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Heterosis and heritability analysis for different crosses in *Brassica juncea* with inheritance of white rust resistance

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Abstract

For estimation of heritability, mid and better parent heterosis among the various traits of Indian mustard [*Brassica juncea* (L) Czern & Coss.] was carried out at N.D. University of Agriculture and Technology, Faizabad. High heritability coupled with high genetic advance % of mean was observed for number of siliquae on main raceme, 1000-seed weight, seed yield per plant and plant height. The magnitude of high heritability and genetic advance % of mean indicated that improvement in this trait could be done through selection feasible. 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. However, significant positive heterobeltiosis was observed for seed yield per plant, number of siliquae on main raceme, and length of main raceme in all crosses except cross-I and plant height and number of secondary branches per plant in crosses-I, II and III showed significant heterobeltiosis and it ranged from 1.01% in cross-I to 24.77% in cross-III. On the basis of ratio obtained in F_2 (3R:1S) and BC_1 (1R:1S) it is concluded that the white rust resistance in WRR-9801 is governed by single dominant gene.

Key words: *Mustard, heritability, heterosis, white rust*

Introduction

Indian mustard crop (*Brassica juncea* (L.) Czern.& Coss.), is an agriculturally and economically important oilseed crop that is widely cultivated in Asia and Europe. The oil content of mustard varies between 28.6 to 45.7 per cent. Oils and fats are essential components of our daily diet and also a major source of raw material for a wide range of products required in our life. Oil extracted from the seeds of these crops is used for cooking, frying, spice, for seasoning of the food articles, vegetables and industrial purposes.

White rust is an important disease of oilseed Brassicas in India and Canada. It caused by *Albugo candida* affects primarily rapeseed (*B. rapa*) and Indian mustard (*B. juncea*). Though some studies showed that resistance to white rust was controlled by few major genes (Verma and Bhowmik, 1989, Sachan *et al.,* 2000 and Chauhan and Sharma, 2001), the resistance to this disease was also reported to be quantitatively inherited conditioned by minor genes (Edward and Williams, 1982). Various researchers studied genetic parameters to determine the selection criteria for yield improvement in rapeseed and mustard, high heritability estimates coupled with high genetic advance for seed yield per plant, primary and secondary branches, pods per plant and seed weight in rapeseed (*B. rapa*) genotypes reported by Sheikh *et al.* (1999).

Breeding in Indian mustard has primarily been confined to exploitation of available genetic variability resulting in establishment of homozygous lines and highly desirable to increase the productivity and stability through development of efficient plant type, which may have the genes for higher seed yield and oil content. Heterosis has extensively been explored and utilized for boosting various agronomic and quality traits in brassica and other crops (Hassan *et al.*, 2006 and Turi *et al.*, 2006). The development of such varieties will depend on the management of genetic variability, which is the key factor in crop improvement. This requires quantitative characterization of variability present in a crop by understanding the nature of gene action involved in the inheritance of economic traits. Therefore, the objectives of this study were to estimate the heritable variation among yield components, and heterotic studies can provide the basis for the exploitation of valuable hybrid combinations in future breeding programs.

Materials and Methods

The experiment was conducted at Research Farm of Narendra Deva University of Agricultural and Technology, Faizabad, UP during 2004-2006. Five genotypes of Indian mustard were collected, in which four genotypes viz., Jagannath, Krishna, Pusa jaikisan and Pusa Bold, used as line and one (WRR-9801) used as tester to obtain four single crosses. A set of six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2) of four crosses viz., Jagannath x WRR-9801 (cross-I), Krishna x WRR-9801 (cross-I), Pusa Jaikisan x WRR-9801 (cross-III) and Pusa Bold x WRR-9801(cross-IV) were evaluated in Compact Family Block Design (CFBD) with three replications in field conditions during *Rabi* 2005-06. Main plot is divided into three replications and each replication is divided into four blocks. The families were randomized among the replication and the progenies *i.e.* generations were randomized within these blocks. Each row length was 3 meter with a space of 30 cm rows and 15 cm between plants. This distance was maintained by thinning of the extra plants germinated in the rows.

The data were recorded on days to 50% flowering, days to maturity, plant height (cm), primary branches per plant, secondary branches per plant, number of siliquae on main raceme, length of main raceme (cm), seeds per siliqua, 1000-seed weight (g), seed yield per plant (g) and per cent oil content.The white rust infection on leaves was recorded in percentage on sampled plants of every genotype in each replication after two weeks of flowering. The plants even having a single pustule on leaf was assigned as susceptible while the plants free from white rust pustules were rated as resistant. Thus, total number of plants were rated as resistant or susceptible under natural condition.

The data were subjected to analyses of variance according to Steel and Torrie (1980) and the percent increase (+) or decrease (-) of F_1 cross over mid-parent as well as better-parent was calculated to observe heterotic effects for all the parameters. The computation of heterosis values was carried out according to the method of Turner, 1953 and Hayes, *et al.*1955. The average F_1 values were used for estimation of heterosis expressed in percentage over mid parent (MP) and better parent (BP) values. Mid parent (MP) value = (P1+P2)/2, Relative heterosis = $[(F_1\text{-MP})/\text{MP}] \times 100$, heterobeltiosis = $[(F_1\text{-BP})/\text{BP}] \times 100$. Heritability was calculated as per formula suggested by Hanson *et al.* (1956) and Genetic advance was computed by using the formula of Johnson *et al.* (1955).

Results and Discussions

Analysis of variance between families for CFBD indicated in Table-1 and revealed highly significant differences for most of the characters except days to 50% flowering, days to maturity, primary branches per plant, seeds per siliqua and 1000-seed weight. This indicated that families under study have wide genetic base for most of the characters and analysis of variance within families in Table-2 were showed highly significant differences for most of the quantitative characters in all crosses except for days to maturity, primary branches per plant, number of siliquae on main raceme, seeds per siliqua and oil content in cross-I; days to 50% flowering, days to maturity and primary branches per plant in cross-II; for days to 50 % flowering and days to maturity in cross-III and days to 50% flowering, days to maturity and seeds per siliqua in cross-IV. Significance differences between progenies indicated that differences between progenies exist for most of the traits under study.

Heterosis has been reported earlier in different crops and has therefore, been of considerable interest to assess it for quantitative characters in Indian

Table 1: Analysis of variance for different traits between families in *Brassica juncea*

Characters	d.f.	Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches per plant	Seconday branches per plant	No. of siliquae on main raceme	Length of main raceme (cm)	Seeds per siliqua	1000-seed weight (g)	Seed yield per plant (g)	Oil content (%)
Replication	2	1.27	14.79	151.66*	0.98	5.62	22.53	4.60	16.71	0.10	21.63*	2.41
Families	3	3.56	1.95	1161.43**	0.19	14.52*	375.72**	203.26**	17.45	4.99*	299.72**	61.88**
Error	6	4.76	6.68	24.72	0.64	1.87	12.27	4.10	14.00	0.58	2.54	5.98

Note- *, ** significant at 5% and 1% probability levels, respectively

mustard. Significant positive heterosis over mid parent was observed for pant height, secondary branches per pant and seed yield per plant in cross-I; for plant height secondary branches per plant, number of siliquae on main raceme and seed yield per pant in cross-II; for most of the characters except days to 50 % flowering, days to maturity, 1000-seed weight and oil content in cross-III and for primary branches per plant, seed yield per plant and oil content in cross-IV (Table-3). The mid parent heterosis ranged from 1.87 % (cross-II) to 30.24 % (cross-IV) for length of main raceme and for seed yield per plant, respectively. The significant heterosis over mid parent indicated the presence of dominance; similarly, Asthana and Pandey (1977) reviewed high heterosis over mid parent for seed yield in *B. juncea*.

The significant positive heterobeltiosis (better parent heterosis) was observed for plant height and secondary branches per plant in cross-I, for plant height secondary branches per plant, number of siliquae on main raceme, length of main raceme and seed yield per plant in cross-II; except for days to 50 % flowering, days to maturity, primary branches per plant, 1000-seed weight and oil content in cross-III and for primary branches per plant, number of siliquae on main raceme, length of main raceme and seed yield per plant in cross-IV. The heterobeltiosis were ranged from 1.01 % in cross-II to 24.77 % in cross-III for length of main raceme and for seed yield per plant, respectively. Similarly, in earlier studies (Rai and Verma, 2005 and Turi *et al.*, 2006) were reported higher magnitude of heterobeltiosis in mustard. Most of the metric traits have shown the positive heterobeltiosis except length of main raceme and seeds per siliqua in cross-I; for seeds per siliqua and oil content in cross-II; for 1000-seed weight and oil content in cross-III and for plant height and 1000-seed weigh in cross-IV.

Utilization of heterosis is an important way of increasing yield and improving quality in crops. F1 hybrids in maize, rice and sorghum have been successfully developed and cultivated. Significant heterosis of agronomic traits in the F_2 generation has been reported rapeseed (Engqvist and Becker, 1991), however, the utilization of heterosis in

Table 2: Analysis of variance for differences between progenies (within families, cross wise) among various traits in *Brassica juncea*

Characters		d.f.	Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches per plant	Secondary branches per plant	No. of siliquae on main raceme	Length of main raceme (cm)	Seeds per siliqua	1000 seed weight (g)	Seed yield per plant (g)	Oil content (%)
Replication	I	2	0.37	0.19	21.78	0.04	0.79	3.37	0.01	0.32	0.04*	1.10	1.34
	II	2	0.47	0.24	10.20*	0.33	0.48	3.77	1.63	0.28	0.01	1.25	1.29
	III	2	0.99	0.55	3.03	0.03	0.42	2.47	0.94	0.11	0.09	1.26	0.37
	IV	2	0.49	4.79	2.78	0.09	0.18	0.28	0.26	9.08	0.17**	1.27	0.38
Progenies	I	5	1.25*	0.47	331.33**	0.18	3.08*	3.86	61.44**	0.77	0.17**	6.51**	0.51
	II	5	0.45	0.57	568.27**	0.25	1.95*	77.00**	21.89**	2.23**	0.05**	3.77*	14.12**
	III	5	0.25	0.29	710.62**	0.43*	10.85**	93.41**	42.47**	1.15*	0.72**	3.61*	1.61**
	IV	5	0.47	0.13	46.53**	0.27*	2.38**	33.97**	30.45**	5.32	0.53**	25.08**	2.61**
Error	I	10	0.27	0.62	27.96	0.09	0.62	2.34	3.86	0.39	0.01	0.46	0.53
	II	10	0.37	0.56	7.36	0.08	0.5	2.34	3.13	0.15	0.01	0.92	2.35
	III	10	0.41	0.43	2.31	0.12	0.46	0.69	3.25	0.23	0.04	0.75	0.24
	IV	10	0.18	0.27	2.23	0.06	0.29	0.86	1.63	5.44	0.03	0.59	0.29

Note-*, ** significant at 5% and 1% probability levels, respectively; I, II, III and IV are Crosses

Table-3: Heterosis (%) and inbreeding depression (%) in F_2 over F_1 for eleven metric traits in cross I to IV

Characters	Cross-I			Cross-II			Cross-III			Cross-IV		
	M.P.	B.P.	I.D.	M.P.	B.P.	I.D.	M.P.	B.P.	I.D.	M.P.	B.P.	I.D.
Days to 50% flowering	1.34** ±0.27	1.92** ±0.72	-0.22 ±0.78	-0.44 ±0.38	0.13 ±0.35	-0.97** ±0.26	0.48 ±0.47	0.80 ±0.51	0.13 ±0.58	0.49 ±0.26	0.53 ±0.32	-0.61* ±0.16
Days to maturity	-0.47 ±0.45	-0.22 ±0.62	-0.01 ±0.43	-0.09 ±0.52	0.11 ±0.67	0.03 ±0.45	-0.17 ±0.62	0.11 ±0.67	-0.44 ±0.71	0.14 ±1.03	0.34 ±1.11	-0.03 ±1.06
Plant height(cm)	7.30** ±2.16	3.08** ±2.46	9.26** ±6.36	11.35** ±1.04	2.75** ±1.49	-0.54** ±2.05	15.60** ±0.81	7.21** ±0.78	0.31 ±1.04	-0.49 ±1.63	-1.32** ±1.87	-6.35** ±1.61
Primary branches per plant	3.67 ±0.13	-0.66 ±0.17	5.33 ±0.36	3.71 ±0.32	5.86 ±0.31	4.33 ±0.11	14.70** ±0.18	12.77 ±0.08	9.75 ±0.22	14.40** ±0.17	14.08** ±0.27	8.05* ±0.19
Secondary branches per plant	19.50** ±0.66	12.70** ±0.70	12.44** ±0.83	17.33** ±0.50	17.08** ±0.55	5.80** ±0.57	21.50** ±0.41	7.61* ±0.46	8.18** ±0.37	3.11 ±0.32	3.35 ±0.42	10.49** ±0.33
No. of siliquae on main raceme	-0.16 ±0.87	-0.72 ±1.01	4.56** ±0.96	12.84** ±1.25	1.80** ±1.28	1.57** ±2.11	20.30** ±0.64	7.37** ±0.72	5.30** ±0.44	14.30 ±0.59	6.06** ±0.80	9.94** ±0.74
Length of main raceme (cm)	-1.90 ±0.79	-4.91** ±0.97	6.00** ±2.17	1.87** ±0.68	1.01** ±0.63	9.42** ±1.05	11.10** ±0.73	7.00** ±0.69	6.58** ±0.87	10.29** ±0.85	10.22** ±0.86	7.92** ±1.34
Seeds per siliqua	-1.62 ±0.69	-5.54** ±0.72	4.99** ±0.79	-12.57 ±0.22	-16.71** ±0.26	-9.35** ±0.34	11.16** ±0.20	7.13** ±0.18	5.14 ±0.52	15.1 ±1.75	1.04 ±0.12	0.26 ±0.45
1000- seed weight (g)	-14.4 ±0.05	-12.27 ±0.06	-1.85 ±0.07	-1.60 ±0.04	-8.85 ±0.04	0.15 ±0.05	-4.30 ±0.11	-19.99** ±0.06	-1.27 ±0.33	-8.80 ±0.10	-21.45** ±0.18	-1.78 ±0.09
Seed yield per plant (g)	18.17** ±0.67	2.06 ±0.71	21.32** ±0.74	29.67** ±0.42	17.68** ±0.49	34.72** ±0.62	21.81** ±0.76	24.77** ±0.77	18.38 ±0.75	30.24** ±0.46	4.84** ±0.64	13.71** ±0.43
Oil content (%)	0.84 ±0.51	-0.35 ±0.27	1.16 ±0.25	-0.51 ±0.44	-7.20** ±0.44	-0.29 ±0.45	-2.69 ±0.41	-3.87** ±0.42	-0.51 ±0.44	3.20** ±0.39	0.27 ±0.40	3.27** ±0.37

Note-*, ** significant at 5 and 1% probability levels, respectively. Where, M.P. – Mid Parent, B.P. – Better Parent, I.D. – Inbreeding Depression mustard is still limited. Heterosis over environments is variable and environment dependent, climatic changes from year to year could modify strongly the response for various agronomic traits were shown in Indian mustard (Lionneton *et al.,* 2004). Parmar *et al.* (2004) found significant negative heterosis for plant height; however, Chauhan and Singh (1979) observed significant positive heterosis for most of yield contributing traits.

In most of the cross the inbreeding depression was associated with heterobeltiosis this indicated that most of the characters showed higher magnitude of dominance gene action. The cross showing absence of inbreeding depression may be used for further selection programme because in such crosses the additive and additive x additive gene interactions are present. Negative inbreeding depression was observed for days to 50 % flowering in cross-II and cross-IV, for days to maturity and 1000-seed weight significant inbreeding depression was not observed in any cross. Significant positive inbreeding depression was observed for plant height in cross-II and IV; for primary branches per plant in cross-IV and for secondary branches per plant in all crosses (cross 1, II, III and IV). For number of siliquae on main raceme and length of main raceme significant positive inbreeding depression was observed in all crosses, for seeds per siliqua in cross-I and negative inbreeding depression was observed in cross-II, for seed yield per plant significant positive inbreeding depression was reported in cross-I, II and IV and for oil content significant positive inbreeding depression was found in cross-IV. This indicates that most of the characters in all crosses showed inbreeding depression, thus, most of the characters showed non-additive gene effects. Similarly, Singh *et al.* (2003) reported that most of the high heterotic cross combinations for different characters showed low inbreeding depression in F_2 generation.

Heritability denotes a useful statistical concept and has been used in estimating expected progress in determining the degree to which the character may be transmitted from parents to offspring. The response to selection for quantitative character is directly proportional to its heritability and genetic advance. Therefore, it is essential to assess the relative effect of genotype and environment and to have an estimate of the extent to which improvement is possible in the traits under consideration.

Broad sense heritability ranged from 18% (number of siliquae on main raceme) to 89.00% (1000-seed weight) in cross I; 0.30% (days to maturity) to 96.00% (plant height) in cross II; 46.00% (primary branches per plant) to 99.00% (plant height) in cross III; 35.00% (days to 50% flowering) to 93.00% (number of siliquae on main raceme and seed yield per plant) in cross IV (Table-4). High heritability was observed for plant height, number of siliquae on main raceme, length of main raceme, 1000-seed weight and seed yield per plant in all crosses except cross-I (number of siliquae on main raceme), cross-II (for length of main raceme, 1000-seed weight and seed yield per plant) and cross-III (for seed yield per plant). This indicates that mostly high heritability is observed for these characters, similar finding were reported by Singh *et al.* (2003). Moderate heritability in broad sense was observed for secondary branches per plant and oil content in all crosses except cross II and III (for secondary branches per plant) and cross-I (for oil content), these findings were similar to Singh (1973). Low heritability in broad sense was observed for days to 50 % flowering, days to maturity and primary branches per plant in most of the crosses except cross-I (for days to 50 % flowering) cross-IV (for primary branches per plant).

High heritability coupled with high genetic advance in % of mean was recorded for plant height, number of siliquae on main raceme, 1000-seed weight and seed yield per plant in most of the crosses. High heritability coupled with moderate genetic advance for length of main raceme, moderate heritability with moderate genetic advance for secondary branches per plant, moderate heritability with low genetic advance for oil content and low heritability with low genetic advance for days to 50 % flowering, days to maturity and primary branches per plant in most of the crosses. High heritability coupled with high genetic advance was observed for plan height, number of siliquae on

Table 4: Heritability in broad sense and genetic advance in % of mean for different characters in *Brassica juncea*

Characters	Heritability (%)				Genetic advance				Genetic advance in % of mean			
	Cross I	Cross II	Cross III	Cross IV	Cross I	Cross II	Cross III	Cross IV	Cross I	Cross II	Cross III	Cross IV
Days to 50% flowering	55.20	7.00	@	35.00	0.88	0.09	@	0.38	1.16	0.12	@	0.50
Days to maturity	@	0.30	@	@	0.00	0.05	@	@	@	0.04	@	@
Plant height(cm)	78.0	96.00	99.00	87.00	18.34	27.63	31.50	7.38	11.36	16.57	19.14	4.36
Primary branches per plant	24.00	43.00	46.00	53.00	0.18	0.33	0.44	0.39	3.53	6.69	8.87	7.91
Secondary branches per plant	57.00	49.00	88.00	70.00	1.40	1.00	3.60	1.44	11.32	8.38	30.88	12.42
No. of siliquae on main raceme	18.00	91.00	98.00	93.00	0.62	9.83	11.33	6.59	1.29	22.42	24.78	13.90
Length of main raceme	83.00	67.00	80.00	86.00	8.24	4.20	6.67	5.90	10.89	5.61	8.82	7.56
Seeds per siliquae	24.00	83.00	57.00	@	0.35	1.56	0.86	@	2.68	11.88	6.56	@
1000- seed weight (g)	89.00	75.00	84.00	86.00	0.45	0.23	0.89	0.78	13.14	7.05	24.08	21.68
Seed yield per plant (g)	81.00	51.00	56.00	93.00	2.64	1.43	1.50	5.68	23.32	16.15	14.38	44.39
Oil content (%)	@	63.00	65.00	73.00	@	3.23	1.12	1.55	@	8.13	2.75	3.78

Note : @ - Negative estimate

Table-5: Inheritance of white rust in *Brassica juncea*

Generations	Cross I		Cross II		Cross III		Cross IV	
	Reaction	Chi-square value	Reaction	Chi-square value	Reaction	Chi-square value	Reaction	Chi-square value
P_1	S	-	S	-	S	-	S	-
P_2	R	-	R	-	R	-	R	-
F_1	R	-	R	-	R	-	R	-
F_2	3R:1S	2.22	3R:1S	2.67	3R:1S	3.33	3R:1S	1.67
BC_1	1R:1S	1.11	1R:1S	3.33	1R:1S	2.25	1R:1S	2.36
BC_2	R	-	R	-	R	-	R	-

main raceme, 1000-seed weight and seed yield per plant in most crosses, thus selection is advocated for these traits indicates the presence of additive gene effects, hence their improvement can be done through mass selection. These results confirm the findings of Sheikh *et al.* (1999). In addition, Chaudhary *et al.* (2003) found high heritability coupled with high genetic advance in % of mean for secondary branches per plant, seed yield per plant and number of siliquae per plant and Singh *et al.* (2003) also reported high heritability coupled with high genetic advance for seed yield per plant and 1000-seed weigh.

In all crosses, parent one was noted susceptible to white rust while parent two, F_1 and B_2 noted resistant reaction to white rust; F_2 segregated in 3 : 1 ratio (3 resistance : 1 susceptible) to white rust (Table-5). However, BC-$_1$ segregated in 1:1 ratio (one resistant and one susceptible). This indicates that the white rust resistance in WRR-9801 is governed by single dominant gene over susceptible one. Sachan *et al.* 2000, Chauhan and Sharma, 2001 and Sudhir *et al.* 2002 also reported that the white rust resistance is controlled by single dominant gene.

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