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ANALYSIS OF YIELD AND ITS COMPONENTS BASED ON HETEROSIS AND COMBINING ABILITY IN INDIAN MUSTARD (*BRASSICA JUNCEA* L. CZERN & COSS)

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ABSTRACT

A study of Diallel analysis excluding reciprocal cross, of seven parents was carried out to identify high heterotic crosses and their relationship in terms of general and specific combining ability (GCA and SCA) in Indian mustard in year 2010-11 and 2011-12 . Out of 21specific crosses, highest economic heterosis was observed in case of five crosses viz ; RK03-3 X RK03-4(43.90%), RK03-2 X RK03-4(34.55%), Varuna x RK03-4(31.75%), RH-819 X RH-9801 (25.00%) and RH-819 X RK02-4(24.22%). ANOVA study of GCA and SCA variances for all the characters were significant except in case of secondary branches per plant. For all the character,ratio of GCA and SCA variances were below unity. Varuna and RK03-2 are the best parent for almost all traits as their GCA and per se performance are highest. Varuna X RK03-4 and Varuna X RK03-1showed high per se performance as well as SCA effects. The above best parent and best crosses can be used in hybridisation and heterosis breeding respectively.

INTRODUCTION

Indian mustard (*Brassica juncea*) is a naturally autogamous species, yet in this crop frequent out-crossing occurs which varies from 5 to 30% depending upon the environmental conditions and random variation of pollinating insects. Cytologically Indian mustard is an amphidiploid (2n = 36), derived from interspecific cross of *Brassica campestris* (2n = 20) and *Brassica nigra* (2n = 16) followed by natural chromosome doubling. These relationships have been confirmed by the artificial synthesis of amphidiploids species by hybridizing basic diploid species and also by analysis of chloroplast and mitochondrial DNA restriction pattern of basic and amphidiploid species. The improved mustard seeds contain 39-44% oil. For International acceptance, erucic acid content should be < 2%.In India the area of rape and mustard 5.92Mha, Production 6.78MT and yield 1145kg/ha in 2011-12.

Seed quality,Seed yield and other yield related parameters of Brassica oil seed crop has been tried to imorve by several researchers(Rakow, 1995 and Singh, 2003). Heterosis is the best way to improve crop varieties. 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). Development of hybrid cultivars has been successful in many Brassica spp. (Miller, 1999). For the study of inheritance of quantitative characters and evaluation of various possible breeding procedures in heterosis phenomena, the comprehensive study of combining ability is immensely essential(Allard, 1960). Combining ability studies emphasized the preponderance effect of GCA on yield and most of the yield components, indicating the importance of additive gene action (Wos et al., 1999). On the other hand, Pandey et al. (1999) reviewed evidences for the presence of signiûcant SCA effects for yield and yield components, indicating the importance of non-additive gene action. Singh et al. (2005) reported that non-additive genetic effects in addition to additive effects accounted for yield heterosis.

In Indian mustard Singh *et al*. (2006) observed that general and specific combining ability variance were highly significant for almost all the characters and reported that high GCA for 1000 seed weight and oil content. High SCA for seed yield and oil content. Kumar *et al*. (2007) observed that economic heterosis on the basis of per se performance and SCA effects in F_1 crosses. Out of 45 crosses only 4 crosses exhibited desirable SCA effects namely Varuna x Kranti, Varuna x NDR-8501, Pusa Bold x KRV-Tall and Kranti x Rohini had high economic heterosis (58.83, 54.84, 52.56 and 37.67% respectively. Gupta *et al*. (2010) observed heterosis and heterobeltiosis and It is found to be the highest with respect to seed yield per 100 siliquae and days from sowing to 50% flowering in case of cross IC-199715 × IC-199714, EC-289602 × Prakash in the number of primary branches per plant and harvest index, Agra Local × Pusa Bahar in the length of main axis, Poorbijaya × Agra Local in the number of siliquae on main axis and EC-289602 × Pusa Bahar in the biological yield per plant and seed yield per plant. They also found that days to maturity, number of secondary branches per plant, plant height and 1000-seed weight. GCA and SCA variances were signiûcant in all characters. Nasrin et al (2011) reported that GCA effect was significant for plant height days to 50% flowering, days to maturity and thousand seed weight and significant SCA was also observed for all the trait except days to flowering and number of seeds per siliqua. Therefore, this paper deals with estimation of relative importance of GCA and SCA variances and heterosis for yield and its components.

MATERIALS AND METHODS

There are seven morphological diverse genotypes/varieties viz., Varuna, RH-819, RH-9801, RK03-1, RK03-2, RK03-3, RK03-4 and their 21 direct crosses *i.e.,* the F_1 populations. All the 28 treatments (7 parents and 21 F_1s) were grown in Randomized Complete Block Design with three replications at Oilseed Research Farm, Kalyanpur, C. S. Azad University of Agriculture and Technology, Kanpur during *Rabi* 2011-2012. The parents and F_1s were grown in single row of five meter length spaced 45 cm apart. The distance of 20 cm between the plants in a row was maintained by thinning. All the recommended agronomic practices were adopted for raising the crop.

These genotypes/varieties have been taken on the basis of their differences in plant height, Number of primary branches per plant, number of secondary branches per plant, length of main raceme, number of siliquae per plant, number of seeds per siliqua, days to flowering, days to maturity maturity period, grain yield per plant, test weight and oil content. The mean data of each plot was used for statistical analysis. The combining ability analysis was done by the procedure suggested by Griffing's (1956 b) Method 2, Model I. The mathematical model for the combining ability analysis is assumed to be:

$Y_{ijkl} = u + g_i + g_j + s_{ij} + 1/bc \sum i \sum e_{ijkl}$

(i,j) = 1, 2, 3... n;

k = 1, 2, 3...b;

l = 1, 2, 3... c)

Where,

Y_{ijkl} = mean of i x jth genotype in kth replication

u = the population mean

g_i = the general combining ability (gca) effect of ith parent

g_j = the gca effect of jth parent

s_{ij} = the specific combining ability (gca) effect for the cross between ith, jth parent such that $s_{ij} = s_{ji}$

$\sum i \sum e_{ijkl}$ = the environmental effect associated with the ijklth individual observation on ith individual in the kth block with ith as female parent and jth as male parent.

The heterosis was calculated (in per cent) as increase or decrease in relation to economic parent. The formula used, are given below:

Heterosis over economic parent (%) = [F_1 – EP/ EP] x 100

Where,

F_1 and EP are the mean of F_1 and economic parent, respectively.

Test of significance:

Significance of heterosis over economic parent was tested as:

$SE_{EP} = (2M_{el}/r)^{0.5}$

Where,

Table 1: ANOVA of parents F_1's for 11 characters in a 7 parental diallel cross of Indian mustard (mean sum of squares)

Source of variation	d.f.	Days to 50% flowering	Days to maturity	Plant height (cm)	Length of main raceme	Number of siliquae per plant	Number of primary branches per plant	Number of secondary branches per plant	Oil content	Number of seeds per siliqua	Test weight	Seed yield per plant
Replications	02	1.15	0.58	0.09	0.26	29.23	0.18	0.97	0.06	0.55	0.01	0.26
Treatments	27	15.22**	14.76**	4.89**	30.46**	753.84**	0.91**	2.96**	9.70**	1.93**	0.20**	21.77**
Parents	06	12.19**	13.65**	0.72	33.39**	888.59**	1.16**	1.13**	16.54**	0.23**	0.20**	7.26**
F1's	20	4.69**	4.31**	2.57**	12.85**	297.71**	0.39**	0.66	4.86**	0.95**	0.12**	6.68**
Parents Vs F1	01	244.06**	230.46**	77.80**	364.79*	9069.30**	9.60**	59.83**	67.42**	27.59**	1.84 **	410.44**
Error	54	1.34	1.75	0.36	2.24	16.83	0.06	0.46	0.07	0.36	0.03	0.94

*Significant at p = 0.05; **Significant at p = 0.01

Table 2: ANOVA for combining ability and related statistics of 11 characters in a 7 parental diallel cross of F_1's in Indian mustard

Source of variation	d.f.	Days to 50% flowering	Days to maturity	Plant height (cm)	Length of main raceme	Number of siliquae per plant	Number of primary branches per plant	Number of secondary branches per plant	Oil content	Number of seeds per siliqua	Test weight	Seed yield per plant
GCA	6	3.95**	7.00**	1.31**	21.55**	375.72**	0.74**	0.21	1.83**	1.04**	0.17**	5.20**
SCA	21	5.39**	4.32**	1.75**	6.89**	215.71**	0.17**	1.20**	3.66**	0.53**	0.04**	7.84**
Error	54	0.44	0.58	0.13	0.74	5.60	0.02	0.15	0.02	0.12	0.01	0.04
σ^2gca		0.39	0.75	0.14	2.31	41.12	0.08	0.00	0.20	0.10	0.02	0.54
σ^2sca		4.95	3.74	1.62	6.15	210.11	0.15	1.05	3.64	0.41	0.03	7.53
GPR		0.13	0.28	0.15	0.43	0.28	0.52	0.00	0.10	0.33	0.57	0.13

*Significant at p = 0.05; **Significant at p = 0.01

Table 3: Estimates of gca effects of 7 parents for 11 characters in F_1's of a diallel cross in Indian mustard

Parents	Days to(50%) flowering gca effect	Mean	Days to maturity gca effect	Mean	Plant height gca effect	Mean	Length of main raceme gca effect	Mean	No. of siliquae/plant gca effect	Mean
Varuna	0.60**	78	-0.32**	130.33	0.33**	179.6	-0.14	61.26	12.34**	354.66
RH-819	0.30**	77	0.72**	131.66	-0.49**	178.86	-1.81**	57.46	4.52**	342.93
RH-9801	-0.88**	75	-0.39**	128.66	-0.39**	178.36	-1.83**	57.53	-2.50**	331.2
RK03-1	-0.99**	76	0.83**	133	-0.12**	178.5	-0.19*	61.86	-2.01**	336
RK03-2	0.56**	80.33	-1.69**	127.33	-0.14**	178.33	2.57**	66.66	-4.69**	330.33
RK03-3	0.12*	79	0.39**	132	0.34**	178.63	0.94**	63.13	-0.98	332.8
RK03-4	0.30**	80	0.46**	132.66	0.47**	179	0.46**	63.33	-6.68**	298.46
$\bar{x}_p$	77.9		130.81		178.72		61.53		332.54	
SE (g_i) ±	0.04		0.05		0.01		0.07		0.53	
SE $(g_i - g_j)$ ±	0.09		0.13		0.02		0.16		1.24	

Table 3: Cont.......

Parents	No. of primary branches/ plant gca effect	Mean	No. of secondary branches/ plant gca effect	Mean	Oil content gca effect	Mean	No. of seeds per siliqua Gca effect	Mean	Test weight gca effect	Mean	Seed yield / plant gca effect	Mean
Varuna	0.03	6.5	0.16**	17.33	0.46**	40.97	-0.17*	11.8	0.21**	5.33	1.39**	21.95
RH-819	0.16**	6.7	-0.10**	16.6	0.26**	40.84	-0.32**	11.5	0.09**	5.14	-0.28**	20.19
RH-9801	-0.11*	6.2	-.021**	15.73	-0.65**	35.42	0.36**	12.6	-0.10**	4.79	0.25**	20.05
RK03-1	-0.18**	6	-0.08**	15.86	0.47**	40.29	0.36**	12.4	-.015**	4.64	0.14**	20.92
RK03-2	0.56**	7.4	0.23**	17.2	-0.44**	36.04	-0.17**	11.8	0.09**	5.12	-0.46**	18.64
RK03-3	-0.18**	5.7	-0.04**	16.53	0.18*	40.36	-.40**	11	-0.14**	4.71	-1.08**	17.47
RK03-4	-0.28**	5.6	0.03*	16.86	-0.28**	38.06	0.34**	12.4	-0.01	4.95	0.04	18.46
$\bar{x}_p$	6.3		16.59		38.85		11.96		4.95		19.67	
SE (g_i) ±	0.03		0.01		0.05		0.01		0.02		0.02	
SE $(g_i - g_j)$ ±	0.01		0.03		0.02		0.02		0.01		0.06	

*Significant at p = 0.05; **Significant at p = 0.01

M_{el} = error variance obtained from parents and F_l combination

r = number of replications

CD = SE x't' ('t' value at 5% and 1%)

RESULTS AND DISCUSSION

The analysis of variance was carried out for eleven characters and showing the significant difference amongst all the parents except plant height, among the F_1's except number of secondary branches per plant and parents vs F_1's for all the characters revealed significant difference Vaghela *et al*. (2011), Patel *et al*. (2012), Arifullah (2013) Highly significant differences were recorded among the treatments for all the characters namely, days to (50%) flowering, days to maturity, plant height, length of main raceme, number of siliquae per plant, number of primary branches per plant, number of secondary branches per plant, number of seeds per siliqua, oil content, test weight and seed yield per plant. (Table 1)

The analysis of variance for combing ability (Table 2) indicated that variance due to general combining ability (gca) and specific combining ability (sca) were highly significant for all the characters Vaghela *et al*. (2011), Yadav *et al*. (1993). The variance due to sca is higher than the gca for the characters viz. days to flowering Gupta et al (2010), plant height, number of secondary branches per plant, oil content and seed yield per plant indicated that role of non-additive gene action inheritance of these traits. On the other hand the estimates gca is higher than sca for days to maturity, length of main raceme, number of siliquae per plant, number of primary branches per plant, number of seeds per siliqua and test weight.

The gca and sca ratio (GPR) was less than one for all the characters. This indicated that non-additive component played more role in inheritance of these characters. This is in agreement with the studies of Rao and Gulati (2001) and Patel *et al*. (1993).

The promising combiners based on per se performances and signficant gca effects (Table 3) were RK03-1 and RH-9808 for days to flowering; Varuna, RH-9808 and RK03-2 for days to maturity; RK03-2 for dwarf plant type; RK03-2,RK03-3 and RK03-4 for lenghth of main raceme; Varuna and RH-819 for Number of siliquae per plant; RK03-2 and RH-819 for number of primary branches per plant;RK03-2 and Varuna for number of secondary branches per plant; parent Varuna and RH-819 for high percentage of oil content; RH-819 and RK03-4 for number of seeds per slilqua;Varuna, RK03-2 and RH-819 for bolder seed size and Varuna for higher seed yield per plant were found more desirable combiners. These results accordance with Singh *et al*. (2005), Singh *et al*. (2007), Sadanand *et al*. (2009), Patel *et al*. (2012) and Gami and Chauhan (2013). RH-819, RK03-2, RH-9801 and RH-819 appeared to be good general combiner for most of the characters. The parents discussed above had high general combining ability and fixable component of gene action additive and additive x additive type of epistasis, these could be successfully exploited by developing homozygous line have used for improved character for which improvement was desired. These parental lines might be utilized for producing the intermatting population in order to get desirable recombinants in Indian mustard.

Analysis of specific combining ability is important parameter for judging the specific combinations for exploiting it though

Table 4: Estimates of sca effects for 11 characters of 21 F_1's derived from a 7 parents of diallel cross in Indian mustard.

Hybrid combination	Days to (50%) flowering		Days to maturity		Plant height		Length of main raceme		No. of siliquae/plant		No. of primary branches / plant	
	sca effect	Mean	sca effect	Mean	sca effect	Mean	sca effect	Mean	sca effect	Mean	sca effect	Mean
Varuna x RH-819	-0.85*	75	-0.01	128.33	1.16**	181.14	0.87	64.06	-1.2	366	0.12**	7.2
Varuna x RH 9801	-1.33**	73.33	0.44	127.66	0.56**	180.09	0.23	63.4	7.4	367.6	-0.01	7
Varuna x RK03-1	-0.022	74.33	-0.79	127.66	1.00**	181.6	1.72**	6.53	12.00*	372.66	0.26**	7
Varuna x RK03-2	-0.44	75.66	-1.27*	124.66	-0.05	180.53	1.83**	69.4	4.47	362.46	0.11**	7.6
Varuna x RK30-3	-1.00**	74.66	-2.68**	126.66	0.47**	181.2	2.06**	68	-1.1	360.6	0.26**	7
Varuna x RK30-4	0.15	76	-1.75**	126.33	-0.23*	180.96	1.14	65.93	19.13**	375.13	0.16**	6.8
RH-819 x RH-9801	-0.7	73.66	-0.6	127.66	0.01	179.53	-0.44	61.06	-4.23	348.13	0.06**	7
RH-819 x RK03-1	1.07**	74.66	-1.16*	128.33	-1.05**	179.4	0.85	64	-0.25	352.6	0.20**	7
RH-819 x RK03-2	-1.15**	75.33	-1.31*	125.66	0.23*	180	2.36**	68.26	8.16	358.33	0.26**	7.8
RH-819 x RK03-3	-1.04**	74.33	-1.05*	128	0.75**	181	3.06**	67.33	11.26*	365.13	0.13**	7
RH-819 x RK03-4	-0.22	75.33	-0.45	128.66	0.02	180.33	1.67*	65.46	19.15**	364	0.23**	7
RH-9801 x RK03-1	0.59	73.66	-1.05*	127.33	0.11	180	1.74**	64.86	-2.03	343.8	-0.13**	7
RH-9801 x RK03-2	-0.3	74.33	0.14	126	1.06**	180.93	2.45**	68.33	3.31	346.46	0.12**	6.4
RH-9801 x RK03-3	-0.19	74	-0.94	127	0.32**	180.66	2.21**	68.86	9.34	356.2	0.40**	7.4
RH-9801 x RK03-4	-1.70**	72.66	-1.01*	127	0.46**	180.93	1.83**	65.6	14.50**	355.66	0.50**	7
RK03-1 x RK03-2	-2.19**	72.33	-1.08*	126	0.60**	180.73	1.34*	68.53	-0.84	342.8	0.26**	7
RK03-1 x RK03-3	-2.41**	71.66	-0.49	128.33	1.19**	181.93	0.04	65.93	4.46	351.8	0.27**	7.6
RK03-1 x RK03-4	-2.93**	71.66	-2.23**	127	1.46**	182.2	0.12	65.53	7.29	348.3	0.17**	6.8
RK03-2 x RK03-3	-1.63**	74.33	-0.64	125.66	0.67**	182.26	-0.52	68.13	-1.8	342.86	0.32**	6.6
RK03-2 x RK03-4	-2.81**	73	-1.38**	125.33	1.47**	182.2	-0.24	67.93	7.96	346.93	0.16**	7.6
RK03-3 x RK03-4	-1.37**	74	-0.79	128	1.47**	180.33	0.93	67.46	8.99	351.66	0.23**	6.66
		73.96		126.98		180.95		60.01		356.33		7.08
SE (sij) ±	0.35		0.47		0.1		0.6		4.51		0.01	
SE (sij - sik) ±	0.79		1.4		0.23		1.33		9.97		0.04	

Table 4: Cont........

Hybrid combination	No. of secondary branches / plant		Oil content		No. of seeds per siliquqa		Test weight		Seed yield / plant	
	sca effect	Mean	sca effect	Mean	Sca effect	Mean	sca effect	Mean	sca effect	Mean
Varuna x RH-819	-0.05	18.06	0.61**	41.74	-0.19*	12.26	0.11**	5.52	-1.14**	23.52
Varuna x RH 9801	-0.07	17.93	2.2**	42.43	0.53**	13.66	0.24**	5.89	2.08**	2720
Varuna x RK03-1	1.26**	19.4	0.43**	41.76	0.19*	13.3	0.02	5.28	2.13**	27.22
Varuna x RK03-2	0.22	18.66	2.19**	42.62	-0.01	12.6	0.10**	5.66	1.22**	25.47
Varuna x RK30-3	0.43**	18.6	-2.64**	38.4	0.22*	12.6	0.03**	5.31	0.37	24.17
Varuna x RK30-4	0.29*	18.53	-2.09**	38.5	0.74**	13.8	0.09**	5.5	3.99**	28.25
RH-819 x RH-9801	-0.08	17.66	-0.31**	39.71	0.28**	13.2	0.11**	5.3	1.77**	25.24
RH-819 x RK03-1	0.86**	18.73	-0.28**	40.85	0.28**	13.2	0.30**	5.45	0.66*	24.69
RH-819 x RK03-2	0.94**	19.13	1.81**	42.03	0.54**	13	-0.23**	5.16	0.81*	23.56
RH-819 x RK03-3	0.35**	8.26	-0.96**	39.88	0.1	12.3	0.08**	5.24	1.58**	23.72
RH-819 x RK03-4	0.49**	18.46	-0.70**	39.68	0.56**	13.5	0.12**	5.41	1.82**	25.01
RH-9801 x RK03-1	0.30*	18.06	-0.8**	39.75	0.66**	14.3	0.04**	4.99	1.00**	24.89
RH-9801 x RK03-2	1.32*	19.4	1.75**	41.7	0.39**	13.5	0.14**	5.33	1.56**	24.85
RH-9801 x RK03-3	1.06**	18.86	2.18**	42.2	0.28**	13.2	-0.02	4.94	1.54**	24.21
RH-9801 x RK03-4	1.26**	19.13	2.03**	41.51	0.01	13.6	0.02	5.12	-0.05	23.74
RK03-1 x RK03-2	0.39**	18.6	0.47**	40.91	0.59**	13.7	0.16**	5.31	1.42**	24.6
RK03-1 x RK03-3	0.73**	18.66	0.90**	41.98	0.55**	13.4	0.06**	4.97	0.72**	23.28
RK03-1 x RK03-4	0.83**	18.53	1.07**	41.66	0.14	13.8	-0.04**	5.01	-0.20**	23.46
RK03-2 x RK03-3	0.09	18.33	-0.59**	39.5	0.08	12.4	0.17**	5.33	0.84**	22.79
RK03-2 x RK03-4	-0.31*	18	1.35**	41.04	0.07	13.2	0.19**	5.48	2.01**	25.09
RK03-3 x RK03-4	0.23	18.26	1.92**	42.22	0.96**	13.8	-0.1	5.16	2.68**	25.14
		18.54		40.92		13.28		5.29		24.77
SE (sij) ±	0.12		0.01		0.09		0.01		0.25	
SE (sij - sik) ±	0.27		0.04		0.21		0.02		0.55	

*Significant at P = 0.05; **Significant at P = 0.01

heterosis breeding programme. The good specific cross combinations are selected based on their sca effects. The specific combining ability effects and per se performance obtained from the analysis presented in Table 4. A perusal of the table revealed that the F_1 crosses, RK03-1 X RK03-4, RK03-1 X RK03-3 and RK03-1 X RK03-2 for early flowering; RK03-2 X RK03-4 for early maturity; RH-819 X RK03-1 for dwarfness; RH-819 X RK03-1 for length of main raceme; Varuna X RK03-4 and Varuna x RK03-1 for number of more siliquae per plant; RH-9801 X RK03-4, RH-9801 X RK03-3, RK03-2 X RK03-3

Table 5: Estimates of heterosis over economic parent (Varuna) for11 characters in 21 F_1's derived from a 7 diallel cross in Indian mustard

Source of variance	Days to 50% flowering	Days to maturity	Plant height (cm)	Length of main raceme	Number of siliquae per plant	Number of primary branches per plant	Number of secondary branches per plant	Oil content	Number of seeds per siliqua	Test weight	Seed yield per plant
	EH	EH	EH	EH	EH	EH	EH	EH	EH	EH	EH
Varuna x RH-819	-3.85**	-1.53	1.00**	5.14**	3.20**	10.77*	4.23**	1.88	3.37	5.31	6.91
Varuna x RH 9801	-5.98**	-2.05*	0.72**	4.05*	3.65**	4.62	3.46**	3.56**	15.17**	4.06	23.99**
Varuna x RK03-1	-4.70**	-2.05*	1.11**	9.19**	5.08**	7.69	11.92**	1.94*	12.36**	-0.94	2.75**
Varuna x RK03-2	-2.99*	-4.35**	0.52*	13.89**	2.20*	16.92*	7.69**	4.02**	6.18**	5.12	16.83**
Varuna x RK03-3	-4.27**	-3.84**	1.08**	11.60**	1.67*	7.69	7.31**	-6.27**	6.18**	-0.50	10.13**
Varuna x RK03-4	-2.56*	-3.07**	0.76**	9.30**	5.77**	4.62	6.92**	-6.03**	16.85**	3.06	31.75**
RH-819 x RH-9801	-4.33**	-3.04*	0.37	6.51	1.52*	4.48	6.43	-2.76*	15.03**	3.11	25.00**
RH-819 x RK03-1	-2.16**	-2.53**	-0.07*	11.63**	2.82	5.47	12.85**	0.02	15.03**	6.02	19.00*
RH-819 x RK03-2	- 3.03**	-4.56**	0.63	19.07**	4.49	17.41**	15.26**	2.93*	12.72**	0.32	16.72*
RH-819 x RK03-3	-3.46**	-2.78*	1.18*	17.4**	6.47**	4.48	10.04**	-2.35*	6.94**	1.94	17.50*
RH-819 x RK03-4	-2.16**	-2.28	0.86	14.19**	7.12**	4.48	11.24**	-2.84**	13.34**	5.18	24.22**
RH-9801 x RK03-1	-1.78**	-1.04**	0.92	12.88**	3.80**	4.30	14.83**	12.23*	13.76**	5.42*	24.12**
RH-9801 x RK03-2	-0.89**	-2.07**	1.44**	18.91**	4.61	20.43*	23.31**	15.94	7.41**	12.60	23.92**
RH-9801 x RK03-3	-1.33**	-1.30**	1.22*	15.66**	7.55	12.90	19.92**	18.91*	4.76**	4.36*	20.72**
RH-9801 x RK03-4	-3.11**	-1.30**	1.44**	14.15*	7.39	12.90	21.61**	17.19	8.47**	8.09	18.36*
RK03-1 x RK03-2	-4.82**	-5.26**	1.25**	11.31**	2.02**	25.56*	17.23**	1.53	10.16**	14.51	17.57**
RK03-1 x RK03-3	-5.70**	-3.26	1.85**	6.57**	4.70	13.33	17.65**	4.14	8.02**	7.26*	11.25
RK03-1 x RK03-4	-6.14**	-4.51**	2.07**	5.93**	3.85*	10.00	16.81**	3.40	10.70**	8.05*	12.22
RK03-2 x RK03-3	-7.88**	-1.0**	1.76**	2.20**	3.79	2.70*	6.51**	9.76**	5.65**	4.17	22.26
RK03-2 x RK03-4	- 9.13**	-1.57**	2.28**	1.90**	5.03*	-0.90	4.65**	13.86	11.86**	7.03	34.55**
RK03-3 x RK03-4	-6.33**	- 3.03**	2.26**	6.86**	5.67	16.28	10.48**	4.61*	25.30**	9.40	43.90**
SE(EP)	0.94	1.08	0.49	1.22	3.34	0.21	0.55	0.22	0.49	0.16	0.79

*Significant at P = 0.05; **Significant at P = 0.01

based only sca effects for more number of primary branches per plant; RH-9801 X RK03-2 and RH-9801 X RK03-4 for number of secondary branches per plant; Varuna X RK03-2 for more oil content; RK03-3 X RK03-4, Varuna X RK03-4 and RH-9801 X RK03-1 for more number of seeds per siliqua; Varuna X RH-9801 for greater test weight and Varuna X RK03-4 and Varuna X RK03-1 for more seed yield per plant were superior/best specific combiners these findings also reported by different workers viz; Dixit *et al*. (2007), Yadav *et al*. (2009) Vaghela *et al*. (2011) and Maurya *et al*. (2012).

Therefore, based on outstanding performance of selective parents (donor to get high yield) and crosses concluded that possessing high SCA effect and high heterosis for grain yield may further be used for future under different breeding programmes.

The heterosis are estimated of all the cross combinations (Table-5) over the economic parent Varuna Tyagi *et al*. (2000) and Chauhan *et al*. (2000). All the crosses show negative heterosis but the maximum negative and significant heterosis was observed RKO3-2 X RKO3-4 (-9.13) for days to flowering; RK03-1 X RK03-2 (-5.26) for days to maturity; for plant height only the cross RH-819 X RK03-1 (-0.07) show negative heterosis; and the positive significant heterosis RH-9801 X RK03-4 (7.12) for number of siliquae per plant; for number of primary branches per plant RK03-1 X RK03-2 (25.56); for number of secondary branches per plant RH-9801 X RK03-2 (23.31); for oil content RH-9801 X RK03-3 (18.91); for number of seeds per siliqua Varuna x RK03-4 (16.85); for test weight RK03-1 X RK03-4 (8.05) and for seed yield per plant RK03-3 X RK03-4 (43.90) Kumar *et al*. (2007). Top ranking five economic crosses which have significant sca effect and high per se performance for seed yield are RK03-3 X RK03-4, RK03-2 X RK03-4, Varuna X RK03-4, RH-819 X RH-9801, and RH-819 X RK03-4 Nasrin *et al*. (2011).

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