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ESTIMATE THE RELATIVE HETEROSIS AND HETEROBELTIOSIS FOR YIELD COMPONENTS IN INDIAN MUSTARD (BRASSICA JUNCEA (L.) CZERN & COSS)

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ABSTRACT

The extent of heterosis has been measured from the diallel cross over the mid and better parent in Indian mustard [*Brassica juncea (L.)* Czern & Coss]. Twenty- one F_1 crosses along with seven diverse parental genotypes planted at the Division of Plant Breeding and Genetics, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu, during the year 2013-2016 were evaluated for twelve characters, including days to bloom, days to reproductive phase, primary branches per plant, secondary branches per plant, pod intensity, seed yield per plant (g), harvest index (%), plant height (cm), pod length (cm), seeds per siliqua, seed weight per siliqua and 1000-seed weight (g). Analysis of variance revealed considerable genetic variability among parents and F_1 crosses for all the traits except seed weight per siliqua. Heterosis ranged from 3.41(PM-21 x PM-24) to 101.34 per cent (PM-22 x Pusa-Karishma) for yield per plant. The present study also revealed that the crosses viz., PM-21 ×PM-22, PM-21 ×Pusa-Karishma, PM-22 ×PM-24, PM-22 × Pusa-Karishma and PM-24 × Pusa-Karishma had high postive heterosis for seed yield per plant.

KEYWORDS: Relative heterois, heterobeltiosis, non-allelic interaction. .

I. INTRODUCTION

Rapeseed mustard is the second most important oilseed crop in India after soybean. Generally four species viz., *Brassica juncea,* L. *Brassica napus*,L. *Brassica rapa*,L and *Brassica carinata*, L are cultivated in India. Out of these four species, Indian mustard (*B. juncea,* L) has contributed more than 80 per cent to total rapeseed production and the productivity is hovering around 10 qha^{-1}. In order to break the yield plateau, the potential of *B. juncea,* L has to increase to make India self sufficient in oil production. In this direction, an ideal plant type has to be developed which could give high performance in per unit area per unit time.

The term heterosis was first used by Shull (1914). Hayes, Immer and Smith (1955) defined heterosis as increased vigour of F_1 over the mean of parents as or over the superior parent. Abercrombie *et al.,* (1961) described heterosis as increased vigour of growth, fertility etc., in cross between two genetically different lines as compared with growth etc., in either of the parental lines associated with increased heterozygosity. It occurs widely in cross and self-pollinated crops. An essential factor in breeding for heterosis is the identification of hybrids that are more productive than the best parents/cultivars. In some species, male sterility and fertility restores systems and self-imcompatibility mechanisms have made the utilization of heterosis relatively easy. Singh *et al.,* (2012) investigated for estimation of mid and better parent heterosis among the various traits of Indian mustard [*Brassica juncea* (L) Czern & Coss.]. Significant positive heterosis over mid parent was registered for plant height, secondary branches per plant, seed yield per plant in all crosses and for number of siliquae on main raceme, and length of main raceme in cross-II and III. Patel *et al.,* (2012) studied heterosis over mid parents and better parent with ten diverse parents and their 45 F_1's in half diallel mating design in Indian mustard for nine quantitative and quality traits. The average performance of hybrids differed significantly from the average performance of parents indicating the presence of overall heterosis, which was also evident from the significance of parents vs. hybrids comparison for all the traits except for plant height, 1000 seed weight and oil content. Nasim *et al.,* (2014) studied heterosis for yield and yield contributing traits in 5 x 5 diallel cross in *Brassica rapa,* L. Primary branches/plant, pods/main raceme, pod length, 1000-seed weight and seed yield/plant

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were significantly different. Abbas *et al.*, (2015) studied three yield traits in five varieties representing two *Brassica napus* types and *B. campestris* var. toria along with their hybrids from a half-diallel set of crosses.

II. MATERIAL AND METHODS

The investigation was carried out at the Division of Plant Breeding and Genetics, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu, during the year 2013-2016. The experimental material comprised of seven diverse genotypes of *Brassica juncea* were crossed to produce F_1 half diallel set of crosses during 2013-14 (Table No. 1). Twenty-one crosses were generated through half diallel mating design following Method 2, Model I of Griffing (1956) for the estimation of hetersois over mid and better parents. F_1 along with seven parents were sown in a randomized block design with three replications. Each entry was represented by three rows of 5 meter long, 30 cm apart with plant to plant distance being 15 cm.

Table No. 1: Distinguishing of genotypes used in the study is tabulated below

S.No.	Genotypes	Pedigree	Characteristic feature
1.	RSPR-01	*B. juncea×D. muralis*	High percentage of glucosinolate and erucic acid
2.	RSPR-03	Kranti × Pusa Bold	High percentage of glucosinolate and erucic acid
3.	PM-21	Pusa Bold x Zem-2	Erucic acid < 2.2%
4.	PM-22	Pusa Barani x Zem-2	Erucic acid < 2%
5.	PM-24	(Pusa Bold x LEB-15) x LES-29	Erucic acid < 2%
6.	Varuna	Selection from Varanasi Local 786,02.021976	High percentage of glucosinolate and erucic acid, high yield.
7.	Pusa Karishma	Pusa Basanti x Zem-1	Erucic acid 0.6%

Relative Heterosis: The superiority of F_1 hybrid over the mid-parental value (i.e., mean value of two parents involved in the cross is known as mid-parent or relative heterosis.

$$\text{Relative Heterosis} = \frac{F_1 - MP}{MP} \times 100$$

Heterobeltiosis: The superiority of F_1 hybrid over the better-parent out of the two parents involved in the cross is refered to as better-parent heterosis or heterobeltiosis.

$$\text{Heterobeltiosis} = \frac{F_1 - BP}{BP} \times 100$$

Where, F_1 = Mean performance of F_1 hybrid
P_1 = Mean performance of parent one
P_2 = Mean performance of parent two
MP = Mean performance of mid parent
BP = Mean performance of better parent
The difference of F_1 mean from the respective mid-parent and better parent value was evaluated by using a t-test according to Wynne *et al*. (1970).

$$t = \frac{(F_{1ij}-MP_{ij})}{(3/8\ \sigma^2_e)^{1/2}} \times 100$$

Where,
F_{1ij} = The mean of ijth F_1 cross
MP_{ij} = Mid parent value of the ijth cross
σ^2_e = Estimate of error variance
The significance of heterosis was ascertained by critical difference (CD) values calculated as follows:

$$\text{C.D. for mid parents heterosis and better heterosis} = \sqrt{\frac{2Me}{r}} \times t$$

Where,
r = Number of replication
t = Tabulated value at error degree of freedom

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M_e = Error mean square

The significance was tested at 5 percent and 1 percent probability level at the error degrees of freedom.

III. RESULTS

The analysis of variance revealed significant differences among treatments, parents and hybrids were significant for almost all the traits except seed weight per siliqua. Mean squares due to parents vs hybrids were also significant for all the traits except days to reproductive phase, primary branches per plant and pod length (Table No. 2). The estimates of the heterosis over mid parent and over the better parent presented in Table No. 3 and 4.

Table No. 2: Analysis of variance for different characters in a diallel cross

Sources	Replications	Treatments	Parents	Hybrids	Parent vs. Hybrids	Error
d.f.	2	27	6	20	1	54
Days to bloom	4.71	69.03**	69.63**	70.11**	43.92**	1.7
Days to reproductive phase	9.72	36.86**	34.65**	39.30**	1.4	3.6
Primary branches per plant	0.26	1.70**	1.95**	1.69**	0.28	0.17
Secondary branches per plant	3.11	21.12**	9.17**	12.98**	255.61**	1.47
Seeds per siliqua	0.11	1.48**	0.38	1.80**	1.65*	0.34
Seed weight per siliqua	628.97	766.86	1976.00*	206.45	4720.28**	627.14
Pod length	0.2	0.39**	0.66**	0.32**	0.12	0.09
1000 seed weight	0.04	0.73**	0.23**	0.82**	1.93**	0.03
Pod intensity	0.01	0.02**	0.01*	0.03**	0.02*	0
Plant height	0.1	83.59**	62.63**	92.08**	39.52*	5.85
yield per plant	2.93	40.56**	51.62**	15.10**	483.57**	3.22
Harvest index	26.91	632.89**	913.22	549.53**	617.71**	142.25

*,** significant at 0.05 and 0.01 level, respectively

For days to bloom, heterosis ranged from -21.50 to 12.34 per cent. Out of twenty-one hybrids, fourteen hybrids gave negative heterosis, among them eleven hybrids viz., RSPR-01 x RSPR-03, RSPR-01 x PM-21, RSPR-01 x PM-22, RSPR-01 x Pusa-Karishma, RSPR-03 x PM-21, RSPR-03 x PM-22, RSPR-03 x Pusa-Karishma, PM-21 x Varuna, PM-22 x PM-24, PM-24 x Pusa-Karishma and Varuna x Pusa-Karishma gave significant heterosis. Sixteen crosses showed negative and significant heterobeltiosis for days to bloom. Cross PM-24 x Pusa-Karishma exhibited highest negative heterobeltiosis. Heterosis for days to reproductive phase ranged from -13.23 to 22.31 per cent. Ten cross combinations out of twenty-one showed positive heterosis, among them five crosses shown significant heterosis namely RSPR-01 x RSPR-03, RSPR-01 x PM-22, RSPR-03 x PM-22, RSPR-03 x Varuna followed by PM-21 x Pusa Karishma. RSPR-01 x RSPR-03 expressed the highest heterosis for this character. Only two hybrids viz., RSPR-01 x RSPR-03 and RSPR-03 x Varuna exhibited positive and significant values for heterobeltiosis. Heterosis ranged from -15.68 to 52.10 per cent for primary branches per plant. Nine hybrids showed positive heterosis, out of these five cross combinations viz., RSPR-01 x Pusa-Karishma, PM-22 x Varuna, PM-22 x Pusa-Karishma, PM-24 x Pusa-Karishma and Varuna x Pusa-Karishma showed significant heterosis. Varuna x Pusa-Karishma showed highly heterosis for primary branches per plant. The estimates for heterobeltiosis revealed that seven hybrids showed positive values for this character but none of these exhibited significant values. The percentage for heterosis in secondary branches per plant ranged from

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1.92 to 61.27. All cross combinations exhibited positive heterosis, among them all hybrids showed significant except Varuna x Pusa-Karishma. PM-21 x PM-22 exhibited highly heterosis for this character. The percentage for heterobeltiosis in secondary branches per plant ranged from -17.62 to 60.85. The estimates for heterobeltiosis showed that all hybrids have positive heterosis for this character except Varuna x Pusa-Karishma. Out of these hybrids, seventeen cross combinations gave significant values.PM-21 x PM-24 showed highly heterobeltiosis for secondary branches per plant. Manifestation of heterosis was found in seeds per siliqua in both positive and negative directions. For this trait, cross PM-22 x PM-24 exhibited significant positive heterosis. Five crosses exhibited non-significant positive heterobeltiosis viz., RSPR-01 x PM-22, RSPR-03 x PM-22, RSPR-03 x Varuna, PM-22 x PM-24 and PM-24 x Pusa-Karishma. For Seed weight per siliqua, the percentage of heterosis ranged from -71.33 to 46.90. Heterosis for Seed weight per siliqua for five crosses viz., RSPR-01 x PM-21, RSPR-03 x PM-21, PM-21 x Varuna, PM-24 x Pusa Karishma and Varuna x Pusa Karishma showed positive mid-parental heterosis but none of these crosses exhibited positive significant heterosis. All cross combinations showed negative heterobeltiosis for Seed weight per siliqua except PM-21 x Varuna. Heterosis for pod length ranged from -20.32 to 34.04 per cent. Out of twenty- one hybrids, three cross combinations viz., RSPR-01 x Varuna, RSPR-03 x PM-24 and RSPR-03 x Varuna showed highly significant positive mid-parental heterosis. Two hybrids namely.

Table No. 3: Heterosis over the mid and better parent for different characters

Crosses	**Days to bloom**		**Days to reproductive phase**		**Primary branches per plant**		**Secondary branches per plant**		**Seeds per siliqua**		**Seed weight per siliqua**	
	Mid-parent	Better-parent	Mid-parent	Better-parent	Mid-parent	Better-parent	Mid-parent	Better-parent	Mid-parent	Better-parent	Mid-parent	Better-parent
RSPR-01× RSPR-03	-7.75**	-9.16**	22.31**	17.09**	7.69	4.26	22.65**	16.84*	-1.16	-1.73	-26.21	-46.15
RSPR-01× PM-21	-5.67**	-7.17**	0.17	-4.07	-3.74	-9.09	37.40**	31.22**	-1.46	-2.31	4.28	-4.46
RSPR-01× PM-22	-10.45**	-17.08**	6.72**	5.53	-6.45	-11.22	23.60**	19.57*	5.17	4.57	-34.95	-52.57
RSPR-01× PM-24	3.43	-5.40**	-4.48	-8.58**	1.15	0.00	22.22**	17.02*	-13.41**	-16.21**	-64.26*	-78.47**
RSPR-01× Varuna	5.37**	2.64	3.13	3.00	-13.23**	-18.81	20.55**	13.99	-3.98	-5.59	-17.63	-30.79
RSPR-01× Pusa-Karishma	-9.59**	-13.38**	2.15	1.30	14.29*	0.00	33.33**	12.79	-3.98	-5.59	-40.52	-58.09
RSPR-03× PM-21	-4.59*	-4.66*	-2.40	-10.35**	-8.81	-11.11	42.48**	42.11**	-6.16	-6.44	18.43	-8.10
RSPR-03× PM-22	-9.79**	-17.65**	5.22*	-0.35	4.17	2.04	22.46**	20.53*	1.74	0.58	-21.22	-21.32
RSPR-03× PM-24	4.27*	-5.95**	4.13	-4.40	-7.78	-11.70	30.69**	30.00**	-4.49	-8.11*	-68.36*	-77.13**
RSPR-03× Varuna	7.35**	3.02	11.36**	6.48*	-4.62	-7.92	43.08**	41.97**	4.00	1.68	-39.66	-49.46
RSPR-03×	-7.35**	-12.53**	-2.55	-7.46**	8.75	-7.45	50.16**	22.11**	-6.86	-8.94*	-55.11	-57.57

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Pusa-Karishma												
PM-21× PM-22	12.34**	2.49	-3.53	-6.61*	-13.71**	-14.14	30.29**	28.57**	-9.56*	-10.85*	-35.07	-49.66
PM-21× PM-24	9.22**	-1.54	-11.06**	-11.11**	-15.68**	-21.21	61.27**	60.85**	-8.17*	-11.89**	-65.48*	-78.49**
PM-21× Varuna	-4.01*	-7.93**	-9.94**	-13.66**	-14.00**	-14.85	50.26**	48.70**	-6.59	-8.94*	46.90	33.49
PM-21× Pusa-Karishma	-2.77	-8.27**	6.33**	2.64	23.64**	3.03	40.26**	14.29	0.86	-1.67	20.70	-9.99
PM-22× PM-24	-13.06**	-14.21**	-1.08	-4.29	-5.43	-11.22	23.66**	22.34**	7.78*	4.86	-71.33**	-79.26**
PM-22× Varuna	-0.24	-5.32**	2.55	1.53	14.57**	12.87	28.38**	25.39**	-14.12**	-15.08**	-26.64	-38.62
PM-22× Pusa-Karishma	0.59	-2.94	-9.97**	-10.24**	18.29**	-1.02	52.48**	25.54**	-3.39	-4.47	-54.20	-56.66
PM-24× Varuna	-2.59	-8.70**	-8.50**	-12.32**	-5.88	-12.87	29.66**	27.98**	0.01	-1.62	-66.90*	-78.47**
PM-24× Pusa-Karishma	-21.50**	-25.22**	-13.23**	-16.28**	18.42**	4.65	55.70**	27.13**	6.59	4.86	-68.26**	-76.18**
Varuna× Pusa-Karishma	-7.18**	-8.76**	-4.29	-4.97	52.10**	25.74	1.92	-17.62*	-1.12	-1.12	13.64	-9.02
S.E	0.92	1.07	1.34	1.55	0.29	0.34	0.86	0.99	0.42	0.48	1.96	2.26

*,** significant at 0.05 and 0.01 level, respectively

Table No. 4: Heterosis over the mid and better parent for different characters

Crosses	Pod length		1000 seed weight		Pod intensity		Plant height		yield per plant		Harvest index	
	Mid-parent	Better-parent	Mid-parent	Better-parent	Mid-parent	Better-parent	Mid-parent	Better-parent	Mid-parent	Better-parent	Mid-parent	Better-parent
RSPR-01× RSPR-03	4.42	-0.35	0.10	-3.47	7.91	2.65	-3.43**	-4.62**	25.93**	21.91*	45.06	-0.81
RSPR-01× PM-21	9.90	0.48	21.32**	17.04**	-0.69	-6.49	-3.15**	-6.13**	50.08**	28.46**	-16.05	-18.52
RSPR-01× PM-22	-8.42	-21.78**	1.69	-2.48	10.00	-1.17	-4.56**	-4.63**	45.00**	21.13*	51.32*	16.55
RSPR-01× PM-24	8.45	-2.18	-21.36**	-22.02**	12.73	5.08	5.86**	3.77**	41.73**	19.59	8.95	4.35
RSPR-01× Varuna	20.00**	14.61*	-7.27**	-8.45**	13.86	12.75	1.24	0.69	4.36	-10.69	-5.72	-11.78
RSPR-01× Pusa-	7.16	-4.26	0.33	-2.26	-12.68	-13.11	1.24	-0.91	52.58**	30.84**	89.18**	29.31

Karishma												
RSPR-03× PM-21	-0.75	-5.13	-1.14	-7.90**	-6.78	-7.79	-5.16**	-6.96**	38.14**	15.10	-52.78*	-68.22**
RSPR-03× PM-22	-1.46	-12.33*	-0.76	-8.08**	2.07	-3.91	-1.00	-2.29*	44.86**	17.90	87.47*	57.48
RSPR-03× PM-24	14.03*	7.47	17.48**	14.22**	-2.60	-4.66	-0.52	-1.27	32.26**	8.69	51.50*	1.24
RSPR-03× Varuna	34.04**	33.92**	4.71	2.24	11.27	4.87	1.64	0.93	16.02*	2.11	21.64	-19.70
RSPR-03× Pusa-Karishma	2.94	-3.96	-3.81	-4.81	6.02	1.33	2.63**	1.69	53.67**	28.27**	180.02**	179.83 **
PM-21× PM-22	-3.55	-10.55	24.33**	23.55**	22.79**	16.80*	-5.28**	-8.27**	78.70**	73.53**	32.90	0.26
PM-21× PM-24	1.34	-0.16	17.45**	12.40**	15.63*	14.41	-0.02	-1.17	3.41	1.65	9.32	7.83
PM-21× Varuna	-9.40	-13.46*	8.15**	3.07	19.72**	11.69	-2.07*	-4.58**	30.39**	-1.78	-39.72*	-41.95*
PM-21× Pusa-Karishma	-0.39	-2.89	17.29**	10.35**	8.92	3.03	-3.79**	-4.75**	97.48**	97.04**	-50.43*	-66.65 **
PM-22× PM-24	-20.32**	-25.07**	13.02**	7.51*	14.23*	9.77	0.90	-1.16	97.61**	95.19**	29.64	-3.11
PM-22× Varuna	-4.93	-15.48**	4.13	-1.35	-6.14	-16.41*	-1.72	-2.32*	19.38*	-11.82	20.75	-11.18
PM-22× Pusa-Karishma	-8.87	-13.42*	8.85**	1.81	-5.63	-14.84*	1.96*	-0.28	101.34**	95.10**	106.02**	72.96
PM-24× Varuna	5.53	-0.62	19.02**	18.50**	0.46	-7.20	-1.68	-3.10**	34.76**	0.34	1.90	-0.54
PM-24× Pusa-Karishma	1.54	0.46	21.40**	19.26**	-2.71	-8.90	-0.16	-0.32	78.23**	74.80**	25.89	-15.90
Varuna× Pusa-Karishma	5.14	-1.98	14.08**	12.54**	0.00	-1.46	-0.66	-2.25*	8.62	-18.05*	-52.42 *	-68.60**
S.E	0.21	0.25	0.12	0.14	0.05	0.06	1.71	1.97	1.27	1.47	2.21	2.55

*,** significant at 0.05 and 0.01 level, respectively

RSPR-01 x Varuna and RSPR-03 x Varuna showed significantly positive heterobeltiosis for pod length. Heterosis ranged from -21.36 to 24.33 per cent for 1000 seed weight. Eleven hybrids viz., RSPR-01 x PM-21, RSPR-03 x PM-24, PM-21 x PM-22, PM-21 x PM-24, PM-21 x Varuna, PM-21 x Pusa-Karishma, PM-22 x PM-24, PM-22 x Pusa Karishma, PM-24 x Varuna, PM-24 x Pusa-Karishma and Varuna x Pusa-Karishma exhibited significant positive mid-parental heterosis. The percentage heterobeltiosis range from -22.02 to 23.55.

The results for heterobeltiosis estimates for 1000 seed weight revealed that out of twenty-one hybrids, twelve crosses gave positive heterobeltiosis, and nine crosses viz., RSPR-01 x PM-21, RSPR-03 x PM-24, PM-21 x PM-22, PM-21 x PM-24, PM-21 x Pusa-Karishma, PM-22 x PM-24, PM-24 x Varuna, PM-24 x Pusa-Karishma and Varuna x Pusa-Karishma among them showed significant values. For pod intensity, heterosis ranged from -12.68 to 22.79 per cent. Heterosis for pod intensity showed highly significant positive mid-parental heterosis displayed by four crosses viz., PM-21 x PM-22, PM-21 x PM-24, PM-21 x Varuna and PM-22 x PM-24. Cross PM-21 x PM-22 showed significant positive heterobeltiosis for pod intensity. Heterosis for plant height ranged from -5.28- 5.86 per cent. Fourteen out of twenty-one crosses showed negative heterosis, and seven crosses were found to be significant heterosis for plant height. The highest value was found in the cross PM-21 x PM-22 which gave short plant height among single cross hybrids. The results for heterobeltiosis estimates for plant height revealed that highly significant negative better-parental heterobeltiosis was displayed by eleven crosses viz., RSPR-01 x RSPR-03, RSPR-01 x PM-21, RSPR-01 x PM-22, RSPR-03 x PM-21, RSPR-03 x PM-22, PM-21 x PM-22, PM-21 x Varuna, PM-21 x Pusa-Karishma, PM-22 x Varuna, PM-24 x Varuna and Varuna x Pusa-Karishma. For yield per plant, heterosis ranged from 3.41 to 101.34 per cent. All the crosses except RSPR-01 x Varuna and PM-21 x PM-24 exhibited highly significant mid-parental heterosis. Cross PM-22 x Pusa-Karishma exhibited highly positive significant heterosis. Ten cross combinations viz., RSPR-01 x RSPR-03, RSPR-01 x PM-21, RSPR-01 x PM-22, RSPR-01 x PusaKarishma, RSPR-03 x Pusa-Karishma, PM-21 x PM-22, PM-21 x Pusa-Karishma, PM-22 x PM-24, PM-22 x Pusa-Karishma and PM-24 x Pusa-Karishma showed positive significant heterobeltiosis. The percentage of heterosis for harvest index ranged from -52.78 to 180.02. Fifteen out of twenty-one gave positive heterosis for harvest index and six among them showed significant positive heterosis. Cross RSPR-03 x Pusa-Karishma exhibited highly significant positive heterosis. The estimates of heterobeltiosis for harvest index revealed that RSPR-03 x Pusa-Karishma exhibited highly significant positive better-parental heterobeltiosis.

IV. DISCUSSION

The term heterosis was first used by Shull (1914) for the superiority in vigour of certain hybrids over parents. Afterwards, Hayes, Immer and Smith (1955) defined heterosis as increased vigour of F_1 over the mean of the parents or over the superior parents. Jinks (1956) suggested that non-allelic interaction is more likely and frequent cause of heterosis rather than specific relation between the genes at same locus. There are number of techniques for the estimation of heterosis, however the diallel cross analysis is ‘one such’ technique which has been used for determining the extent of heterosis in the present study. F_1 hybrids exhibited heterosis for yield upto 95.19 percent over the high yielding parent. This is in agreement with Grant and Berersdorf (1985), Labana and Banga (1983a), Gami and Chauhan (2013) and Shrimali *et. al.*, (2016). The magnitude of heterosis for seed yield per plant is of paramount importance for developing high yielding hybrids/cultivars. In the present study, out of 21 crosses, 18 crosses exhibited positive relative heterosis while 11 crosses showed positive heterobeltiosis. Heterosis over the mid parent for seed yield was found to be 101.34 percent in a cross (PM-22 × Pusa-Karishma).

Secondly, significant positive heterosis to this extent may be attributed to non-additive gene action. Non-allelic interaction which can either increase or decrease the expression of heterosis (Hayman, 1957, 1958) might bear some responsibility. For primary branches, the F_1 hybrid exhibited heterosis upto 52.10 and 25.74 percent over the mid and better parent, respectively. Similar results have been reported by Kumar *et al.*, (2013) and Patel *et al.*, (2012). This can be attributed to partial dominance for this character. The information based on the present investigation with respect to gene effects clearly demonstrate that heterosis in *Brassica juncea*, L will not be commercially viable among the present germplasm as the heterosis for commercial exploitation, F_1 maximum out yield available cultivar’s by significant margin so as to compensate for high cost of F_1 seed. Secondly, the heterosis can be exploited provided high viable cytoplasmic and genetic system of male sterility for proper maintenance and exploitation should exist in *Brassicas.*

V. CONCLUSION

The extent of heterosis has been measured from the diallel cross over the mid and better parent. The maximum heterosis to the extent of 180.02% on mid parent and 179.83% over better parent was recorded for harvest index in cross RSPR-03 × Pusa-Karishma. In case of seed yield per plant, the maximum heterosis (101.34%) over the mid parent and 95.10% over the better parent was observed in cross PM-22 × Pusa- Karishma. The present study also revealed that the crosses viz., PM-21 ×PM-22, PM-21 ×Pusa-Karishma, PM-22 ×PM-24, PM-22 × Pusa-Karishma and PM-24 × Pusa-Karishma had high postive heterosis for seed yield per plant. Therefore, these crosses can be further utilized in hybrid breeding programmes for the development of high yielding cultivars in *Brassic juncea*, L.

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VII. REFERENCES

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