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Heterosis and combining ability for seed yield and its components in *Brassica juncea L.*

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Abstract:

The heterosis and combining ability of six Indian mustard (*Brassica juncea* L.) genotypes were estimated using 6 × 6 diallel crosses. The analysis of variance indicated significant differences among parents and their hybrids in the F1 generation for all the traits studied. The cross combinations namely CR-5 × RAS 3189, DP 7-91 × INDIA III, RAS 3189 × DP 7-91, RAS 3189 × 0714-A and RAS 3189 × INDIA III exhibited significant heterosis for most of the studied traits thus may be exploited using heterosis breeding. The parent INDIA III and DP 18-9 was best general combiners for majority of traits. The cross combination DP 7-91 × INDIA III proved best specific combiner for plant height, number of siliquae per plant, number of seeds per siliquae and seed yield per plant. The GCA and SCA mean squares significance determined the presence of both additive and non-additive gene action that execute role for the expression of these traits.

Keywords: Pakistan, heterosis, Combining ability

1. Introduction

The genus *Brassica* belongs to *Cruciferae* family that includes a number of important species. These species produce roots, stems, leaves, buds and seeds which are edible. Some species are used as oilseed crops and some are used as forage. *Brassica juncea*, an important species of this genus, is an important oilseed crop of the world. The oil content of *Brassica juncea* varies between 28.6 to 45.7% [16]. Its oil, in indian subcontinent, is mainly used for edible purposes, hair oil and lubricants. Its seed residue is used in fertilizers and as feed for cattle. *Brassica juncea* is largely grown as an oilseed crop in Pakistan, China, India and also widely cultivated in Europe, Canada, Australia and Russia. In Pakistan, the rapeseed and mustard yield is generally low compared to that of other countries. In Pakistan, during 2010-11, rapeseed and mustard was cultivated on an area of 439 thousand acres and its seed production was 157 thousand tons contributing 50 thousand tons in total edible oil production of 696 thousand tons [2]. There are a number of factors that are responsible in low production of rapeseed and mustard in Pakistan. One important factor is the lack of improved and high yielding cultivars that can be helpful to some extent in reducing the production and consumption gap of edible oil. Direct competition of *Brassica* with wheat and other rabi fodders has squeezed its area and inputs. Therefore, there is a dire need to evolve high yielding varieties. Plant breeders have recognized, for many years that the progeny from a specific cross can out yield either of the two parents used in the cross. This is called heterosis. In plant breeding, the observation of heterosis for yield has lead to the development of hybrid cultivars that exhibit a heterotic yield advantage.

Sprague and Tatum [13] described the concepts of general combining ability (GCA) and specific combining ability (SCA). General combining ability and Specific combining ability are associated to additive and non additive genetic effects respectively [8]. The information on combining ability and type of gene action that controls the expression of different traits might be helpful in proper planning of a successful breeding programme. Griffing's diallel analysis [4] provides an efficient estimation of combining ability and nature of gene action involved. [17] reported significant heterosis in several Indian mustard varieties. [7] reported significant heterotic effects for primary and secondary branches and yield per plant. The present research work was planned with the objectives to estimate heterosis and combining ability of *Brassica juncea* accessions for seed yield and its components. This will help to sort out the

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breeding material for exploitation in breeding programmes to evolve new varieties of *Brassica juncea.*

2. Material and Methods

The experimental material consisted of six genotypes of *Brassica juncea* (CR-5, DP 18-9, DP 7-91, RAS 3189, 0714-A, INDIA III) obtained from the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. These genotypes were grown in the field during rabi 2009 and crossed in a complete diallel fashion through controlled pollinations. Seed of 30 F1 crosses and their parents were sown with dibbler in a randomized complete block design with three replications during October 2010. Plant to plant distance of 30 cm and row to row 60 cm was maintained. There were three rows for each entry and the length of each row was 6 m. All the agronomic practices recommended for *Brassica* were followed uniformly for all entries throughout growing season. Data were recorded on five randomly selected plants of each entry per replication of traits like days taken to 50% flowering, days taken to 50% maturity, plant height**,** number of primary branches per plant**,** number of secondary branches per plant, number of siliquae per plant, number of seeds per siliqua, 1000 seed weight and seed yield per plant. The data collected were subjected to analysis of variance [14] Percent heterosis over mid parent and better parent were calculated using formulae proposed by [3] .Analysis for combining ability effects was carried out by using Griffing's [4] Method I, Model II.

3. Results and Discussion

3.1 Analysis of variance

Days taken to 50% flowering, days taken to 50% maturity, plant height, number of primary branches, number of secondary branches, number of siliquae per plant, number of seeds per siliquae, 1000 seed weight and seed yield per plant exhibited significant ($p \geq 0.01$-0.05) differences among all the entries (Table 1). These results revealed that genetic variability existed in the breeding material that allowed analyzing the data further for heterosis and combining ability. Mean sum of squares due to general combining ability were significant ($p \geq 0.01$-0.05) for all the traits except 1000 seed weight and seed yield per plant while the mean sum of squares due to specific combining ability and reciprocal effects were significant ($p \geq 0.01$-0.05) for all the traits under study (Table 2). Similar findings were reported by earlier workers [6, 9, 11, 12, 18]

3.2 General and specific combining ability

Variances due to GCA and SCA were estimated for assessing the contribution of both additive and non-additive effects for all the traits studied. It was observed that GCA and SCA mean squares were significant for almost all the traits however, magnitude of GCA was greater than SCA effects. [17] reported higher magnitude of SCA variance than GCA variance for seed yield per plant. Based on the data in Table 3, the parent INDIA III exhibited significant and positive general combining ability effects for plant height, number of primary branches per plant, number of secondary branches per plant and number of siliquae per plant thus showing additive effects for these traits. The parent DP 18-9 had significant and positive GCA effects for plant height, primary branches per plant, and number of siliquae per plant [5] reported significant GCA effects for plant height using half diallel cross supporting the current studies, but observed significant SCA effects for secondary branches per plant and number of siliqua per plant. Bothe these parents may be used in future breeding programmes for the improvement of seed yield of *brassica*.

Regarding specific combining ability studies the cross combination DP 7-91 × INDIA III had significant and positive specific combining ability for plant height, number of siliquae per plant, number of seeds per siliquae and seed yield per plant while six cross combinations CR-5 × DP 18-9, CR-5 × 0714-A, DP 18-9 × INDIAIII, DP 7-91 × RAS 3189, RAS 3189 × 0714-A and RAS 3189 × INDIAIII had significant and positive specific combining ability for three characters (Table 4). Non additive genetic effects for plant height, siliqua per plant and seed yield were observed in the studies of [5,10, 15]. These cross combinations may be further evaluated for development of improved hybrids with higher yield potential.

3.3 Heterosis

According to Table 5, the cross combination CR-5 × RAS 3189 had significant and positive heterosis for number of primary branches, number of secondary branches, number of siliquae per plant, number of

Table 1: Mean squares from analysis of variance of various traits in *Brassica junceae*

Source of variation	*Degree of freedom*	*DTF*	*DTM*	*PH (cm)*	*PB*	*SB*	*SP*	*SS*	*SW (g)*	*YP (g)*
Reps	**2**	30.46	27.17	19.2	0.18	3.22	49.39	0.34	0.001	6.89
Genotypes	**35**	49.31**	73.87**	165.82**	1..95**	27.90**	5651.27**	1.90**	0.14*	16.66**
Error	**70**	17.5	17.03	15.37	0.18	6.15	57.38	0.71	0.08	2.85

* Significant (α=0.05) ** Highly significant (α=0.01)

Table 2: Mean squares from analysis of variance of various traits for combining ability analysis

Source of variation	*Degree of freedom*	*DTF*	*DTM*	*PH (cm)*	*PB*	*SB*	*SP*	*SS*	*SW (g)*	*YP (g)*
GCA	**2**	25.40**	38.02**	231.53**	0.78**	11.79**	8738.37**	0.75*	4.32	0.69
SCA	**15**	20.24**	23.66**	17.23**	0.79**	6.17**	793.15**	0.52**	0.06**	6.76**
RCA	**15**	9.63**	21.11**	34.58**	0.46**	11.59**	689**	0.70**	2.92**	5.96**
Error	**70**	5.83	5.67	5.12	6.13	2.05	19.12	0.23	2.7	0.95

* Significant (α=0.05) ** Highly significant (α=0.01)
GCA= General combining ability effects , SCA= Specific combining ability effects, RCA= Reciprocal effect

Table 3: Estimates of GCA effects of six parents for nine traits in *Brassica junceae*

Parents	*DTF*	*DTM*	*PH(cm)*	*PB*	*SB*	*SP*	*SS*	*SW (g)*	**YP(g)**
CR 5	-2.50**	-1.98**	0.24	0.23**	0.32	28.60**	-0.01	0.07	-0.03
DP 18-9	-0.68	-1.57**	4.51**	0.12*	0.40	24.84**	0.21	0.01	0.13
DP 7-91	1.23**	2.92**	-4.11**	-0.18**	-1.04**	-30.04**	0.16	-0.10	0.01
RAS 3189	0.88	-0.48	-2.52**	-0.33**	-0.81*	-34.43**	0.20	0.02	0.22
0714-A	1.22*	0.43	-4.10**	-0.14*	-0.50	0.20	-0.41**	-0.03	0.12
INDIA III	-0.15	0.69	5.99**	0.30**	1.62**	10.82**	-0.15	0.02	-0.45
SE(gi) ±	0.63	0.62	0.59	0.06	0.37	1.15	0.12	4.33	0.25

Table 4: Estimates of SCA effects for nine characters in *B. junceae*

Hybrids	*DTF*	*DTM*	*PH(cm)*	*PB*	*SB*	*SP*	*SS*	*SW (g)*	**YP(g)**
CR5 × DP 18-9	1.28	0.57	4.11**	0.59**	2.37**	2.05	0.16	0.18	0.39
CR5 × DP 7 91	-0.28	4.07**	-1.41	-0.83**	-2.00*	-37.4*	-0.23	0.04	-1.48*
CR5 × RAS 3189	-1.29	-2.40	-0.04	-0.08	0.71	9.6**	0.18	-0.2	0.09
CR5 × 0714-A	1.55	-0.50	2.11	0.83**	1.67*	15.8**	-0.64*	-0.15	0.33
CR5 × INDIA III	-1.35	-0.10	-6.60**	-0.22	-2.30**	-8.27**	-0.03	0.19	-1.50**
DP 18-9 × DP 7-91	1.02	0.85	-3.07*	-0.16	0.28	33.2**	-0.62*	0.25	1.38*
DP 18-9 × RAS 3189	2.26	1.30	-3.91**	-0.55**	-2.08*	-42.6**	-0.17	0.17	-2.19**
DP 18-9 × 0714 A	-0.01	0.62	0.16	0.16	-0.30	0.42	0.18	-0.26	0.28
DP 18-9 × INDIA III	4.42**	5.42**	0.12	-0.51**	0.84	3.93	0.41	-0.22	1.13**
DP 7 91 × RAS 3189	-2.34	-0.62	0.78	1.16**	2.83**	0.98	-0.27	-0.06	1.99**
DP 7-91 × 0714-A	-0.90	2.44	-0.37	0.57**	-0.77	-2.98	0.23	-0.01	-1.05
DP 7-91 × INDIA III	-1.12	-3.78**	4.84**	0.19	1.11	9.66**	0.69*	-0.01	3.61**
RAS 3189 × 0714-A	5.08*	4.45**	0.17	-0.72**	-1.60	2.03	0.97**	0.25	0.32
RAS 3189 × INDIA III	-4.22**	2.03	2.50	0.52**	2.08*	24.27**	0.04	-0.02	0.47
0714-A × INDIAIII	-2.00	-4.21**	-0.53	0.01	0.26	-11.7**	-0.84**	0.18	-0.16
SE (Sij) ±	1.45	1.43	1.36	0.14	0.86	2.62	0.29	9.88	0.58

* Significant (α=0.05) ** Highly significant (α=0.01)

List of Abbreviations used

DTF Days taken to 50% flowering DTM Days taken to 50% maturity PH Plant height (cm) PB Number of primary branches
SB Number of secondary branches SP Number of siliquae per plant SS Number of seeds per siliqua SW 1000 seed weight YP Yield per plant (g)

Table 5: Mid Parent and Better Parent Heterosis in different character of *Brassica juncea*

Hybrids	DF		DM		PH (cm)		PB		SB		SP		SS		SW (g)		YP(g)	
	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH
CR-5 × DP 18-9	15.02**	11.10**	11.90**	8.67**	0.78**	-1.40**	8.21	2.59	6.09*	5.08**	-1.28**	-2.78**	-5.46	-5.70	16.84*	13.26**	-2.91	-7.93
CR-5 × DP 7-91	0.01	-6.07	10.03*	6.08**	1.42**	-1.38**	1.38**	-15.0	1.57*	-5.71	-3.50**	-12.48**	-4.44	-4.51	3.86	-4.08	-1.68**	-13.45
CR-5 × RAS 3189	-1.32	-5.41	-1.06	-1.12	-1.69**	-3.35**	19.65	4.34**	18.82**	10.29**	6.92**	-3.00**	8.70	5.05**	-9.94*	-12.24*	6.72	2.13*
CR-5 × O714-A	6.22	3.88*	-0.20	-1.82	0.76**	-2.21**	31.69	12.60**	9.48**	8.51**	-0.16**	-5.41*	-12.28**	-16.49**	-3.66	-6.12	3.09	0.14
CR-5 × INDIAIII	-4.89**	-9.68*	-1.97*	-5.16	-1.05**	-3.21**	-10.54*	-14.47*	-19.50**	-21.02**	0.83**	-3.99**	-5.80*	-9.77	5.75	3.06	-4.58**	-16.00
DP 18-9 × CR-5	-0.10	-3.51	-1.06	-3.91	1.03**	-1.15**	12.32	6.49**	18.15**	17.02**	-1.02**	-2.53**	3.44	3.18	0.01	-3.06	1.40	-3.84
DP 18-9 × DP 7-91	0.04**	-9.05	4.94	-1.63**	-4.75**	-9.33**	-10.50**	-28.11*	-10.78**	-16.45**	2.36**	-5.85**	-2.68	-3.00	19.99*	14.13**	3.22	-4.59
DP 18-9 × RAS 3189	8.26	0.38**	8.59*	5.52**	-2.30**	-6.00**	-23.64**	-36.36**	-12.30**	-17.87**	-7.17**	-14.60**	0.41	-2.71	13.51*	12.90**	-3.89	-4.81
DP 18-9 × O714-A	8.19	2.28**	7.15	2.43**	-4.17**	-8.96**	-14.84**	-30.32**	-15.21**	-15.26**	-2.56**	-6.31**	3.72	-1.01	-7.02	-7.52	-11.63**	-13.80**
DP18-9× INDIAIII	8.93	0.11**	8.06	1.64**	-0.69**	-0.70**	-16.60**	-17.33**	17.86**	14.54**	2.29**	-1.16**	9.96	5.58**	-7.02	-7.52	10.51	2.13**
DP 7-91 × CR-5	-5.07**	-10.85*	1.12	-2.50	-3.38**	-6.06**	-12.96**	-27.02*	-10.19**	-16.64**	-9.71**	-18.11**	-4.97	-5.04	7.18	-1.02	-1.14**	-12.98
DP 7-91 × DP 18-9	8.94	-0.95**	7.16	0.45**	0.83**	-4.02**	13.74	-8.63**	23.78**	15.93**	7.70**	-0.94**	-8.60**	-8.90**	8.57	3.26	33.03**	22.95**
DP 7-91 × RAS 3189	-4.00	-6.03	8.28	4.33**	0.12**	-0.99	55.73**	48.68**	20.02**	20.02**	0.02	-0.02	1.12	-2.34	9.09	3.22	22.26*	12.00**
DP 7-91 × O714-A	1.66	-2.46	4.70	2.56**	0.44	0.24**	13.47	10.81*	-13.75**	-19.27**	-3.69**	-8.05**	-1.40	-6.20	1.13	-4.30	4.63	-5.48
DP7-91× INDIAIII	-8.67**	-9.74**	-2.93	-3.29	4.41**	-0.62**	18.26	-4.36**	14.20	4.15**	0.75**	-4.27**	15.91*	10.94**	3.40	-2.15	28.65**	28.65**
RAS 3189 × CR-5	-2.52*	-6.56	2.51	2.45	0.48**	-1.20**	-8.10**	-19.85	-3.21**	-10.16	-7.57**	-16.15**	-4.18	-7.39	1.57	-1.02	-11.60**	-15.40**
RAS 3189 × DP 18-9	7.89	0.03**	6.56	3.55**	-2.98**	-6.65**	-5.49**	-21.23	7.60	0.77**	-6.93**	-14.38**	2.69	-0.50	5.94	5.37	-6.99	-7.88*
RAS 3189 × DP 7-91	-5.95*	-7.94*	-2.61*	-6.16	0.81*	-0.32**	54.30**	47.32**	20.32**	20.32**	-0.03	-0.06	-0.96	-4.36	-2.27	-7.52	17.71	7.84**
RAS 3189 × O714-A	8.31	6.10**	7.94*	6.13**	1.07	-0.25**	-16.29*	-18.20*	1.17*	-5.30	2.26**	-2.33**	6.87	5.22*	12.90*	12.90**	7.71	6.06*
RAS 3189× INDIAIII	-9.53**	-10.39**	0.74	-2.58	-0.43**	-4.20**	20.23	0.92**	24.12**	13.20**	1.92**	-3.14**	9.28	8.28**	3.22	3.22	8.79	-0.33*
O714-A × CR-5	2.04	-0.20	3.28	1.61	1.21**	-1.77**	40.08**	19.78**	2.17	1.27	2.57**	-2.81**	-3.10	-7.75	-4.71	-7.14	-9.79**	-12.37**
O714-A × DP 18-9	7.90	2.00**	4.66	0.05*	3.83**	-1.35**	31.74	7.79**	14.17**	14.10**	2.76**	-1.19**	-1.78	-6.26	-5.94	-6.45	16.76**	13.89**
O714-A × DP 7-91	-3.66*	-7.57	4.47	2.33*	0.37	0.17**	78.99**	74.79**	10.29	3.23**	3.86**	-0.83**	2.67	-2.32	4.54	-1.07	4.30	-5.77
O714-A × RAS 3189	7.41	5.22**	6.80	5.02**	-0.35**	-1.66**	8.91	6.42	-9.60**	-15.39**	-1.95**	-6.36**	14.73**	12.96**	7.52	7.52	-3.49	-4.97
O714-A × INDIAIII	-2.89	-5.76	-6.04**	-7.63**	-4.18**	-8.97**	0.04**	-17.58	4..08	1.22*	-0.50**	-1.01**	0.08	-0.55	5.37	5.37	15.80	4.61**
INDIAIII × CR-5	-3.51*	-8.36	2.68	-0.65	-5.96**	-8.01**	6.87	2.18	11.40**	9.29**	-3.20**	-7.84**	3.16	-1.18	12.04	9.18**	-2.21**	-13.92
INDIAIII × DP 18-9	7.74	-0.97**	9.12	2.63**	-0.24	-0.24*	-13.13*	-13.89**	0.25	-2.56	0.95**	-2.45**	-1.32	-5.25	0.54	0.00	19.59*	10.52**
INDIAIII × DP 7-91	-2.68	-3.82	-1.52	-1.88	0.89**	-3.97**	13.93	-7.86**	8.71	-0.85**	5.58**	0.31**	-4.29	-8.39	6.81	1.07	44.59**	44.59**
INDIAIII × RAS 3189	-5.57*	-6.48*	6.46	2.95**	2.80**	-1.09**	12.28	-5.75*	8.44	-1.10**	7.54**	2.20**	0.16	-0.75	3.22	3.22	13.84	4.29**
INDIAIII × O714-A	-2.42	-5.31	0.62	-1.07	4.59**	-0.63**	20.89	-0.39**	2.57	-0.24	0.18**	-0.32*	-12.48**	-13.04**	10.75	10.75*	-3.21**	-22.56

* Significant (α=0.05) ** Highly significant (α=0.01)

List of abbreviations used

DTF Days taken to 50% flowering DTM Days taken to 50% maturity PH Plant height (cm) PB Number of primary branches

SB Number of secondary branches SP Number of siliquae per plant SS Number of seeds per siliqua SW 1000 seed weight YP Yield per plant (g) seeds per siliquae, seed yield per plant and showed significant and negative heterosis for plant height. The cross DP 7-91 × INDIA III exhibited significant and positive heterosis for number of primary branches, number of secondary branches, number of siliquae per plant, number of seeds per siliquae, seed yield per plant and showed significant and negative heterosis for days taken to 50% flowering. The cross combination RAS 3189 × DP 7-91 had significant and positive heterosis for number of primary branches, number of secondary branches and seed yield per plant while exhibited significant and negative heterosis for days taken to 50% flowering, days taken to 50% maturity and plant height. The cross combination RAS 3189 × 0714-A showed significant and positive heterosis for number of secondary branches, number of siliquae per plant, number of seeds per siliquae, 1000 seed weight, seed yield per plant and showed significant and negative heterosis for plant height. The cross combination RAS 3189 × INDIA III had significant and positive heterosis for number of primary branches, number of secondary branches, number of siliquae per plant, number of seeds per siliquae and showed significant and negative heterosis for days taken to 50% flowering and plant height. Similar findings were found in the studies of [1, 5].

4. Conclusions

The five cross combinations CR-5 × RAS 3189, DP 7-91 × INDIA III, RAS 3189 × DP 7-91, RAS 3189 × 0714-A and RAS 3189 × INDIA III proved best heterotic crosses. The parent INDIA III and DP 18-9 was best general combiners for majority of traits. The cross combination DP 7-91 × INDIA III proved best hybrid. So these crosses may further be exploited in the development of *Brassica juncea* varieties which can help to improve yield of this important oilseed crop.

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