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Economic Heterosis for Yield and Yield Characters in Taramira (*Eruca sativa* Mill.)

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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. Specific heterosis ($S_{ii'}$) was also significant for all characters in all the environments except days to flowering in the environment I and days to flowering and days to maturity in environment-III. Among the parents (varieties) RTM-1359 and RTM-1375 in all the environments, RTM-314 in the environment-II and III were found to be superior based on vi effects and per se performance not only for seed yield per plant but for some of the other yield traits studied. The parents worth considered on the basis of hi values were RTM-1375 in environment-I, RTM-314 in environment-II, while RTM-1415 and RTM-1359 in the environment-III and RTM-314, RTM-1359 in environment-IV. It was therefore recommended to include these parents in hybridization programme to improve seed yield and seed quality. 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, high $s_{ii'}$ values, with high economic heterosis not only for seed yield per plant but for some than the other yield traits studied. Development of inbred 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, Economic heterosis, Taramira, Eruca sativa.*

INTRODUCTION

Taramira (*Eruca sativa* Mill.) is important winter season oil seed crop of the family Brassicaceae. It is an introduced crop in India. South Europe and North Africa are believed to be the native place of it. It has diploid number of chromosomes 2n=22 and the chromosomes are very small. Taramira has desirable traits particularly resistance to powdery mildew that can be transferred to *Brassica campestris* and *Brassica juncea* both of which are important crops.

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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 in taramira ranges from 31.6-41.31 per cent which is affected by manuring, irrigation and disease management. Taramira (*Eruca sativa* Mill.) is important winter season oil seed crop of the family Brassicaceae. It is an introduced crop in India. Taramira (*Eruca sativa* Mill.) is successfully grown on dry land areas of north-west India on poor sandy soils with conserved moisture. Taramira has sporophytic type of self-incompatibility therefore; highly cross-pollinated crop. Taramira oil is mainly used in industries. 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 of taramira is used as manure for improving the soil physical condition and soil fertility and it can also be used as nutritional feed for animals.

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. The observations on days to flowering, days to maturity, plant height (cm), primary branches per plant, secondary branches per plant, siliquae per plant, siliqua length (cm), number of seeds per siliqua, seed yield per plant, test weight (g) and oil content (%) were recorded 10 randomly selected plants except days to flowering, days to maturity which was recorded on whole plot basis. The data were subjected to the estimation of mean magnitude of heterosis and analysis of variance according to Gardner and Eberhart[3], analysis II. Oil content was also estimated using the pooled seed sample using Soxlet's method. The data were subjected to the varietal diallel analysis as suggested by Gardner and Eberhart[3] 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. Superiority of F_1 over standard check is more useful than superiority of F_1 over better parent is determining the feasibility of commercial exploitation of heterosis.

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 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, economic heterosis for most of the characters studied (Table 1 to 6). For economic heterosis a check/standard variety used T-27, because it is a high yielding variety.

Economic heterosis for different environments

Environment-I

Out of 28 crosses, for seed yield per significant positive desirable economic heterosis was observed in 26 crosses, for plant height in 23 cross, for primary branches per plant in 7 crosses, for secondary branches per plant in 5 crosses, for siliquae per plant in 5 crosses, for siliqua length in 15 cross, for number of seeds per siliqua in 3 crosses, for test weight in 11 crosses and oil content in 13 crosses, for days to flowering 11 and days to maturity 2 crosses exhibited significant positive, desirable economic heterosis.

Environment-II

Out of 28 crosses, for seed yield per plant significant positive (desirable) economic heterosis was observed in 26 crosses, for plant height in 27 crosses, for primary branches per plant in 6 crosses, for secondary branches per plant in 1 cross, for siliquae per plant in 3 crosses, for siliqua length in 15 crosses, for number of seeds per plant in 7 crosses, test weight in 14 crosses and for oil content in 10 crosses. Significant negative (desirable) heterobeltiosis and economic heterosis was observed no any crosses for all the characters out of 28 crosses.

Environment-III

Out of 28 crosses, for seed yield per plant significant positive (desirable) economic heterosis was observed in 26 crosses, for plant height in 26 crosses, for primary branches per plant in 13 crosses, for secondary branches per plant in 2 crosses, for siliquae per plant in 2 crosses, for siliqua length in 16 crosses, for number of seeds per plant in 10 crosses, test weight in 13 crosses and for oil content 9 crosses.

Environment-IV

Out of 28 crosses, for seed yield per plant significant positive (desirable) economic heterosis was observed in 23 crosses, for plant height in 25 crosses, for primary branches per plant in 8 crosses, for secondary branches per plant in 24 crosses, for siliquae per plant in 3 crosses, for siliqua length in 12 crosses, for number of seeds per plant in 11 crosses, test weight in 6 crosses and for oil content 3 crosses by Nassimi *et al*[7]. Significant negative (desirable) economic heterosis crosses were not observed in all the four environments, out of 28 crosses. Thus, in the present investigation, high degree of desirabl economic heterosis 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. High heterosis over mid parent for seed yield per plant and its components were also reported by Gupta *et al*[1]., Nehra and Sastry[8], Mahmood *et al*[6]., Goswami *et al*[2]., Verma *et al*[10]. Economic heterosis for seed yield and its components were reported by Nehra and Sastry[8], Patel *et al*[9]. Standard heterosis were reported by Kumar *et al*[4].

The top three crosses having desirable economic heterosis for each of the characters are summarized in Table 7. For seed yield per plant, cross RTM-314 x RTM-1359 showed significant with high positive economic heterosis in all the four environments, while cross RTM-1415 x RTM-2002 showed significant with high positive economic heterosis in the environment II,III.IV and for seed yield per plant in cross RTM-1375 x RTM-1212 showed significant with high positive economic heterosis in the four environment-I, Interestingly, these crosses also had desirable s_{ii}, effects in all the environments. Perusal of Table 7 indicated that these crosses were also consistently superior for several other characters in each environment. The parent's worth considered on the basis of economic heterosis were RTM-314, RTM-1415, RTM-2002 and T-27 which gave better performance in all the environments (Table 7). These parents had acceptable, mean ranking and h_i for most of the yield contributing traits.

Table: 1 Average per cent economic heterosis (CH) for characters in all environments

Parents/F_1s	Days to flowering and days to maturity							
	Environment I		Environment II		Environment III		Environment IV	
	CH	CH	CH	CH	CH	CH	CH	CH
P1 x P2	8.16**	2.16**	8.76**	2.70**	3.52*	0.74	8.13**	-0.25
P1 x P3	9.52**	0.00	11.68**	0.74	0.70	-0.25	4.88*	-1.75
P1 x P4	4.08	-0.24	10.22**	-0.49	-0.70	-0.99	7.32**	-1.75
P1 x P5	6.12*	0.72	10.22**	0.25	2.11	0.74	4.07	-1.25
P1 x P6	3.40	-1.44	8.76**	-0.49	-3.52	-0.25	8.13**	-0.50
P1 x P7	3.40	0.48	6.57*	-0.98	2.11	-1.24	7.32**	3.24**
P1 x P8	5.44	0.48	8.76**	-0.74	0.00	-0.74	5.69*	-2.49
P2 x P3	5.44	2.16**	6.57*	-0.74	-4.23	-0.50	8.13**	-1.75
P2 x P4	2.04	-0.24	19.71**	2.45**	-3.52	0.25	8.13**	-1.50
P2 x P5	5.44	-1.44	8.76**	0.25	2.11	-0.74	4.88*	-1.50
P2 x P6	7.48*	-1.68	9.49**	0.25	-1.41	-0.25	4.88*	-1.50
P2 x P7	4.08	-0.96	8.76**	-0.74	-1.41	0.00	5.69*	-1.25
P2 x P8	5.44	-0.96	4.38	-1.23	-3.52	-0.50	5.69*	-1.00
P3 x P4	10.20**	-0.48	5.11	-0.25	3.52*	0.99	1.63	-1.25
P3x P5	3.40	-0.96	8.03*	-0.49	-2.82	0.99	8.94**	-1.00
P3 x P6	17.01**	-2.16	4.38	-0.49	2.11	0.74	6.50**	-1.50
P3 x P7	4.76	0.96	9.49**	-0.74	2.11	0.25	2.44	-1.25
P3 x P8	6.12*	0.48	10.22**	2.70**	-0.70	0.00	8.13**	-0.75
P4 x P5	4.76	-0.48	14.60**	-0.98	1.41	0.00	8.94**	-1.50
P4 x P6	6.80*	-2.40	3.65	-0.98	-0.70	-1.49	7.32**	-0.75
P4 x P7	9.52**	-0.96	10.95**	-0.74	-0.70	0.00	6.50**	-0.75
P4 x P8	2.72	0.96	11.68**	-0.74	0.00	0.25	8.13**	-1.00
P5 x P6	4.76	0.00	7.30*	2.21**	0.00	-0.25	4.88*	-1.75
P5 x P7	8.84**	-0.48	2.92	1.47*	-0.70	0.50	8.94**	-1.50
P5 x P8	4.08	-0.96	5.84	-0.74	2.11	0.50	-2.44	-1.25
P6 x P7	5.44	0.24	8.03*	-0.74	2.11	0.50	5.69*	0.00
P6 x P8	5.44	0.96	9.49**	0.74*	0.70	0.99	4.07	-0.25
P7 x P8	6.80*	0.00	10.95**	1.47	2.82	1.49*	7.32**	-0.50
SEm ±	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 economic heterosis (CH) for characters in all environments

Parents/F_1s	Plant height and Primary branches per plant							
	Environment I		Environment II		Environment III		Environment IV	
	CH	CH	CH	CH	CH	CH	CH	CH
P1 x P2	6.04**	3.13	10.32**	-26.67	10.56**	-22.73	11.93**	-27.08
P1 x P3	8.63**	-2.50	11.51**	-16.00	10.48**	-13.64	10.70**	-15.97
P1 x P4	1.69	13.75**	9.47**	-4.67	9.13**	-17.53	6.43**	-25.69
P1 x P5	6.48**	-9.38	9.14**	0.67	9.13**	3.90	10.81**	3.47
P1 x P6	8.74**	20.63**	14.43**	-11.33	12.64**	17.53**	8.90**	-2.78
P1 x P7	4.62*	-4.37	0.48	-10.00	-0.07	-1.95	1.42	-0.69
P1 x P8	5.09**	-3.12	8.44**	0.67	8.95**	-0.65	6.47**	4.17
P2 x P3	3.31	5.63	14.87**	5.33	10.37**	-3.90	10.55**	-4.86
P2 x P4	4.72*	1.87	11.02**	3.33	12.66**	7.79*	10.36**	6.25
P2 x P5	1.82	19.38**	6.99**	23.33**	2.85	29.22**	3.52**	29.86**
P2 x P6	19.09**	1.87	16.91**	3.33	12.38**	11.04**	14.29**	9.72*
P2 x P7	9.31**	-11.25	15.72**	-15.33	8.66**	-5.84	13.09**	-5.56
P2 x P8	6.95**	0.63	17.50**	-2.67	13.11**	12.99**	15.19**	4.86
P3 x P4	4.96**	-12.50	9.91**	8.67*	4.27*	9.74**	2.92	-18.06
P3x P5	20.74**	28.75**	4.77*	10.00*	12.20**	29.22**	-1.16	-9.03
P3 x P6	12.28**	-8.75	15.28**	-6.67	14.65**	-7.14	15.90**	1.39
P3 x P7	8.67**	-9.38	16.09**	0.00	15.16**	-4.55	17.47**	-0.69
P3 x P8	14.37**	-10.63	12.99**	-13.33	14.35**	-8.44	14.18**	-5.56
P4 x P5	9.78**	7.50	18.09**	8.67*	17.35**	11.04**	17.85**	13.89**
P4 x P6	7.12**	13.75**	13.17**	13.33**	14.06**	20.13**	12.76**	18.75**
P4 x P7	17.30**	7.50	22.86**	8.67*	26.81**	13.64**	21.85**	11.81**
P4 x P8	0.03	18.13**	13.21**	17.33**	15.08**	14.29**	17.70**	19.44**
P5 x P6	11.87**	-1.25	21.94**	3.33	22.46**	7.79*	21.17**	4.86
P5 x P7	13.56**	9.38*	19.53**	-15.33	18.70**	6.49	16.65**	-16.67
P5 x P8	10.08**	0.00	16.20**	3.33	13.15**	7.14*	19.19**	6.25
P6 x P7	2.12	3.75	8.73**	6.67	6.87*	7.79*	9.20**	9.03*
P6 x P8	18.58**	0.00	21.20**	4.67	22.94**	4.55	21.92**	6.25
P7 x P8	7.96**	0.00	17.98**	2.67	16.62**	1.95	19.30**	8.33*
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 economic heterosis (CH) for characters in all environments

Parents/F$_1$s	Secondary branches per plant							
	Environment I		Environment II		Environment III		Environment IV	
	CH	CH	CH	CH	CH	CH	CH	CH
P1 x P2	-3.42	-8.87	-21.94	-10.94	-19.53	-15.98	3.07	-15.75
P1 x P3	8.55**	-14.41	-30.48	-15.62	-29.88	-46.57	-11.11	-15.39
P1 x P4	-18.80	0.90	-21.08	-1.89	-19.82	-3.63	1.15	-0.03
P1 x P5	-9.40	-9.68	-11.68	-10.62	-2.66	-7.26	23.37**	-7.60
P1 x P6	-7.69	4.96	-10.83	4.68	-4.73	3.72	21.07**	4.86
P1 x P7	-2.85	3.35	-3.13	3.43	-2.07	2.78	22.61**	4.25
P1 x P8	3.42	-1.75	1.42	-3.38	1.78	-7.64	26.44**	-6.58
P2 x P3	-17.38	-14.85	-18.52	-14.69	-17.46	-15.75	6.51*	-14.67
P2 x P4	-1.14	-5.81	-6.55	-7.39	-5.62	-6.47	19.54**	-6.37
P2 x P5	-1.14	15.78*	-7.41	11.70**	-4.73	9.69	21.07**	7.45*
P2 x P6	4.27	6.62	0.00	1.98	0.59	0.64	26.44**	3.74
P2 x P7	-3.42	55.57**	-3.99	-16.88	-1.78	-16.57	23.37**	-14.06
P2 x P8	-0.57	5.60	-3.99	4.22	-1.78	3.83	24.52**	4.28
P3 x P4	5.98	13.21*	-27.92	-15.45	19.82**	-18.00	-12.26	-17.29
P3x P5	8.55**	17.04**	-16.24	-16.38	-13.02	-15.63	9.58**	-13.07
P3 x P6	6.27*	3.85	3.42	-0.32	4.73	-4.71	34.48**	-3.44
P3 x P7	1.99	-21.82	-17.09	-22.64	-15.68	14.84*	6.51*	-14.48
P3 x P8	6.27*	4.14	2.85	4.22	3.85	4.98	31.42**	4.83
P4 x P5	0.57	-5.63	-3.70	-5.56	-0.30	-6.41	26.44**	-1.51
P4 x P6	1.14	7.73	-1.99	4.60	-1.48	1.99	23.75**	2.87
P4 x P7	-5.70	3.50	-7.98	0.03	-7.69	-1.93	16.09**	-2.41
P4 x P8	-10.54	6.30	-13.11	2.44	-9.17	-1.55	15.33**	-3.92
P5 x P6	-8.26	4.61	-12.82	2.09	-11.83	-2.93	12.26**	-0.57
P5 x P7	-3.70	-0.32	-5.98	-1.40	-3.55	-3.63	22.22**	-3.29
P5 x P8	-10.83	-5.46	-14.25	-5.85	-13.02	-7.73	9.58**	-7.21
P6 x P7	-1.99	5.37	-3.99	1.37	-3.25	0.35	23.37**	1.99
P6 x P8	17.38**	7.09	12.25**	34.22**	14.79**	15.54*	45.21**	8.42**
P7 x P8	5.41	30.51**	2.28	20.02**	4.14	11.56	31.42**	6.94*
SEm ±	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 economic heterosis (CH) for characters in all environments

Parents/F_1s	Siliqua length and Number of seeds/siliqua							
	Environment I		Environment II		Environment III		Environment IV	
	CH	CH	CH	CH	CH	CH	CH	CH
P1 x P2	-3.59	-6.23	-1.10	5.66	0.77	6.30	-3.59	3.53
P1 x P3	17.94**	-9.41	17.30**	-2.65	18.83**	2.28	17.94**	2.42
P1 x P4	27.61**	6.80*	21.70**	-10.80	21.14**	8.23*	27.61**	-8.18
P1 x P5	19.50**	12.52**	20.75**	29.20**	16.51**	23.64**	19.50**	32.34**
P1 x P6	8.42	-3.69	8.81*	3.54	7.25	-0.35	8.42	13.57**
P1 x P7	5.30	10.78**	6.76	-0.88	5.56	8.93*	5.30	-0.37
P1 x P8	17.78**	4.82	-12.58	-16.28	-12.19	7.62	-16.54	-10.97
P2 x P3	-1.87	-10.36	3.46	-2.12	7.25	-1.75	-1.87	5.20
P2 x P4	-1.72	-14.18	3.30	-3.89	-9.41	-3.85	-1.72	-0.93
P2 x P5	4.37	2.19	0.31	-12.57	-1.39	9.81*	4.37	-5.39
P2 x P6	11.23	2.51	-13.84	-15.75	17.59**	-16.64	-10.14	-12.08
P2 x P7	16.07**	-0.99	18.87**	3.01	31.02**	6.83	16.07**	14.31**
P2 x P8	33.39**	-10.68	10.22*	-2.12	35.80**	-3.33	-7.18	3.90
P3 x P4	23.40**	2.67	25.63**	13.63**	35.65**	17.86**	23.40**	17.29**
P3x P5	20.90**	-14.49	23.43**	-8.67	38.58**	-1.93	20.90**	1.30
P3 x P6	31.20**	-13.22	12.11**	-5.49	37.96**	-1.40	31.20**	-7.62
P3 x P7	0.47	4.58	-6.13	24.96**	22.99**	7.88*	0.47	18.59**
P3 x P8	32.92**	-10.92	26.73**	34.69**	39.66**	22.42**	32.92**	32.71**
P4 x P5	-0.62	-11.00	8.02	-0.88	33.02**	-8.93	-0.62	3.72
P4 x P6	-0.62	2.19	-4.25	11.68**	15.59**	11.21**	-0.62	16.36**
P4 x P7	-2.96	-11.16	8.96*	-3.72	4.48	-2.45	-2.96	3.90
P4 x P8	29.95**	2.99	15.09**	11.68**	3.24	13.31**	29.95**	18.77**
P5 x P6	30.27**	-14.34	-19.34	-6.55	-15.74	-7.18	-6.08	0.00
P5 x P7	33.85**	-15.45	23.58**	-8.67	17.59**	-11.73	33.85**	-4.46
P5 x P8	-2.81	-4.80	-6.13	1.77	13.89*	-1.75	4.99	12.64**
P6 x P7	19.34**	-10.04	19.97**	-4.42	18.83**	-3.68	19.34**	3.16
P6 x P8	32.76**	1.40	21.86**	10.62**	10.03	8.06*	32.76**	22.30**
P7 x P8	9.05	-4.96	8.02	3.01	7.56	-1.40	9.05	8.74*
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 economic heterosis (CH) for characters in all environments

Parents/F1s	Seed yield per plant and Test weight							
	Environment I		Environment II		Environment III		Environment IV	
	CH	CH	CH	CH	CH	CH	CH	CH
P1 x P2	34.22*	7.75	29.33**	13.55**	26.04**	15.65*	34.42**	5.84
P1 x P3	56.38**	3.03	23.52**	6.91	44.49**	8.59	25.60**	2.59
P1 x P4	67.46**	22.97**	11.06	4.61	51.25**	1.79	16.27	-2.22
P1 x P5	48.37**	3.56	42.92**	-0.92	45.04**	13.77*	46.33**	-0.65
P1 x P6	74.88**	-5.25	63.82**	-0.28	57.46**	-8.68	74.50**	-3.06
P1 x P7	39.37**	3.29	40.58**	5.71	25.76**	8.59	30.16**	2.69
P1 x P8	53.81**	5.79	35.15**	9.77*	-15.85	1.79	-9.42	12.97
P2 x P3	69.63**	12.11*	55.95**	18.99**	67.10**	17.53**	59.23**	23.35**
P2 x P4	31.36*	6.68	25.40**	14.93**	39.57**	14.04*	27.28**	0.19
P2 x P5	67.75**	14.16**	23.99**	18.71**	9.08	22.81**	2.38	20.48**
P2 x P6	21.76	30.72**	-7.97	13.18**	16.13	-5.19	-4.46	-0.09
P2 x P7	65.68**	6.95	65.98**	15.39**	61.72**	11.45	60.32**	14.55*
P2 x P8	33.14*	3.12	35.61**	15.21**	30.12**	-12.16	27.18**	-3.71
P3 x P4	69.44**	31.34**	55.58**	5.07	58.85**	-1.43	58.04**	-4.91
P3x P5	96.34**	8.28	39.36**	21.47**	24.65**	22.90**	16.77	22.89**
P3 x P6	91.00**	2.40	25.21**	7.28	22.43*	7.16	30.06**	-3.43
P3 x P7	35.01*	0.18	25.77**	1.29	30.86**	8.14	29.96**	5.65
P3 x P8	65.68**	2.40	50.14**	8.76*	55.14**	15.92*	33.23**	-1.02
P4 x P5	40.85**	28.76**	35.24**	2.21	40.04**	16.73*	30.95**	0.46
P4 x P6	81.01**	34.73**	72.26**	5.62	63.58**	-0.81	80.95**	-7.23
P4 x P7	54.01**	21.02**	44.99**	31.52**	43.10**	19.77**	55.56**	30.58**
P4 x P8	64.29**	12.56*	57.26**	9.31*	58.67**	14.13*	82.94**	0.56
P5 x P6	36.60**	29.12**	31.68**	-4.61	34.48**	37.39**	38.69**	-6.30
P5 x P7	66.17**	12.02*	15.56*	23.32**	48.38**	19.59**	51.79**	17.33*
P5 x P8	67.85**	5.61	63.54**	8.94*	47.82**	10.47	68.25**	1.48
P6 x P7	-2.18	-9.62	62.51**	-5.53	31.60**	-0.89	58.53**	-9.92
P6 x P8	65.97**	-4.99	59.98**	-2.40	57.18**	-10.91	56.75**	-6.30
P7 x P8	91.30**	9.97	52.11**	23.96**	87.95**	16.64*	90.08**	7.41
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 of economic heterosis (CH) for characters in all environments

Parents/ F_1s	Oil content			
	Environment I	Environment II	Environment III	Environment IV
	CH	CH	CH	CH
P1 x P2	1.36	1.25	1.83	2.17
P1 x P3	2.49*	-0.40	1.72	4.20*
P1 x P4	1.79	1.09	2.53	0.41
P1 x P5	-0.81	-2.93	-1.63	3.26
P1 x P6	1.16	0.33	5.10**	1.08
P1 x P7	1.25	0.28	2.34	2.95
P1 x P8	1.51	1.03	1.96	1.85
P2 x P3	2.59*	-0.97	1.07	4.46*
P2 x P4	3.90**	-0.33	3.65**	5.39*
P2 x P5	2.42*	1.11	2.55*	-1.36
P2 x P6	4.00**	2.90	4.40**	4.58*
P2 x P7	1.80	0.21	1.65	-0.30
P2 x P8	2.30	0.05	2.28	0.93
P3 x P4	2.98*	2.35	3.15*	4.39*
P3x P5	0.69	-0.22	2.09	3.01
P3 x P6	1.43	0.75	1.13	0.15
P3 x P7	0.14	-1.22	1.01	2.19
P3 x P8	2.25	0.63	1.93	1.71
P4 x P5	3.71**	0.78	3.04*	3.00
P4 x P6	2.83*	-0.52	2.31	1.73
P4 x P7	1.05	-1.60	2.01	-1.87
P4 x P8	1.94	0.59	3.14	2.98
P5 x P6	5.57**	2.19	4.06**	1.73
P5 x P7	2.20	-0.28	0.84	1.91
P5 x P8	5.65**	4.70**	5.74**	3.57
P6 x P7	5.00**	4.29**	7.33**	6.98**
P6 x P8	2.39	1.39	2.02	2.25
P7 x P8	2.58*	-0.45	1.96	5.93**
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 over standard heterosis (CH) heterosis in all the environments

Characters	- Heterosis			
	Over standard heterosis (CH)			
	I	II	III	IV
Plant height (cm)	RTM-1375 x RTM- 1212* (20.24) RTM-1351 x RTM-2002* (19.09) RTM-2002 x RTM-1359* (18.58)	RTM-1415 x RTM-14* (22.86) RTM-1212 x RTM-2002* (21.94) RTM-2002 x RTM1359* (21.20)	RTM-1415 x RTM-314* (26.81) RTM-2002 x RTM-1359* (22.94) RTM-1212 x RTM-2002* (22.46)	RTM-2002 x RTM-1359* (21.92) RTM-1415 x RTM-314* (21.85) RTM-1212 x RTM-2002* (21.17)
Primary branches per plant	RTM-1375 x RTM-1212* (28.75) T-27 x RTM-2002* (20.63) RTM-1351 x RTM-1212* (19.38)	RTM-1351 x RTM-1212* (23.33) RTM-1415 x RTM-1359* (17.33) RTM-1415 x RTM-2002* (13.33)	RTM-1375 x RTM-1212* (29.22) RTM-1351 x RTM-1212* (29.22) RTM-1415 x RTM-2002* (20.13)	RTM-1351x RTM-1212* (29.86) RTM-1415 x RTM-1359* (19.44) RTM-1415 x RTM-2002* (18.75)
Secondary branches per plant	RTM-2002 x RTM-1359* (17.38) T-27 x RTM-1375* (8.55) RTM-1375 x RTM-1212* (8.55)	RTM-2002 x RTM-1359* (12.25)	RTM-1375 x RTM-1415* (19.82) RTM-2002 x RTM-1359* (14.79)	RTM-2002 x RTM-1359* (45.21) RTM-1375 x RTM-2002* (34.48) RTM-1375 x RTM-1359* (31.42)
Siliquae per plant	RTM-1351 x RTM-314* (55.57) RTM-314 x RTM-1359* (30.51) RTM-1375 x RTM-1212* (17.04)	RTM-2002 x RTM-1359* (34.22) RTM-314 x RTM-1359* (20.02) RTM-1351 x RTM-1212* (11.70)	RTM-2002 x RTM-1359* (15.54) RTM-1375 x RTM-314* (14.84)	RTM-2002 x RTM-1359* (8.42) RTM-1351 x RTM-1212* (7.45) RTM-314 x RTM-1359* (6.94)
Siliqua length (cm)	RTM-1212 x RTM-314* (33.85) RTM-1351 x RTM-1359* (33.39) RTM-1375 x RTM-1359* (32.92)	RTM-1375 x RTM-1415* (25.63) RTM-1212 x RTM-314* (23.58) RTM-1375 x RTM-1212* (23.43)	RTM-1375x RTM1359* (39.66) RTM-1375 x RTM-1212* (38.58) RTM-1375 x RTM-2002* (37.96)	RTM-1212 x RTM-314* (33.85) RTM-1375 x RTM-1359* (32.92) RTM-2002 x RTM-1359* (32.76)
Number of seeds per siliqua	T-27 x RTM-1212* (12.52) T-27 x RTM-314* (10.78) T-27 x RTM-1415* (6.80)	RTM-1375 x RTM-1359* (34.69) T-27 x RTM-1212* (29.20) RTM-1375 x RTM-314* (24.96)	T-27 x RTM-1212* (23.64) RTM-1375 x RTM-1359* (22.42) RTM-1375 x RTM-1415* (17.86)	RTM-1375 x RTM-1359* (32.71) T-27 x RTM-1212* (32.34) RTM-2002 x RTM-1359* (22.30)
Seed yield per plant (g)	RTM-1375 x RTM-1212* (96.34) RTM-314 x RTM-1359* (91.30) RTM-1375 x RTM-2002* (91.00)	RTM-1415 x RTM-2002* (72.26) RTM-1351 x RTM-314* (65.98) T-27 x RTM-2002* (63.82) RTM-314 x RTM-1359* (51.30)	RTM-314 x RTM-1359* (87.95) RTM-1351 x RTM-1375* (67.10) RTM-1415 x RTM-2002* (63.58)	RTM-314 x RTM-1359* (90.08) RTM-1415 x RTM-1359* (82.94) RTM-1415 x RTM-2002* (80.95)
Test weight (g)	RTM-1415 x RTM-2002* (34.73) RTM-1375 x RTM-1415* (31.34) RTM-1351 x RTM-2002* (30.72)	RTM-1415 x RTM-314* (31.52) RTM-314 x RTM-1359* (23.96) RTM-1212 x RTM-314* (23.32)	RTM-1212 x RTM-1359* (37.39) RTM-1375 x RTM-1212* (22.90) RTM-1351 x RTM-1212* (22.81)	RTM-1415 x RTM-314* (30.58) RTM-1351 x RTM-1375* (23.35) RTM-1375 x RTM-1212* (22.89)
Oil content (%)	RTM-1212 x RTM-1359* (5.65) RTM-1212 x RTM-2002* (5.57) RTM-2002 x RTM-314* (5.00)	RTM-1212 x RTM-1359* (4.70) RTM-2002 x RTM-314* (4.29)	RTM-2002 x RTM314* (7.33) RTM-1212 x RTM-1359* (5.74) RTM-1351 x RTM-2002* (4.40)	RTM-2002 x RTM-314* (6.98) RTM-314 x RTM-1359* (5.93) RTM-1351 x RTM-2002* (4.58)

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