

Original Research Article

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Heterosis Studies in Indian Mustard [*Brassica juncea* (L.) Czern & Coss.] for Yield and its Related Attributes

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ABSTRACT

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Above titled experiment was conducted at two locations, College of Agriculture, Bikaner and ARS, Sri Ganganagar respectively. In this experiment, 125 F₁s, 25 parent genotypes (20 lines and 5 testers) and one check were analyzed at each location. For the study, a total of four environments were created, each location had two environments, timely sown and late sown, respectively. Subsequently, on the basis of pooled data of four environments standard heterosis was estimated for twelve yield and yield related attributes over the check variety RGN-13. Through the study, significant standard heterosis results were obtained for most of the traits including seed yield per plant. From the performance point of view, crosses RGN 73 x Kranti, Vardan x Kranti; Vardan x RB-50 and; RH-749 x RB-50 reported significant standard heterosis for many characters. For almost all the characters variable number of crosses depicted standard heterosis in both positive and negative direction, indicating that genes with negative as well as positive effects were dominant. This show of unpredictability highlights the role of non additive gene actions, which in turn may be due to dominance and/or epistasis.

Introduction

The oilseeds occupy significant place in Indian economy next to food grain. India is the third largest producer of oilseeds in the world. Oilseed *Brassic*as are the second most important oilseed crops of the world after Soybean (Anonymous, 2015). India, China, Canada, Japan and European Union are the major Brassica growing regions of the world (Anonymous, 2016).

The mustard is grown not only as oilseed crop but also as condiments and for medicinal use. The oil content in mustard seed ranges from 30-42%. Its leaves and tender stem form the most popular winter greens in some Indian states. Mustard oil has peculiar pungency due to the presence of sulphur compound, thus making it suitable for condiments and for preparation of pickles, curries and vegetables. Its leaves are rich in protein, minerals and vitamin A and C. After extraction of oil from seeds, the remnant is used as food for milching cattle.

The mustard is cultivated during the rabi season in India and requires relatively cool temperature, a fair supply of soil moisture during the growing period and a dry weather during the harvest period. The plant can tolerate wide range of soil pH and can be successfully grown in light sandy to marginal soils, though light loam to heavy loam soils are the best suited. This crop is grown both under rainfed as well as irrigated conditions either as a pure crop or as a mixed crop.

To cope up with the increasing population and demand of oilseeds, various strategies have been evolved to improve the yield levels in the country that are far below the world levels. The systematic genetic improvement efforts have resulted into release of about 158 varieties. Further, taking the advantage of recently available CMS system in addition to barnasebarstar system six hybrids have also been developed.

However, yield realization falls much behind the world average and need genetic interventions to further improve the potential of the varieties and hybrids. In this background the present study is justifiable and necessary timely effort. However, in future available male sterile lines may be involved allowing direct exploitation of heterosis at commercial level. The identified hybrid combinations for high heterosis may be tested again with larger plot size to determine their potential for commercial exploitation.

Materials and Methods

The present investigation was carried out at Research farm of College of Agriculture, Beechwal, Bikaner (Zone Ic) and at ARS, Sri Ganganagar (Zone Ib) during 2015-16 Rabi season. The experimental material consisted of 25 lines, 5 testers, their 125 cross combinations and one check. The crosses for

the study were developed at ARS, Sri Ganganagar during 2014-15 Rabi season through Line x Tester mating design. During 2015-16 Rabi season all the genotypes (crosses, parents and check) were sown in each of the four environments in randomized block design with three replications. Each genotype was sown in single row plot of 3 m row length. Row to row and plant to plant distances were maintained at 45 cm and 15 cm respectively, in each replication. Recommended package of practices were adopted to raise a good crop.

The characters studied were: days to 50% flowering, days to maturity, plant height, number of primary branches per plant, number of siliqua per plant, siliqua length, number of seeds per siliqua, 100-seed weight, stover yield per plant, seed yield per plant, harvest index and oil content.

Results and Discussion

In the study, standard heterosis was estimated over the check variety RGN-13. In matters of performance for different traits various crosses were found to be giving top performances viz, RH-749 x RB-50, RGN-236 x RGN-145 and RGN-236 x RB-50 were identified as highly heterotic crosses for days to 50% flowering and days to maturity.

In case of plant height, best significant and positive standard heterosis results were reported by RH-749 x RB-50 (17.95%), Vardan x RL-1359 (17.18%) and Vardan x RGN-145 (16.22%). For number of primary branches per plant and 100-seed weight, Vardan x Kranti reported best standard heterosis of 47.92% and 24.19% respectively, followed by Vardan x RGN-145 (47.73%) for number of primary branches per plant and Vardan x RL-1359 for 100-seed weight; showing the superior performance of Vardan for various characters.

Table.1.2 Estimates of standard heterosis over check (RGN-13) on pooled data basis

S.N.	Hybrids	Days to 50% Flowering	Days to Maturity	Plant height (cm)	No. of Primary branches per plant	No. of siliqua per plant	Siliqua length (cm)	No. of seeds per siliqua	100- seed weight (gm)	Stover yield per plant (gm)	Seed Yield per plant (gm)	Harvest Index (%)	Oil Content (%)
1	RGN13 x RGN145	3.14*	1.70*	-4.63	19.59	47.50*	0.97	-13.44	-3.43	6.54	23.23	5.55	-0.56
3	RGN13 x RL-1359	3.14*	0.95	-0.37	1.11	23.99	-2.95	-19.25*	-7.06	-21.72	-3.54	13.58*	0.55
6	RGN73 x RGN145	2.32	1.64*	10.19	31.48*	43.28*	3.30	7.84	-1.21	18.28	40.59*	12.77*	-3.57
7	RGN73 x Kranti	-3.42**	-1.84*	13.75	30.14*	73.84**	18.17*	17.29*	20.77**	46.65*	69.65**	9.61	-3.49
8	RGN73 x RL-1359	5.19**	2.19**	14.37*	21.71	62.38**	10.35	8.68	6.85	19.47	34.07	7.74	-9.91**
9	RGN73 x Geeta	3.41**	0.95	2.64	29.95	32.50	4.56	5.23	4.23	4.13	15.61	8.03	-0.29
10	RGN73 x RB-50	3.27*	0.21	1.10	20.77	14.56	7.16	1.76	10.48	30.23	22.19	-6.02	-2.23
11	RGN 48 x RGN145	-4.24**	-3.46**	7.24	19.57	25.74	9.61	0.62	4.84	3.17	24.63	8.88	-1.88
13	RGN 48 x RL-1359	-0.41	-0.29	2.84	6.60	4.42	7.87	-16.4*	-7.66	-18.93	-12.44	4.31	-1.63
14	RGN 48 x Geeta	0.68	0.08	5.30	11.66	10.68	1.08	-15.58*	-1.21	-13.36	-5.15	3.82	-3.53
16	RGN 229 x RGN145	-4.14**	-1.72*	3.01	0.19	7.88	-4.34	-12.79	-3.43	-22.06	-11.53	10.13	-2.09
17	RGN 229 x Kranti	-7.15**	-5.26**	4.58	18.49	62.09**	13.50	2.76	9.48	19.91	16.34	-3.31	1.32
18	RGN 229 x RL-1359	-3.96**	-2.50**	4.68	13.53	58.98**	-1.60	-7.62	13.1*	0.41	13.94	4.87	1.07
19	RGN 229 x Geeta	-2.28	-2.15**	-0.92	8.23	47.12*	-1.82	-11.08	-12.1*	7.55	8.37	-2.04	-4.01
20	RGN 229 x RB-50	-4.60**	-3.08**	-0.02	1.73	12.64	9.59	1.93	5.85	-20.01	-10.54	8.89	0.20
21	RGN 298 x RGN145	-0.55	-1.41	9.30	27.62	34.01	12.32	6.09	0.81	15.88	42.23*	10.87	-2.73
22	RGN 298 x Kranti	-4.24**	-3.27**	3.35	25.96	34.13	12.11	7.42	2.82	11.08	40.91*	16.19**	-1.48
23	RGN 298 x RL-1359	-2.87*	-2.21**	5.82	11.66	25.21	13.90	-0.26	5.04	4.05	30.68	16.61**	-1.20
24	RGN 298 x Geeta	-3.15*	-2.83**	12.71	29.69	42.00*	5.73	4.73	-2.42	7.05	27.04	8.91	-5.07*
25	RGN 298 x RB-50	-5.06**	-3.15**	4.20	28.86	24.41	14.60*	9.55	-4.03	5.35	26.29	7.95	1.25
26	RGN 303 x RGN145	2.59*	0.70	3.42	11.99	13.68	0.91	-5.87	-14.11*	-21.49	-8.56	9.70	-2.15
27	RGN 303 x Kranti	0.27	-0.08	4.03	9.37	14.59	0.58	4.02	-8.06	-8.29	9.21	13.62*	-2.91
28	RGN 303 x RL-1359	1.91	-0.23	3.72	9.67	24.15	5.16	0.71	-13.51*	-11.01	-6.90	0.81	3.32
29	RGN 303 x Geeta	3.14*	0.33	2.47	3.30	20.82	2.26	4.83	-14.52*	-21.99	-11.61	10.34	1.57
30	RGN 303 x RB-50	0.54	0.41	7.49	0.42	16.46	1.84	-11.69	-10.28	-6.11	-11.12	-0.46	-0.62
31	Bio 902 x RGN145	3.96**	0.95	0.13	4.53	-9.74	-1.97	-2.40	-1.61	-5.78	-3.95	1.81	-5.89*
32	Bio 902 x Kranti	-3.55**	-3.27**	8.15	22.12	33.26	16.86*	3.24	4.64	10.65	32.60	11.11	-2.07
33	Bio 902 x RL-1359	1.77	0.46	4.45	15.75	-18.54	3.28	-9.82	-8.67	-10.49	-12.95	-1.53	-6.92**
34	Bio 902 x Geeta	3.00*	1.08	-2.30	17.28	-7.81	-1.07	-0.77	-8.87	-14.04	-17.45	-1.78	-4.77
35	Bio 902 x RB-50	3.82**	2.13**	0.45	0.10	-3.30	-2.44	-15.70*	-10.48	-10.4	4.83	13.02*	-7.44**
36	RGN 236 x RGN145	-7.93**	-6.13**	1.70	18.84	1.59	-7.33	-5.09	-10.28	-0.11	1.89	-2.02	-0.21
37	RGN 236 x Kranti	-7.69**	-5.75**	2.04	16.78	23.55	1.26	11.53	1.01	18.34	15.87	-2.47	-2.89
38	RGN 236 x RL-1359	-7.60**	-5.19**	-0.74	4.30	-13.24	7.57	-8.34	-6.05	14.93	6.37	-3.22	-3.56

39	RGN 236 x Geeta	-7.24**	-5.32**	0.15	14.95	11.95	2.70	-5.05	2.62	-14.45	-13.47	4.70	-3.24
40	RGN 236 x RB-50	-7.88**	-5.75**	8.30	2.64	33.00	3.52	1.75	-15.32**	19.04	8.56	-7.81	-3.39
41	Rohini x RGN145	-2.73*	-1.28	0.06	12.31	-15.64	-0.39	-4.82	-16.53**	-18.77	-20.54	3.20	0.23
42	Rohini x Kranti	2.32	1.20	-2.28	10.89	-26.4	1.57	-7.13	-18.55**	-20.55	-25.30	-3.33	-3.57
43	Rohini x RL-1359	-0.69	-0.54	-4.52	16.96	-34.07	4.07	-6.19	0.60	-2.19	-4.04	1.14	-5.04*
44	Rohini x Geeta	0.82	0.14	-0.63	5.72	-3.65	2.11	-2.52	-8.87	-12.80	-12.49	-0.63	-6.20*
45	Rohini x RB-50	0.82	-0.54	10.71	7.14	10.76	6.41	-9.26	-14.72*	-12.80	-15.09	0.86	-4.55
46	GM 3 x RGN145	-0.69	-0.97	1.64	9.68	0.99	0.01	5.11	11.69*	-3.99	-12.83	-4.34	-10.79**
47	GM 3 x Kranti	-4.10**	-1.78*	-5.54	7.93	23.48	11.31	-0.16	-2.82	-8.47	-15.74	-5.16	-10.52**
48	GM 3 x RL-1359	-2.73*	-2.09**	-3.38	10.43	17.43	0.91	-4.27	-0.60	-11.09	-21.08	-6.01	-10.33**
52	RN 393 x Kranti	2.59*	0.83	-0.35	8.34	12.18	2.72	1.55	-14.31*	-14.16	-26.51	-10.26	-2.42
53	RN 393 x RL-1359	-1.78	-1.18	7.8	13.64	14.37	14.96*	-5.32	-1.81	-11.69	-19.21	-4.62	-4.08
54	RN 393 x Geeta	-2.73*	-1.59*	4.41	16.41	49.68**	-0.15	-3.35	15.32**	-3.49	-12.17	-8.13	-4.32
55	RN 393 x RB-50	3.27*	1.28	2.56	24.01	65.90**	3.34	-1.64	4.03	-1.53	-9.65	-5.46	-1.02
56	CS 52 x RGN145	-0.82	-0.79	-2.4	-3.76	24.01	4.43	-7.07	-12.7*	-13.39	-24.82	-10.91	-9.09**
57	CS 52 x Kranti	-2.05	-1.65*	-1.2	15.49	24.32	8.58	-8.11	-12.1*	-18.80	-25.71	-3.50	-5.68*
58	CS x RL-1359	-2.05	-1.10	-2.55	6.38	9.91	7.84	2.15	-10.69	-6.39	-16.78	-7.46	-7.5**
59	CS 52 x Geeta	-4.78**	-2.59**	-3.16	8.01	11.25	-3.33	-1.36	-12.7*	-18.05	-25.34	-3.82	-6.52*
60	CS 52 x RB-50	-2.73*	-1.97**	-3.25	2.08	16.52	-2.35	-7.07	-12.3*	-23.56	-27.02	2.30	-4.42
61	Pusa Bold x RGN145	-0.82	-0.66	3.24	5.92	4.13	2.01	0.22	-1.81	-14.60	-11.28	1.63	-9.86**
62	Pusa Bold x Kranti	0.95	0.15	0.76	10.78	13.36	2.84	-0.76	-8.47	0.72	4.46	0.54	-6.62**
64	Pusa Bold x Geeta	1.09	0.06	1.67	14.75	17.96	0.69	-0.71	-5.24	-5.16	-0.60	2.62	-6.68**
65	Pusa Bold x RB-50	3.55**	1.14	0.85	3.20	-18.81	-3.04	4.83	-13.17*	-16.72	-8.12	5.49	-10.26**
66	Laxmi x RGN145	-2.19	-2.15**	7.71	23.61	51.28**	12.77	11.14	6.45	32.34	49.14*	4.93	-6.42*
67	Laxmi x Kranti	-1.37	-1.10	-3.44	18.84	32.26	8.23	12.58	-3.63	-12.78	-15.03	-3.17	-6.74**
68	Laxmi x RL-1359	-2.19	-1.74*	3.2	5.26	-6.03	2.48	-2.29	-10.48	-4.87	-9.00	-1.00	-5.8*
69	Laxmi x Geeta	1.09	-0.04	-1.16	8.70	-11.15	1.92	-6.81	2.82	2.34	-4.40	-6.07	-5.26*
71	RH 749 x RGN145	-5.88**	-2.9**	0.93	29.94	25.44	17.43*	9.05	9.07	26.07	27.36	-0.17	-3.00
72	RH 749 x Kranti	1.77	0.52	1.56	20.90	37.44*	2.48	-8.94	-1.81	5.22	11.44	1.33	-2.88
75	RH 749 x RB-50	-9.25**	-5.85**	17.95*	23.79	102.68**	8.65	11.75	16.73**	52.80*	82.92**	13.06*	-1.31
77	NPJ 113 x Kranti	-4.51**	-2.21**	0.01	19.48	52.85**	2.84	0.77	-5.24	-7.78	3.23	6.20	-5.02
78	NPJ 113 x RL-1359	-2.60*	-1.03	-1.90	14.65	28.08	6.59	0.66	-12.3*	4.19	-7.98	-8.25	-8.76**
79	NPJ 113 x Geeta	-3.28*	-0.97	2.21	15.09	21.94	-6.04	-7.40	3.23	-18.92	-14.45	11.34	-3.95
80	NPJ 113 x RB-50	-5.74**	-2.40**	3.01	19.72	19.06	12.09	9.71	-10.48	-10.03	-11.82	-0.05	-1.95
81	PBR 357 x RGN145	1.77	1.26	0.07	9.35	38.82*	5.52	-6.47	15.93**	16.49	26.89	6.27	-5.08*
82	PBR 357 x Kranti	3.82**	1.70*	-1.97	15.73	31.16	4.07	-2.57	-14.31*	11.36	12.24	0.20	-2.90
83	PBR 357 x RL-1359	4.78**	1.70*	0.57	7.71	41.69*	5.67	-3.29	-9.07	-2.96	-0.06	4.95	-5.05*
84	PBR 357 x Geeta	3.14*	0.70	2.82	15.20	29.81	-0.23	2.53	-3.23	-17.62	-15.76	5.51	-3.69
86	NRCDR 2 x RGN145	-0.14	-0.54	1.17	8.23	19.63	11.75	-3.84	-16.94**	-2.73	-13.22	-8.20	-2.87

87	NRCDR 2 x Kranti	-1.37	-0.41	9.38	7.70	50.32**	6.69	-4.17	8.06	-1.82	0.70	1.43	-2.33
88	NRCDR 2 x RL-1359	2.87*	0.77	5.73	5.84	43.49*	2.80	-3.06	-9.68	-7.99	-2.93	4.86	2.05
90	NRCDR 2 x RB-50	1.77	0.46	5.89	24.56	57.35**	9.75	6.43	-14.31*	26.93	10.92	-10.28	-3.75
91	PBR 378 x RGN145	2.73*	0.70	4.77	14.43	48.24**	2.16	0.55	5.24	19.3	17.98	-3.11	-3.92
92	PBR 378 x Kranti	5.46**	1.82*	0.89	-0.45	64.29**	-0.65	-0.81	0.2	-12.55	-5.55	6.25	-2.05
93	PBR 378 x RL-1359	1.91	0.39	1.13	9.44	55.66**	3.12	0.60	-0.2	-9.99	-20.31	-8.41	-1.97
94	PBR 378 x Geeta	2.05	0.64	2.29	7.35	42.75*	-4.83	0.55	-3.63	-1.04	-4.24	2.32	-1.99
96	KDM-10-49 x RGN145	-2.32	-1.16	3.49	0.76	19.89	0.49	-7.84	-7.06	-13.19	-10.21	5.23	-6.13*
97	KDM-10-49x Kranti	-3.14*	-1.97**	-3.98	6.58	14.71	1.37	-8.23	2.42	-17.89	-16.47	5.01	-2.58
98	KDM-10-49 x RL-1359	0.00	-0.41	-2.66	0.19	32.22	-5.89	-3.89	10.28	-12.93	-3.36	7.24	-3.16
99	KDM-10-49 x Geeta	-3.69**	-1.9**	-2.48	2.54	41.33*	-4.95	-11.36	-9.27	-4.81	-4.38	0.55	-3.33
100	KDM-10-49x RB-50	-3.14*	-1.47*	0.24	1.62	39.12*	4.67	1.21	-9.48	-9.62	-2.96	8.74	-1.81
101	RLM 619 x RGN145	2.46	0.58	2.90	14.97	42.85*	-1.99	6.32	-17.54**	5.10	1.00	-3.93	-4.05
102	RLM 619 x Kranti	1.91	0.66	0.27	6.05	18.83	-2.99	-3.50	-8.06	8.55	11.73	2.34	-6.80**
103	RLM 619 x RL-1359	-0.69	-0.48	1.89	6.14	50.71**	2.73	-3.89	-15.52**	-0.94	-6.19	-2.99	-10.62**
104	RLM 619 x Geeta	0.41	-0.41	-2.18	11.66	29.03	6.02	-10.81	-11.49	-5.94	1.92	4.83	-7.63**
105	RLM 619x RB-50	-2.32	-1.41	-0.65	5.05	25.69	-5.79	6.04	-1.81	-7.72	-1.16	6.35	-7.05**
106	Vardan x RGN145	1.64	1.01	16.22*	47.73**	85.88**	27.15**	10.68	17.54**	53.26**	67.45**	6.53	-2.40
107	Vardan x Kranti	-4.87**	-2.21**	15.21*	47.92**	60.06**	24.02**	10.81	24.19**	51.48*	79.32**	12.60*	-3.29
108	Vardan x RL-1359	1.64	0.64	17.18*	36.24*	58.49**	11.75	15.65*	22.38**	46.77*	68.65**	9.25	-3.40
109	Vardan x Geeta	0.68	-0.10	9.39	46.01**	61.60**	7.62	17.30*	9.48	47.63*	55.27**	0.55	-2.15
110	Vardan x RB-50	-5.60**	-3.70**	11.39	42.93**	56.55**	14.21*	18.18*	7.66	51.92*	61.58**	2.74	0.00
111	PCR 7 x RGN145	-0.28	-0.29	-1.42	1.64	42.10*	-6.68	-2.30	10.28	-8.30	-7.14	3.34	-2.37
112	PCR 7 x Kranti	0.41	0.08	-3.62	8.78	33.40	-3.29	-4.11	3.63	-13.59	-3.51	14.48*	-2.58
113	PCR 7 x RL-1359	-0.14	-0.48	-2.07	2.06	22.67	0.83	-7.08	0.20	-26.53	-20.00	7.14	-11.61**
114	PCR 7 x Geeta	0.82	-0.66	1.11	1.55	26.40	-1.14	1.00	-7.86	-17.20	-10.59	5.22	-7.66**
115	PCR 7 x RB-50	0.13	-0.17	3.03	-2.01	28.42	1.42	-2.95	-16.13**	-4.15	-2.01	2.58	-6.49*
116	JMWR-08-3 x RGN145	-3.28*	-2.46**	3.92	-2.96	26.09	1.13	-7.73	-12.50*	-3.35	-5.98	-5.33	-6.37*
117	JMWR-08-3 x Kranti	-3.14*	-2.09**	3.42	-4.74	22.34	3.86	-11.19	-9.68	-1.29	-5.86	-4.35	-4.17
118	JMWR-08-3XRL-1359	-2.60*	-2.15**	0.70	-7.15	20.83	2.43	1.60	6.85	9.03	3.35	-5.57	-5.75*
119	JMWR-08-3 x Geeta	0.27	-0.47	2.14	10.56	58.18**	2.46	-5.59	-14.52*	-1.51	-7.83	-6.33	-10.38**
120	JMWR-08-3 x RB-50	-0.82	-0.54	2.73	17.17	37.15*	0.24	-4.56	-3.23	-6.26	-7.53	-1.73	-7.34**
121	RH-30 x RGN145	-2.01	-1.84*	8.39	23.45	47.57*	11.24	9.08	10.89	45.33*	45.72*	-1.61	-1.34
124	RH-30 x Geeta	-4.64**	-3.08**	6.18	11.31	25.89	10.30	7.14	9.27	25.52	30.73	-2.24	-1.62
125	RH-30 x RB-50	0.13	-0.35	2.08	8.93	18.54	2.26	7.53	13.71*	14.31	13.33	-3.27	-2.06

*, ** Significant at 5% and 1% level of significance, respectively

Similarly, Vardan x RGN-145 reported maximum heterosis for siliqua length through its performance of 27.15%, showing a significant increase over the check followed by Vardan x Kranti (24.02%) and RGN-73 x Kranti (18.17%).

Highest percentage of improvement for number of siliqua per plant over the check variety was reported by RH-749 x RB-50 (102.68%) followed by Vardan x RGN -145 (85.88%) and RGN-73 x Kranti (73.84%). For number of seeds per siliqua, moderate standard heterosis had been reported by various crosses namely, Vardan x RB-50 (18.18%), Vardan x Geeta (17.30%) and RGN-73 x Kranti (17.29%).

In case of seed yield per plant, RH-749 x RB-50 reported the highest standard heterosis of 82.92% followed by Vardan X Kranti (79.32%) and RGN 73 x Kranti (69.65%). None of the hybrids were found to be showing significantly positive heterosis for harvest index and oil content. Similarly, For harvest index, low levels of non significant heterosis to moderate amounts of significantly positive heterosis were reported. RGN-298 x RL-1359 (16.61%), RGN-298 x Kranti (16.19%) and PCR-7 x Kranti (14.48%) reported best performances for harvest index. A small number of crosses reported non significant but positive standard heterosis for oil content viz. RGN-303 x RL-1359 (3.32%), RGN-303 x RB-50 (1.57%) and NRCDR-2 x RL-1359 (2.05%).

In the present study, standard heterosis has been estimated over the best check variety RGN-13. From the performance point of view a few crosses have reported significant standard heterosis for many characters. RGN 73 x Kranti has reported heterosis for most of the traits except plant height, harvest index and oil content; Vardan x Kranti found superiority for all the traits except for number

of seeds per siliqua, harvest index and oil content; Vardan x RB-50 reported significant heterotic effects for all the characters but not for plant height, 100-seed weight, harvest index and oil content and; RH-749 x RB-50 was yet another hybrid with the exception of number of primary branches per plant, siliqua length, harvest index and oil content found superiority for all the traits.

The maximum values of standard heterosis recorded were 82.92% for seed yield per plant while for yield components it was 53.26% for stover yield; 47.92% for number of primary branches per plant; 27.15% for siliqua length; 102.68% for number of siliquae per plant; 18.18% for number of seeds per siliqua; 24.19% for 100-seed weight; -6.13% for days to maturity; -9.25% for days to 50% flowering; and 17.95% for plant height.

In matters of performance for different traits various crosses were found to be giving top performances viz, RH-749 x RB-50, RGN-236 x RGN-145 and RGN-236 x RB-50 have been identified as highly heterotic crosses for days to 50% flowering and days to maturity. Similar results were reported by Gupta, Chaudhary and Lal (2010) and Monpara and Dobariya (2007) for days to 50% flowering and days to maturity from their studies on Indian mustard.

In case of plant height, for which tallness has been considered as a desirable feature, best significant and positive standard heterosis results were reported by RH-749 x RB-50 (17.95%), Vardan x RL-1359 (17.18%) and Vardan x RGN-145 (16.22%). These findings corroborates with the results of Singh, Kumar and Singh (2012) and Meena *et al.*(2014).

For number of primary branches per plant and 100-seed weight, Vardan x Kranti reported best standard heterosis of 47.92% and 24.19% respectively followed by Vardan x RGN-145

(47.73) for number of primary branches per plant and Vardan x RL-1359 for 100-seed weight; showing the superior performance of Vardan for various characters. Findings of similar nature was reported by Gupta, Chaudhary and Lal (2010) for number of primary branches per plant and seed weight and, for seed weight by Tyagi *et al.*, (2000) and Monpara and Dobariya (2007)

Vardan x RGN-145 reported maximum heterosis for siliqua length through their performance of 27.15%, showing a significant increase over the best check followed by Vardan x Kranti (24.02%) and RGN-73 x Kranti (18.17%). Similar findings were reported by Teklewood and Becker (2005) and Monpara and Dobariya (2007). Highest percentage of improvement in performance for number of siliqua per plant over the best check variety was reported by RH-749 x RB-50 (102.68%) followed by Vardan x RGN - 145 (85.88%) and RGN-73 x Kranti (73.84%) showing the superiority of these crosses for this character. These findings are similar to the one reported by the Muhammad (2003) and Aher *et al.*, (2009).

For number of seeds per siliqua, moderate standard heterosis have been reported by various crosses namely, Vardan x RB-50 (18.18%), Vardan x Geeta (17.30%) and RGN-73 x Kranti (17.29%). These findings have also been substantiated by the findings of Tyagi *et al.*, (2000) and Prajapati *et al.*, (2007) as they have also found positive heterosis for number of seeds per siliquae which directly contributes to the positive heterosis for seed yield per plant. In case of seed yield per plant, RH-749 x RB-50 reported the highest standard heterosis of 82.92% followed by Vardan X Kranti (79.32%) and RGN 73 x Kranti (69.65%). None of the hybrids were found to be showing significantly positive heterosis for the traits harvest index and oil content.

Similar to the our findings, moderate to high heterosis and significantly positive results for seed yield have also been reported by Prajapati *et al.*, (2007), Tomar *et al.*, (2014) and Aher *et al.*, (2009).

For harvest index, low levels of non significant heterosis to moderate amounts of significantly positive heterosis were reported. RGN-298 x RL-1359 (16.61%), RGN-298 x Kranti (16.19%) and PCR-7 x Kranti (14.48%) reported best performances for harvest index.

These findings have been substantiated by the findings of Prajapati *et al.*, (2007) and Tyagi *et al.*, (2000) since, they also reported moderate amount of positive heterosis for harvest index. Standard heterosis results for oil content were found to be significantly negative for a few hybrids, where positively significant heterosis for oil content would have been a desirable feature. Nonetheless, a small number of crosses have reported non significant but positive standard heterosis for this trait viz. RGN-303 x RL-1359 (3.32%), RGN-303 x RB-50 (1.57%) and NRCDR-2 x RL-1359 (2.05%). Results of this nature for oil content have also been reported by Prajapati *et al.*, (2007), as low levels of non significant heterotic improvements for oil content were registered by them also.

In almost all the characters variable number of crosses depicted standard heterosis in both positive and negative direction, indicating that genes with negative as well as positive effects were dominant. This show of unpredictability highlights the role of non additive gene actions, which in turn may be due to dominance and/or epistasis.

In conclusion through the study it emerges that a few crosses reported significant standard heterosis for many characters. RGN 73 x Kranti reported heterosis for most of the

traits except for plant height, harvest index and oil content; Vardan x Kranti found superiority for all the traits except for number of seeds per siliqua, harvest index and oil content; Vardan x RB-50 reported significant heterotic effects for all the characters but not for plant height, 100-seed weight, harvest index and oil content and; RH-749 x RB-50 was yet another hybrid with the exception of number of primary branches per plant, siliqua length, harvest index and oil content found superiority for all the traits. These crosses can be utilized for further development of superior cultivars of Indian mustard.

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