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EXPRESSION OF HETEROSIS FOR YIELD AND ITS COMPONENTS IN INDIAN MUSTARD (*BRASSICA JUNCEA* L. CZERN & COSS) UNDER TIMELY SOWN IRRIGATED CONDITIONS

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Abstract

Nine Indian mustard genotypes including standard check, RB-50 and their hybrids were sown under timely sown irrigated condition to study the extent of relative, heterobeltiosis and standard heterosis for seed yield and its components. The analysis of variance revealed that considerable genetic variation existed among the parents and hybrids for most of the traits under study. RB-50×Kranti showed positive and significant value for all the three types of heterosis for 1000 seed weight. RH-119×Giriraj, RGN-298×RH-749, RGN-298×Giriraj, Vardan×RH-749 and Vardan×Giriraj showed standard heterosis for seed yield per plant as well as number of primary and secondary branches. The cross combinations Vardan×Giriraj, RGN-298×RH-749, RGN-298×Giriraj, Vardan×RH-749 and Vardan×RGN-73 were identified on the basis of standard heterosis alogwith *per se* performance for seed yield per plant which, could be exploited for getting transgressive segregants in the subsequent generation for developing high yielding varieties.

Key words : Indian mustard, heterosis, heterobeltiosis, standard check, yield.

Introduction

Indian mustard (*Brassica juncea, AABB, 2n=36),* a major oilseed crop of Indian subcontinent is a natural amphidipolid combining the genomes of two species, *B. campestris* (AA, 2n=20) and *B. nigra* (BB, 2n=16) (Nagaharu, 1935). The oleiferous *Brassica* species, generally referred to as rapeseed-mustard, are one of the economically important agricultural commodities (Dahiya *et al.,* 2018). Being grown in more than 70 countries over an area of 34.19 million hectares, world output of rapeseed-mustard crops rose from about 36 million tonnes in 2001-02 to 63.09 million tons in 2016-17. In India, the production of rapeseed–mustard is around 7.98 million tonnes (2.47 million tonnes oil) from an area of 6.02 million hectare (Agricultural Statistics at a Glance, 2017). In recent years, despite of considerable efforts made to improve different seed yield and yield-related parameters and/or to transfer its useful traits to related Brassica oil crops, there is compelling need to increase and stabilize the productivity of Indian mustard to sustain vast population demands within the country. (Rakow, 1995; Meng *et al.*, 1998; Singh, 2003; Singh *et al.*, 1996). This can be achieved through effective utilization of germplasm resources and integration of genomic tools to add pace to breeding processes (Banga, 2012).

Heterosis is the interpretation of increased vigor, size, fruitfulness, development speed, resistance to disease and insect pests or climatic vigors, manifested by cross-bred organisms as compared with corresponding inbreds (Shull, 1952; Jinks and Jones, 1958). Mustard is predominantly a self pollinated crop although an average of 7.5 to 30 per cent out-crossing does occur under natural field conditions (Abraham, 1994; Rakow & Woods, 1987). Since, hybrid technology has been the most successful approach to enhance the genetic yield potential; it would be very helpful to know the relationship between heterosis for seed yield and its components (Azizinia, 2011). Both positive and negative heterosis is desirable in crop improvement. In general positive heterosis is desired for yield while negative heterosis is desirable for traits like early maturity and plant height (Synrem *et al.*,2015).

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Successful heterosis program should lead to develop the hybrids which are more productive than either of the parents as well as standard check cultivars (Pradhan *et al.,* 1993). Selection of desirable heterotic crosses at an early stage is very important in developing high-yielding genotypes (Synrem *et al.,*2015). Exploitation of heterosis as a viable option may play a very significant role in breaking yield barrier and substantially increasing the production and productivity of Indian mustard (Meena *et al.,* 2015). Reports on the availability of heterosis in this crop dates back to 1943 which had generated interest of plant breeders to harness hybrid vigour. Development of hybrid cultivars has been successful in many Brassica species (Melchinger and Gumber, 1998; Becker and Robbelen, 1999; Miller, 1999). In oilseed Brassicas heterosis was first reported in brown sarson by Singh and Mehta (1954). In *B. juncea,* significant level of heterosis (>100% on plant basis) of 239 percent over the better parent for seed yield per plant was reported by Yadava *et al.,* (1974). Similarly, significant positive heterosis for seed yield and component traits in Indian mustard were reported by many workers (Rawat,1975; Ram *et al.,* 1976; Banga and Labana, 1984; Hirve and Tiwari, 1992; Pradhan *et al.,* 1993; Verma, 2000; Aher *et al.,* 2009; Verma *et al.,* 2011, Meena *et al.,* 2015) using different sets of materials, clearly demonstrating the scope of improving the productivity of Indian mustard through genetic manipulations. 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 is therefore to screen superior cross combination(s) by estimating average heterosis (mid parent heterosis), heterobeltiosis (better parent heterosis) and standard heterosis (economic heterosis) in different F_1 cross combinations of Indian mustard [*Brassica juncea* (L.) Czern & Coss].

Materials and Methods

Nine genotypes of Indian mustard, *Brassica juncea* L. (five lines including check RB-50: RH-406, RB-50, RH-119, RGN-298 and Vardan along with four testers: RGN-73, Kranti, RH-749, and Giriraj were crossed in line×tester fashion during *Rabi* 2016-17 to develop 20 F_1's. The whole experimental material (nine genotypes along with their 20 F_1's was evaluated at the Agriculture Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi in randomized block design (parents and crosses were randomised separately) with 3 replications in irrigated trial conditions to measure the heterosis. All the genotypes and F_1's were grown in two rows of 3m length with row to row and plant to plant spacing of 45cm and 10cm, respectively.

Observations were recorded from five randomly selected plants of each genotype from each plot on: days to maturity, plant height (cm), number of primary and secondary branches per plant, siliqua length (cm), seeds/siliqua, main raceme length (cm), number of siliqua on main raceme, 1000-seed weight (g) and seed yield per plant (g). Heterosis was estimated by using the formulae. The average F1 value was used for estimation of heterosis expressed in percentage over mid parent (MP) and better parent (BP) values, where MP value = (P1ÿP2)/2, Relative heterosis = [(F1-MP)/MP]×100, Better Parent Heterosis (%) = (F1-BP)/BP×100, suggested by Fonseca and Patterson (1968) and SH= [(F1-SP)/SP]×100 suggested Meredith and Bridge (1972) respectively. Where, F1= mean hybrid performance, BP= Mean performance of better parents and SP= mean performance of standard parent/check (RB-50). The significance of heterosis value was tested using 't' test.

$$t = \frac{\text{F1- MP or BP or SC}}{\text{- S.E. of heterosis over MP or BP or SC}}$$

Where; calculated 't' values were compared with tabulated 't' values at error degree of freedom for test of significance.

Results and Discussions

The analysis of variance revealed considerable genetic variation among parents and hybrids for almost all the traits under study. All 20 hybrids were compared with mid parent, better parents and commercial cultivar for the estimation of relative heterosis, heterobeltiosis and standard heterosis, respectively (Table 1). Considerable amount of relative heterosis, heterobeltiosis and standard heterosis were observed for yield and other related traits however, the degree of heterosis varied from cross to cross. Standard heterosis is the most important parameter amongst the three parameters of heterosis.

For days to maturity, 3, 3 and 7 hybrids showed negative significant values for relative, better parent and standard heterosis. RB-50×Giriraj and RGN-298×RGN-73 were common hybrids showing negative desirable values for all the three types of heterosis. RGN-298×RGN-73 showed maximum negative better parent (-9.85) and standard heterosis (-9.18) for the same trait. These hybrids are favourable for earliness. In respect of plant height, out of 20 hybrids, 3 and 4 hybrids exhibited positive and highly significant relative and standard heterosis respectively. Cross RB-50×RH-749 was showing significant positive values for all the three relative (14.09), better parent (13.81), and standard heterosis

Table 1: Relative heterosis, better parent heterosis and standard heterosis for Yield and yield traits in Indian mustard.

Hybrids	Days to maturity			Plant height			No. of primary branches			No. of secondary branches			Siliqua length		
	RH#	BPH$	SH+	RH	BPH	SH	RH	BPH	SH	RH	BPH	SH	RH	BPH	SH
RH-406×RGN-73	0.91	-2.51	-3.72	5.06	-0.21	0.95	33.13**	24.17	27.90*	27.94**	19	19.42	6.58	5.51	-7.68
RH-406×Kranti	-4.20	-5.53	-6.70*	2.18	-0.53	0.63	39.04**	26.21*	30.00*	60.26**	31.54**	-23.74	10.43	8.77	-4.82
RH-406×RH-749	3.34	1.01	-0.25	1.68	1.34	2.53	21.47	12.62	16.00	0.6	-10.39	-10.07	10.08	10.01	-3.62
RH-406×Giriraj	-5.88*	-6.23	-6.70*	-0.7	-1.17	0.94	81.32**	60.19**	65.00**	70.7**	44.09**	44.60*	-0.54	-4.6	-9.10
RB-50×RGN-73	2.58	-1.49	-1.49	12.96**	7.89	7.89	11.55	5.5	5.50	28.96**	20.14	20.14	6.73	-0.88	-0.88
RB-50×Kranti	-5.06	-6.95*	-6.95*	11.55*	9.21	9.21	15.22	6	6.00	49.23**	22.66*	22.66	5.1	-2.85	-2.85
RB-50×RH-749	-2.17	-4.96	-4.96	14.09**	13.81*	14.37**	31.91**	24	24.00	3.63	-7.55	-7.55	15.25**	8.11	8.11
RB-50×Giriraj	-7.71**	-7.94*	-7.94*	6.41	5.31	7.55	24.02	11	11.00	4.68	-11.51	-11.51	16.11**	13.38*	13.38*
RH-119×RGN-73	-0.13	-1.31	-6.45*	9.3	2.58	6.44	8.16	0	5.00	40.88**	27.08*	9.71	1.75	-0.73	-10.53
RH-119×Kranti	-0.13	-0.78	-4.71	3.98	0	3.76	12.17	0.95	6.00	71.24**	65.03**	14.57	15.04*	11.68	0.66
RH-119×RH-749	-0.52	-0.79	-5.96	5.05	3.4	7.29	21.24	11.43	17.00	94.65**	83.49**	43.88*	15.48**	13.87*	2.63
RH-119×Giriraj	-3.19	-5.49	-5.96	4.43	3.61	7.51	69.57**	48.57**	56.00**	141.04**	140.41**	66.91*	15.32**	12.2*	6.91
RGN-298×RGN-73	-5.79*	-9.85**	-9.18**	5.83	-3.64	6.81	29.24*	25.26	19.00	42.3**	36.67**	17.99	9.83	7.61	-3.84
RGN-298×Kranti	0.13	-2.22	-1.49	5.99	-1.2	9.51	32.96*	25.26	19.00	68.5**	52.49**	21.22	13.03*	10.18	-1.54
RGN-298×RH-749	1.27	-1.97	-1.24	7.94	2.91	14.06*	56.28**	50.53**	43.00**	99.54**	98.19**	57.55**	7.56	6.5	-4.82
RGN-298×Giriraj	-1.86	-2.46	-1.74	3.83	-0.24	10.57	52.87**	40**	33.00*	101.94**	88.69**	50.00*	5.46	2.19	-2.63
Vardan×RGN-73	7.75*	6.90*	0.00	15.58**	8.07	13.06*	25.03*	15.09	22.00	38.8**	33.46**	24.82	-5.32	-6.78	-20.07**
Vardan×Kranti	-2.62	-3.88	-7.69*	2.19	-2.12	2.40	9.47	-1.89	4.00	104.56**	72.69**	61.51**	4.7	3.62	-12.06*
Vardan×RH-749	8.32**	7.89*	1.74	6.53	4.43	9.25	38.14**	26.42*	34.00*	105.86**	89.23**	76.98**	10.6	7.76	-5.59
Vardan×Giriraj	4.88	1.75	1.24	4.02	2.78	7.52	65.41**	44.34**	53.00**	90.38**	65.48**	54.77**	1.04	-5.41	-9.87

#Relative heterosis, $Better parent heterosis, +Standard heterosis

* and **, at 0.05 and 0.01 levels of significance.

Table 1 contd....

(14.37). These results were also founded by Yadav *et al.*, (1974) and Choudhary and Sharma (1982). 6 hybrids showed highly significant and positive relative, better parent and standard heterosis for number of primary branches per plant for the season. The hybrid RH-406×Giriraj manifested maximum significant positive relative heterosis (81.32), better parent heterosis (60.19) and standard heterosis (65.00) respectively for the same year. These findings agreed with the results of Prasad and Singh (1985) and Monpara and Dobariya (2007). The highest relative heterosis (141.04) and better parent heterosis (140.41) was registered in cross combination RH-119×Giriraj for number of secondary branches per plant. Vardan×RH-749 exhibited maximum standard heterosis (76.98) for the same trait. Positive and highly significant heterosis was showed by 8 cross combinations for all the three types of heterosis for the trait of number of secondary branch. Similar inclinations were observed by Katiyar *et al.*, (2000). This is also in compliance with earlier findings of Anand and Rawat (1984) and Thakur and Bhateria (1993).

For other yield contributing traits like siliqua length, 3 hybrids RB-50×Giriraj, RH-119×RH-749 and RH-119×Giriraj were showing highly significant positive values for relative and better parent heterosis. Cross combination RB-50×Giriraj manifested highly positive relative (16.11), better parent (13.38) and standard heterosis (13.38) for the trait of siliqua length. A wide range of positive heterosis for number of primary branches and secondary branches per plant, plant height, and number of seeds per siliqua was reported by Rawat (1975). Similarly for seeds per siliqua, 5, 3 and 8 hybrids showed positive significant

Table 1 contd....

Hybrids	Seeds/Siliqua			Main raceme length			Siliqua on main raceme			1000-seed weight			Seed yield per plant		
	RH[#]	BPH[$]	SH[+]	RH	BPH	SH	RH	BPH	SH	RH	BPH	SH	RH	BPH	SH
RH-406×RGN-73	10.27	9.78	17.62*	6.62	2.17	13.94	5.94	4.09	15.85	0.63	-2.16	1.49	4.02	1.45	8.39
RH-406×Kranti	16.63**	13.78*	21.90**	11.91	8.11	10.50	3.49	1.06	12.48	-17.34**	-19.42**	-16.42*	30.05*	22.67	31.06*
RH-406×RH-749	-2.34	-7.11	-0.48	0.72	-0.05	2.15	-9.06	-11.48	4.05	-4.35	-10.62	6.72	-24.63*	-29.82**	-13.04
RH-406×Giriraj	-3.07	-4.33	5.24	19.81**	14.75*	28.09**	13.08	7.42	19.56*	-6.08	-11.46	3.73	14.41	12.32	24.53
RB-50×RGN-73	3.7	0.67	6.90	5.55	0.1	11.63	4.72	1.1	8.60	7.8	6.72	6.72	-10.94	-11.62	-10.25
RB-50×Kranti	21.23**	20.09**	22.38**	28.67**	25.62**	25.62**	10.15	7	13.49	21.05**	20.15**	20.15**	-3.35	-5.9	-5.90
RB-50×RH-749	13.8*	11.9	11.90	9.55	9.2	9.90	9.15	1	18.72	-2.72	-10.62	6.72	-0.14	-9.77	11.80
RB-50×Giriraj	10.2	5.19	15.71*	14.95*	8.97	21.64**	29.23**	29.12**	29.34**	-3.78	-10.83	4.48	8.39	3.08	14.29
RH-119×RGN-73	3.46	0.67	6.90	8.74	-1.54	9.80	5.27	1.88	9.44	14.37*	14.24	11.94	-9.5	-10.71	-6.83
RH-119×Kranti	11.53	10.75	12.86	15.13*	12.2	6.89	-4	-6.52	-0.84	-4.94	-5.3	-6.72	19.5	13.99	18.94
RH-119×RH-749	28.99**	26.54**	27.14**	16.39*	10.48	11.19	5.65	-2.01	15.18	-12.03*	-20**	-4.48	18.91	9.52	35.71**
RH-119×Giriraj	5.88	1.3	11.43	23.81**	12.05	25.08**	21.68**	21.48*	22.09*	2.08	-6.37	9.70	26.41*	22.69	36.02**
RGN-298×RGN-73	11.62*	9.87	16.67*	14.46*	10.42	23.14**	7.2	3.67	19.22*	2.09	-1.42	3.73	-4.76	-9.84	2.48
RGN-298×Kranti	0.47	0	2.86	6.93	2.6	6.35	3.28	-0.73	14.17	9.16	5.67	11.19	-8.49	-16.12	-4.66
RGN-298×RH-749	11.22	7.87	10.95	11.7	10.07	14.10	9.35	8.18	27.15**	-6.31	-11.88**	5.22	23.66*	18.55	46.89**
RGN-298×Giriraj	9.62	6.06	16.67*	6.5	2.7	14.64	11.29	4.11	19.73*	0	-5.1	11.19	30.29**	28.69*	46.27**
Vardan×RGN-73	-3.89	-5.83	0.00	-0.15	-3.57	7.53	16.94*	16.3	26.31**	-14.27*	-16.98*	-18.66*	33.89**	31.9*	38.04**
Vardan×Kranti	11.21	11.21	13.33	18.49**	13.58	17.98*	17.05*	15.68	25.63**	-1.18	-4.55	-5.97	18.69	13.06	18.32
Vardan×RH-749	-3.12	-5.61	-3.81	12.63	10.88	15.18	14.99*	10.62	30.02**	-11.66*	-21.88**	-6.72	22.28*	12.78	39.75**
Vardan×Giriraj	11.01	6.93	17.62*	9.69	5.88	18.19*	25.53**	20.65*	31.03**	8.57	-3.18	13.43	37.46**	33.61**	48.14**

[#]Relative heterosis, [$]Better parent heterosis, [+]Standard heterosis

* and **, at 0.05 and 0.01 levels of significance.

relative, better parent and standard heterosis respectively. 3 hybrids (RH-406×Kranti, RB-50×Kranti and RH-119×RH-749) showed positive significant values for all the three types of heterosis. RH-119×RH-749 showed highest values for all the three types of heterosis (28.99, 26.54 and 27.14) for the same trait. Taking main raceme length into account, RH-406×Giriraj showed maximum positive significant standard heterosis (28.09). Hybrids RB-50×Kranti and RH-406×Giriraj were showing positive significant values for all the three types of heterosis for main raceme length. Considering number of siliqua on main raceme, 6, 3 and 10 hybrids showed positive significant relative, better parent and standard heterosis. Common hybrids showing significant positive values for all the three types of heterosis for the same trait are RB-50×Giriraj, RH119×Giriraj and Vardan×Giriraj. Vardan×Giriraj showed 31.03% of standard heterosis for the trait. Likewise, out of 20 F_1s, RB-50×Kranti cross combination was registered for positive and significant relative (21.05), better parent (20.15) and standard heterosis (20.15) for test weight. Likewise, for seed yield per plant, RGN-298×Giriraj and Vardan×RGN-73 showed highest positive significant values for all the three i.e., relative, better parent and standard heterosis. RGN 298×RH-749 showed maximum significant superiority over standard check, RB-50 for seed yield per plant. The finding are in accordance with that of Katiyar *et al.*, (2000) and Shrivastava *et al.*, (1990). Yadava *et al.* (1974) also reported heterosis over better parent up to 239 per cent for seed yield per plant in Indian mustard. Furthermore, significant positive

Table 2: Cross combinations with significant positive relative, better parent and standard heterosis for different yield and yield contributing traits.

Traits	Relative Heterosis	Better Parent Heterosis (Heterobeltiosis)	Standard Heterosis	Common Hybrids
Days to maturity	RH-406×Giriraj, RB-50×Giriraj, RGN-298×RGN-73	RB-50×Kranti, RB-50×Giriraj, RGN-298×RGN-73	RH-406×Kranti, RH-406×Giriraj , RB-50×Kranti, RB-50×Giriraj, RH-119×RGN-73, RGN-298× RGN-73, Vardan × Kranti	RGN-298×RGN-73
Plant height	RB-50×RGN-73, RB-50×Kranti, Vardan×RGN-73	RB-50 × RH-749	RB-50×RH-749, RGN-298×RH-749, RGN-298×RH-749	RB-50×RB-50×RH-749,
Number of primary branches	RH-406×Kranti, RH-406×RGN-73, RH-406×Giriraj, RB-50×RH-749, RH-119×Giriraj, RGN-298×RGN-73, RGN-298×Kranti, RGN-298× RH-749, RGN-298×Giriraj, Vardan× RGN-73, Vardan×RH -749, Vardan×Giriraj	RH-406×Kranti, RH-406×Giriraj, RH-119×Giriraj, RGN-298×RH-749, RGN-298×Giriraj, Vardan× RH-749, Vardan×Giriraj	RH-406×RGN-73, RH-406× Kranti, RH-406×Giriraj, RH-119× Giriraj, RGN-298×RH-749, RGN-298×Giriraj, Vardan×RH-749, Vardan×Giriraj	RH-406×Giriraj, RH-119× Giriraj, RGN-298×RH-749, RGN-298×Giriraj, Vardan× RH-749, Vardan×Giriraj
Number of secondary brances	RH-406×RGN-73, RH-406× Kranti, RH-406×Giriraj, RB-50× RGN-73, RB-50×Kranti, RH-119× RGN-73, RH-119×Kranti, RH-119× RH-749, RH-119×Giriraj, RGN-298 ×RGN-73, RGN-298×Kranti, RGN -298×RH-749, RGN-298×Giriraj, Vardan×RGN-73, Vardan×Kranti, Vardan×RH-749, Vardan×Giriraj	RH-406×Kranti, RH-406×Giriraj, RB-50×Kranti, RH-119×RGN-73, RH-119×Kranti, RH-119×RH-749, RH-119×Giriraj, RGN-298×RGN-73, RGN-298×Kranti, RGN-298×RH-749, RGN-298×Giriraj, Vardan×RGN-73, Vardan×Kranti, Vardan×RH-749, Vardan×Giriraj	RH-406×Giriraj , RH-119×RH-749, RH-119×Giriraj, RGN-298× RH-749, RGN-298×Giriraj, Vardan×RGN-73, Vardan×Kranti, Vardan×RH-749, Vardan×Giriraj	RH-406×Giriraj, RH-119×Giriraj, RGN-298×RH-749, RGN-298 ×Giriraj, Vardan×Kranti, Vardan× RH-749, Vardan×Giriraj
Siliqua length (cm)	RB-50× RH-749, RB-50 × Giriraj, RH-119×Kranti, RH-119×Kranti, RH-119×RH-749, RH-119×Giriraj RGN-298×RH-749	RB-50 × Giriraj	RB-50 × Giriraj	RB-50 × Giriraj
Seeds/siliqua	RH-406×Kranti, RB-50×Kranti, RB-50×RH-749, RH-119×RH-749, RGN-298×RGN-73	RH-406×Kranti, RB-50× Kranti, RH-119× RH-749	RH-406×RGN-73, RH-406× Kranti, RB-50×Kranti, RB-50× Giriraj, RH-119×RH-749, RGN-298×RGN-73, RGN-298×Giriraj, Vardan×Giriraj	RH-406×Kranti, RB-50× Kranti, RH-119× RH-749
Main raceme length	RH-406×Giriraj, RB-50×Kranti, RB-50×Giriraj, RH-119×Kranti, RH-119×RH-749, RH-119×Giriraj RGN-298×RGN-73	RH-406×Giriraj, RB-50×Kranti	RH-406×Giriraj, RB-50×Kranti, RB-50×Giriraj, RH-119×Giriraj, RGN-298×RGN-73	RH-406×Giriraj, RB-50×Kranti

Table 2 contd....

Table 2 contd....

Traits	Relative Heterosis	Better Parent Heterosis (Heterobeltiosis)	Standard Heterosis	Common Hybrids
Siliqua on main raceme	RB-50×Giriraj, RH-119×Giriraj, Vardan×Giriraj, Vardan × RGN-73, Vardan × Kranti, Vardan × RH-749	RB-50×Giriraj, RH-119×Giriraj, Vardan×Giriraj	RB-50×Giriraj, RH-119×Giriraj, RGN-298×RGN-73, RGN-298× RH-749, RGN-298× Giriraj, Vardan × RGN-73, Vardan × Kranti, Vardan × Rh-749, Vardan×Giriraj	RB-50×Giriraj, RH-119× Giriraj, Vardan×Giriraj
1000-seed weight	RB-50×Kranti, RH-119×RGN-73	RB-50×Kranti	RB-50×Kranti	RB-50×Kranti
Seed yield per plant	RH-406×Kranti, RH-119×Giriraj, RGN-298×RH-749, RGN-298× Giriraj, Vardan×RGN-73, Vardan ×RH-749, Vardan×Giriraj	RGN-298×Giriraj, Vardan×RGN-73	RH-406×Kranti, RH-119×RH-749, RH-119×Giriraj, RGN-298×RH-749, RGN-298×Giriraj, Vardan×RGN-73, Vardan×RH-749, Vardan×Giriraj	RGN-298×Giriraj, Vardan×RGN-73

heterosis for seed yield and component traits in Indian mustard were reported 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) using different sets of materials. It clearly demonstrates the scope of improving the productivity of Indian mustard through genetic manipulations.

Persual of table 2 suggests the name of hybrids depicting significant positive relative, better parent and standard heterosis for different yield and yield contributing traits. Considering earliness, RGN-298×RGN-73 was found best. RB-50×RH-749 showed maximum positive heterosis for plant height. For taking both number of primary branches and secondary branches into account, RH-406×Giriraj, RH-119×Giriraj, RGN-298×RH-749, RGN-298×Giriraj, Vardan×RH-749, Vardan×Giriraj were common hybrids significant for all i.e., relative, better parent and standard heterosis. Cross RB-50×Giriraj showed significant relative, better parent and standard heterosis for siliqua length. RH-406×Kranti, RB-50×Kranti, RH-119× RH-749 were common hybrids showing all the three types of positive heterosis for seeds per siliqua. Considering main raceme length into account, hybrids RH-406×Giriraj and RB-50×Kranti were superior ones. RB-50×Giriraj, RH-119×Giriraj, Vardan×Giriraj were found superior for number of siliqua on main raceme. For 1000 seed weight, RB-50×Kranti depicted significant positive standard heterosis for all the three types of heterosis. Likewise, RGN-298×Giriraj and Vardan×RGN-73 were the most important hybrids in terms of seed yield per plant because of the superiority over the standard check,RB-50.

(Table 3) reveals top five cross combinations for yield and other related traits on the basis of average *per se* and standard heterosis and further identifying five potential crosses *i.e.*, Vardan×Giriraj, RGN-298×RH-749, RGN-298×Giriraj, Vardan×RH-749 and Vardan×RGN-73 for seed yield per plant. Vardan×Giriraj and RGN-298×Giriraj were favourable in the sense that they were showing heterosis for both test weight and seed yield per plant. From the above results we can say that breeding for heterosis is one of the most successful technological options being employed for the improvement of crop varieties. The crosses with favourable traits obtained from this study can be utilized in further breeding programmes for development of high seed yielding cultivars.

Conclusion

The commercial worth of a genotype, depends on the magnitude of improvement in yield *per se* over better parent and standard check. Hence, cross combinations that registered high yield *per se* along with significant positive relative heterosis, heterobeltiosis and economic heterotic responses for yield may be considered ideal for use in breeding program for yield improvement. Cross combinations Vardan×Giriraj, RGN-298×RH-749, RGN-298×Giriraj, Vardan×RH-749 and Vardan×RGN-73 were identified on the basis of standard heterosis alogwith *per se* performance for seed yield per plant are thus amenable for getting transgressive segregants in the subsequent generation and improvement through conventional breeding procedures combined with heterosis breeding for developing high yielding varieties. Large scales testing of these crosses could help to develop strains with high and stable yield in Indian mustard.

Table 3: Top five Cross combinations for standard heterosis and per se performance of yield and yield related traits.

Days at maturity			No. of primary branches			Seeds/siliqua		
Hybrids	SH	*Per se* performance	Hybrids	SH	*Per se* performance	Hybrids	SH	*Per se* performance
RGN-298×RGN-73	-9.18**	122	RH-406×Giriraj	65**	11	RH-119×RH-749	27.14**	17.80
RB-50×Giriraj	-7.94*	123.37	RH-119×Giriraj	56**	10.40	RB-50×Kranti	22.34**	17.13
Vardan×Kranti	-7.69*	124	Vardan×Giriraj	53**	10.20	RH-406×Kranti	21.90**	17.07
RB-50×Kranti	-6.95*	125	RGN-298×RH-749	43**	9.53	Vardan×Giriraj	17.62*	16.47
RH-406×Giriraj	-6.70*	125.33	Vardan×RH-749	34*	8.93	RH-406× RGN-73	17.62*	16.47

1000-seed weight			Seed yield per plant		
Hybrids	SH	*Per se* performance	Hybrids	SH	*Per se* performance
RB-50×Kranti	20.15**	5.37	Vardan×Giriraj	48.14**	31.80
Vardan×Giriraj	13.43	5.07	RGN-298×RH-749	46.89**	31.53
RH-119×RGN-73	11.94	5.00	RGN-298×Giriraj	46.27**	31.40
RGN-298×Kranti	11.19	4.97	Vardan×RH-749	39.75**	30.00
RGN-298×Giriraj	11.19	4.97	Vardan×RGN-73	38.04**	29.63

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