J. Soils and Crops 34 (1) 89-96, June 2024 ISSN 0971-2836 (Print)
ISSN 2582-2756 (Online)

HETEROSIS IN INTERSPCIFIC HYBRIDS BETWEEN *Brassica juncea* AND *Brassica carinata*

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ABSTRACT

Heterosis is proportional to genetic divergence between respective parents in many crops. The heterosis in interspecic hybrids was evaluated between *Brassica juncea* and *Brassica carinata*. Three *Brassica juncea* parents (TAM 108-1, ACN-9 and Kranti) were crossed with two *Brassica carinata* parents (PC-5 and PC-6) both direct and reciprocal way to produce 12 F_1 crosses. In *rabi* 2022, 12 F_1 crosses along with their parents were evaluated in RBD with 3 replications in the Research farm of Agricultural Botany Section, College of Agriculture, Nagpur. The data were recorded on days to first flower, days to maturity, plant height (cm), number of branches plant^{-1}, number of siliquae plant^{-1}, 1000 seed weight (g) and seed yield plant^{-1} (g), and statistically analyzed. Based on the mean performance of F_1 crosses the cross ACN-9 x PC-5 was identified for earliness and seed yield plant^{-1} and the crosses ACN-9 x PC-6, TAM 108-1 x PC-6, Kranti x PC-6, PC-6 x ACN-9 and PC-6 x TAM 108-1 for number of branches plant^{-1}, number of siliquae plant^{-1} and seed yield plant^{-1} as they exhibited significant superiority over both the checks for these characters. The cross combinations ACN-9 x PC-6, TAM 108-1 x P-6, Kranti x PC-6, PC-6 x ACN-9, PC-6 x TAM 108-1 and PC-6 x Kranti exhibited significant positive useful heterosis over both the checks for number of branches plant^{-1}, number of siliqua plant^{-1} and seed yield plant^{-1} hence, were identified as potential crosses for forwarding to next generation. Considering mean performance and useful heterosis five crosses ACN-9 x PC-6, TAM 108-1 x P-6, Kranti x PC-6, PC-6 x ACN-9, PC-6 x TAM 108-1 except PC-6 x Kranti were found to be best crosses which can be forwarded to the next generation to recover transgressive segregates.

(Key words: *Brassica juncea, Brassica carinata,* interspecific heterosis)

INTRODUCTION

Rapeseed-mustard is an important oil seed crop and is being cultivated in 53 countries over the six continents of the world. In Asia it is particularly cultivated in India, Pakistan, China and Bangladesh. In India it is the second essential edible oil seed crop and has important share in the India's oil seed economy (Sapkal *et al*., 2023)

Mustard is minor crop of Eastern Vidarbha region, farmers are growing mustard crop in last week of November to second week of December after harvesting of paddy. Generally delayed planting leads to shortening of vegetative phase, advances flowering time and decreases seed development period resulting into shriveled seed. Similarly, incidence of powdery mildew occurs at flowering and siliqua development stage therefore, farmers receive very poor yield (12 q acre^{-1}). There is need of producing high yielding varieties with early maturity, high oil content and resistance to biotic and abiotic stress.

The aim of any plant breeder to achieve the above target will be to evolve strains superior to those of existing strains. One of the major bottleneck in obtaining higher productivity is reduction in yield due to diseases and pests which cause damages to this crop at different stages and can result in yield losses ranging from 10-90%. Of the various diseases Alternaria blight causes the maximum damages followed by white rust, stem rot and powdery mildew. All the released Indian mustard varieties are susceptible to this diseases. Of the above diseases powdery mildew (*Erysiphe cruciferarum*) causes maximum damages in Vidarbha region upto 17-18% yield loss. There are no usable sources of resistance available for this diseases within *Brassica juncea* germplasm (Kapadia *et al.,* 2019). Therefore, farmers are forced to use frequent application of hazardous chemical pesticides for getting economic yield.

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The increase in productivity in the oilseed Brassicas through breeding is not conspicuous like that in cereal crops. Improvement in Brassicas has mostly confined to the exploitation of the naturally occurring genetic variability in the cultivated species. *Brassica juncea* commonly cultivated in the Indian subcontinent has limited variability left for direct selection for higher yield. Genetic variability being limited, breeders need to resort to wide hybridization, which can be a viable method for incorporation of desirable characters including seed yield (Patil *et al.*, 2021).

The resistance source for powdery mildew is available in *Brassica carinata.* Powdery mildew has been reported to be governed by dominance gene (Kumar *et al.,* 2017). So, it is possible to make interspecific crosses between *Brassica juncea* and *Brassica carinata* and to evaluate their progenies for high yield and powdery mildew resistance. Therefore, in the present research work interspecific crossing between *Brassica juncea* and *Brassica carinata* was done to derive the F_1 hybrids for evaluation and screening for yield and powdery mildew resistance.

MATERIALS AND METHODS

During *rabi* 2021, 5 parents (3 *Brassica juncea viz.,* TAM 108-1, ACN-9 and Kranti, 2 of *Brassica carinata viz.*, PC-5 and PC-6) were raised in the crossing block in the research farm of Agricultural Botany Section, College of Agriculture, Nagpur. The parents were used for making 6 direct and 6 reciprocal crosses between *Brassica juncea* and *Brassica carinata* and the crossed seeds were collected for evaluation of F_1 in *rabi* 2022. During *rabi* 2022, 12 F_1 crosses along with their parents were raised in Randomized Block Design (RBD) with 3 replications for evaluation. Spacing of 45 cm x 15 cm was maintained. Three rows for F_1 and two rows for parents were allocated with 20 plants row^{-1}. Five randomly selected plants from F_1 and parents were considered for recording observations on days to first flower, days to maturity, plant height (cm). Number of branches plant^{-1}, number of siliquae plant $^{-1}$, 1000 seed weight (g), seed yield plant^{-1} (g) and powdery mildew incidence (%). Data as per cent disease severity on leaves was recorded on each of observational plants using 0-9 scale as per the method given by Mayee and Datar (1986). Powdery mildew infestation were recorded at 15 days before maturity on the selected individuals of parent, F_1. The data were subjected to the statistical analysis ie. analysis of variance for the experimental design and heterosis (Panse and Sukhatme, 1954), estimation of heterobeltiosis and useful heterosis over both the check TAM 108-1 and Kranti by using standard formulas.

RESULTS AND DISCUSSION

Three *Brassica juncea* parents TAM 108-1, ACN-9 and Kranti susceptible to powdery mildew were crossed with two *Brassica carinata* parents PC-5 and PC-6 (donors for powdery mildew resistance) to produce 6 direct and 6 reciprocal crosses. The twelve crosses along with five parents were raised for evaluation in *rabi,* 2022. Three crosses which involved PC-5 parent as female did not germinate and hence the data on only nine crosses along with five parents were evaluated and the results are presented and discussed below.

Analysis of variance and mean performance

The analyses of variance for seven characters studied and data are presented in Table 1. The mean squares due to genotypes were highly significant for all the characters studied *i.e.* days to first flower, days to maturity, plant height, number of branches plant^{-1}, number of siliquae plant^{-1}, 1000 seed weight and seed yield plant^{-1}. This indicates the presence of substantial genetic variation among the genotypes (parents and crosses) for all the characters studied which allows further estimation in the experimental material. In accordance to this result Barupal *et al.* (2017), and Kaur *et al.* (2023) also reported wide variability for seed yield and yield contributing characters in mustard.

The data regarding mean performance of parents and crosses for eight characters recorded in mustard are presented in Table 2. Among the five parents under study Kranti was earliest (42.80 days) followed by ACN-9 (49.20 days) and TAM 108-1 (49.53 days) for days to first flower. The parents PC-6 (64 days) followed by PC-5 (60.93 days) were late for days to first flower among all the parents. Among the crosses the days to first flower ranged from 40.13 days (ACN-9 x PC-5) to 65.80 days (PC-6 x ACN-9). The cross ACN-9 x PC-5 (40.13 days) was the earliest to first flower followed by Kranti x PC-5 (41.40 days) and ACN-9 x PC-6 (41.93 days). Four crosses ACN-9 x PC-5 (40.13 days), Kranti x PC-5 (41.40 days), ACN-9 x PC-6 (41.93 days), and TAM 108-1 x PC-5 (42.13 days) were found to show significant superiority over check TAM 108-1 (49.53 days) for early days to first flower and none of the crosses were significantly superior over check Kranti.

Among the five parents, Kranti was earliest to mature (97.00 days) followed by TAM 108-1 (98.33 days) and ACN-9 (99.33 days). The parent PC-6 (125.00 days) was late to mature. The range for days to maturity was from 94.67 days (Kranti x PC-5) to 128.00 days (PC-6 x TAM 108-1). Only two crosses Kranti x PC-5 (94.67 days) and ACN-9 x PC-5 (95.33 days) were found to be significantly superior over the check TAM 108-1 (98.33 days) for days to maturity and none of the crosses were significantly superior over check Kranti.

As increased plant height results in lodging of the plant especially at bearing stage, lesser plant height is always desirable. Plant height ranged from 132.73 cm (ACN-9) to 148.60 cm (TAM 108-1) among the parents. The tallest parent was found to be TAM 108-1 (148.60cm) followed by PC-5 (146.33 cm) and PC-6 (138.27 cm). Among the crosses plant height ranged from 114.00 cm (PC-6 x ACN-9) to 185.80 cm (TAM 108-1 X PC-6). The two crosses PC-6 x ACN-9 (114.00

cm) and PC-6 x Kranti (126.61 cm) alone exhibited significant superiority over check TAM 108-1 (148.60 cm) and Kranti (137.93 cm) for plant height.

Number of branches plant^{-1} ranged from 3.53 (ACN-9) to 8.07 (PC-6) among the parents and from 3.27 (TAM 108-1 x PC-5) to 13.87 (PC-6 x TAM 108-1) among the crosses. Maximum number of branches was produced by the cross PC-6 x TAM 108-1 (13.87) followed by PC-6 x ACN-9 (13.07) and Kranti x PC-6 (7.80). Six crosses PC-6 x TAM 108-1 (13.87), PC-6 x ACN-9 (13.07), Kranti x PC-6 (7.80), TAM 108-1 x PC-6 (7.73), PC-6 x Kranti (7.04) and ACN-9 x PC-6 (6.07) recorded significant superiority over check TAM 108-1 (3.73) and Kranti (3.60) for number of branches plant^{-1}.

Number of siliquae plant^{-1} in parents ranged from 122.00 (Kranti) to 158.87 (PC-6). The highest number of siliquae plant^{-1} was observed in parent PC-6 (158.87) followed by PC-5 (153.27) and TAM 108-1 (136.80). Number of siliquae plant^{-1} ranged from 106.53 (TAM 108-1 x PC-5 to 490.00 (PC-6 x TAM108-1) among the crosses. Maximum number of siliquae plant^{-1} was produced by PC-6 x TAM 108-1 (490.00) followed by TAM 108-1 x PC-6 (307.40) and Kranti x PC-6 (273.60). The six crosses PC-6 x TAM 108-1 (490.00), TAM 108-1 x PC-6 (307.40), Kranti x PC-6 (273.60), ACN-9 x PC-6 (237.13), PC-6 x ACN-9 (227.13) and PC-6 x Kranti (222.75) were found to produce significantly superior number of siliquae plant^{-1} over the check TAM 108-1 (136.80) and Kranti (122.00).

1000 seed weight ranged from 2.47 g (ACN-9) to 3.37 g (Kranti) among the parents and from 2.47g (TAM 108-1 x PC-6) to 3.77g (PC-6 x TAM 108-1) among the crosses. Maximum 1000 seed weight was observed in parent Kranti (3.37 g) followed by PC-6 (3.21 g) and TAM 108-1 (2.97 g). The crosse PC-6 x TAM 108-1 (3.77 g) recorded highest 1000 seed weight followed by ACN-9 x PC-5 (3.49 g) and TAM 108-1 x PC-5 (3.42 g). Only one cross PC-6 x TAM 108-1 (3.77 g) exhibited significant superiority over both the checks TAM 108-1 (2.97 g) and Kranti (3.37 g) for the trait 1000 seed weight. Three other crosses ACN-9 x PC-5 (3.49 g), TAM 108-1 x PC-5 (3.42 g) and PC-6 x ACN-9 (3.41 g) exhibited significant superiority over only one check TAM108-1 for 1000 seed weight.

Among the parents the seed yield plant^{-1} ranged from 3.01 g (ACN-9) to 4.07 g (PC-6) and maximum seed yield plant^{-1} was recorded in PC-6 (4.07 g) followed by PC-5 (3.80 g) and Kranti (3.67 g). Range for mean seed yield plant^{-1} among the crosses was from 1.30 g (ACN-9 x PC-6) to PC-6 x ACN-9 (8.65 g). The cross PC-6 x ACN-9 (8.65 g) exhibited highest seed yield plant^{-1} followed by PC-6 x TAM 108-1 (7.61 g) and TAM 108-1 x PC-6 (6.86 g). Five crosses PC-6 x ACN-9 (8.65 g), PC-6 x TAM 108-1 (7.61 g), TAM 108-1 x PC-6 (6.86 g), Kranti x PC-6 (6.35 g) and ACN-9 x PC-5 (5.66 g) were found to record significant superiority over both the check TAM 108-1 (3.42 g) and Kranti (3.67 g). One cross ACN-9 x PC-6 (5.43 g) exhibited significant superiority over only one check TAM 108-1.

Powdery mildew infestation was recorded at 15 days before maturity on each and every individual plants of each F_1 cross and parents following 0 – 9 scale given by Mayee and Datar (1986). All the nine crosses studied were found to exhibit resistance to powdery mildew as their scale value ranged from 0 to 1. The donor parent PC-5 and PC-6 showed scale value of 0 and were resistant. The three *Brassica juncea* parents ACN-9, TAM 108-1 and Kranti were highly susceptible as they recorded the scale value of 7 to 9. In accordance to this study the different varieties of *Brassica juncea* were reported to be susceptible to powdery mildew and that of *B. carinata* were reported to be resistance to powdery mildew by Gupta *et al.* (2006) and Navabi *et al.* (2010).

Considering the mean performance the ACN-9 x PC-5 was found to be early for days to first flower (40.13 days) and days to maturity (95.33 days) and also high seed yield plant^{-1} (5.66 g) and hence can be identified for earliness. The crosses ACN-9 x PC-6, TAM 108-1 x PC-6, Kranti x PC-6, PC-6 x ACN-9 and PC-6 x TAM 108-1 were found to exhibit high and significant superiority over both the check for number of branches plant^{-1}, number of siliquae plant^{-1} and seed yield plant^{-1} and hence may be identified. Similar to this results identification of crosses for earliness and for seed yield and yield components on the basis of mean performances were also reported by Nanjundan *et al.* (2020) and Gong *et al.* (2020) in mustard.

Analysis of variance for heterosis and estimates of heterobeltiosis and useful heterosis

The analysis of variance for heterosis was estimated for days to first flower, days to maturity, plant height (cm), number of branches plant^{-1}, number of siliquae plant^{-1}, 1000 seed weight and seed yield plant^{-1} and data are presented in Table 3. The mean squares due to genotypes and crosses were significant for all the seven characters under study indicating substantial genetic variability among them for all the traits studied. The mean square due to parents were found to be significant for all the characters studied except for number of siliquae plant^{-1} and seed yield plant^{-1} indicating substantial genetic variability among the parents. The mean squares due to parents vs crosses were found to be highly significant for all the characters studied except for 1000 seed weight which suggested the suitability of data for estimation of heterobeltiosis and useful heterosis for all the characters studied except for 1000 seed weight as its the mean square due to parents vs crosses is non significant. . Similar results were also observed by Chaudhari *et al.* (2023) and Kaur *et al.* (2023) for seed yield and it's contributing characters. The above scientists concluded the presence of variability among genotypes from the significant mean squares due to genotypes, crosses, parents and parent vs crosses observed by them in mustard.

Heterosis is the most effective tool for use in estimating performance of various quantitative traits in hybrid combinations. Heterosis is the common occurrence in nature of offspring from genetically contrasting individuals by showing increased vigour over their parents. Heterosis has been explored and used for several quantitative and quality traits for different crops. It has been seen that heterosis is quick, cheap as well as easy method for increasing crop production. Heterosis breeding can be one of the most viable options for breaking the present yield barrier. Study of heterosis provides information about gene action which helps in identifying the desirable gene action for selection (Chaudhari *et al.*, 2023 and Kaur *et al*., 2023). Heterosis may be positive or negative. Both positive as well as negative heterosis used in the crop improvement depend on breeding objectives. Heterosis in positive direction was considered for number of branches plant^{-1}, number of siliquae plant^{-1}, 1000 seed weight (g) and seed yield plant^{-1} (g) and negative direction was considered for days to first flower, days to maturity and plant height (cm).

Heterobeltiosis and useful heterosis over TAM 108-1 and Kranti were estimated for six different characters and the results are presented in Table 4. Out of 9 crosses, 7 crosses exhibited negative significant heterobeltiosis in desired direction. For this character negative heterosis is usually more desirable. The highest negative significant heterobeltiosis was noted in the cross ACN-9 x PC-6 (-34.89%) followed by ACN-9 x PC-5 (-34.14%) and Kranti x PC-5 (-32.06%). Useful heterosis worked out over both the checks TAM 108-1 and Kranti for days to first flower. Only three crosses ACN-9 x PC-6 (-15.34%) ACN-9 x PC-5 (-18.98%) and Kranti x PC-5 (-16.42%) were found to be significant over the check TAM 108-1 in the desirable direction and none of the crosses were found to be significant over the check Kranti in the desirable direction. Similar kind of results for heterosis was also observed by Turi *et al.* (2006), Barupal *et al.* (2017) and Chaudhari *et al.* (2023) for days to first flower.

Three out of nine cross combinations exhibited negative significant heterobeltiosis. For this character negative heterosis is usually more desirable. In this regard there were three combinations which exhibited negative heterobeltiosis *viz*., Kranti x PC-5 (-23.24%), ACN-9 x PC-5 (-22.70%) and TAM 108-1 x PC-5 (-21.89%). Useful heterosis worked out over both the checks TAM 108-1 and Kranti for days to maturity. Only two crosses ACN-9 x PC-5 (-3.05 %) and Kranti x PC-5 (-3.73%) were found to be significant over the check TAM 108-1 in the desirable direction and none of the crosses were found to be significant over the check Kranti in the desirable direction. Similar findings were also reported in their study by different workers *viz*, Barupal *et al.* (2017), Chaudhari *et al.* (2023) and Kaur *et al.* (2023) for the character days to maturity in mustard.

As increased plant height results in lodging of the plant especially at bearing stage, lesser plant height is always desirable. Only one cross PC-6 x ACN-9 (-17.55%) exhibited significant negative heterobeltiosis, while three crosses reported for positive significant heterobeltiosis. Two out of nine crosses PC-6 x ACN-9 (-23.28%) and PC-6 x Kranti (-14.80%) recorded significant negative useful heterosis over check TAM 108-1 and only one cross PC-6 x ACN-9 (-17.35%) recorded negative significant useful heterosis over check Kranti for plant height. Similar kind of desirable heterosis for plant height in mustard were noted by Turi *et al.* (2006), Barupal *et al.* (2017) and Chaudhari *et al.* (2023)in their investigations.

In nine F_1 crosses, two crosses exhibited positive significant heterobeltiosis and seven crosses exhibited negative significant heterobeltiosis for number of branches plant^{-1}. The cross PC-6 x TAM 108-1 (71.90%) had highest positive significant heterobeltiosis followed by PC-6 x ACN-9 (61.98%) in desirable direction. Positive significant useful heterosis over check TAM 108-1 was recorded by eight crosses which ranged from 12.50% (Kranti x PC-5) to 271.43% (PC-6 x TAM 108-1). Maximum positive significant useful heterosis over check TAM 108-1 was found in cross PC-6 x TAM 108-1 (271.43%) followed by PC-6 x ACN-9 (250.00%) and Kranti x PC-6 (108.93%) for number of branches plant^{-1}. Positive significant useful heterosis over check Kranti was noticed in seven crosses which ranged from 285.19% (PC-6 x TAM 108-1) to 16.67% (Kranti x PC-5). Maximum positive significant useful heterosis over superior check Kranti was found in cross PC-6 x TAM 108-1 (285.19%) followed by PC-6 x ACN-9 (262.96%) and Kranti x PC-6 (116.67%) for number of branches plant^{-1}. Similar kind of result for heterosis in number of branches plant^{-1} wasfound by Barupal *et al.* (2017) and Chaudhari *et al.* (2023) in mustard.

Among the nine crosses, three crosses were found to be positively significant for heterobeltiosis for number of siliquae plant^{-1}. The PC-6 x TAM108-1 (208.43%) recorded highest positive significant heterobeltiosis followed by TAM 108-1 x PC-6 (93.50%) and Kranti x PC-6 (72.22%). Six crosses exhibited positive significant useful heterosis over superior check TAM 108-1. The cross PC-6 x TAM 108-1 (258.19%) exhibited maximum positive significant useful heterosis over check TAM 108-1 followed by TAM 108-1 x PC-6 (124.71%) and Kranti x PC-6 (100.00%). Six crosses exhibited positive significant useful heterosis over check Kranti. The cross PC-6 x TAM 108-1 (301.64%) exhibited maximum positive significant useful heterosis over check Kranti followed by TAM 108-1 x PC-6 (151.97%) and Kranti x PC-6 (124.26 %). In accordance to the present results Chaudhari *et al.* (2023) and Kaur *et al.* (2023) also reported positive significant useful heterosis over check in mustard for number of siliquae plant^{-1}.

In case of seed yield plant^{-1} eight crosses reported positive significant heterobeltiosis whereas only one crosses showed negative significant heterobeltiosis for seed yield plant^{-1}. The cross PC-6 x ACN-9 (112.27%) recorded maximum positive significant heterobeltiosis followed by PC-6 x TAM 108-1 (86.82%) and TAM108-1 x PC-6 (68.41%). All the nine crosses possessed positive significant useful heterosis over TAM 108-1 and eight crosses except the cross TAM 108-1 x PC-5 possessed positive significant useful heterosis over Kranti. The cross PC-6 x ACN-9 (152.58%) exhibited highest positive significant useful heterosis over check TAM 108-1 followed by PC-6 x TAM 108-1 (122.30%) and TAM 108-1 x PC-6 (100.39%). The cross PC-6 x ACN-9 (135.82%) exhibited highest positive significant useful heterosis over check Kranti followed by PC-6 x TAM 108-1 (107.55%) TAM 108-1 x PC-6 (87.09%).

Table 1. Analysis of variance for various yield and yield contributing characters in F_1 crosses and parents

Sources of variation	Degrees of freedom	Mean squares						
		Days to first flower	Days to maturity	Plant height (cm)	number of branches plant^{-1}	Number of siliquae plant^{-1}	1000 seed weight (g)	Seed yield plant^{-1} (g)
Replications	2	25.5856	4.3095	18.2162	0.7159	433.0429	0.0279	0.3799
Genotypes	13	245.5493**	670.4029**	814.9829**	35.3277**	31544.2233**	0.5096**	8.899**
Error	26	17.9906	3.0788	41.1629	0.5825	966.7186	0.0585	1.1765

**** = Significant at 1 %**

Table 2. Analysis of variance for heterosis

Source of variation	Degrees of freedom	Mean squares						
		Days to first flower	Days to maturity	Plant height (cm)	Number of branches plant^{-1}	Number of siliquae plant^{-1}	1000 seed weight (g)	Seed yield plant^{-1} (g)
Replications	2	25.5856	4.3095	18.2162	0.7159	433.0429	0.0279	0.3799
Genotypes	13	245.5493**	670.4029**	814.9829**	35.3277**	31544.2233**	0.5096**	8.8994**
Parents	4	242.0240**	608.9000**	128.3707*	15.3933**	694.6493	0.3874**	0.4868
Crosses	8	257.4632**	718.2870**	1205.1805**	44.2016**	39065.6933**	0.6078**	7.4324**
Parents vs Crosses	1	164.3396**	533.3418**	439.8510**	44.0739**	94770.7587**	0.2122	54.2917**
Error	26	17.9906	3.0788	41.1629	0.5825	966.7186	0.0585	1.1765

***, ** = Significant at 5 % and 1 % level respectively**

Table 3. Mean performance of parents and their F_1 crosses for different characters

Sr. No.	Crosses / Parents	Days to first flower	Days to maturity	Plant height (cm)	Number of branches $plant^{-1}$	Number of siliquae $plant^{-1}$	1000 seed weight (g)	Seed yield $plant^{-1}$ (g)	Powdery mildew reaction
1	ACN-9 x PC-6	41.93*	125.33	157.67	6.07*#	237.13*#	2.56	5.43*#	R
2	TAM 108-1 x PC-6	48.67	126.67	185.80	7.73*#	307.40*#	2.47	6.86*#	R
3	Kranti x PC-6	48.27	125.00	154.93	7.80*#	273.60*#	3.24	6.35*#	R
4	ACN-9 x PC-5	40.13*	95.33*	150.80	3.60	134.93	3.49*	5.66*#	R
5	TAM 108-1 x PC-5	42.13*	96.33	146.47	3.27	106.53	3.42*	3.60	R
6	Kranti x PC-5	41.40*	94.67*	148.13	4.20	158.27	3.24	4.50	R
7	PC-6 x ACN-9	65.80	126.33	114.00*#	13.07*#	227.13*#	3.41*	8.65*#	R
8	PC-6 x TAM 108-1	53.67	128.00	143.33	13.87*#	490.00*#	3.77*#	7.61*#	R
9	PC-6 x Kranti	61.21	126.67	126.61*#	7.04*#	222.75*#	2.62	5.06	R
10	ACN-9	49.20	99.33	132.73	3.53	132.13	2.47	3.01	S
11	TAM 108-1	49.53	98.33	148.60	3.73	136.80	2.97	3.42	S
12	Kranti	42.80	97.00	137.93	3.60	122.00	3.37*	3.67	S
13	PC-5	60.93	123.33	146.33	7.40	153.27	2.76	3.80	R
14	PC-6	64.40	125.00	138.27	8.07	158.87	3.21	4.07	R
	Mean	**50.72**	**113.38**	**145.12**	**6.64**	**204.34**	**3.05**	**5.12**	
	SE (m)±	**3.46**	**1.43**	**5.24**	**0.62**	**25.39**	**0.20**	**0.89**	
	CD (5%)	**6.94**	**2.87**	**10.49**	**1.25**	**50.86**	**0.39**	**1.77**	

*** Significantly superior over TAM 108-1 and**

 # Significantly superior over Kranti

Table 4. Heterobeltiosis (H1) and Useful Heterosis over TAM108-1 (H2) and Kranti (H3) for various characters

Sr. No.	Crosses	Days to first flower			Days to maturity			Plant height (cm)		
		H1	H2	H3	H1	H2	H3	H1	H2	H3
1	ACN-9 x PC-6	-34.89**	-15.34**	-2.02	0.27	27.46**	29.21**	14.03**	6.10	14.31**
2	TAM 108-1 x PC-6	-24.43**	-1.75	13.71**	1.33	28.81**	30.58**	25.03**	25.03**	34.70**
3	Kranti x PC-6	-25.05**	-2.56	12.77**	0.00	27.12**	28.87**	12.05*	4.26	12.32*
4	PC-6 x ACN-9	2.17	32.84**	53.74**	1.07	28.47**	30.24**	-17.55**	-23.28**	-17.35**
5	PC-6 x TAM 108-1	-16.67**	8.34*	25.39**	2.40	30.17**	31.96**	-3.54	-3.54	3.91
6	PC-6 x Kranti	-4.96	23.56**	43.00**	1.33	28.81**	30.58**	-8.43	-14.80**	-8.21
7	ACN-9 x PC-5	-34.14**	-18.98**	-6.23	-22.70**	-3.05*	-1.72	3.05	1.48	9.33
8	TAM 108-1 x PC-5	-30.85**	23.01**	-1.56	-21.89**	25.42**	-0.69	-1.44	0.00	6.19
9	Kranti x PC-5	-32.06**	-16.42**	-3.27	-23.24**	-3.73*	-2.41	1.23	-0.31	7.39
	SE (d)	**3.46**	**3.46**	**3.46**	**1.43**	**1.43**	**1.43**	**5.24**	**5.24**	**5.24**

***, ** = Significant at 5 % and 1 % level respectively**

Sr. No.	Crosses	Number of branches plant^{-1}			Number of siliquae plant^{-1}			Seed yield plant^{-1} (g)		
		H1	H2	H3	H1	H2	H3	H1	H2	H3
1	ACN-9 x PC-6	-24.79**	62.50**	68.52**	49.27	73.34**	94.37**	33.31**	58.62**	48.09**
2	TAM 108-1 x PC-6	-4.13**	107.14**	114.81**	93.50**	124.71**	151.97**	68.41**	100.39**	87.09**
3	Kranti x PC-6	-3.31**	108.93**	116.67**	72.22**	100.00**	124.26**	55..89**	85.49**	73.18**
4	PC-6 x ACN-9	61.98**	250.00**	262.96**	42.97	66.03*	86.17**	112.27**	152.58**	135.82**
5	PC-6 x TAM 108-1	71.90**	271.43**	285.19**	208.43**	258.19**	301.64**	86.82**	122.30**	107.55**
6	PC-6 x Kranti	-12.71**	88.60**	95.59**	40.21	62.83*	82.58**	24.14**	47.71**	37.91**
7	ACN-9 x PC-5	-51.35**	-3.57**	0.00	-11.96	-1.36	10.60	48.90**	65.43**	54.45**
8	TAM 108-1 x PC-5	-55.86**	98.21**	-9.26**	-30.49	12.04	-12.68	-5.43**	11.10**	-1.91*
9	Kranti x PC-5	-43.24**	12.50**	16.67**	3.26	15.69	29.73	18.23**	31.35**	22.64**
	SE (d)	**0.62**	**0.62**	**0.62**	**25.39**	**25.39**	**25.39**	**0.89**	**0.89**	**0.89**

***, ** = Significant at 5 % and 1 % level respectively**

Note: Heterobeltiosis and useful heterosis for 1000 seed weight were not estimated as the mean square due to parents vs crosses was non significant

Significant positive heterosis for seed yield plant^{-1} in their study were noted by earlier worker Barupal *et al.* (2017), Chaudhari *et al.* (2023) and Kaur *et al.* (2023) which supported to the present finding.

Heterosis over better parent may not be useful for assessing superiority of F_1 but heterosis over the check variety is of practical importance in plant breeding. From data of useful heterosis over check Kranti and TAM 108-1 six cross combinations ACN-9 x PC-6, TAM 108-1 x PC-6, Kranti x PC-6, PC-6 x ACN-9, PC-6 x TAM 108-1 and PC-6 x Kranti were found to exhibit significant positive useful heterosis over both the check for number of branches plant^{-1}, number of siliquae plant^{-1} and seed yield plant^{-1}. These crosses may be identified as superior for forwarding to next generation. When the useful heterosis and mean performance were considered together all the above mentioned crosses ACN-9 x PC-6, TAM 108-1 x PC-6, Kranti x PC-6, PC-6 x ACN-9 and PC-6 x TAM 108-1 except PC-6 x Kranti were found to exhibit superiority over check for mean as well as useful heterosis. In the improvement of self-pollinated crop, breeders often focus on the production of homozygous lines and the attention of breeder normally rest on transgressive segregates shown by the crosses. Hence, in such crops the breeder is restricted to produce true breeding varieties only, as the non-additive portion of phenotypic variation is not fixable in later generation. Potentiality of the crosses to be forwarded to next generation was decided on the basis of high mean performance and high useful heterosis. Among the nine crosses studied the cross combinations ACN-9 x PC-6, TAM 108-1 x P-6, Kranti x PC-6, PC-6 x ACN-9 and PC-6 x TAM 108-1 were observed to exhibit significant superiority over check for mean as well as for useful heterosis for number of branches plant^{-1}, number of siliquae plant^{-1} and seed yield plant^{-1}. These five crosses were therefore found to be best crosses which can be forwarded to the next generation. Biparental mating may be used in selected progeny and further selection of segregant generation may also be used for improvement of yield and yield components.

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Rec. on 02.11.2023 & Acc. on 17.11.2023