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Estimation of Heterobeltiosis for Yield and its Contributing Characters in Taramira (*Eruca sativa* Mill.) Under Irrigated and Drought Condition

Rajdeep Mundiyara[1*], M. L. Jakhar[1] and Rahul Bhardwaj[2]

[1]Department of Plant Breeding and Genetics, SKN College of Agriculture (SKNAU), Jobner (Raj.) India

[2]Department of Plant Breeding and Genetics, Rajasthan Agriculture Research Institute, Durgapura (SKNAU), Jobner 303329 (Raj.) India

*Corresponding Author E-mail: rmundiyara5@gmail.com

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ABSTRACT

The Eight genetically diverse open pollinated populations were crossed in all possible combination (excluding reciprocals) during Rabi season of 2013-2014 in a varietal diallel fashion. The resultant 28 F_1 progenies along with eight parents were evaluated in RBD with four environments with 3 replications during, Rabi 2014-15 at the Agricultural Research Farm of S.K.N. College of Agriculture, Jobner.

In the present investigation, highly heterotic crosses RTM-1351 x RTM-314, RTM-314 x RTM-1359, RTM-1415 X RTM-2002 and T-27 x RTM-2002 in all the four environments, were desirable as they had high seed yield per plant, with high heterobeltiosis not only for seed yield per plant but for some than the other yield traits studied. For seed yield per plant, cross T-27 x RTM-2002 and RTM-1415 x RTM-2002 showed significant with high positive heterobeltiosis in all the four environments, while, cross RTM-1375 x RTM-1212 showed significant with high positive heterobeltiosis in environments- I, cross RTM-2002 x RTM-1359 showed significant with high positive heterobeltiosis in environment II, cross T-27 x RTM-1351 showed significant with high positive heterobeltiosis in environment III, cross RTM-1415 x RTM-2002 showed significant with high positive heterobeltiosis in environment IV. For oil content, cross T-27 x RTM-1351 and RTM-1212 x RTM-2002 showed significant with high positive heterobeltiosis in environment-I, while, cross RTM-1351 x RTM-2002 showed significant with high positive heterobeltiosis in environments-II, cross RTM-2002 x RTM-314 and cross T-27 x RTM-2002 showed significant with high positive heterobeltiosis in environment III, cross T-27 x RTM-1212 and cross RTM-1212 x RTM-2002 showed significant with high positive heterobeltiosis in environment IV.Development of inbreds is at present is not feasible because of sporophytic self-incompatibility. Parents RTM-1375, RTM-1415, RTM-314, T-27 and RTM-1359 can be used in population improvement to develop high yielding synthetic varieties having high seed yield and oil content.

Key words: *Varietal diallel, Heterobeltiosis, Taramira, Eruca sativa.*

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INTRODUCTION

Taramira is a highly drought tolerant crop, it can be successfully grown as a rainfed crop even on soils with moderate water retaining capacity. The oil content ranges from 31.6-41.31 per cent which is affected by manuring, irrigation and disease management. It is important winter season oil seed crop of the family Brassicaceae. It is an introduced crop in India and successfully grown on dry land areas of north-west India on poor sandy soils with conserved moisture. It has sporophytic type of self-incompatibility therefore; highly cross-pollinated crop[15]. However, the crop has limited improved varieties adapted to wide agro-climatic conditions. Taramira oil is mainly used in adulteration of mustard oil to increase pungency. The cake is used as manure for improving the soil physical condition and soil fertility and it can also be used as nutritional feed for animals Heterosis breeding could be a potential alternative for achieving quantum jump in production and productivity of crop plants. Commercial exploitation of heterosis has not been made in taramira for want of adequate information on extent of heterosis; therefore, it is necessary to examine magnitude of heterosis in taramira. The magnitude of heterobeltiosis particularly for seed yield is of paramount importance and if the exploitation of heterosis is practically and economically feasible it can help to reach high field levels in taramira.

MATERIALS AND METHODS

The eight genetically diverse open pollinated populations were crossed in all possible combination (excluding reciprocals) during *Rabi* season of 2013-2014 in a varietal diallel fashion. 10-15 plants randomly selected in a variety were crossed with a number of randomly selected plants from other parent so that a population crosses were obtained. The resulting 28 F_1 s along with parents were sown in randomized block design under 4 environments during the season (2014-15) as detailed below- Normal date of sowing (17.10.2014) with two irrigations, designated as E-I, Normal date of sowing (17.10.2014) with conserved moisture, designated as E-II, In late sowing (5.11.2014) with one irrigations, designated as E-III, In late sowing (5.11.2014) with conserved moisture, designated as E-IV, in each of the above environments, the whole set of experimental material was planted in 3 replication at the Agricultural Research Farm of S.K.N. College of Agriculture, Jobner. Non-experimental rows were planted all around the experiment to eliminate the border effects, if any. Observations on various morphological traits were noted. The data were subjected to the varietal diallel analysis as suggested by Gardner and Eberhart (1966) method II.

RESULTS AND DISCUSSION

The possibility of commercial exploitation of hybrid vigour depends on the magnitude of heterosis. The superiority of hybrid over better parent might be either due to dominance or epistasis or over dominance or combined effect of these.

Heterosis breeding could be a potential alternative for achieving quantum jump in production and productivity of crop plants. Commercial exploitation of heterosis has not been made in taramira of adequate information on extent of heterosis; therefore, it is necessary to examine magnitude of heterosis in taramira. The magnitude of heterosis particularly for seed yield is of paramount importance and if the exploitation of heterosis is practically and economically feasible it can help to reach high field levels in taramira. In taramira, we require tall plant, more number of primary branches per plant, secondary branching per plant, siliquae per plant, higher siliqua length, test weight, seed yield per plant and oil content. Varieties should be early flower and early mature. In the present investigation, heterobeltiosis for most of the characters studied (Table 1 to 6).

Heterobeltiosis for different environments

The extent of heterobeltiosis were estimated as percents, for all the characters under individual environment and results were presented in (Table 1 to 6) character wise results are describe below-

Environment-I

Out of 28 crosses, for seed yield per plant significant positive (desirable) heterobeltiosis was observed in 12 crosses, for plant height in 20 cross (desirable tallness), for primary branches per plant 7 crosses, for secondary branches per plant 11 crosses, for siliquae per plant 3 crosses, for siliqua length in 12 cross, for number of seeds per siliqua in 6 cross, for test weight in 11 crosses and for oil content in 5 crosses, for days to flowering in 2 crosses and days to maturity 2 crosses exhibited significant negative with desirable heterobeltiosis.

Environment-II

Out of 28 crosses, for seed yield per plant significant, positive (desirable) heterobeltiosis were observed in 11 crosses, for plant height in 13 crosses (desirable tallness), for primary branches per plant in 4 crosses, for secondary branches per plant in 13 crosses, for siliquae per plant in 3 crosses, for siliqua length in 5 crosses, for number of seeds per siliqua in 7 crosses, for test weight in 12 crosses and for oil content only 1 crosses.

Environment-III

Out of 28 crosses, for seed yield per plant significant positive (desirable) heterobeltiosis was observed in 6 crosses, for plant height in 12 crosses (desirable tallness), for primary branches per plant in 7 crosses, for secondary branches per plant in 9 crosses, for siliquae per plant in 2 crosses, for siliqua length in 5 crosses, for number of seeds per siliqua in 4 crosses, for test weight in 6 crosses and for oil content in 3 crosses.

Environment-IV

Out of 28 crosses, for seed yield per plant significant positive (desirable) heterobeltiosis was observed in 14 crosses, for plant height in 11 crosses (desirable tallness), for primary branches per plant in 3 crosses, for secondary branches per plant in 10 crosses, for siliquae per plant in 6 crosses, for siliqua length in 12 crosses, for number of seeds per siliqua in 8 crosses, for test weight in 7 crosses and for oil content in only 1 cross.

Thus, in the present investigation, high degree of desirable heterobeltiosis observed for most of the traits indicated the scope for exploitation of heterosis at commercial level in taramira crop for different quantitative and qualitative characters. Significant positive heterosis over better parent for seed yield per plant reported by Patel *et al*.[9] in Indian mustard. Heterosis over better parent (heterobeltiosis) for seed yield and its components were also reported by Pradhan *et al*.[10], Gupta *et al*.[5], Gupta *et al*.[3], Rai and Singh[11], Nehra and Sastry[8], Thakur and Sagwal[16], Verma *et al*.[17], Yadav *et al*.[19], Dar *et al*.[1], Verma *et al*.[18], Singh *et al*.[14] for seed yield per plant, number of siliquae on main raceme, and length of main raceme in all crosses except days to flowering and plant height and number of secondary branches per plant, Gami and Chauhan[2] for oil content, Gupta *et al*.[4], Meena *et al*.[7] and Saini *et al*.[13], heterobeltiosis were reported by Ranjeet and Shweta[12] and Kumar *et al*.[6].

The top three crosses having desirable heterobeltiosis for each of the characters are summarized in Table 7. For seed yield per plant, cross T-27 x RTM-2002 and RTM-1415 x RTM-2002 showed significant with high positive heterobeltiosis in all the four environments, while, cross RTM-1375 x RTM-1212 showed significant with high positive heterobeltiosis in environments- I, cross RTM-2002 x RTM-1359 showed significant with high positive heterobeltiosis in environment II, cross T-27 x RTM-1351 showed significant with high positive heterobeltiosis in environment III, cross RTM-1415 x RTM-2002 showed significant with high positive heterobeltiosis in environment IV. For oil content, cross T-27 x RTM-1351 and RTM-1212 x RTM-2002 showed significant with high positive heterobeltiosis in environment-I, while, cross RTM-1351 x RTM-2002 showed significant with high positive heterobeltiosis in environments-II, cross RTM-2002 x RTM-314 and cross T-27 x RTM-2002 showed significant with high positive heterobeltiosis in environment III, cross T-27 x RTM-1212 and cross RTM-1212 x RTM-2002 showed significant with high positive heterobeltiosis in environment IV.

Table 1: Average per cent heterobeltiosis (BP) for characters in all environments

Parents/F_1s	Days to flowering (a) and Days to maturity (b)							
	Environment I		Environment II		Environment III		Environment IV	
	BP (a)	BP (b)	BP (a)	BP (b)	BP (a)	BP (b)	BP (a)	BP (b)
P1 x P2	0.63	0.71	5.67	1.70**	2.08	0.74	4.72*	-0.25
P1 x P3	9.52**	0.00	-1.29	0.74	0.70	-0.25	0.00	-1.75
P1 x P4	-3.16	-0.24	1.34	-0.49	-0.70	-0.99	5.60*	-1.75
P1 x P5	6.12*	0.72	3.42	0.25	2.11	0.74	-3.03	-1.25
P1 x P6	0.00	-1.44	4.20	-0.49	-3.52	-0.98	0.76	-0.50
P1 x P7	-4.40	0.48	-4.58	-0.98	2.11	-2.21	4.76*	3.24**
P1 x P8	1.31	-0.24	0.00	-2.17	0.00	-0.74	-2.99	-2.49
P2 x P3	-1.90	0.71	-5.81	-1.70	-5.56	-0.50	3.10	-1.25
P2 x P4	-5.06	-1.65	10.07**	1.46*	-4.86	0.25	4.72*	0.00
P2 x P5	-1.90	-2.84	2.05	-0.73	0.69	-0.74	-2.27	0.00
P2 x P6	0.00	-3.07	4.90	-0.73	-2.78	-0.98	-2.27	0.00
P2 x P7	-3.77	-2.36	-2.61	-1.70	-2.78	-0.98	2.36	-1.00
P2 x P8	-1.90	-2.36	-4.03	-2.66	-4.86	-0.50	-2.99	-0.25
P3 x P4	2.53	-0.48	-7.10	-0.25	4.26	1.75*	-3.10	-0.75
P3x P5	4.11	-0.24	-4.52	0.25	-2.13	2.00**	1.52	-0.50
P3 x P6	13.16**	-1.45	-7.74	0.25	2.84	0.00	-0.76	-1.00
P3 x P7	-3.14	1.69*	-3.23	-0.25	2.84	-0.74	-2.33	-1.00
P3 x P8	1.96	-0.24	-2.58	1.21	0.00	0.50	-0.75	-0.25
P4 x P5	-2.53	-0.48	5.37	-0.98	6.67**	0.75	1.52	0.00
P4 x P6	-0.63	-2.40	-4.70	-0.98	3.68	-2.21	0.00	0.76
P4 x P7	1.26	-0.96	-0.65	-0.74	6.82**	-0.98	3.97	-0.50
P4 x P8	-4.43	0.24	2.68	-2.17	5.97*	0.75	-0.75	-0.25
P5 x P6	8.45	0.97	0.68	3.99**	5.19	1.51	-2.27	-0.25
P5 x P7	5.26	0.48	-3.42	2.48**	3.68	-0.25	1.52	0.00
P5 x P8	-3.77	0.00	-5.23	-0.25	7.41**	-0.49	-9.09	-1.00
P6 x P7	-2.52	1.46*	-3.27	-0.25	6.62**	-0.49	-1.52	0.25
P6 x P8	1.31	0.24	0.67	-0.72	5.15*	0.25	-4.48	0.50
P7 x P8	-1.26	-0.71	-0.65	0.00	8.96**	0.49	-1.49	-0.25
SEm $\pm$	1.604	0.945	1.495	0.900	1.019	0.913	0.906	0.854

*** Significant at p=0.05 and ** Significant at p=0.01**

V_1 = T-27, V_2 = RTM-1351, V_3 = RTM-1375, V_4=RTM -1415, V_5 = RTM-1212, V_6 = RTM-2002, V_7 = RTM-314, V_8 = RTM-1359

Table 2: Average per cent heterobeltiosis (BP) for characters in all environments

Parents/F_1s	Plant height (a) and Primary branches per plant (b)							
	Environment I		Environment II		Environment III		Environment IV	
	BP (a)	BP (b)	BP (a)	BP (b)	BP (a)	BP (b)	BP (a)	BP (b)
P1 x P2	6.04**	3.13	2.40	-26.67	0.97	-22.73	-0.89	-27.08
P1 x P3	8.63**	-2.50	1.04	-16.00	2.47	-16.35	-1.50	-17.69
P1 x P4	-1.15	7.69	3.82	-7.14	8.01**	-23.49	-4.37	-31.85
P1 x P5	6.48**	-9.38	9.14**	-2.58	9.13**	-8.05	10.65**	-7.45
P1 x P6	8.74**	20.63**	11.22**	-11.33	9.01**	17.53**	5.20**	-6.67
P1 x P7	4.27*	-4.37	-5.00	-11.76	-5.59	-2.58	-3.69	-3.38
P1 x P8	-2.69	-3.12	-6.24	-1.95	-6.90	-4.38	-8.66	-1.32
P2 x P3	5.08**	9.74*	4.09*	6.76	0.80	-6.92	-2.12	-6.80
P2 x P4	1.80	-3.55	3.05	0.65	2.89	0.00	-2.29	-2.55
P2 x P5	4.50*	22.44**	-0.69	19.35**	-6.07	14.37**	-8.35	16.15**
P2 x P6	24.51**	6.54	8.51**	15.67**	2.64	11.76**	1.19	5.33
P2 x P7	8.94**	-7.19	7.41**	-16.99	-0.77	-6.45	0.13	-8.11
P2 x P8	-0.97	5.23	1.60	-5.19	-3.34	8.75**	-1.19	-0.66
P3 x P4	2.03	-17.16	-0.40	5.84	-3.29	1.81	-8.43	-24.84
P3x P5	22.81**	32.05**	-5.06	6.45	4.07*	14.37**	-12.06	-18.63
P3 x P6	14.20**	-5.19	4.46*	-5.41	6.33**	-10.06	3.12*	-2.67
P3 x P7	8.30**	-5.84	5.20**	-1.96	6.81**	-7.55	4.52**	-3.38
P3 x P8	5.90**	-7.14	-2.30	-15.58	-2.28	-11.88	-2.05	-10.53
P4 x P5	6.72**	1.78	12.00**	5.16	16.14**	-1.72	5.88**	1.86
P4 x P6	4.13*	7.69	7.33**	10.39**	10.39**	11.45**	1.31	8.92*
P4 x P7	14.03**	1.78	16.16**	5.84	19.81**	5.42	9.48**	2.55
P4 x P8	-7.37	11.83**	-2.11	14.29**	-1.65	6.02	0.96	9.55*
P5 x P6	14.81**	1.28	23.08**	0.00	23.86**	-4.60	20.99**	-6.21
P5 x P7	16.55**	12.18**	16.18**	-18.06	14.88**	-5.75	12.69*	-25.47
P5 x P8	9.71**	2.56	9.86	0.00	6.90	-5.17	13.18**	-4.97
P6 x P7	1.78	8.50	2.80	4.58	0.97	7.10*	3.69*	4.67
P6 x P8	9.81**	12.68**	4.80*	1.95	5.06**	0.63	4.59**	0.66
P7 x P8	-0.03	4.58	2.02	0.00	-0.34	-1.87	2.34	2.63
SEm ±	1.830	0.239	1.922	0.199	1.420	0.154	1.345	0.174

*** Significant at p=0.05 and ** Significant at p=0.01**

V_1 = T-27, V_2 = RTM-1351, V_3 = RTM-1375, V_4=RTM -1415, V_5 = RTM-1212, V_6 = RTM-2002, V_7 = RTM-314, V_8 = RTM-1359

Table 3: Average per cent heterobeltiosis (BP) for characters in all environments

Parents/F_1s	Secondary branches per plant (a) and Siliqua per plant (b)							
	Environment I		Environment II		Environment III		Environment IV	
	BP (a)	BP (b)	BP (a)	BP (b)	BP (a)	BP (b)	BP (a)	BP (b)
P1 x P2	-3.42	-8.87	-21.94	-13.34	-19.53	-20.78	3.07	-15.75
P1 x P3	8.55**	-21.47	-30.48	-22.54	-29.88	-49.29	-28.83	-15.39
P1 x P4	-18.80	0.90	-21.08	-9.28	-19.82	-8.99	-4.00	-5.07
P1 x P5	-9.40	-10.13	-11.68	-10.62	-2.66	-7.26	10.27**	-7.60
P1 x P6	-12.67	-7.41	-10.83	4.68	-4.73	3.72	-10.48	4.86
P1 x P7	-2.85	-6.62	-3.13	-1.71	-2.07	2.78	5.26*	4.25
P1 x P8	3.42	-13.84	1.42	-3.38	1.78	-7.64	5.10*	-6.58
P2 x P3	-16.18	-21.87	-15.63	-21.69	-15.71	-20.56	-14.72	-12.50
P2 x P4	16.84**	-0.15	13.49*	-14.37	13.52**	-11.81	13.45**	-11.09
P2 x P5	10.86**	15.21**	8.33**	8.69*	8.42*	3.42	8.22**	8.73**
P2 x P6	-1.35	-5.94	20.62**	-0.76	14.48**	-5.11	-6.52	6.37*
P2 x P7	10.42**	40.56**	25.28**	-21.01	4.40	-21.34	5.92*	-11.88
P2 x P8	1.45	-7.39	25.28**	1.42	3.43	-2.10	3.50	6.93*
P3 x P4	7.51*	3.88	-25.37	-22.38	22.36**	-22.56	-29.75	-21.46
P3x P5	10.12**	7.39	-13.27	-23.24	-11.18	-19.92	-12.27	-12.03
P3 x P6	0.54	-8.39	7.08*	-8.49	6.95	-9.56	-0.57	1.88
P3 x P7	3.47	-29.36	-14.16	-28.98	-13.90	9.00	-14.72	-12.07
P3 x P8	7.80*	-8.67	6.49	-4.33	6.04	-0.36	5.21*	10.60**
P4 x P5	12.78**	-6.10	12.67**	-12.67	13.47**	-11.61	13.01**	-6.48
P4 x P6	-4.31	-4.97	18.21**	-3.28	12.12**	-3.68	-8.50	-2.32
P4 x P7	7.82*	-6.48	11.76**	-7.51	-1.89	-7.38	-0.33	-7.34
P4 x P8	-8.72	-6.78	5.54	-5.27	-4.36	-7.02	-4.14	-8.77
P5 x P6	2.88	4.09	2.00	2.96	0.34	-1.98	0.34	0.61
P5 x P7	-8.89	-12.07	10.00**	-0.56	9.76*	-2.69	-9.63	-2.14
P5 x P8	0.00	-14.58	0.33	-10.53	-7.55	-6.83	-5.92	-6.11
P6 x P7	-7.28	-7.05	15.81**	-3.68	2.83	2.88	-8.78	4.87
P6 x P8	11.05**	-6.09	35.40**	47.43**	20.87**	23.58**	7.37**	14.72**
P7 x P8	7.56*	14.45**	33.96**	14.04**	9.66*	14.38*	9.24**	9.96**
SEm $\pm$	0.360	6.895	0.372	4.411	0.357	3.070	0.234	3.006

*** Significant at p=0.05 and ** Significant at p=0.01**

V_1 = T-27, V_2 = RTM-1351, V_3 = RTM-1375, V_4=RTM -1415, V_5 = RTM-1212, V_6 = RTM-2002, V_7 = RTM-314, V_8 = RTM-1359

Table 4: Average per cent heterobeltiosis (BP) for characters in all environments

Parents/F_1s	Siliqua length (a) and Number of seeds/ siliqua (b)							
	Environment I		Environment II		Environment III		Environment IV	
	BP (a)	BP (b)	BP (a)	BP (b)	BP (a)	BP (b)	BP (a)	BP (b)
P1 x P2	-9.78	-6.23	-1.10	5.29	0.77	6.30	-3.59	3.53
P1 x P3	12.33**	-9.41	4.92	-4.18	6.21	-15.61	12.33**	-5.00
P1 x P4	27.61**	4.35	3.20	-10.80	1.03	0.00	22.09**	-11.01
P1 x P5	8.81	12.52**	2.95	29.20**	-11.90	23.64**	8.81*	30.64**
P1 x P6	8.42	-3.69	8.81*	3.54	7.25	-0.35	8.42	13.57**
P1 x P7	-1.03	10.78**	5.60	-1.93	-20.47	8.93*	-1.03	-9.61
P1 x P8	15.09*	4.82	-16.77	-16.28	-26.68	7.62	-22.46	-18.81
P2 x P3	-8.18	-5.84	-7.45	-3.66	-4.14	-18.93	-6.54	-2.41
P2 x P4	-8.03	-16.15	-12.40	-4.23	-24.45	-11.17	-5.97	-3.98
P2 x P5	-4.97	14.82**	-14.48	-12.87	-25.44	13.79**	-4.97	-6.61
P2 x P6	4.09	16.64**	-13.84	-16.05	18.51**	-12.66	-5.11	-11.92
P2 x P7	8.61	4.53	17.57**	1.93	-1.28	7.77	9.09*	3.71
P2 x P8	24.82**	-4.91	4.94	-2.47	13.40**	-1.60	-13.77	-5.25
P3 x P4	17.53**	0.31	6.53	11.85**	13.13**	-2.75	17.53**	8.79**
P3x P5	10.09	-10.18	5.23	-10.10	4.78	-19.08	10.09*	-6.03
P3 x P6	24.96**	-8.85	0.28	-6.97	23.31**	-18.64	24.96**	-14.31
P3 x P7	-5.57	9.85**	-16.03	23.00**	-7.33	-10.98	-5.57	7.59*
P3 x P8	26.60**	-6.43	13.36**	32.58**	16.62**	1.01	23.48**	21.02**
P4 x P5	-9.52	-13.04	-8.40	0.72	0.58	-15.86	-9.52	0.52
P4 x P6	2.25	-0.16	-18.80	13.49**	-3.60	2.75	-4.93	12.77**
P4 x P7	-8.80	-13.20	-7.60	-4.73	-21.28	-9.87	-8.80	-5.73
P4 x P8	26.98**	0.62	-2.40	13.49**	-13.90	4.69	20.72**	8.31*
P5 x P6	18.61**	-3.75	-31.23	-2.04	-36.29	-3.81	-14.49	-1.28
P5 x P7	21.88**	-5.00	5.36	-5.32	-11.09	-8.53	21.88**	-5.69
P5 x P8	-11.51	0.50	-19.97	0.70	-14.19	-0.88	-4.40	2.19
P6 x P7	12.17*	-5.03	18.66**	-5.43	-10.47	-2.83	12.17*	-6.41
P6 x P8	29.73**	7.95*	16.02**	12.41**	-8.12	9.98*	23.33**	11.53**
P7 x P8	2.49	0.34	2.84	1.93	-18.95	-0.53	1.30	-1.35
SEm ±	0.121	0.655	0.087	0.644	0.112	0.672	0.090	0.527

*** Significant at p=0.05 and ** Significant at p=0.01**

V_1 = T-27, V_2 = RTM-1351, V_3 = RTM-1375, V_4=RTM -1415, V_5 = RTM-1212, V_6 = RTM-2002, V_7 = RTM-314, V_8 = RTM-1359

Table 5: Average per cent heterobeltiosis (BP) for characters in all environments

Parents/F$_1$s	Seed yield per plant (a) and Test weight (b)							
	Environment I		Environment II		Environment III		Environment IV	
	BP (a)	BP (b)	BP (a)	BP (b)	BP (a)	BP (b)	BP (a)	BP (b)
P1 x P2	22.14*	7.75	26.72**	8.36*	26.04**	15.55*	20.12**	5.84
P1 x P3	7.84	-0.86	-7.18	-3.01	0.32	7.34	-3.73	2.59
P1 x P4	25.87*	16.93**	0.42	4.61	21.79**	0.89	-6.24	-2.22
P1 x P5	7.53	3.56	8.46	-0.92	1.56	-6.26	16.32*	-0.65
P1 x P6	60.73**	-5.25	55.65**	-3.48	35.81**	-14.70	68.16**	-3.06
P1 x P7	39.37**	3.29	-11.76	-3.29	-15.35	-11.32	5.81	2.69
P1 x P8	-6.04	5.79	22.72**	9.77**	-44.36	1.79	-29.28	12.97
P2 x P3	16.98	7.88	17.18**	7.94*	16.02*	16.18*	22.05**	24.74**
P2 x P4	-1.26	1.44	13.39**	9.67**	12.39	13.03*	2.64	7.56
P2 x P5	21.58*	14.67**	-5.90	13.28**	-23.62	1.18	-18.61	34.85**
P2 x P6	10.80	31.31**	-12.56	8.00*	0.16	-11.45	-14.63	1.22
P2 x P7	50.77**	7.42	4.18	5.56	8.86	-8.98	30.32**	25.48**
P2 x P8	-18.67	3.58	23.15**	9.94**	-13.97	-12.24	-0.70	5.16
P3 x P4	16.85	24.89**	16.90**	-4.68	10.30	-2.56	21.14**	-3.84
P3x P5	35.40**	4.20	4.72	10.20**	-13.45	1.25	-10.49	24.27**
P3 x P6	31.72**	-1.46	-5.92	-2.68	-14.99	0.08	-0.30	-2.34
P3 x P7	-6.89	-3.60	-21.06	-8.11	-11.92	-11.69	-0.38	6.84
P3 x P8	1.21	-1.46	12.82**	-1.34	2.57	14.59*	2.13	0.09
P4 x P5	2.08	22.44**	2.63	5.92	-1.95	-3.83	4.10	7.86
P4 x P6	36.06**	28.11**	55.76**	2.23	31.72**	-7.35	45.92**	-6.01
P4 x P7	15.76	15.07**	-9.00	20.32**	-3.68	-2.19	25.44**	40.20**
P4 x P8	0.36	7.03	42.20**	12.42**	4.90	13.12*	42.84**	7.96
P5 x P6	-1.00	45.29**	-0.07	1.37	-5.84	13.19*	10.25	4.88
P5 x P7	20.43*	17.90**	-12.30	19.36**	3.89	-1.47	20.66**	18.87**
P5 x P8	21.65*	8.41**	2.65	-0.34	-0.50	-9.79	33.75**	11.17
P6 x P7	-10.09	-7.22	2.00	-13.58	-11.42	-19.07	28.87**	-8.73
P6 x P8	1.39	0.00	45.28**	-5.53	3.92	-16.79	22.39**	-5.07
P7 x P8	16.86*	12.89**	-4.53	13.41**	24.26**	-4.75	48.41**	17.31*
SEm ±	0.309	0.193	0.198	0.132	0.262	0.218	0.199	0.216

*** Significant at p=0.05 and ** Significant at p=0.01**

V_1 = T-27, V_2 = RTM-1351, V_3 = RTM-1375, V_4=RTM -1415, V_5 = RTM-1212, V_6 = RTM-2002, V_7 = RTM-314, V_8 = RTM-1359

Table 6: Average per cent heterobeltiosis (BP) for characters in all environments

Parents/ F_1s	Oil content			
	Environment I	Environment II	Environment III	Environment IV
	BP	BP	BP	BP
P1 x P2	1.36*	1.25	0.76	-0.29
P1 x P3	-0.25	-2.75	-0.16	2.70
P1 x P4	-0.59	1.09	1.38	0.41
P1 x P5	-4.64	-5.32	-6.29	3.26*
P1 x P6	-2.04	0.33	2.91*	-1.13
P1 x P7	-3.21	-1.69	-1.87	-1.77
P1 x P8	-2.48	-1.24	-1.87	1.85
P2 x P3	-0.15	-3.30	-0.80	1.95
P2 x P4	1.46*	0.21	2.48	2.85
P2 x P5	-1.54	-1.38	-2.32	-3.73
P2 x P6	0.72	3.46*	2.22	2.06
P2 x P7	-2.69	-1.77	-2.53	-4.87
P2 x P8	-1.73	-2.20	-1.56	-1.50
P3 x P4	0.23	-0.06	1.24	2.89
P3x P5	-3.20	-2.68	-2.75	1.53
P3 x P6	-1.78	-1.63	-0.98	-2.04
P3 x P7	-4.28	-3.55	-3.14	-2.50
P3 x P8	-1.78	-1.74	-1.90	0.25
P4 x P5	-0.30	-1.70	-1.85	3.37
P4 x P6	-0.42	0.43	0.17	-0.50
P4 x P7	-3.40	-3.54	-2.19	-6.37
P4 x P8	-2.07	-1.67	-0.73	3.35
P5 x P6	1.49*	-0.33	-0.87	8.19**
P5 x P7	-1.75	-2.74	-3.94	-0.32
P5 x P8	0.99	2.12	0.73	-1.18
P6 x P7	0.37	2.23	2.91*	2.08
P6 x P8	-1.64	-0.89	-1.81	0.01
P7 x P8	-1.95	-2.69	-2.23	1.08
SEm ±	0.472	0.565	0.507	0.771

*** Significant at p=0.05 and ** Significant at p=0.01**

V_1 = T-27, V_2 = RTM-1351, V_3 = RTM-1375, V_4=RTM -1415, V_5 = RTM-1212, V_6 = RTM-2002, V_7 = RTM-314, V_8 = RTM-1359

Table 7: Top crosses showing high significant desirable magnitude of better parent heterosis in all the environments

Characters	Heterosis Over better parent (BP)			
	I	**II**	**III**	**IV**
Plant height (cm)	RTM-1351 x RTM-2002 (24.51) RTM-1375 x RTM-1212 (22.81) RTM-1212 x RTM-314 (16.55)	RTM-1212 x RTM-2002 (23.08) RTM-1212 x RTM-314 (16.18) RTM-1415 x RTM-314 (16.16)	RTM-1212 x RTM-2002 (23.86) RTM-1415 x RTM-314 (19.81) RTM-1415 x RTM-1212 (16.14)	RTM-1212 x RTM-2002 (20.99) RTM-1212 x RTM-1359 (13.18) RTM-1212 x RTM-314 (12.69)
Primary branches per plant	RTM-1375 x RTM-1212 (32.05) RTM-1351 x RTM-1212 (22.44) T-27 x RTM-2002 (20.63)	RTM-1351 x RTM-1212 (19.35) RTM-1351 x RTM-2002 (15.67) RTM-1415 x RTM-1359 (14.29)	T-27 x RTM-2002 (17.53) RTM-1351 x RTM-1212 (14.37) RTM-1375 x RTM-1212 (14.37) RTM-1351 x RTM-1212 (16.15)	RTM-1351 x RTM-1212 (16.15) RTM-1415 x RTM-1359 (9.55) RTM-1415 x RTM-2002 (8.92)
Secondary branches per plant	RTM-1351 x RTM-1415 (16.84) RTM-1415 x RTM-1212 (12.78) RTM-2002 x RTM-1359 (11.05)	RTM-2002 x RTM-1359 (35.40) RTM-314 x RTM-1359 (33.96) RTM-1351 x RTM-314 (25.28)	RTM-1375 x RTM-1415 (22.36) RTM-2002 x RTM-1359 (20.87) RTM-1351 x RTM-2002 (14.48)	RTM-1351 x RTM-1415 (13.45) RTM-1415 x RTM-1212 (13.01) T-27 x RTM-1212 (10.27)
Siliquae per plant	RTM-1351 x RTM-314 (40.56) RTM-314 x RTM-1359 (14.45) RTM-1351 x RTM-1212 (15.21)	RTM-2002 x RTM-1359 (47.43) RTM-314 x RTM-1359 (14.04) RTM-1351 x RTM-1212 (8.69)	RTM-2002 x RTM-1359 (23.58) RTM-314 x RTM-1359 (14.38)	RTM-2002 x RTM-1359 (14.72) RTM-1375 x RTM-1359 (10.60) RTM-314 x RTM-1359 (9.96)
Siliqua length (cm)	RTM-2002 x RTM-1359 (29.73) T-27 x RTM-1415 (27.61) RTM-1415 x RTM-1359 (26.98)	RTM-2002 x RTM-314 (18.66) RTM-1351 x RTM-314 (17.57) RTM-2002 x RTM-1359 (16.02)	RTM-1375 x RTM-2002 (23.61) RTM-1351 x RTM-2002 (18.61) RTM-1375 x RTM-1359 (16.62)	RTM-1375 x RTM-2002 (24.96) RTM-1375 x RTM-1361 (23.48) RTM-2002 x RTM-1359 (23.33)
Number of seeds per siliqua	RTM-1351 x RTM-2002 (16.64) RTM-1351 x RTM-1212 (14.82) T-27 x RTM-1212 (12.52)	RTM-1375 x RTM-1359 (32.58) T-27 x RTM-1212 (29.20) RTM-1375 x RTM-314	T-27 x RTM-1212 (23.64) RTM-1351 x RTM-1212 (13.79) RTM-2002 x RTM-1359 (9.98)	T-27 x RTM-1212 (30.64) RTM-1375 x RTM-1359 (21.02) T-27 x RTM-2002 (13.57)
Seed yield per plant (g)	T-27 x RTM-2002 (60.73) RTM-1415 x RTM-2002 (36.06) RTM-1375 x RTM-1212 (35.40)	RTM-1415 x RTM-2002 (55.76) T-27 x RTM-2002 (55.65) RTM-2002 x RTM-1359	T-27 x RTM-2002 (35.81) RTM-1415 x RTM-2002 (31.72) T-27 x RTM-1351 (26.04)	T-27 x RTM-2002 (68.16) RTM-314 x RTM-1359 (48.41) RTM-1415 x RTM-2002 (45.92)
Test weight (g)	RTM-1212 x RTM-2002 (45.29) RTM-1415 x RTM-2002 (28.11) RTM-1415 x RTM-1212 (22.44)	RTM-1415 x RTM-314 (20.32) RTM-1212 x RTM-314 (19.36) RTM-314 x RTM-1359 (13.41)	RTM-1351 x RTM-1375 (16.18) T-27 x RTM-1351 (15.55) RTM-1375 x RTM-1359 (14.59)	RTM-1415 x RTM-314 (40.20) RTM-1351 x RTM-1212 (34.85) RTM-1351 x RTM-314 (25.48)
Oil content (%)	RTM-1212 x RTM-2002 (1.49) T-27 x RTM-1351 (1.36)	RTM-1351 x RTM-2002 (3.46)	RTM-2002 x RTM-314 (2.91) T-27 x RTM-2002 (2.91)	RTM-1212 x RTM-2002 (8.19) T-27 x RTM-1212 (3.26)

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