The Pharma Innovation Journal 2022; 11(12): 5754-5757

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(12): 5754-5757

www.thepharmajournal.com
Received: 14-10-2022
Accepted: 23-11-2022

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Heterosis and inbreeding depression analysis for fruit yield and its related attributes in Okra [*Abelmoschus esculentus* L. Moench]

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Abstract
The present investigation was conducted at experimental research farm of Department of Horticulture, College of Agriculture Latur, during *summer*-2021 (Crossing) and *kharif* - 2021 (evaluation), with a view to study the heterosis and inbreeding depression of three crosses in a Randomized block design with two replications. The F_1 of cross, Arka Abhay x Varsha Uphar and Kashi Pragati x Arka Abhay for Plant height, Number of nodes per plant, Number of branches per plant, Length of fruit, Diameter of fruit, Fruit yield per plant, Fruit yield per plot and Fruit yield per hectare recorded significant relative heterosis and heterobeltiosis. Relationship between heterotic response and inbreeding depression suggests the importance of non- additive gene in okra.

Keywords: Heterosis, better parent, mid parent, inbreeding depression, okra, fruit yield

Introduction
Okra [*Abelmoschus esculentus* (L) Moench] is one of the significant vegetable crops grown in the rainy spring and summer months. Due to its widespread adoption, it has a high nutritional value and export potential. Okra is a year-round, extremely nutritious vegetable with a variable top ranking. It is also referred to as a lady's finger or bhindi. It is a member of the family Malvaceae, order Malvales, and class Dicotyledonae. Okra flowers frequently cross-pollinate with other species due to their somatic chromosome 2n=130.

Okra is cultivated throughout the tropical and subtropical regions, as well as in the warmer climes of temperate regions. In India, okra is a newly introduced vegetable crop. It is widely cultivated for its tender pods, which are used to make a very well-liked, delectable, and gelatinous vegetable. It is extremely energising and rich in beneficial nutrients. It has enormous socioeconomic potential for enhancing livelihoods in both rural and urban areas. It is cooked into soups, stewed with meat, and used in curries. Fruits in the off-season can also be dried or green. Okra stems and roots are used to clean the cane juice when making "gur," or brown sugar. The production of paper uses mature fruits and stems that contain crude fibre. Extracts from okra seeds are used as a stand-in for edible oil. The seed has a high oil content of about 40%. Due to its consistent yield, simple cultivation, and ability to adapt to different moisture conditions, it is quite well-liked in India. In India, West Africa, Brazil, and many other nations, the sweet okra fruits are consumed as vegetables. For the off-season, okra is also available in dried and canned forms. It offers tremendous export potential as a fresh vegetable.

New hybrids with higher fruit yields must be created for India's various agro-climatic zones as plant demand increases. The biology of various characters must be understood, hybrid vigour must be utilized, and production aspects must be improved with an eye toward the export market in okra development programs. It is acknowledged as a helpful technique for breeders trying to boost okra yields. Crop improvement is challenging due to okra's wide range of outcrossing. The heterogeneous and variable nature produced by the use of population breeding techniques results in a lack of uniformity in growth and agricultural character, especially in vegetation and development, in many pollinated varieties. (Sargar *et al.*, 2021) [10]

Despite the fact that hybrid development results in higher yields for growers, dwarfness is unusual in its resistance to diseases and environmental tolerance.

Materials and Methods
The current okra research (Abelmoschus esculentus L. Moench) was conducted from the summer of 2021 to the kharif of 2021 at the Vasantrao Naik Marathwada Krishi Vidyapeeth,

Parbhani, at the Instructional-Cum-Research Farm, Department of Horticulture. Crossing between four different parents developed three F_1 crosses *viz*., Phule Vimukta x Arka Abhay, Kashi Pragati x Varsha Uphar and Kashi Pragati x Arka Abhay. From these F_1·s by selfing developed F_2 for each cross. During the *karif* season 2021, these materials were tested using a Randomized Block Design with two replications at the Instructional-Cum-Research Farm, Horticulture Department, College of Agriculture, Latur. The crop was raised using the suggested set of practises with a spacing of 45 x 20 cm. The genetic analysis of fifteen yield and yield contributing characters was studied in the experimental material composed of three F_1·s and its F_2·s.

Five randomly chosen plants from each of the parents and F_1 generations as well as 20 plants from the F_2 generation were used to collect data on ten quantitative traits. To test the significance of differences between treatments, the analysis of variance for Randomized Block Design (RBD) was carried out as per procedure given by Panse and Sukhatme (1985) [9] for all metric characters under study According to Fonseca and Patterson (1968) [5], the performance of the F_1 hybrid was calculated as the heterosis over baseline tests and better parent. Inbreeding depression was computed by the formula, [(F1- F2)/ F1] x 100.

Result and Discussion

Analysis of variance for various characters revealed highly significant differences, and those were present among the crosses taken into consideration. This indicated that there was enough variety for effective character selection across the entire cast of the study's material. Heterosis results in an improvement in overall vigour and quality, yield, reproductive capacity, adaptability, and disease and insect resistance. A decrease in fitness and vigour brought on by inbreeding and decreased heterozygosity is referred to as inbreeding depression. It happens because unfavourable recessive genes are fixed in the F_2 generation, whereas in heterosis, unfavourable dominant genes from one parent suppress unfavourable recessive genes from the other parent. For all the characters under study, the relative heterosis (RH), heterobeltiosis (HB), and inbreeding depression (ID) effects' magnitudes were estimated. Table 1 shows the mid parent heterosis, better parent heterosis, and inbreeding depression for different characters in three crosses.

There was significant positive and negative midparent and better parent heterosis in all three crosses for the various characters studied. The large diversity of the study's parents was further supported by the high values for heterotic effects. The traits, plant height, fruit length, fruit yield per plant, fruit yield per plot, and fruit yield per hectare all showed positive and significant heterosis values for all three hybrids, Phule Vimukta x Arka Abhay, Kashi Pragati x Arka Abhay, and Kashi Pragati x Varsha Uphar.

The results showed that the highest value was seen in the cross between Phule Vimukta and Arka Abhay (53.20%) and that the cross between Kashi Pragati and Varsha Uphar (49.65%) showed an intermediate value. According to Table 1, the cross between Kashi Pragati and Arka Abhay showed the lowest relative heterosis value (38.92%). Positive significance was found for all of the mid parent heterosis resultant values. The crosses Phule Vimukta x Arka Abhay (22.96%), Kashi Pragati x Arka Abhay (11.37%), and Kashi Pragati x Varsha Uphar (10.03%) showed positive and significant heterobeltosis. From 50.51% (Kashi Pragati x Arka Abhay) to 34.17% (Kashi Pragati x Varsha Uphar) to 28.51%, inbreeding depression was observed (Phule Vimukta x Arka Abhay). The similar results were confirmed with previous findings by Akotkar *et al*., (2014) [1], Wakode *et al*., (2015) [13] and Mahajan *et al*., (2017) [7].

The estimated outcome showed that the highest value was seen in the cross between Phule Vimukta and Arka Abhay (53.40%) and that an intermediate value was seen in the cross between Kashi Pragati and Varsha Uphar (49.70%). The cross between Kashi Pragati and Arka Abhay showed the lowest value for relative heterosis (38.85%). Positive significance was found for all of the mid parent heterosis resultant values. According to Table 1, the crosses Phule Vimukta x Arka Abhay (23.10%), Kashi Pragati x Arka Abhay (11.20%), and Kashi Pragati x Varsha Uphar (10.00%) all showed positive and significant heterobeltosis. From 50.66% (Kashi Pragati x Arka Abhay) to 33.99% (Kashi Pragati x Varsha Uphar) to 28.88%, inbreeding depression was observed (Phule Vimukta x Arka Abhay). These results are harmony with the Singh (2012) [11], Soher *et al.* (2013) [12] and Akotkar *et al.* (2014) [1]

The inbreeding depression results showed that the inbreeding depression for its constituent parts was primarily responsible for the positively significant inbreeding depression for fruit yield per plant, fruit yield per plot, and fruit yield per hactare. Kashi Pragati x Arka Abhay was found to have a higher inbreeding depression than the other two crosses. The importance of the non-additive gene in okra is suggested by the relationship between heterotic response and inbreeding depression (*i.e*., crosses showing high heterosis also show high inbreeding depression). The results for relative heterosis were also generally higher than the results for inbreeding depression in all characters, with the exception of plant height, internodal length, and number of nodes per plant in the cross between Phule Vimukta and Arka Abhay, and number of nodes per plant, length of fruit, number of fruits per plant, weight, fruit yield per plant, fruit yield per plot, and fruit yield per hactare in the cross between Kashi Pragati and Arka This was expected because, theoretically, estimates of inbreeding depression only account for 50% of the anticipated change and, as a result, are typically much lower than estimates of heterosis.

The three main factors that contribute to yield in okra are the number of branches per plant, the number of fruits per plant, and the weight of the fruit. Table 1 lists the fruit yield per plant of three heterotic crosses along with the heterosis and inbreeding depression values for these four components. In actuality, heterosis for fruit yield per plant only required the manifestation of appreciable heterosis for one or two components. In the current study, heterosis in branches per plant, fruit weight, and fruit number per plant accompanied heterosis in fruit yield per plant in all three hybrids. Therefore, the number of branches per plant, weight of the fruit, and number of fruits per plant could be regarded as the most crucial characteristics for okra's fruit yield. Cross, Phule Vimukta x Arka Abhay and cross, Kashi Pragati x Arka Abhay except cross, Kashi Pragati x Varsha Uphar depicted negative heterobeltiosis and cross, Phule Vimukta x Arka Abhay except cross, Kashi Pragati x Varsha Uphar exhibited negative mid-parent heterosis indicating desired direction in the case of days to 50% flowering, negative hetero

Kashi Pragati x Arka Abhay, one of the three F_2 crosses, had the highest inbreeding depression in terms of fruit yield per plant. However, there was a significant inbreeding depression value in the same trait in the crosses between Phule Vimukta and Arka Abhay and Kashi Pragati and Varsha Uphar. Inbreeding depression has been found to be negatively significant for traits like days to 50% flowering in all three crosses, with Kashi Pragati x Varsha Uphar showing the highest level of inbreeding depression. Significant negative inbreeding depression in terms of days to 50% flowering suggests that F_2s matured and flowered later than their F_1 counterparts. The Kashi Pragati x Varsha Uphar cross showed significant heterobeltosis in the F_1 generation for the number of branches per plant and the number of days needed for 50% flowering, and the F_2 generation showed low inbreeding depression in the cross, indicating the predominance of additive and additive x additive gene actions for these traits, which is thought to be advantageous to obtain better segregants via pedigree method. The similar results were confirmed with previous researchers Arora *et al.* (2010) [3], Akthar *et al.* (2010) [2], Mistry (2013) [8], Soher *et al.* (2013) [12] and Chavan *et al.*, (2021) [4].

Table 1: Estimate of relative, better parent heterosis and inbreeding depression in three crosses of okra

Crosses	Percent heterosis over		Inbreeding depression (%)
	Mid-parent (%)	Better parent (%)	
Plant height (cm)			
Phule Vimukta x Arka Abhay	22.125**	8.924**	31.563%
Kashi Pragati x Arka Abhay	22.244**	5.446**	14.539%
Kashi Pragati x Varsha Uphar	11.066**	7.843**	5.427%
Internodal length (cm)			
Phule Vimukta x Arka Abhay	8.855*	4.391	13.333%
Kashi Pragati x Arka Abhay	-6.583	-14.046**	-28.486%
Kashi Pragati x Varsha Uphar	-25.352**	-34.050**	-46.741%
Number of nodes per plant			
Phule Vimukta x Arka Abhay	23.746**	10.778	25.946%
Kashi Pragati x Arka Abhay	19.328**	5.97*	23.944%
Kashi Pragati x Varsha Uphar	37.383**	18.454**	27.00%
Number of branches per plant			
Phule Vimukta x Arka Abhay	17.857*	13.793	15.152%
Kashi Pragati x Arka Abhay	25.490*	14.286*	21.875%
Kashi Pragati x Varsha Uphar	36.364**	25.00**	-6.667%

Table 1: Continued…

Crosses	Percent heterosis over		Inbreeding depression (%)
	Mid-parent (%)	Better parent (%)	
Node at which first flower appeared			
Phule Vimukta x Arka Abhay	-26.531**	-30.76*	-38.889%
Kashi Pragati x Arka Abhay	-5.556*	-19.048*	-11.765%
Kashi Pragati x Varsha Uphar	-22.857*	-28.947*	-69.630
Length of fruit (cm)			
Phule Vimukta x Arka Abhay	21.427**	9.56**	13.045%
Kashi Pragati x Arka Abhay	17.299**	3.578**	27.812%
Kashi Pragati x Varsha Uphar	38.523**	8.303**	0.000%
Diameter of fruit (mm)			
Phule Vimukta x Arka Abhay	12.185**	-3.001**	6.920%
Kashi Pragati x Arka Abhay	24.720**	6.398**	24.706%
Kashi Pragati x Varsha Uphar	19.140**	5.020*	15.285%
Days to 50% flowering			
Phule Vimukta x Arka Abhay	-3.582	-2.018	-11.459%
Kashi Pragati x Arka Abhay	-0.863	1.506	-11.637%
Kashi Pragati x Varsha Uphar	3.926*	6.511**	-1.415%

Table 1: Continued…

Crosses	Percent heterosis over		Inbreeding depression (%)
	Mid-parent (%)	Better parent (%)	
Number of fruits per plant			
Phule Vimukta x Arka Abhay	31.034*	11.765**	20.526%
Kashi Pragati x Arka Abhay	19.718**	3.659	29.353%
Kashi Pragati x Varsha Uphar	15.108*	2.564	7.500%
Fruit weight (g)			
Phule Vimukta x Arka Abhay	18.799**	10.331*	10.206%
Kashi Pragati x Arka Abhay	14.504	3.693	30.098%
Kashi Pragati x Varsha Uphar	34.201**	8.001	28.394
Fruit yield per plant (kg)			
Phule Vimukta x Arka Abhay	53.203**	22.964**	28.510%
Kashi Pragati x Arka Abhay	38.922**	11.374**	50.512%

Kashi Pragati x Varsha Uphar	49.654**	10.037**	34.171%
Fruit yield per plot (kg)			
Phule Vimukta x Arka Abhay	53.409**	23.10**	28.889%
Kashi Pragati x Arka Abhay	38.858**	11.209**	50.663%
Kashi Pragati x Varsha Uphar	49.704**	10.00**	33.992%

Table 1: Continued…

Crosses	Percent heterosis over		Inbreeding depression (%)
	Mid-parent (%)	Better parent (%)	
Fruit yield per hectare (q)			
Phule Vimukta x Arka Abhay	53.199**	22.96**	28.507%
Kashi Pragati x Arka Abhay	38.840**	11.365**	48.935%
Kashi Pragati x Varsha Uphar	49.675**	10.055*	34.177%
Fruit and shoot borer (%)			
Phule Vimukta x Arka Abhay	-26.606	-33.333	-75.000%
Kashi Pragati x Arka Abhay	-19.048*	-26.087	-23.235%
Kashi Pragati x Varsha Uphar	-25.00*	-30.769*	22.222%
Yellow vein mosaic virus (%)			
Phule Vimukta x Arka Abhay	46.667*	37.500**	6.818%
Kashi Pragati x Arka Abhay	3.371	-2.128	2.717%
Kashi Pragati x Varsha Uphar	-50.00**	-52.941**	-71.875%

* and ** Significant at 5 and 1 per cent level respectively

Conclusion

For characters that contribute to yield in crosses Phule Vimukta x Arka Abhay and Arka Abhay x Varsha Uphar, significant relative heterosis and heterobeltiosis in the desired direction were observed; thus, heterosis breeding would be a more practical strategy for greater yield. Days to 50% flowering, a character that is desirable as a breeding goal in the Phule Vimukta x Arka Abhay cross, had a negative estimate. Population improvement techniques like reciprocal recurrent selection would be helpful for enhancing these traits in addition to high fruit yield. Population improvement is a good option to improve all of these traits because heterosis breeding may result in lower yields for the crosses that showed positively significant heterosis.

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