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Study of Heterosis and Combining Ability of Faba bean (*Vicia faba* L.)

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ABSTRACT

Background: Faba bean is used as a green vegetable as well as pulse which meet the requirementof protein in human diet. It can grow in a wide range of agro climatic conditions because faba bean least affected by biotic, abiotic stress and having the ability to fix ample amount of atmospheric nitrogen in the soil.

Methods: The present investigation was conducted during 2020-21 and 2021-2022 at Bhola Paswan Shastri Agricultural College, Purnea. Bihar. The experimental material was based on a line × tester mating design comprising 24 hybrids (F_1's) developed by crossing 8 lines (females) and 3 tester. The 24 F_2's along with their parents were evaluated during 2021-2022 in randomized block design with two replications row to row and plant to plant distance was maintained at 45 and 15 cm respectively.

Result: The analysis of variance for combining ability for all the studied traits is highly significant except for traits *viz*; Pod length at maturity and No. of seeds per pod. The estimates of specific combining ability (SCA) effects among all the cross combinations were observed significant and negative relative heterosis and heterobeltiosis for traits days to 50% flowering and days to maturity it might be due to non-additive gene action for expression of these traits and selection of these traits may be effective for early maturity and further breeding programme. Days to 50% flowering were exhibited significant and positive inbreeding depression for traits days to 50% flowering (Bak-15/Bak-11, Bak-16/Bak-11 and Bak-16/Bak-20), plant height and number of pod per plant except in cross Bak-1/Bak-5.

Key words: Bakala, Heterosis, Inbreeding depression.

INTRODUCTION

Faba bean also known as bakala, (*Vicia faba* L.) belongs to the family fabaceae and has a long history of cultivation in the human civilization. It is an annual diploid (2n= 2x= 12) cropit is a self-pollinating plant with significant levels of out-cross and inter-cross, ranging from 20 to 50% depending on genotype and environmental effect (Suso and Moreno, 1999, Bishnoi *et al.,* 2015). The rate of out crossing depends on the genotype, environmental factors, row space and the number of pollinating insects, especially honeybees. Faba bean is world's fourth most important legume crop after pea, chickpea and lentil, widely cultivated for human food, animal feed and fodder. It plays an important role in world agriculture because of its high seed protein content which ranges from 20 to 40% depending upon the genotype and the environmental conditions in which it has been grown (Kaur *et al.,* 2014). It is an efficient nitrogen fixer and improves soil fertility through symbiotic nitrogen fixation. It can grow well on high fertility soil to N-deficient marginal lands. Faba bean can withstand salinity conditions especially chloride and sulphate salts to a greater extent than chickpea. It has a potential yield of 60-75 quintals per hectare and average yield of 40-45 quintals per hectare (Bishnoi, 2016). It is grown as a *Rabi* crop in India in Bihar and adjoining states where its raw pods are eaten as a vegetable (Kumar *et al*., 2017). Faba bean has been recognized as a potential grain legume and included in the All India Coordinated Research Network on Potential crops (Kumar *et al*., 2016). It has also been identified as one of the eight major food legumes by the CGIAR research programme for priority focus and gaining importance as a grain legume for protein security of demographically expanding and climatically changing world (Bishnoi, 2016). Unrealized yield potential and yield instability are the major constraints in faba bean cultivation. The increased yield caused by heterozygosity due to out-crossing is well documented in faba bean. Therefore, heterosis, resulting from the combined action and interaction of allelic and inter-allelic genes is effective in faba bean and improved yield can be obtained by hybrid combinations (Bishnoi *et al.,* 2012). The heterotic effects in *Vicia faba* may range from significantly positive to significantly negative for different traits depending on the genetic makeup of the parents. Exploitation of heterosis in the form of hybrid varieties may contribute in the improvement of yield and its component traits (Bishnoi *et al.,* 2015). The present study was carried

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out with an objective to estimate heterosis, inbreeding depression,types of gene action for earliness and yielding ability in some bakala crosses which may be utilized further in breeding programmes.

MATERIALS AND METHODS

The present investigation was conducted during 2020-21 and 2021-2022 at Bhola Paswan Shastri Agricultural College, Purnea. Bihar. The experimental material was based on a line x tester mating design comprising 24 hybrids (F_1's) developed by crossing 8 lines (females) *viz;* Bak-1, Bak-2, Bak-3, Bak-4, Bak-12, Bak-13, Bak-15 and Bak-16with 3 testers (males) *viz*., Bak-5, Bak-11 and Bak-20. The 24 F_2's along with their parents were evaluated during 2021-2022 in randomized block design with two replications row to row and plant to plant distance was maintained at 45 and 15 cm respectively. Data were collected based on 5 randomly selected plants for 8 characters *viz*., days to 50 per cent flowering, days to maturity, plant height (cm), number of pods per plant, pod length at maturity (cm), number of seeds per pod,Green pod yield(g)/plant and Seed yield(g)/plant. The combining ability analysis was done using the line x testers procedure as suggested by Cochran and Cox (1957) and Kempthorne (1957). Heterosis was calculated as the percentage of increase as decrease relative to better parent. Significance of heterosis was tested according to Wynne *et al*. (1970).

RESULTS AND DISCUSSION

The analysis of variance for combining ability for all the studied traits are presented in (Table 1). The mean squares for general and specific combining ability were found highly significant for all the studied traits except for traits *viz*; Pod length at maturity and no. of seeds per pod indicating the additive and nonadditive components were important in the inheritance of these traits. These findings are in agreement with Gasim and Link (2007); Alghamdi (2009); El-Bramawy *et al.* (2012); Sharma *et al.* (2023); Alaa *et al.* (2023) and Mohamed *et al.* (2023). In a breeding programme, once the appropriate parents and potential crosses are identified, the next important step is to adopt a suitable breeding strategy for the management of generated variability which largely depends upon type of gene action in the population for the traits under genetic improvement (Cockerham, 1961; Sprauge 1966). Parent Bak-3 had shown high positive and significant GCA effect for traits *viz*; no. of pod/plant, green pod yield/plant and seed yield/plant, while Bak-11 also exhibited high positive and significant GCA effect for trait *i.e*. plant height (Table 2). Parents Bak-3 and Bak-11 may be used as a donor parent in hybridization programme. Similar finding corroborated by Lal *et al.* (2019); Patial *et al*. (2020) and Debbarma *et al*. (2022). The expression of heterosis in percentage over mid parent (relative heterosis) and over better parent (heterobeltiosis) as well as estimates of inbreeding depression of twenty four crosses were studied for eight characters and have

Table 1: Analysis of variance of F_1 hybrids for qualitative and quantitative traits of hybrids.

Source of variance	df	DFF	DM	Plant height (cm)	No. of pod/plant	Pod length at maturity (cm)	No. of seeds per pod	Green pod yield(g)/plant	Seed yield(g)/plant
Replications	1	1.429**	1.157**	22.210**	63.175**	-0.000	0.001	39.175**	70.118**
Parents	10	1.309**	1.545**	33.123**	277.011**	0.349	0.286	231.230**	108.670**
Males	2	1.167**	0.500**	59.661**	12.500**	0.197	0.247	49.606**	12.995**
Female	7	1.491**	2.063**	25.644**	145.141**	0.241	0.309	308.281**	149.030**
Male vs Female	1	0.320**	0.017**	32.403**	1,729.129**	1.409	0.205	55.128**	17.497**
Crosses	23	15.822**	16.228**	70.985**	1,088.079**	0.380	0.278	1,114.899**	631.997**
Parents vs. Crosses	1	88.935**	88.381**	459.365**	10.524**	0.583	1.113	207.814**	85.022**
Error	34	1.546	2.187	1.260	13.954	0.018	0.042	4.214	2.683
Variance (GCA)		-0.090	0.074	5.526	71.439	0.019	0.007	63.834	40.394
Variance (SCA)		6.155	5.496	23.988	331.266	0.126	0.113	392.289	223.278
GCA/SCA		-0.01	0.01	0.23	0.22	0.15	0.06	0.16	0.18

* and ** significant at 0.01 and 0.05 level respectively.
DFF = Days to 50% flowering, DM = Days to maturity.

been given in Table 3,4,5. Heterosis breeding has come to play a pivotal role in crop improvement programme for obtaining higher yield production. Heterosis is a complex genetic phenomena depending upon the balance of additive, dominance and interaction components as well as the distribution of the genes in the parental lines. The presence or absence of heterosis is not itself an indication of the presence or absence of any particular type of gene action or interactions. Heterosis response has been expressed as a deviation of F_1 mean from values of either mid parent or better parent or standard check variety. It may however be kept in mind that while selecting best cross combination besides heterotic response, the *per se* performance of the crosses should also be given due consideration Bhushan *et al.* (2021). Among lines and testers *viz*; Bak-1, Bak-2 and Bak-20 were showed positive and highly significant GCA effects for traits no. of pod/plant, green pod yield(g)/plant and yield(g)/plant. It indicated that these lines are good combiner for yield and yield attributing traitsfor inclusion in the production of synthetic cultivars. Similar findings reported by Obiadalla-Ali *et al.* (2013); Saad *et al.* (2015); Abd *et al.* (2018); Yassien *et al.* (2019); Patial *et al.* (2020); Sharma *et al.* (2023); Mohammed *et al.* (2023); Alaa *et al.* (2023) and Mohamed *et al.* (2023).

The estimates of specific combining ability (SCA) effects were presented in (Table 6). Three crosses *viz*, Bak-1/Bak-11, Bak-3/Bak-20 and Bak-13/Bak-5 were exhibited highly positive and significant (SCA) effects for traits number of pods/plant, green pod yield (g)/plant and seeds yield(g)/plant. Similarly cross Bak-1/Bak-5, Bak-2/Bak-11 and Bak-16/Bak-20 were also exhibited highly positive and significant (SCA) effects for traits plant height, no. of pod/plant and green pod yield (g)/plant respectively in F_2. Therefore, these crosses may be considered as the best combiner for these traits. Similar results were reported by Mohammed *et al.* (2018); Yassien *et al.* (2019); EL Hosary (2020); Sharma *et al.* (2023); Alaa *et al.* (2023) and Mohamed *et al.* (2023).

Significant and positive relative heterosis were observed for traits no. of seed per pod, green pod yield/plant and seed yield/plant in cross combination Bak-1/Bak-5, Bak-1/Bak-11, Bak-1/Bak-20, Bak-2/Bak-5, Bak-2/Bak-11,Bak-2/Bak-20, Bak-3/Bak-5, Bak-3/Bak-11, Bak-15/Bak-11 and Bak-16/Bak-20, while for traits days to 50% flowering and days to maturity only two crosses *viz;* Bak-1/Bak-20 and Bak-15/Bak-11 were also exhibited significant and positive relative heterosis. Similarly significant and positive heterobeltiosis was also exhibited for traits *viz;* no. of seed per pod, green pod yield/ plant and seed yield/ plant in cross combination Bak-2/Bak-20, Bak-3/Bak-20 and Bak-4/Bak-20 while in cross Bak-16/Bak-20 was also exhibited significant and positive heterobeltiosis for traits pod length at maturity, green pod yield/ plant and seed yield/ plant it might be due to additive gene action for expression of these characters and selection of these traits may be effective for further breeding programme. Among all the cross combinations most of the crosses were observed significant and negative

Table 2: General combining ability of Bakala genotypes for qualitative and quantitative traits.

Name of the genotypes	DFF	DM	Plant height (cm)	No. of pod/plant	Pod length at maturity (cm)	No. of seeds per pod	Green pod yield (g)/plant	Seed yield (g)/plant
Bak-1	2.29*	2.04	1.13	11.06**	-0.03	0.24	11.74**	5.32**
Bak-2	1.13	1.71	-2.27	-9.44**	-0.60	0.20	-7.40**	-5.31**
Bak-3	-3.38**	-3.63**	3.10**	39.48**	-0.13	-0.13	37.95**	29.06**
Bak-4	-0.38	-0.46	6.03**	1.31	-0.17	-0.46	-7.38**	-4.33**
Bak-12	-2.21*	-2.13*	-0.87	-5.69**	-0.04	0.00	-10.40**	-7.35**
Bak-13	-0.54	-0.63	0.97	-9.94**	0.37	0.00	-10.89**	-7.92**
Bak-15	1.63	1.88	-8.03**	-12.60**	0.25	0.04	-4.62**	-2.67**
Bak-16	1.46	1.21	-0.07	-14.19**	0.36	0.10	-9.01**	-6.79**
Bak-5	-0.33	-0.44	-1.86	-1.19	0.14	0.08	-5.99**	-0.78
Bak-11	0.04	0.19	3.11**	-7.19**	-0.15	-0.18	-4.18**	-6.88**
Bak-20	0.29	0.25	-1.25	8.38**	0.01	0.10	10.17**	7.66**
S.E. GCA(Lines)	0.46	0.59	0.38	1.45	0.04	0.07	0.76	0.63
S.E.S.E. GCA(Tester)	0.25	0.31	0.20	0.77	0.02	0.04	0.41	0.34

* and ** significant at 0.01 and 0.05 level respectively.
DFF= Days to 50% flowering, DM= Days to maturity.

Table 3: Relative heterosis (%) of Bakala genotypes for qualitative and quantitative traits.

Name of the genotypes	DFF	DM	Plant height (cm)	No. of pod/plant	Pod length at maturity (cm)	No. of seeds per pod	Green pod yield(g)/plant	Seed yield(g)/plant
Bak-1/Bak-5	-0.42	-0.25	2.93**	15.09**	-2.99**	29.63**	22.08**	19.91**
Bak-1/Bak-11	0.00	0.00	-24.93**	24.39**	-2.12*	16.00**	97.37**	71.68**
Bak-1/Bak-20	3.36**	2.26*	-11.99**	24.68**	-1.75	36.17**	84.93**	109.86**
Bak-2/Bak-5	-4.07**	-1.47	-15.60**	-39.93**	-20.05**	26.92**	-54.98**	-63.19**
Bak-2/Bak-11	-2.86**	-0.74	-18.30**	-1.60	-16.94**	25.00**	4.58**	25.81**
Bak-2/Bak-20	-2.06*	-1.97	-20.79**	-39.93**	-23.77**	42.22**	42.35**	24.95**
Bak-3/Bak-5	-14.40**	-8.91**	-0.11	127.88**	-3.38**	8.00**	43.20**	239.56**
Bak-3/Bak-11	-11.57**	-6.70**	4.04**	-44.71	-8.46**	21.74**	63.62**	-71.17**
Bak-3/Bak-20	-1.67	-1.49	-13.07**	181.25**	-11.57**	39.54**	569.10**	587.02**
Bak-4/Bak-5	-1.64	-1.48	7.18**	-16.34**	-13.82**	-1.70	-33.44**	-35.17**
Bak-4/Bak-11	-1.24	-0.25	10.77**	-21.52**	-26.45**	-45.46**	-27.19**	-35.11**
Bak-4/Bak-20	-11.20**	-7.43**	-4.12**	41.89**	3.24**	19.23**	64.27**	77.48**
Bak-12/Bak-5	-11.84**	-6.67**	-2.96**	-32.56**	-9.76**	6.90**	-24.99**	-13.08**
Bak-12/Bak-11	-8.20**	-4.95**	-11.18**	-15.25**	-7.17**	3.70**	-3.17**	-25.73**
Bak-12/Bak-20	-4.13**	-1.74	-29.08**	-32.93**	-14.53**	17.65**	-10.63**	-20.41**
Bak-13/Bak-5	-2.44*	-1.48	-9.56**	-27.09**	3.52**	-5.09**	-5.51**	-20.49**
Bak-13/Bak-11	-11.84**	-6.17**	-3.95**	-69.71**	-17.40**	1.82	-60.46**	-65.56**
Bak-13/Bak-20	-2.88**	-1.98	-15.86**	-41.41**	-1.53	26.92**	-59.94**	-55.77**
Bak-15/Bak-5	-3.67**	-1.97	-37.02**	-66.48**	-6.03**	0.00	-24.00**	-28.97**
Bak-15/Bak-11	2.46*	1.24	-20.65**	-47.28**	-7.37**	14.29**	-62.57**	-58.61**
Bak-15/Bak-20	-4.13**	-1.49	-21.43**	-20.69**	6.35**	5.66**	-27.91**	-25.79**
Bak-16/Bak-5	-2.88**	-2.22**	-27.35**	-72.07**	-16.50**	0.00	-38.30**	-43.31**
Bak-16/Bak-11	0.00	0.00	1.01	-59.78**	4.86**	17.86**	-54.00**	-58.75**
Bak-16/Bak-20	-0.83	-1.24	-27.60**	-12.64**	2.89**	9.43**	36.12**	31.11**

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

DFF= Days to 50% flowering, DM= Days to maturity.

Table 4: Heterobeltiosis (%) of Bakala genotypes for qualitative and quantitative traits.

Name of the genotypes	DFF	DM	Plant height (cm)	No. of pod/plant	Pod length at maturity (cm)	No. of seeds per pod	Green pod yield(g)/plant	Seed yield(g)/plant
Bak-1/Bak-5	-2.44**	-1.48	-2.57**	-12.86**	-17.90**	20.69**	4.00**	-5.29**
Bak-1/Bak-11	-1.64	-0.99	-26.97**	-7.27**	-13.35**	16.00**	63.65**	36.59**
Bak-1/Bak-20	2.50*	1.49	-15.88**	-4.00**	-12.02**	28.00**	79.59**	84.31**
Bak-2/Bak-5	-4.07**	-1.95	-20.04**	-56.67**	-29.90**	13.79**	-64.24**	-71.40**
Bak-2/Bak-11	-3.25**	-1.46	-20.60**	-30.00**	-23.65**	20.00**	-18.91**	-1.53
Bak-2/Bak-20	-3.25**	-2.93**	-24.37**	-56.00**	-29.09**	39.13**	27.29**	7.66**
Bak-3/Bak-5	-15.45**	-9.36**	-0.66	79.05**	-15.79**	-6.90**	11.50**	161.43**
Bak-3/Bak-11	-12.30**	-6.93**	-3.56**	-57.27**	-16.39**	12.00**	24.45**	-77.65**
Bak-3/Bak-20	-1.67	-1.49	-20.76**	125.00**	-18.27**	36.36**	484.13**	485.47**
Bak-4/Bak-5	-2.44*	-1.48	5.99**	-39.05**	-21.90**	-3.33**	-48.28**	-48.51**
Bak-4/Bak-11	-1.64	-0.49	1.12	-43.64**	-29.98**	-50.00**	-44.73**	-48.08**
Bak-4/Bak-20	-11.57**	-7.88**	-13.90**	5.00**	-0.48**	3.33**	43.07**	56.87**
Bak-12/Bak-5	-12.20**	-6.90**	-7.27**	-44.76**	-17.26**	6.90**	-44.04**	-32.67**
Bak-12/Bak-11	-8.20**	-4.95**	-14.42**	-31.82**	-10.54**	-3.45**	-29.31**	-42.06**
Bak-12/Bak-20	-4.92**	-1.98	-32.85**	-44.00**	-16.59**	3.45**	-25.88**	-31.69**
Bak-13/Bak-5	-2.44*	-1.48	-12.29**	-29.52**	-0.84	-6.67**	-11.01**	-26.88**
Bak-13/Bak-11	-12.20**	-6.40**	-8.80**	-71.36**	-18.16**	-6.67**	-61.56**	-68.62**
Bak-13/Bak-20	-4.07**	-2.46*	-21.48**	-42.00**	-3.68**	10.00**	-66.75**	-63.67**
Bak-15/Bak-5	-4.07**	-1.97	-37.23**	-71.43**	-14.74**	-3.23**	-40.11**	-44.24**
Bak-15/Bak-11	2.46**	0.99	-26.59**	-55.91**	-11.71**	3.23**	-69.76**	-67.73**
Bak-15/Bak-20	-4.92**	-1.97	-28.52**	-31.00**	2.64**	-9.68**	-48.44**	-46.69**
Bak-16/Bak-5	-4.07**	-2.46*	-33.94**	-76.19**	-21.68**	-3.23**	-45.16**	-50.32**
Bak-16/Bak-11	-0.82	0.00	-0.54	-66.36**	3.51**	6.45**	-60.27**	-63.54**
Bak-16/Bak-20	-0.83	-1.49	-27.80**	-24.00**	2.89**	-6.45**	33.45**	29.96**

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

DFF= Days to 50% flowering, DM= Days to maturity.

Table 5: Inbreeding depression from F_1 to F_2 generation for qualitative and quantitative traits.

Name of the genotypes	DFF	DM	Plant height (cm)	No. of pod/plant	Pod length at maturity (cm)	No. of seeds per pod	Green pod yield(g)/plant	Seed yield(g)/plant
Bak-1/Bak-5	-11.67**	-6.50**	-82.52**	90.16**	-1105.13**	-32.86**	-415.81**	-182.95**
Bak-1/Bak-11	-9.17**	-5.50**	30.77**	83.53**	-1810.81**	-63.79**	-204.85**	-95.92**
Bak-1/Bak-20	-1.63	0.49	45.82**	84.17**	-1080.33**	-46.88**	-207.91**	-38.39**
Bak-2/Bak-5	-7.63**	-1.99	32.26**	58.24**	-1987.09**	-39.39**	-1013.07**	-590.20**
Bak-2/Bak-11	-7.56**	-0.99	34.20**	76.10**	-2209.82**	-56.67**	-328.86**	-104.83**
Bak-2/Bak-20	-11.76**	-6.53**	37.23**	70.00**	-1557.63**	-57.81**	-158.37**	-44.11**
Bak-3/Bak-5	-28.85**	-16.30**	51.21**	92.45**	-1130.00**	-87.04**	7.41**	79.91**
Bak-3/Bak-11	-22.43**	-12.23**	62.91**	67.66**	-1317.37**	-66.07**	-60.63**	-364.77**
Bak-3/Bak-20	-11.02**	-4.55**	52.16**	93.42**	-1182.35**	-51.67**	55.55**	78.92**
Bak-4/Bak-5	-5.00**	-2.50**	55.86**	85.00**	-935.04**	-67.24**	-191.56**	-39.23**
Bak-4/Bak-11	-17.50**	-8.91**	64.81**	81.61**	-1097.32**	-216.67**	-181.25**	-58.15**
Bak-4/Bak-20	-41.12**	-22.99**	56.60**	88.00**	-1064.25**	-72.58**	-126.69**	8.97**
Bak-12/Bak-5	-14.81**	-10.05**	53.81**	82.07**	-996.69**	-70.97**	-321.43**	-85.86**
Bak-12/Bak-11	-7.14**	-4.17**	56.89**	83.20**	-1098.95**	-66.07**	-144.04**	-62.81**
Bak-12/Bak-20	-0.86	0.51	47.31**	78.93**	-1012.39**	-63.33**	-186.74**	-55.63**
Bak-13/Bak-5	-0.83	-1.00	61.52**	88.92**	-456.26**	-83.93**	-71.31**	0.69
Bak-13/Bak-11	-26.85**	-14.21**	63.86**	77.78**	-616.29**	-83.93**	-246.38**	-128.25**
Bak-13/Bak-20	-7.63**	-4.04**	54.60**	85.86**	-637.47**	-46.97**	-363.13**	-114.37**
Bak-15/Bak-5	-3.39**	-2.51**	37.89**	60.67**	-751.85**	-60.00**	-45.89**	27.53**
Bak-15/Bak-11	5.60**	2.44**	56.89**	83.09**	-544.56**	-37.50**	-155.16**	-10.03**
Bak-15/Bak-20	-5.17**	-1.01	53.28**	87.25**	-860.19**	-78.57**	-126.26**	-4.18**
Bak-16/Bak-5	-5.08**	-4.04	44.78**	47.20**	-690.32**	-65.00**	-221.39**	-78.64**
Bak-16/Bak-11	2.48**	0.99	64.96**	69.73**	-823.08**	-36.36**	-251.90**	-116.67**
Bak-16/Bak-20	5.04**	3.52**	48.75**	85.00**	-993.46**	-84.48**	-136.65**	-18.49**

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

DFF= Days to 50% flowering, DM= Days to maturity.

Table 6: Specific combining ability of Bakala genotypes for qualitative and quantitative traits.

Name of the genotypes	DFF	DM	Plant height (cm)	No. of pod/plant	Pod length at maturity (cm)	No. of seeds per pod	Green pod yield(g)/plant	Seed yield(g)/plant
Bak-1/Bak-5	-0.17	-0.23	6.13**	-1.31	0.01	0.23	-3.91**	-4.84**
Bak-1/Bak-11	-0.54	-0.85	-9.05**	9.94**	0.09	-0.13	15.12**	8.97**
Bak-1/Bak-20	0.71	1.08	2.92*	-8.63**	-0.11	-0.10	-11.21**	-4.13**
Bak-2/Bak-5	0.00	0.60	0.63	-3.81**	0.02	0.06	-4.80**	-7.21**
Bak-2/Bak-11	0.13	0.48	-2.25*	17.94**	0.23	0.01	8.34**	12.26**
Bak-2/Bak-20	-0.13	-1.08	1.62	-14.13**	-0.24	-0.07	-3.54**	-5.05**
Bak-3/Bak-5	-2.50	-2.56*	0.26	18.52**	0.21	-0.21	-27.91**	4.20**
Bak-3/Bak-11	-1.38	-1.19	1.49	-45.98**	0.06	0.14	-23.39**	-36.79**
Bak-3/Bak-20	3.88**	3.75**	-1.75	27.46**	-0.27	0.07	51.30**	32.59**
Bak-4/Bak-5	2.50*	2.27*	-0.17	-5.31**	-0.04	0.33	-0.13	-3.69**
Bak-4/Bak-11	2.13*	2.65*	1.05	-0.31	-0.48	-0.83	0.22	2.30**
Bak-4/Bak-20	-4.63**	-4.92**	-0.88	5.63**	0.52	0.50	-0.09	1.39
Bak-12/Bak-5	-1.67	-1.56	4.83**	-1.31	0.06	0.06	4.13**	2.45*
Bak-12/Bak-11	-0.04	-0.69	-0.35	13.19**	0.23	0.01	8.07**	6.48*
Bak-12/Bak-20	1.71	2.25*	-4.48**	-11.88**	-0.28	-0.07	-12.20**	-8.93**
Bak-13/Bak-5	2.67*	2.44*	-0.80	10.94**	0.42	-0.24	17.76**	6.91**
Bak-13/Bak-11	-3.71**	-3.19**	0.82	-4.31**	-0.45	0.01	-0.85	3.24**
Bak-13/Bak-20	1.04	0.75	-0.02	-6.63**	0.03	0.23	-16.91**	-10.15**
Bak-15/Bak-5	-0.50	-0.56	-5.40**	-8.40**	-0.12	-0.08	12.44**	3.76**
Bak-15/Bak-11	2.63*	1.81	0.32	6.85**	-0.11	0.38	-4.48**	1.76
Bak-15/Bak-20	-2.13*	-1.25	5.08**	1.54	0.23	-0.30	-7.96**	-5.52**
Bak-16/Bak-5	-0.33	-0.40	-5.47**	-9.31**	-0.56	-0.14	2.41*	-1.58
Bak-16/Bak-11	0.79	0.98	7.95**	2.69*	0.43	0.41	-3.03**	1.78
Bak-16/Bak-20	-0.46	-0.58	-2.48*	6.63**	0.13	-0.27	0.62	-0.20
S.E. SCA(Lines)	0.65	0.83	0.53	2.05*	0.06	0.10	1.07	0.90

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

DFF= Days to 50% flowering, DM= Days to maturity.

relative heterosis and heterobeltiosis for traitsdays to 50% flowering and days to maturity it might be due to non-additive gene action for expression of these traits and selection of these traits may be effective for early maturity and further breeding programme similar finding corroborated by Bishnoi *et al.* (2017); Lal *et al.* (2019); Sharma *et al.* (2023); Mohammed *et al.* (2023); Alaa *et al.* (2023) and Mohamed *et al.* (2023). The estimates of the inbreeding depression from F_1 to F_2 in 24 hybrids for eight characters are presented in the Table 6. Most of the cross combination were exhibited significant and positive inbreeding depression for traits days to 50% flowering (Bak-15/Bak-11, Bak-16/Bak-11 and Bak-16/Bak-20), plant height and number of pod per plant except in cross Bak-1/Bak-5 it might be due to lack of segregation of desirable genes responsible for dominance effect or tight linkage of desirable genes or phenomenon of fixing of heterozygocity in segregating generation. Similarly most of crosses were recorded significant and negative inbreeding depression for all the studied traits except for traits green pod yield and seed yield per plant in crosses Bak-3/Bak-5 and Bak-3/Bak-20. Similar findings were reported by Poulsen and Knudsen (1980); Nassib and Khalil (1982); Hebblethwaite *et al.* (1984); Attia (1998); Gasim and Link (2007); EL-Harty *et al.* (2007); Obiadalla-Ali *et al.* (2015); Bishnoi *et al*. (2017); Sharma *et al.* (2023); Mohammed *et al.* (2023); Alaa *et al.* (2023) and Mohamed *et al.* (2023). In cross combination Bak-16/Bak-20 had exhibited highly significant and positive combining ability as well as inbreeding depression for traits days to 50% flowering it might be governed by non-additive gene action and this line may be selected for early maturity effect.

CONCLUSION

The analysis of variance for combining ability for all the studied traits is highly significant except for traits *viz*; pod length at maturity and no. of seeds per pod. The estimates of specific combining ability (SCA) effects among all the cross combinations were observed significant and negative relative heterosis and heterobeltiosis for traitsdays to 50% flowering and days to maturityit might be due to non-additive gene action for expression of these traits and selection of these traits may be effective for early maturity and further breeding programme. Days to 50% flowering were exhibited significant and positive inbreeding depression for traits days to 50% flowering (Bak-15/Bak-11, Bak-16/Bak-11 and Bak-16/Bak-20), plant height and number of pod per plant except in cross Bak-1/Bak-5.

Conflict of interest

All authors declare that they have no conflict of interest.

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