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Studies on F2 and First Backcross Population of Interspecies Crosses (*Brassica spp.*)

Treio Dkhar[1], **Shanti R. Patil**[2], **Achal B. Jagzape**[1] **and Harish Kumar**[3]

[1]Department of Genetics and Plant Breeding, Dr. PDKV University Akola, College of Agriculture, Nagpur, Maharashtra, India
[2]Department of Botany Section, College of Agriculture, Gadchiroli, Maharashtra India
[3]Department of Genetics and Plant Breeding, College of Agriculture, CAU, Imphal, Manipur, India

ABSTRACT

An experiment was conducted at the research farm of College of Agriculture, Nagpur to determine the nature and magnitude of genetic variability in F_2 and BC_1F_1 crosses in terms of various genetic parameters for the different characters. In rabi 2022 three BC_1F_1 crosses (TAM 108-1 x PC-6) x TAM 108-1, (Kranti x PC-6) x Kranti and (ACN-9 x PC-6) x ACN-9 done for transfer of powdery mildew resistance from B. carinata (PC-6 donor) to B. juncea varieties and their three F_2 crosses of TAM 108-1 x PC-6, ACN-9 x PC-6 and Kranti x PC-6 along with their four parents ACN-9, TAM 108-1, Kranti and PC-6 , were evaluated in RBD with 3 replications. 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. In many of the F_2 or BC_1F_1 crosses seed yield plant^{-1} was less though their number of siliquae plant^{-1} which was more due to the involvement of two species i.e., juncea and carinata. Wide range was observed for all the seven characters studied among the three F_2 crosses and the three BC_1F_1 crosses. Moderate to high per cent of GCV and PCV were exhibited for plant height, number of branches plant^{-1}, number of siliquae plant^{-1}, 1000 seed weight and seed yield plant^{-1} in all F_2 and BC_1F_1crosses. High to moderate heritability coupled with high moderate genetic advance as per cent of mean was exhibited in all the F_2 and BC_1F_1crosses except BC_1F_1cross (ACN-9 x PC-6) x ACN-9. Selection of potential material were done in F_2 and BC_1F_1generation. In F_2generation, 29 single plants were identified based on the characters seed yield plant^{-1}, number of siliquae plant^{-1} and number of branches plant^{-1} for forwarding to F_3 generation by plant to row method for their exploitation. In BC_1F_1 crosses 64 single plants selected on the basis of resistance to powdery mildew less than 3 score were backcrossed with their respective B. juncea parents to get seeds of BC_2F_1 which will be forwarded to next generation with an aim to transfer the genetic constitution of B. juncea to improve its yield level.

Keywords: *Brassica juncea, Brassica carinata, interspecific crosses, genetic parameters*

INTRODUCTION

Rapeseed-mustard is an important oilseed 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 oilseed crop and has an important share in India's oilseed economy (Kamdi *et al.,* 2022). Nowadays mustard is maintaining its increasing trend in productivity while the area is continuously declining resulting in its stagnant production in India. Yet, India meets 57% of the domestic edible oil requirement through import and is ranked 7th largest importer of edible oils in the world. The further boom in human population and improved living standards has led to a rapid increase in the capita^{-1} oil consumption and has been estimated to be 28.40 million tonnes for year 2030 and 41.6 million tonnes for the year 2050 (Kumar, 2017). Therefore there is an urgent need of the development of high yielding varieties. Mustard is a minor crop of the Eastern Vidarbha region, farmers grow mustard crops in last week of November to the second week of December after harvesting of paddy. Generally delayed planting leads to the shortening of the vegetative phase, advances flowering time and decreases seed development period resulting into shriveled seed. Similarly, the incidence of powdery mildew occurs at the flowering and siliqua development stage therefore, farmers receive very poor yield (12q acre^{-1}). There is need 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 bottlenecks in obtaining higher productivity is a reduction in yield due to diseases and pests which cause damage 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 damage followed by white rust, stem rot and powdery mildew. All the released Indian mustard varieties are susceptible to these diseases. Of the above diseases, powdery mildew (*Erysiphe cruciferous*) causes maximum damage in the Vidarbha region up to 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 to get economic yield.

The resistance source for powdery mildew is available in *Brassica carinata.* Powdery mildew has been reported to be governed by a dominance gene (Kumar *et al.,* 2017).

Corresponding Author:* ***Treio Dkhar*

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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 for which this study was conducted.

MATERIALS AND METHODS

The experiment was conducted at the research farm of the College of Agriculture, Nagpur during *rabi* 2022. Four parents ACN-9, TAM 108-1, Kranti and PC-6 , three BC_1F_1 crosses (TAM 108-1 x PC-6) x TAM 108-1, (Kranti x PC-6) x Kranti and (ACN-9 x PC-6) x ACN-9 done for transfer of powdery mildew resistance from *B. carinata* (PC-6 donor) to *B. juncea* varieties and their three F_2 crosses of TAM 108-1 x PC-6, ACN-9 x PC-6 and Kranti x PC-6 were raised in Randomized Block Design (RBD) with 3 replications for evaluation. A spacing of 45 cm x 15 cm was maintained. Five rows for F_2, four rows for BC_1F_1 and two rows for parents were allocated with 20 plants row^{-1}. Five randomly selected plants from parents 20 plants from BC_1F_1 and 50 plants from F_2 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 the 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. The data were subjected to statistical analysis ie. analysis of variance for the experimental design and heterosis (Panse and Sukhatme, 1954), estimation of genetic parameters was done by using standard formulas.

RESULTS AND DISCUSSION

Three BC_1F_1 crosses (TAM 108-1 x PC-6) x TAM 108-1, (Kranti x PC-6) x Kranti and (ACN-9 x PC-6) x ACN-9 done for transfer of powdery mildew resistance from *B. carinata* (PC-6 donor) to *B. juncea* varieties and their three F_2 crosses of TAM 108-1 x PC-6, ACN-9 x PC-6 and Kranti x PC-6 along with their respective parents ACN-9, TAM 108-1, Kranti and PC-6 were evaluated and the results obtained are being presented and discussed below. The mean squares due to genotypes (BC_1F_1 crosses, F_2 crosses and parents) were highly significant for all the seven characters *viz*. 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} indicating the substantial genetic variability among the genotypes for these characters (Table 1). Hence, the genetic parameters were worked out for all the significant characters. Tiwari *et al.* (2017), Gupta *et al*. (2019) and Choudhary *et al.* (2023) have reported similar results in their study in mustard.

Mean Performance and Range

The mean performance of parents and crosses of each of the three F_2 crosses and three BC_1F_1 crosses for seven different characters are presented in Table 2. None of them were found to be significantly superior over the check TAM 108-1 and Kranti for days to first flower. Two BC_1F_1 crosses (ACN-9 x PC-6) x ACN-9 (94.57 days) and (Kranti x PC-6) x Kranti (98.03 days) were found to exhibit significant superiority over the Check TAM 108-1 and none of them were superior over check Kranti for days to maturity. Two F_2 cross ACN-9 x PC-6 (125.02 cm) and TAM 108-1 x PC-6 (141.82 days) and one BC_1F_1 cross (ACN-9 x PC-6) x ACN-9 (147.07 cm) exhibited significant superiority over both the check TAM 108-1 and Kranti for plant height in the desirable direction. Two F_2 cross ACN-9 x PC-6 (4.81) and TAM 108-1 x PC-6 (4.55) and one BC_1F_1 cross (ACN-9 x PC-6) x ACN-9 (4.67) were found to produce significantly more number of branches plant^{-1} as compared to both the check TAM 108-1 and Kranti. Only one BC_1F_1 cross (ACN-9 x PC-6) x ACN-9 (364.15) was found to exhibit significant superiority over both the check TAM 108-1 and Kranti for number of siliquae plant^{-1}. Another BC_1F_1 cross (Kranti x PC-6) x Kranti (227.12) exhibited superiority over only Kranti for this trait. Only the F_2 cross TAM 108-1 x PC-6 (4.08g) exhibited significant superiority over the check Kranti for 1000 seed weight and none were superior over the check TAM 108-1. Only one BC_1F_1 cross (ACN-9 x PC-6) x ACN-9 exhibited significant superiority over both the check TAM 108-1 and Kranti for seed yield plant^{-1}.

The mean performance of all the characters when compared only one BC_1F_1 cross (ACN-9 x PC-6) x ACN-9 was found to exhibit significant superiority over either both the check or any one check for the characters days to maturity (94.57 days), plant height (147.07 cm), number of branches plant^{-1} (4.67), number of siliquae plant^{-1} (364.15) and seed yield plant^{-1} (8.87g). Hence, this BC_1F_1 cross may be identified as the promising cross based on mean performance. But in many of the F_2 or BC_1F_1 crosses, though the number of siliquae plant^{-1} is more, the seed yield plant^{-1} are observed to be low. This may be due to the reason that as two different species are involved many of the siliquae formed are not filled with seed. The overall mean value of seed yield plant^{-1} are also low in many of F_2 or BC_1F_1 crosses. In accordance to these results Gupta *et al.* (2006), Dahiya *et al.* (2019), Nanjundan *et al.,* (2020) and Gong *et al.* (2020) also observed low mean value for yield and yield components in early segregating generation.

Powdery mildew infestation was recorded at 15 days before maturity on each and every individual plant of each F_2 and BC_1F_1 cross following 0-9 scale given by Mayee and Datar, (1986) and the result are presented in Table 2. The powdery mildew score value ranged from 0-9 in one BC cross (ACN-9 x PC-6) x ACN-9 and 1-9 in all other BC and F_2 crosses. The percentage of a plants with score value less than 3 ranged from 4.23 in F_2 cross ACN-9 x PC-6 to 9.49 in BC_1F_1 cross (ACN-9 x PC-6) x ACN-9. A percentage of plants with a score of 3 were found to be more in BC_1F_1 crosses as compared to F_2 crosses.

The range of each of the three F_2 crosses and three BC_1F_1 for seven different characters are presented in Table 3. A wide range was observed for all the seven characters studied among the three F_2 crosses and three BC_1F_1 crosses which reveals a great opportunity for making individual plant selection for forwarding to the next generation. Similar to this result Bhattacharjee *et al.* (2008), Liu *et al.* (2010) and Choudhary *et al.* (2023) also reported a wide range of yield and yield components in mustard early segregating generation.

Genetic parameters

The genotypic coefficient of variation, phenotypic coefficient of variation, heritability and genetic advance as a percentage of the mean of each of the three F_2 crosses and three BC_1F_1 crosses for seven different characters are presented in Table 4.

1) Days to first flower

Low values (<10%) of the genotypic coefficient of variation and phenotypic coefficient of variation were observed for days to the first flower in all the F_2 and BC_1F_1 crosses. This revealed the low variability for these characters. The low difference between the genotypic coefficient of variation and the phenotypic coefficient of variation indicates that this character is least influenced by the environment. The present results are in accordance with reports of Singh *et al*. (2022) who also reported low GCV and PCV for days to first flower. The estimates of heritability in all the F_2 crosses and two BC_1F_1 crosses except (ACN-9 x PC-6) x ACN-9 exhibited moderate heritability per cent. Maximum estimate of heritability was recorded by the F_2 cross ACN-9 x PC-6 (55.81%) followed by BC_1F_1 cross (TAM 108-1 x PC-6) x TAM 108-1 (52.54%) and BC_1F_1 cross (Kranti x PC-6) x Kranti (51.18%). Low genetic advance and genetic advance as per-cent of mean (GAM) were exhibited in all the F_2 and BC_1F_1 crosses studied. High heritability with low genetic advance as per-cent of the mean was recorded for this character indicating that the character is governed by non-additive gene action. The high heritability is being exhibited due to favorable influence of the environment rather than genotype and selection for such traits may not be rewarding. Similar to this result Yadav *et al.* (2021) and Singh *et al*. (2022) also reported high heritability with low genetic advance for days to first flower in mustard.

2) Days to Maturity

Low values (<10%) of the genotypic coefficient of variation and phenotypic coefficient of variation were observed for days to maturity in all the F_2 and BC_1F_1 crosses. This revealed the low variability for these characters. Low difference between the genotypic coefficient of variation and phenotypic coefficient of variation indicates that this character is least influenced by the environment. High heritability was exhibited by all the F_2 and BC_1F_1 crosses for days to maturity. Maximum heritability was estimated by the F_2 cross ACN-9 x PC-6 (99.67%), Kranti x PC-6 (99.25%) and BC_1F_1 cross (ACN-9 x PC-6) x ACN-9 (98.77%). Moderate genetic advance as a percentage of mean for days to maturity was exhibited by only one F_2 cross Kranti x PC-6 (10.65%) and all other F_2 and BC_1F_1 crosses exhibited low genetic advance as a percentage of mean. This indicated a significant role of non-additive gene action and a significant role of environment influencing this character hence selection is not effective for early maturing plants in F_2 and BC_1F_1 generation.

3) Plant height (cm)

The GCV per cent and PCV per cent ranged from low (<10%) to high (>20%) for plant height. The GCV and PCV per cent was found to be high in BC_1F_1 cross (TAM 108-1 x PC-6) x TAM 108-1 (22.23% and 22.64%). Moderate GCV and PCV per cent was exhibited by F_2 cross ACN-9 x PC-6 (17.51% and 18.55%) followed by F_2 cross TAM 108-1 x PC-6 (17.16% and 17.91%), BC_1F_1 cross (Kranti x PC-6) x Kranti (16.53% and 17.07%) and F_2 cross Kranti x PC-6 (12.22% and 13.00 %). Similar to this result Ullah *et al.* (2015), Gupta *et al*. (2019) and Choudhary *et al.* (2023) also reported moderate and high GCV and PCV for plant height. The heritability estimated for the plant height was maximum in BC_1F_1 cross (TAM 108-1 x PC-6) x TAM 108-1 (96.39%) followed by BC_1F_1 cross (Kranti x PC-6) x Kranti (93.82%) and F_2 cross TAM 108-1 x PC-6 (91.84%). All the F_2 and BC_1F_1 crosses possessed high heritability. Genetic advance as per cent of mean was observed to be high in all the F_2 and BC_1F_1 crosses except one BC_1F_1 cross (ACN-9 x PC-6) x ACN-9 which exhibited moderate genetic advance as per cent of mean. Maximum genetic advance as per cent of mean was exhibited by BC_1F_1 cross (TAM 108-1 x PC-6) x TAM 108-1 (44.96%) followed by F_2 cross ACN-9 x PC-6 (34.05%) and F_2 cross TAM 108-1 x PC-6 (33.88%). High heritability coupled with high or moderate genetic advance as per cent mean was observed for plant height in all F_2 and BC_1F_1 crosses indicating the predominance of additive gene action for the trait. So, this trait would be helpful for indirect selection in the improvement of seed yield. In accordance to this result Ullah *et al.* (2015) and Gupta *et al*. (2019) also reported high heritability coupled with high genetic advance as per cent of mean for plant height and indicated that the heritability is due to additive gene effects and selection was effective.

4) Number of branches plant^{-1}

Moderate (10-20%) to high (>20%) GCV and PCV per cent was exhibited by number of branches plant^{-1}. Maximum GCV and PCV per cent was recorded by BC_1F_1 cross (ACN-9 x PC-6) x ACN-9 (29.50% and 30.73%) followed by F_2 cross TAM 108-1 x PC-6 (26.25% and 27.75%) and BC_1F_1 cross (Kranti x PC-6) x Kranti (25.86% and 27.63%). Pal *et al.* (2019), Gupta *et al*. (2019), Yadav *et al.* (2021), Singh *et al*. (2022) and Choudhary *et al.* (2023) also observed high GCV and PCV per cent for number branches plant^{-1}. The heritability estimates for number of branches was maximum in BC_1F_1 cross (ACN-9 x PC-6) x ACN-9 (92.19%) followed by F_2 population of ACN-9 x PC-6 (90.02%) and F_2 cross TAM 108-1 x PC-6 (89.46%). All the F_2 and BC_1F_1 crosses possessed high heritability. Genetic advance as per-cent of mean was also high for all the F_2 and BC_1F_1 crosses. Genetic advance as per cent of mean was maximum in BC_1F_1 cross (ACN-9 x PC-6) x ACN-9 (58.36%) followed by F_2 cross TAM 108-1 x PC-6 (51.14%) and BC_1F_1 cross (Kranti x PC-6) x Kranti (49.85%). The genetic parameters calculated for a number of branches plant^{-1} revealed that all the F_2 and BC_1F_1 crosses exhibited high heritability coupled with high genetic advance. This indicates that there is a lesser influence of environment and exhibits additive gene action in the expression of this character which is amenable for selection. Similar to this result Tiwari *et al.* (2017), Pal *et al.* (2019), Singh *et al*. (2022) and Choudhary *et al.* (2023) also observed high heritability coupled with high genetic advance for a number of branches plant^{-1} in mustard.

5) Number of siliquae plant^{-1}

The GCV and PCV per cent was observed to exhibit high in all the F_2 and BC_1F_1 crosses for number of siliquae plant^{-1}. The GCV and PCV per cent was found maximum in BC_1F_1 cross of (ACN-9 x PC-6) x ACN-9 (90.09% and 90.48%) followed by F_2 cross Kranti x PC-6 (86.46% and 87.72%) and F_2 cross TAM 108-1 x PC-6 (80.43% and 84.65%). Similar findings were also observed by Tiwari *et al.* (2017), Pal *et al.* (2019), Gupta *et al*. (2019) and Choudhary *et al.* (2023) who also reported high GCV and PCV per cent for number of siliquae plant^{-1}. The maximum heritability estimate for number of siliquae plant^{-1} recorded by BC_1F_1 cross (ACN-9 x PC-6) x ACN-9 (99.16%) followed by BC_1F_1 cross (Kranti x PC-6) x Kranti (97.85%) and F_2 cross Kranti x PC-6 (97.14%). All the F_2 and BC_1F_1 crosses recorded high heritability. Maximum genetic advance as per cent of mean was recorded by BC_1F_1 cross (ACN-9 x PC-6) x ACN-9 (184.81%) followed by F_2 cross Kranti x PC-6 (175.55%) and F_2 cross TAM 108-1 x PC-6 (157.42%). Like heritability all the F_2 and BC_1F_1 crosses also recorded high genetic advance as per cent of mean. High heritability coupled with high genetic advance as per cent mean was observed for number of siliquae plant^{-1}. This indicates the lesser influence of environment in expression of this characters and prevalence of additive gene action in their inheritance. Naturally, selection based on phenotypic observations for this character would be effective. Several workers had reported similar findings of high heritability and genetic advance for number of siliquae plant^{-1} *viz*., Tiwari *et al.* (2017) and Gupta *et al*. (2019) in mustard.

6) 1000 seed weight (g)

Genotypic and phenotypic coefficient of variation ranged from low to high for 1000 seed weight. GCV per cent was found to be moderate in two F_2 crosses Kranti X PC-6 (19.88%) and ACN-9 x PC-6 (17.73%) and two BC_1F_1 crosses TAM 108-1 x PC-6) x TAM 108-1 (13.12%) and (Kranti x PC-6) x Kranti (10.94%). Low GCV per cent was recorded in one F_2 cross TAM 108-1 x PC-6 (9.66%) and one BC_1F_1 cross (ACN-9 x PC-6) x ACN-9 (5.03%). PCV per cent was observed to be high in one F_2 cross Kranti x PC-6 (21.74%) and low in one BC_1F_1 cross (ACN-9 X PC-6) x ACN-9 (8.42%). Moderate PCV per cent was recorded in two F_2 crosses Kranti x PC-6 (21.74%) and ACN-9 X PC-6 (19.48%) and two BC crosses (TAM 108-1 x PC-6) x TAM 108-1 (14.69%) and (Kranti x PC-6) x Kranti (14.15%). Present results are following the results reported by Gupta *et al*. (2019) and Singh *et al*. (2022) who also observed low to high GCV and PCV per cent for 1000 seed weight. The heritability estimates for 1000 seed weight ranged from moderate to high among the F_2 and BC_1F_1 crosses. Moderate heritability was recorded two BC_1F_1 crosses (ACN-9 x PC-6) x ACN-9 (35.69%) and (Kranti x PC-6) x Kranti (59.75%). High heritability for 1000 seed weight was recorded by F_2 cross Kranti x PC-6 (83.64%) followed by F_2 cross ACN-9 x PC-6 (82.85%), BC_1F_1 cross (TAM 108-1 x PC-6) x TAM 108-1 (79.72%) and F_2 cross TAM 108-1 x PC-6 (73.88 %). Genetic advance as per cent of mean ranged from low to high. High genetic advance as per cent of mean was recorded by Kranti x PC-6 (37.45%) followed by ACN-9 x PC-6 (33.25%) and (TAM 108-1 x PC-6) x TAM 108-1 (79.72%). Moderate genetic advance as per cent of mean was recorded by BC_1F_1 cross (Kranti x PC-6) x Kranti (17.42%) followed by TAM 108-1 x PC-6 (17.09%) and low genetic advance as per cent of mean was recorded by BC_1F_1 cross (ACN-9 x PC-6) x ACN-9 (6.19%).

High to moderate heritability coupled with high to moderate genetic advance as per-cent of mean was recorded in all the F_2 and BC_1F_1 crosses except BC_1F_1 cross (ACN-9 x PC-6) x ACN-9. This indicated that the least influence of environment on the expression of character and prevalence of additive gene action in their inheritance, hence amenable for the simple selection by visual means. High heritability along with high genetic advance as per-cent of the mean were also reported by Gupta *et al*. (2019), Yadav *et al.* (2021), Singh *et al*. (2022) and Choudhary *et al.* (2023) for 1000 seed weight in mustard.

7) Seed yield plant^{-1} (g)

High GCV per cent was recorded by all the F_2 and BC_1F_1 crosses except F_2 cross ACN-9 x PC-6 for seed yield plant^{-1}. High PCV per cent was recorded by all the F_2 and BC_1F_1 crosses. Maximum GCV and PCV per cent was exhibited by F_2 cross TAM 108-1 x PC-6 (178.08% and 200.24%) followed by BC_1F_1 crosses (ACN-9 x PC-6) x ACN-9 (118.88% and 120.20%) and BC_1F_1 cross (TAM 108-1 x PC-6) x TAM 108-1 (79.12% and 87.16%). Similar to these results Pal *et al.* (2019), Gupta *et al*. (2019), Yadav *et al.* (2021) and Singh *et al*. (2022) also reported high GCV and PCV for seed yield plant^{-1}. The maximum heritability estimates was recorded in BC_1F_1 cross (ACN-9 x PC-6) x ACN-9 (97.81%) followed by BC_1F_1 cross (Kranti x PC-6) x Kranti (94.19%) and F_2 cross Kranti x PC-6 (87.96 %). Maximum genetic advance as per cent of mean was recorded in F_2 cross TAM 108-1 x PC-6 (326.24%) followed by BC_1F_1 cross (ACN-9 x PC-6) x ACN-9 (242.19%) and BC_1F_1 cross (Kranti x PC-6) x Kranti (156.64%).

High heritability coupled with high genetic advance as per cent of mean was observed in all the F_2 and BC_1F_1 crosses except F_2 cross ACN-9 x PC-6. High heritability coupled with high genetic advance as per cent mean was observed for seed yield plant^{-1}. This indicated less influence of environment in the expression of character and prevalence of additive gene action in their inheritance. Naturally, selection based on phenotypic observations for this character would be effective. Earlier workers Pal *et al.* (2019), Gupta *et al*. (2019), Singh *et al*. (2022) and Choudhary *et al.* (2023) had also reported high heritability and genetic advance as per cent of mean for seed yield plant^{-1} in their study which were supported to the present finding.

The genotypic and phenotypic coefficient of variation calculated for seven different characters revealed all the F_2 and BC_1F_1 crosses exhibited moderate to high per cent of GCV and PCV for plant height, number of branches plant^{-1}, number of siliquae plant^{-1}, 1000 seed weight and seed yield plant^{-1}. This indicates that there is substantial variation for these characters in the F_2 and BC_1F_1 crosses and it also suggest that there is greater scope for selection to improve upon these characters. Low difference between GCV and PCV indicates that there is a lesser influence of environment and exhibits additive gene action in the expression of these characters which is amenable for selection. When the heritability and genetic advance as per cent of mean were observed for all the characters, moderate to high heritability was coupled with moderate to high genetic advance was exhibited for plant height, number of branches plant^{-1}, number of siliquae plant^{-1}, 1000 seed weight and seed yield plant^{-1} in all the F_2 and BC_1F_1 crosses except for F_2 cross ACN-9 x PC-6 for seed yield plant^{-1} and BC_1F_1 cross (ACN-9 x PC-6) x ACN-9 for 1000 seed weight. Hence these five characters plant height, number of branches plant^{-1}, number of siliquae plant^{-1}, 1000 seed weight and seed yield plant^{-1} in most of the F_2 and BC_1F_1 cross were found to be due to additive gene effect and selection may be effective for these characters.

Selection of potential material

Any appraisal of the breeding material permitting early elimination of material of low potential is clearly advantageous because all improvement programes have limitations and elimination of poor material enhances the probability of finding superior segregants in the remaining material by Allard (1960). One of the criteria for identification of a potential F_2 population was with high mean yield, high genotypic coefficient of variation and high expected genetic advance. Since only the genetic portion of the total variability contributes to gain under selection, the importance of information about the parameter of genotype-environment complex should be clear to the breeder. As better estimates of these parameters are obtained for a variety of plant materials, the breeder will be able to anticipate the gain, as he can expect from different intensity of selection. Therefore, in an actual breeding programe with limited facilities, the highest advance may result from such crosses. In the present study, three F_2 populations were evaluated for important genetic parameters such as genotype coefficient of variation, heritability and expected genetic advance for seven quantitative traits. Characters namely plant height, number of branches plant^{-1}, number of siliqua plant^{-1}, 1000 seed weight and seed yield plant^{-1}. This indicates that there is substantial variation for these characters in F_2. Moderate to high heritability associated with moderate to high estimated genetic advance as per cent of mean was exhibited in these characters indicating the significance of additive gene action.

Hence, these characteristics can be considered for the selection of potential F_2 plants for further improvement. The study of correlation and path coefficient analysis indicated that the number of siliquae plant^{-1} and the number of branches plant^{-1} had a positive high direct effect coupled with a positive significant correlation with seed yield plant^{-1} and hence direct selection can be made based on these traits for improving seed yield in Indian mustard. Hence the three F_2 to crosses studied would be useful for obtaining potential segregants with a high number of branches, number of siliquae plant^{-1} and seed yield plant^{-1}. So, single plants were selected on the basis of these three traits at 10% selection intensity from each cross and are listed in Table 5. All the selected 29 plants were superior having better performance than mean performance of respective crosses. These single plants selected are suggested to be carried forward to F_3 generation by plant to row method for exploiting improvement in the selected material.

Three BC_1F_1 crosses were also evaluated for important genetic parameters such as genotypic coefficient of variation, heritability and expected genetic advance for seven quantitative traits and also correlation and path coefficient analysis. Number of branches plant^{-1}, number of siliquae plant^{-1} and seed yield plants^{-1} along with resistance to powdery mildew were identified as criteria of selecting single plants in BC_1F_1 crosses. But it was observed that single plants that recorded superior seed yield plant^{-1} and siliquae plant^{-1} showed PM score values 4 - 9 and hence were susceptible. Those plants of BC_1F_1 crosses that exhibited PM score value less than 3 (resistant) recorded low seed yield plant^{-1} and less siliquae plant^{-1}. This indicates that resistant plants of these BC_1F_1 crosses are to be backcrossed with respective *B. juncea* parents for few more generations to transfer the genetic constitution of *B. juncea* to improve its yield level. Hence, 64 single plants were selected (Table 6) on the basis of resistance to powdery mildew (less than 3 scores) and were backcrossed with their respective *B. juncea* parents to get seeds of BC_2F_1 which will be forwarded to next generation.

Table 1. Analysis of variance in crosses of F_2 and BC_1F_1 generation for various characters in mustard
***** = Significant at 1 %***

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	10.34	1.90	76.57	0.25	421.45	0.19	2.69
Genotypes	9	120.70**	430.14**	411.83**	3.75**	17849.73**	0.99**	13.91**
Error	18	4.95	0.66	26.20	0.15	530.38	0.10	1.26

Table 2. Mean performance in crosses of F_2 and BC_1F_1 generation for various characters

Sr. No.	Crosses	Days to first flower	Days to maturity	Plant height (cm)	No. of branches plant^{-1}	No. of siliquae plant^{-1}	1000 seed wt. (g)	Seed yield plant^{-1} (g)
	F_2 Crosses							
1	TAM 108-1 x PC-6	44.00	123.61	141.82	4.55	193.90	4.08	1.91
2	ACN-9 x PC-6	47.46	115.52	125.02	4.81	208.29	2.40	1.34
3	Kranti x PC-6	42.14	107.68	158.40	3.55	169.44	3.36	4.31
	BC_1F_1 crosses							
4	(TAM 108-1 x PC-6) x TAM 108-1	45.33	99.75	168.78	3.58	178.87	3.54	4.78
5	(ACN-9 x PC-6) x ACN-9	41.75	94.57	147.07	4.67	364.15	2.87	8.87
6	(Kranti x PC-6) x Kranti	41.82	98.03	165.70	4.13	227.12	3.29	6.43
	Parents							
7	ACN-9	42.53	94.67	149.13	3.60	144.60	3.31	4.23
8	TAM 108-1	45.13	100.00	165.20	4.20	205.80	4.23	5.45
9	Kranti	41.00	95.33	162.20	3.53	171.20	3.27	4.72
10	PC-6	62.33	125.00	163.07	7.20	100.93	4.21	4.08
	S.E.(m) ±	**1.28**	**0.47**	**2.96**	**0.23**	**13.30**	**0.18**	**0.65**
	CD (5%)	**3.82**	**1.39**	**8.78**	**0.68**	**39.51**	**0.54**	**1.92**
	CV (%)	**4.95**	**0.77**	**3.23**	**8.78**	**10.44**	**9.12**	**21.88**

Sr. No.	Crosses	Powdery Mildew Incidence			
		No. of plants screened	Range of score value	No. of plants with score value less than 3	Percentage of plants with score less than 3
	F_2 Crosses				
1	TAM 108-1 x PC-6	483	1-9	24	4.97
2	ACN-9 x PC-6	213	1-9	9	4.23
3	Kranti x PC-6	717	1-9	32	4.46
	BC_1F_1 crosses				
4	(TAM 108-1 x PC-6) x TAM 108-1	320	1-9	28	8.75
5	(ACN-9 x PC-6) x ACN-9	158	0-9	15	9.49
6	(Kranti x PC-6) x Kranti	411	1-9	21	5.11

Table 3. Minimum, Maximum and range in crosses of F_2 and BC_1F_1 generation for various characters

Sr. No.	Crosses	Days to first flower			Days to maturity			Plant height (cm)		
		Min.	Max.	Range	Min.	Max.	Range	Min.	Max.	Range
	F_2 Crosses									
1	TAM 108-1 x PC-6	39.00	50.00	11.00	120.00	130.00	10.00	79.00	205.00	126.00
2	ACN-9 x PC-6	41.00	52.00	11.00	110.00	127.00	17.00	65.00	190.00	125.00
3	Kranti x PC-6	38.00	45.00	7.00	102.00	116.00	14.00	113.00	260.00	147.00
	BC_1F_1 crosses									
4	(TAM 108-1 x PC-6) x TAM 108-1	41.00	49.00	8.00	94.00	105.00	11.00	50.50	230.00	179.50
5	(ACN-9 x PC-6) x ACN-9	39.00	44.00	5.00	89.00	99.00	10.00	117.00	182.00	65.00
6	(Kranti x PC-6) x Kranti	38.00	45.00	7.00	96.00	101.00	5.00	100.00	230.00	130.00

Sr. No	Crosses	Number of branches plant^{-1}			Number of siliquae plant^{-1}			1000 seed weight (g)			Seed yield plant^{-1} (g)		
		Min.	Max.	Range	Min.	Max.	Range	Min.	Max.	Range	Min.	Max.	Range
	F_2 Crosses												
1	TAM 108-1 x PC-6	3.00	9.00	6.00	41.00	978.00	937.00	2.90	5.15	2.25	0.09	34.17	34.08
2	ACN-9 x PC-6	3.00	11.00	8.00	29.00	856.00	827.00	1.56	4.00	2.44	0.04	10.41	10.37
3	Kranti x PC-6	2.00	7.00	5.00	41.00	949.00	908.00	1.56	4.89	3.33	0.43	17.75	17.32
	BC_1F_1 crosses												
4	(TAM 108-1 x PC-6) x TAM 108-1	2.00	7.00	5.00	41.00	553.00	512.00	2.60	4.61	2.01	0.48	16.71	16.23
5	(ACN-9 x PC-6) x ACN-9	3.00	8.00	5.00	82.00	1850.00	1768.00	2.10	3.30	1.20	1.34	61.30	59.96
6	(Kranti x PC-6) x Kranti	2.00	7.00	5.00	37.00	827.00	790.00	2.30	4.50	2.20	0.66	20.69	20.03

Table 4. Genotypic and phenotypic coefficient of variation in crosses of F_2 and BC_1F_1 generation for various characters

Sr. No.	Crosses	Days to first flower				Days to maturity			
		GCV (%)	PCV (%)	Heritability (%)	Genetic advance as per cent of mean (%)	GCV (%)	PCV (%)	Heritability (%)	Genetic advance as per cent of mean (%)
	F_2 crosses								
1	TAM 108-1 x PC-6	2.355	4.071	33.46	2.81	2.57	2.66	93.39	5.12
2	ACN-9 x PC-6	4.143	5.546	55.81	6.38	5.18	5.19	99.67	10.65
3	Kranti x PC-6	2.365	3.606	43.03	3.19	3.68	3.69	99.25	7.54
	BC_1F_1 crosses								
4	(TAM 108-1 x PC-6) x TAM 108-1	3.391	4.678	52.54	5.06	3.55	3.65	94.62	7.12
5	(ACN-9 x PC-6) x ACN-9	-	2.845	--	--	3.27	3.29	98.77	6.70
6	(Kranti x PC-6) x Kranti	2.808	3.926	51.18	4.14	1.48	1.53	94.68	2.98

Sr. No.	Crosses	Plant height (cm)				Number of branches plant^{-1}			
		GCV (%)	PCV (%)	Heritability (%)	Genetic advance as per cent of mean (%)	GCV (%)	PCV (%)	Heritability (%)	Genetic advance as per cent of mean (%)
	F_2 Crosses								
1	TAM 108-1 x PC-6	17.16	17.91	91.84	33.88	26.25	27.75	89.46	51.14
2	ACN-9 x PC-6	17.51	18.55	89.09	34.05	25.03	26.38	90.02	48.91
3	Kranti x PC-6	12.22	13.00	88.34	23.66	17.99	21.27	71.64	31.38
	BC_1F_1 crosses								
4	(TAM 108-1 x PC-6) x TAM 108-1	22.23	22.64	96.39	44.96	23.74	26.35	81.17	44.05
5	(ACN-9 x PC-6) x ACN-9	9.26	10.62	75.96	16.62	29.50	30.73	92.19	58.36
6	(Kranti x PC-6) x Kranti	16.53	17.07	93.82	32.99	25.86	27.63	87.58	49.85

--- Not estimable

Sr. No.	Crosses	Number of siliquae plant^{-1}				1000 seed weight (g)			
		GCV (%)	PCV (%)	Heritability (%)	Genetic advance as per cent of mean (%)	GCV (%)	PCV (%)	Heritability (%)	Genetic advance as per cent of mean (%)
	F_2 crosses								
1	TAM 108-1 x PC-6	80.43	84.65	90.27	157.42	9.66	11.23	73.88	17.09
2	ACN-9 x PC-6	65.39	66.99	95.30	131.52	17.73	19.48	82.85	33.25
3	Kranti x PC-6	86.46	87.72	97.14	175.55	19.88	21.74	83.64	37.45
	BC_1F_1 crosses								
4	(TAM 108-1 x PC-6) x TAM 108-1	56.56	63.39	79.62	103.97	13.12	14.69	79.72	24.14
5	(ACN-9 x PC-6) x ACN-9	90.09	90.48	99.16	184.81	5.03	8.42	35.69	6.19
6	(Kranti x PC-6) x Kranti	74.55	75.36	97.85	151.90	10.94	14.15	59.75	17.42

Sr. No.	Crosses	Seed yield plant^{-1}			
		GCV (%)	PCV (%)	Heritability (%)	Genetic advance as per cent of mean (%)
	F_2 crosses				
1	TAM 108-1 x PC-6	178.08	200.24	79.09	326.24
2	ACN-9 x PC-6	-	100.52	--	--
3	Kranti x PC-6	78.51	83.71	87.96	151.69
	BC_1F_1 crosses				
4	(TAM 108-1 x PC-6) x TAM 108-1	79.12	87.16	82.41	147.95
5	(ACN-9 x PC-6) x ACN-9	118.88	120.20	97.81	242.19
6	(Kranti x PC-6) x Kranti	78.35	80.73	94.19	156.64

--- Not estimable

Table 5. List of superior individual plant selected from all F2 crosses

Sr. No.	Single plant selected in F_2	Seed yield plant^{-1}	No. of siliqua plant^{-1}	No of branches plant^{-1}
1	C_1-4	10.41	856	11
2	C_1-10	7.74	767	7
3	C_2-1	17.48	978	7
4	C_2-3	9.45	616	5
5	C_2-8	34.17	761	7
6	C_2-9	10.81	614	7
7	C_2-21	23.29	483	4
8	C_3-1	17.75	670	4
9	C_3-3	10.29	215	3
10	C_3-7	14.63	949	7
11	C_3-9	12.48	395	4
12	C_3-15	14.71	597	4
13	C_3-19	9.56	305	4
14	C_3-20	12.94	369	5
15	C_3-22	10.83	349	4
16	C_3-23	9.92	377	5
17	C_3-24	16.16	694	5
18	C_3-25	10.94	275	5
19	C_3-27	14.77	786	6
20	C_3-29	8.41	246	4
21	C_3-30	11.5	450	4
22	C_3-32	8.38	203	3
23	C_3-37	11.73	363	3
24	C_3-40	12.16	243	5
25	C_3-42	10.68	245	3
26	C_3-44	10.23	361	4
27	C_3-51	8.33	395	4
28	C_3-69	8.84	299	4
29	C_3-73	10.87	617	5

Table 6. Plants selected for backcrossing

Sr. No	BC_1F_1 crosses	No. of plants selected for Backcrossing
1	(TAM 108-1 x PC-6) x TAM 108-1	28
2	(Kranti x PC-6) x Kranti	21
3	(ACN-9 x PC-6) x ACN-9	15
	Total	64

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