the DRMR, Bharatpur during 2010-11 and 2012-13. The experimental material comprised of nine diverse advanced breeding lines and four released varieties (Table 1) of *Brassica juncea* selected from germplasm collection at DRMR, Bharatpur. Thirty six F_1 crosses were generated through a 9 × 4 line × tester mating design during *rabi* 2010–11. The experiment was laid out in a randomized complete block design with three replications during *rabi* 2012–13. The treatments were seeded in rows of 3 m length with a distance of 30 cm between rows, and 15 cm between plants where each treatment was represented by a single row. Standard agronomic practices were followed, recommended doses of fertilizers *viz.*, 80:40:40:40 kg/ha of N:P:K:S, respectively, were applied, and experimental plots irrigated thrice including pre-sowing irrigation. Observations from each parent and F_1's were recorded on randomly selected five competitive plants for twelve quantitative traits, including seed yield per plant (g), plant height (cm), point to first branch (cm), number of primary branches, main shoot length (cm), point to first siliqua (cm), number of siliquae on main shoot, siliqua length (cm), number of seeds per siliqua, 1000-seed weight (g), days to maturity and percent oil content. The mean of three replications for parents and F_1 crosses for twelve traits were subjected to statistical analysis of variance according to Steel *et al*. (1997). Heterosis was estimated in relation to better parent (heterobeltiosis) and standard check (standard heterosis) as per standard procedure. Variety NRCDR 2 was taken as standard check for calculation of standard heterosis.

Table 1: Thirteen parental genotypes utilized for generation of 36 crosses and their pedigree

Parental genotype	Pedigree
Lines	
DRMR 2178*	(RH 819/BPKR 13)/(RH 819/MDOC 3)
DRMR 2243*	GSL 1/Bio 902
DRMR 2269*	(GSL 1/Bio 902)/(PYSR 2/ *Brassica nigra*)
DRMR 2326*	(RH 819/BPKR 13)/(PYSR 2/PBR 181)
DRMR 2341*	(RH 819/BPKR 13)/(NBPGR 272/RK 9903)
DRMR 2398*	(PYSR 2/*Brassica nigra*)/(Kranti/GSL 1)
DRMR 2448*	(RH 819/Kranti)/(GSL 1/PYSR 2)
DRMR 2486*	GSL 1/Bio 902
DRMR 2613*	(IC 199733/*Sinapis alba*)/(BEC 107/NRCG 411)
Testers	
NRCDR 2**	MDOC 43/NBPGR 36
NRCHB101**	BL 4/Pusa bold
Rohini**	selection from natural population of Varuna
Ashirwab**	Krishna/Vardan

*, ** Unreleased advanced breeding lines and released high yielding varieties, respectively

Results and Discussion

Analysis of variance (Table 2) revealed highly significant (at P=0.01) differences among parents and F_1 crosses for all 12 traits indicating existence of considerable genetic variability in the experimental material. All 36 crosses were compared with better parent and standard check for estimation of better parent heterosis and standard heterosis, respectively.

Table 2: Analysis of variance for twelve yield traits in Indian mustard

S.O.V		Replication	Treatments	Error
Character	D.F	2	48	96
Plant height (cm)		4.07	35.04**	4.12
Point to first branch (cm)		16.58**	98.51**	2.94
Number of primary branches		0.1	0.23**	0.09
Main shoot length (cm)		2.23	176.94**	2.56
Point to first siliquae (cm)		0.05	7.10**	0.42
Number of siliqua on main shoot		0.083	93.71**	1.9
Siliqua length (cm)		0.33**	0.70**	0.07
Number of seeds / siliqua		0.09	5.41**	0.11
1000- seed weight (g)		0.0006	0.75**	0.0024
Seed yield / plant (g)		3.86*	131.15**	0.85
Oil content (%)		0.06**	1.76**	0.01
Days to maturity		0.52	18.21**	0.42

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

The estimates of better parent heterosis for 12 traits are presented in Table 3. Results showed that out of 36 crosses, 21 exhibited significant negative heterosis for plant height which ranged from -2.09 to -5.98%. For point to first branch, 23 crosses showed >15% highly significant negative better parent heterosis, and of them five F_1's namely, DRMR 2486 × NRCHB 101 (-52.22%), DRMR 2243 × NRCHB 101 (-44.33%), DRMR 2426 × Rohini (-43.19%), DRMR 2486 × Ashirwad (-42.18%) and DRMR 2341 × NRCDR 2 (-40.15%) exhibited more than 40% heterosis over the better parent. For days to maturity, thirty three crosses showed significant negative better parent heterosis ranging from -0.97 to -8.20%. Our findings were similar to those reported by several researchers (Das *et al.*, 2004; Turi *et al.*, 2006; Nasrin *et al.*, 2011; Yadav *et al.*, 2012). Short and medium plant stature less vulnerable to lodging due to heavy winds is also preferred in *Brassica*. Early maturity is useful in most plant species especially *Brassica* where delayed maturity cause losses in yield and quality of oil due to high temperature (Turi *et al.*, 2006). Similarly, initiation of branches near the base of plant is also desirable for profuse branching with vigorous stature. Negative heterosis, therefore, is useful regarding plant height, point to first branch and days to maturity. Early maturing genotypes suffer lower losses due to shattering, tolerate or escape heat stress and provide sufficient time for seeding the next crop. Similarly, shorter plants with greater numbers of branches are desirable due to their ability to withstand winds. In the present study, negative heterotic values for these traits were noted for many of the crosses (Table 3). Crosses showing significant negative values suggested that these crosses could be used to develop new early maturing lines. Pourdad and Sachan (2003) also reported significant negative heterosis for days to 50% flowering and maturity and high negative heterosis for plant height in *Brassica napus*. Similarly, Nassimi *et al.* (2006) also obtained significant negative better-parent heterosis for maturity and plant height. Engqvist and Becker (1991) found that rapeseed hybrids with earlier flowering and higher yields were slightly late maturing. However, Hu *et al.* (1996) reported significant positive heterotic effects for plant height and seed yield per plant. The differences in the results could be due to the differences in genotypes and weather conditions.

In *Brassica*, positive heterosis for number of primary branches is desirable, because plants with vigorous stature containing more branches provide opportunity for higher yields. Heterosis estimates over better parent showed that out of 36 crosses, 5 crosses had positive effects with the maximum values of 19.23% and 17.86% observed in crosses

Table 3: Estimates of better parent heterosis (heterobeltiosis) for 12 yield traits in F_1 crosses of *Brassica juncea*

Crosses	Plant height (cm)	Point to first branch (cm)	Number of primary branches	Main shoot length (cm)	Point to first siliquae (cm)	Number of siliqua on main shoot	Siliqua length (cm)	Number of seeds / siliqua	1000-seed weight (g)	Seed yield / plant (g)	Oil content (%)	Days to maturity
DRMR 2178 × NRCDR 2	-2.37**	-13.38**	4.65	-5.07**	-10.19	4.70*	4.60	2.22	-9.39**	-19.79**	0.06	-5.15**
DRMR 2178 × NRCHB 101	1.50	-16.18**	19.23**	-12.58**	-46.72**	2.10	-3.01	1.10	-12.99**	-20.04**	-6.32**	-2.18**
DRMR 2178 × Rohini	0.50	12.79**	-2.38	9.74**	-28.57**	12.61**	-13.26**	-2.35	-13.02**	-14.06**	-1.19**	-2.44**
DRMR 2178 × Ashirwad	0.37	8.80	7.23	0.46	21.58**	4.45*	11.33**	0.00	-17.73**	-10.59**	-2.20**	-4.73**
DRMR 2243 × NRCDR 2	-3.40**	-20.07**	0.00	7.92**	-1.92	1.75	5.46	-14.44**	3.45**	-31.28**	2.10**	-4.92**
DRMR 2243 × NRCHB 101	0.26	-44.33**	0.00	-8.52**	-9.70*	-14.94**	1.37	9.89**	-8.06**	67.62**	-1.49**	-1.45**
DRMR 2243 × Rohini	6.16**	-26.23**	8.05	-4.73**	-43.03**	0.45	-2.88	-6.02**	-9.87**	5.10	-0.60**	-0.73
DRMR 2243 × Ashirwad	-3.14**	-34.70**	4.60	10.93**	-7.13	1.69	8.95*	0.00	-13.48**	1.49	0.87**	-1.18**
DRMR 2269 × NRCDR 2	-2.34**	-13.73**	-7.45	-2.70	-9.04	-2.46	-6.32	-13.33**	-17.10**	-28.78**	-1.41**	-6.09**
DRMR 2269 × NRCHB 101	-4.03**	-33.22**	-5.32	-17.53**	-5.97	-19.11**	4.66	14.29**	-15.91**	46.32**	-2.48**	-2.18**
DRMR 2269 × Rohini	-0.86	-9.07*	-6.38	1.63	-22.52**	0.58	-7.78*	3.61	-11.34**	-0.06	-2.91**	-2.93**
DRMR 2269 × Ashirwad	-4.13**	-39.15**	-7.45	4.76**	-23.54**	5.54*	-10.12**	-10.84**	-10.42**	15.17**	1.87**	-5.91**
DRMR 2326 × NRCDR 2	-2.76**	1.82	-2.33	-4.93**	-5.77	-9.39**	-0.86	5.56**	-18.02**	-17.89**	0.21	-6.09**
DRMR 2326 × NRCHB 101	0.79	-9.31*	3.49	-9.55**	-22.39**	-3.67	-6.58	1.10	-14.29**	23.20**	-2.96**	-3.13**
DRMR 2326 × Rohini	-4.42**	-2.92	-4.65	-1.55	-2.02	-3.56	-8.07*	-6.17**	-8.22**	-7.19*	-2.50**	-1.45**
DRMR 2326 × Ashirwad	-3.42**	-36.86**	0.00	19.03**	39.31**	8.07**	-0.33	12.16**	-3.82**	-4.45	-1.61**	-5.91**
DRMR 2341 × NRCDR 2	-5.02**	-40.15**	-1.16	6.37**	5.26	-11.50**	-12.07**	-13.33**	-7.98**	35.37**	-0.69**	-6.79**
DRMR 2341 × NRCHB 101	0.69	-3.15	6.10	-8.59**	-23.28**	3.54	-3.84	0.00	-18.02**	-2.66	-2.36**	-0.97*
DRMR 2341 × Rohini	1.89*	-15.34**	10.71*	-5.50**	-32.61**	-21.53**	2.31	19.75**	-1.32	-2.78	-1.59**	-0.98*
DRMR 2341 × Ashirwad	-1.11	-13.66**	9.64*	-3.28*	0.00	5.37**	4.40	15.79**	-7.20**	-29.35**	1.53**	-5.67**
DRMR 2398 × NRCDR 2	-5.98**	3.02	-2.33	-17.26**	-21.54**	-15.79**	0.00	-8.89**	-13.27**	-30.86**	0.72**	-7.26**
DRMR 2398 × NRCHB 101	-2.30*	-33.39**	4.88	-11.89**	-11.94*	6.20**	-8.49*	-7.69**	-18.34**	23.31**	0.02	-0.97*
DRMR 2398 × Rohini	0.00	-18.96**	17.86**	-4.73**	-37.65**	11.84**	5.19	8.64**	-15.30**	4.56	-0.74**	-0.49
DRMR 2398 × Ashirwad	-1.79	-32.72**	4.82	8.99**	2.38	8.46**	13.67**	9.21**	-7.53**	-15.37**	-1.61**	-1.89**
DRMR 2448 × NRCDR 2	-3.08**	-5.86	-9.09	-4.50**	-24.04**	-4.21	13.79**	-6.67**	-16.50**	-31.34**	-0.13	-8.20**
DRMR 2448 × NRCHB 101	-2.43**	-34.55**	-1.14	-19.18**	-20.90**	-15.57**	-7.95*	-9.89**	-21.54**	-36.68**	-0.33	-3.86**
DRMR 2448 × Rohini	*0.25	-28.68**	1.14	8.99**	-10.92*	-12.62**	-5.19	9.88**	-18.72**	2.51	-2.90**	-4.11**
DRMR 2448 × Ashirwad	-2.72**	-36.45**	-6.82	23.55**	30.24**	-10.58**	10.33*	28.38**	-17.40**	14.39**	1.35**	-6.62**
DRMR 2486 × NRCDR 2	-1.45	-23.82**	-1.15	1.07	-26.92**	-14.56**	2.01	-4.44*	-27.89**	-20.92**	3.27**	-5.15**
DRMR 2486 × NRCHB 101	-2.49**	-52.22**	5.75	-16.01**	-32.09**	-10.13**	-3.01	-8.79**	-24.19**	15.23**	0.20	-0.72
DRMR 2486 × Rohini	-2.09*	-43.19**	2.30	-1.70	-29.41**	-19.09**	-13.26**	8.64**	-10.86**	29.84**	0.30	-3.61**
DRMR 2486 × Ashirwad	-4.12**	-42.18**	1.15	8.99**	1.51	3.64	-12.85**	0.00	-11.84**	129.22**	2.28**	-5.91**
DRMR 2613 × NRCDR 2	-1.31	-12.83**	3.49	3.13*	-16.35**	-5.93**	-5.17	-16.67**	-17.91**	31.35**	3.23**	-5.39**
DRMR 2613 × NRCHB 101	-4.77**	-15.15**	7.23	-17.18**	-25.37**	-17.67**	-5.48	3.30	-20.62**	14.95**	0.06	-0.97*
DRMR 2613 × Rohini	-4.27**	-17.86**	2.38	1.94	-31.43**	-21.79**	-15.56**	2.47	-23.28**	-12.52**	-2.08**	-3.15**
DRMR 2613 × Ashirwad	-5.40**	-26.60**	10.84*	2.35	-9.29	-19.65**	-4.33	-8.00**	-13.15**	22.99**	-0.72**	-5.44**

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

DRMR 2178 × NRCHB 101 and DRMR 2398 × Rohini, respectively. Significant positive heterosis for number of primary branches were earlier reported by Turi *et al*. (2006) and Nasrin *et al*. (2011). Significant positive better parent heterosis for main shoot length was exhibited by 11 crosses with the maximum values being observed for crosses DRMR 2326 × Ashirwad (19.03%) and DRMR 2448 × Ashirwad (23.55%). Similarly, for number of siliqua on main shoot, the significant positive better parent heterosis was observed for seven crosses with the values ranging from 4.45 to 12.61%. Five crosses for siliqua length, 11 crosses for number of seeds per siliqua, and one cross for 1000-seed weight showed significant positive better parent heterosis. Nine out of 36 crosses exhibited significant positive better parent heterosis for oil content with the values ranging from 0.72 to 3.27%.

The presence of significantly positive heterosis for branches per plant in F_1 crosses indicates the potential of their use for developing high-yielding genotypes. The results of our study are in agreement with the earlier findings of Nassimi *et al*. (2006) and Turi *et al*. (2006) who reported significant positive heterosis for number of branches per plant in *Brassica napus* and in *Brassica juncea*, respectively. Several researchers reporting significant positive heterosis including Satwinder *et al*. (2000) for number of primary branches, number and length of siliqua, seeds per siliqua, yield per plant and oil content; Jorgensen *et al*. (1995) for primary and secondary branches and other yield parameters; Krzymanski *et al*. (1997) for seed yield, oil content and some flowering traits; Fray *et al*. (1997) for primary branches, seed yield and number of siliqua per plant; and Liu (1996) for more branches with greater plant height, and longer flowering period.

Thirteen out of 36 crosses exhibited highly significant positive better parent heterosis for seed yield and from them, 11 crosses showed >15% better parent heterosis (Table 3). Five crosses *viz*., DRMR 2486 × Ashirwad (129.22%), DRMR 2243 × NRCHB 101 (67.62%), DRMR 2269 × NRCHB 101 (46.32%), DRMR 2341 × NRCDR 2 (35.37%), and DRMR 2613 × NRCDR 2 (31.85%) possessed high heterosis over better parent with higher *per se* performance. Seven crosses exhibiting highly significant positive standard heterosis for seed yield with their percent estimated heterosis values, in decreasing order are: DRMR 2243 × NRCHB 101 (51.31%), DRMR 2486 × Ashirwad (46.85%), DRMR 2341 × NRCDR 2 (35.36%), DRMR 2269 × NRCHB 101 (32.07%), DRMR 2398 × NRCHB 101 (11.32%), and 11.21% in DRMR 2326 ×

Table 4: Mean performance of F_1 hybrids and estimates of standard heterosis for seed yield

Lines	Testers			
	NRCDR 2	NRCHB 101	Rohini	Ashirwad
DRMR 2178	22.88(-19.09**)	22.80(-19.38**)	24.51(-13.33**)	25.50(-9.83**)
DRMR 2243	19.43(-31.29**)	42.79(51.31**)	24.57(-13.12**)	18.39(-34.97**)
DRMR 2269	20.14(-28.78**)	37.35(32.07**)	23.36(-17.40**)	22.40(-20.79**)
DRMR 2326	23.22(-17.89**)	31.45(11.21**)	21.70(-23.27**)	17.45(-38.30**)
DRMR 2341	38.28(35.36**)	26.64(-5.80)	26.60(-5.62)	19.33(-31.65**)
DRMR 2398	19.55(-30.87**)	31.48(11.32**)	24.44(-13.58**)	16.54(-41.51**)
DRMR 2448	19.42(-31.33**)	16.16(-42.86**)	23.96(-15.28**)	20.72(-26.73**)
DRMR 2486	22.36(-20.93**)	29.41(4.00)	30.35(7.32*)	41.53(46.85**)
DRMR 2613	37.29(31.86**)	29.34(3.75)	20.45(-27.69**)	22.36(-20.93**)
Mean seed yield of standard check (g)		28.280		

Values in parentheses represent economic heterosis (standard heterosis)

**,*: significant at P=0.01 and P=0.05, respectively.

NRCHB 101 (Table 4). Heterobeltiosis values as high as 54.38% in hybrid Pusa Mustard 25 × RGN 145, and 44.8% in hybrid RSK 28 × RH(0E)0103 with higher *per se* performance have been reported, respectively, by Yadav *et al.* (2012) and Vaghela *et al.* (2011). Better parent heterosis to the extent of 161% and 113.6% in Indian mustard hybrids RAU RP 4 × PR 18 (Hirve and Tiwari, 1991) and RLM 198 × RK 2 (Dhillon *et al.*, 1990), respectively, 102.7% in yellow seeded Indian colza hybrid YS 51 × YS 9 (Duhoon and Basu, 1981), and 204% in raya hybrid F 48 × IB 494 (Yadava *et al.*, 1974) have been reported. Heterosis for seed yield ranging from 24.36 to 80.97% was also reported by Verma *et al.* (2011). Moderate level of heterosis for seed yield/plant, number of siliquae/plant and number of secondary branches/plant was also reported by Aher *et al.* (2009). From the present study the high yielding cross combinations can be utilized in future breeding programmes for developing high yielding genotypes; parents used in developing heterotic hybrids shall be converted to well adapted cytoplasmic male sterile or restorer lines.

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