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Heterobeltiosis, inbreeding depression, heritability and genetic advance study in okra [*Abelmoschus esculentus* (L.) Moench]

■ **P.R. NANAWARE, S. N. SARAVAIYA[1], A. I. PATEL[1] AND V. B. SHINDE[1]**

Members of the Research Forum

Associated Authors:
[1]Department of Vegetable Science, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, NAVSARI (GUJARAT) INDIA

Author for correspondence :
P. R. NANAWARE
Department of Vegetable Science, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, NAVSARI (GUJARAT) INDIA
Email : npkumar972@gmail.com

ABSTRACT : Field experiment was carried out to assess the genetic potential of okra genotypes through breeding and selection in 6 genotypes of four crosses (Arka Abhay × GAO-5, GJO-3 × VRO-6, Phule Utkarsha × GAO-5 and P-8 × VRO-6). Narrow sense heritability and genetic advance varied across crosses and traits. For fruit yield, narrow sense heritability were moderate and genetic advance were moderate and high, respectively for crosses *viz.*, Arka Abhay × GAO-5 and Phule Utkarsha × GAO-5 while both were moderate for crosses *viz.*, GJO-3 × VRO-6 and P-8 × VRO-6; appeared to be better indicator for selection. Among the crosses, Phule Utkarsha × GAO-5 exhibited significant relative heterosis as well as heterobeltiosis for fruit yield and its contributing traits .

KEY WORDS : Heterobeltiosis , Heritability, Inbreeding depression

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Okra [*Abelmoschus esculentus* (L.) Moench] has a prominent position in vegetables due to its wide adaptability, wide popularity, year round export potential and high nutritive value. It is commonly known as *Bhindi*, lady's finger or gumbo, being native of tropical Africa and belongs to family Malvaceae. The chromosome numbers (2n) of okra varied from 56 to 199 (Siemonsma, 1982) but species with 2n=130 belongs to *esculentus* types. It is an often cross pollinated crop and occurrence of out crossing to an extent of 4 to 19 per cent with the maximum of 42.2 per cent is noticed through the insect assisted pollination. Heterosis leads to increase in yield, reproductive ability, adaptability, biotic and abiotic resistance, general vigour and quality. The expression of heterosis may be due to factors such as heterozygosity, allelic interaction such as dominance or over-dominance, non-allelic interaction or epistasis and maternal interactions. The degree of heterosis depends upon the number of heterozygous alleles. Higher the number of heterozygous alleles, more is the heterosis expected. Inbreeding depression defines to decrease in fitness and vigour due to inbreeding effect. It increases homozygosity in the genotype by continuous selfing. It results due to fixation of undesirable recessive genes in F_2. While in case of heterosis, favourable dominant genes of one parent are masking the effect of recessive genes of other parent. Heritability in narrow sense may helps more in the selection of elite types from the mixed parental populations or segregating populations.

RESEARCH METHODS

Six generation *viz.*, P_1, P_2, F_1, F_2, BC_1 and BC_2 were derived from four crosses involving six contrasting genotypes of okra. Four were female lines *viz.*, Arka Abhay, GJO-3, Phule Utkarsha and P-8 and two male lines, GAO-5 and VRO-6. Selfed seeds of parental lines used to make four crosses *viz*., Arka Abhay × GAO-5, GJO-3 × VRO-6, Phule Utkarsha × GAO-5 and P-8 × VRO-6; F_1, F_2 and BC_1 and BC_2 were developed by selfing and backcrossing. These six generations of each of four crosses were grown in Randomized Block Design with three replications at the Regional Horticultural Research Station, Navsari Agricultural University, Navsari in late *Kharif* 2015. Each plot consisted of one row of P_1, P_2, F_1, two rows of BC_1 and BC_2 and four rows of F_2 generations. Each row was three meters long. The row-to-row and plant-to-plant distances were kept as 60 cm and 45 cm, respectively. Five plants from each of the P_1, P_2, F_1, 20 plants from F_2 and 10 plants from each of the BC_1 and BC_2 generations were randomly selected per replication and observations were recorded on single plant basis. Heterobeltiosis were calculated for percentage increase in F_1 over mid parent and better parent, respectively. Inbreeding depression was calculated as percentage reduction in F_2 over F_1. The narrow sense heritability (h^2_{ns}) from the estimates of basic generations was calculated by the formula suggested by Warner (1952).

RESEARCH FINDINGS AND DISCUSSION

The findings of the present study as well as relevant discussion have been presented under following heads :

Heterosis and inbreeding depression :

In case of fruit yield per plant, three out of four crosses *viz*., Arka Abhay × GAO-5, GJO-3 × VRO-6 and Phule Utkarsha × GAO-5 displayed highly significant average heterosis as well as heterobeltiosis in desired direction (Table 1). It was further observed that the cross combination who had significant relative heterosis or heterobeltiosis for fruit yield per plant in general, occupied significant relative heterosis or heterobeltiosis for number of fruit per plant, fruit length, fruit diameter, number of seeds per fruit, intermodal length and 100 seed weight. This indicated that yield contributing traits had positive association with fruit yield per plant, therefore, population improvement and selection programme should be adapted for improvement of fruit yield. The heterotic effects for fruit yield per plant and its related traits was also reported by Kalpande *et al*. (2009); Khanorkar and Kathiria (2010); Patel *et al*. (2010); Kumar and Pathania (2011); Hazem *et al*. (2013); Pathak and Prabhat (2014) and Katagi *et al*. (2015).

The significant and negative relative heterosis as well as heterobeltiosis for days to 50 per cent flowering and number of nodes at which first flower appear was depicted by the all crosses except P-8 x VRO-6. Similar findings were reported by Borgaonkar *et al*. (2005); Mehta *et al*. (2007) and Kumar and Pathania (2011).

For plant height, only a cross GJO-3 ×VRO-6 exhibited significant relative heterosis and heterobeltiosis in negative direction while other crosses showed significant heterosis in positive direction. For stem diameter, crosses GJO-3 × VRO-6, Phule Utkarsha × GAO-5 and P-8 × VRO-6 exhibited relative heterosis in desired direction, while only one cross Arka Abhay × GAO-5 had significant and negative heterobeltiosis. In case of number of branches per plant only one cross Phule Utkarsha × GAO-5 expressed significant relative heterosis and heterobeltiosis in desired direction. These results are in accordance with the findings of Kumar *et al*. (2005) and Khanorkar and Kathiria (2010) for plant height and stem diameter and Kumar *et al*. (2005) for number of branches per plant.

The magnitude of mean performance of F_2 populations for fruit yield per plant showed significant inbreeding depression in three out of four crosses studied but none had negative value revealed the presence of undesirable transgressive segregants.

The crosses, Arka Abhay × GAO-5 and Phule Utkarsha × GAO-5 manifested significant and positive high relative heterosis and heterobeltiosis for fruit yield per plant also showed significant inbreeding depression. This indicated that degree of inbreeding depression expressed by the F_2 populations was somewhat related to the amount of heterosis in F_1 for fruit yield per plant. The results further revealed that the crosses which depicted significant inbreeding depression for fruit yield per plant also exhibited positive inbreeding depression for fruit length, fruit diameter, number of fruits per plant, plant height and number of branches per plant.

For days to flowering, plant height and number of nodes at which first flower appear, three crosses *i.e.* Arka Abhay × GAO-5, GJO-3 × VRO-6 and Phule Utkarsha × GAO-5 had negative, while one cross showed positive inbreeding depression, this suggested the chances of getting desirable transgressive segregants for earliness in crosses which expressed significant and positive inbreeding depression. These crosses might be useful for getting dwarf stature in segregating generations.

In general, most of the crosses, those who exhibited positive inbreeding depression for fruit yield per plant

Table 1 : Magnitude of heterobeltiosis (%), inbreeding depression (%), heritability in narrow sense (%) and genetic advance (%) for different characters in four crosses of okra

Crosses	Heterobeltiosis (%)	Inbreeding depression (%)	Narrow sense heritability (h^2_{ns})	Genetic advance (%)
Days to 50% flowering				
Arka Abhay × GAO-5	-5.61**	-1.72	38.28	7.97
GJO-3 × VRO-6	-3.86**	-1.36	23.13	4.55
Phule Utkarsha × GAO-5	-11.83**	-11.63	28.07	5.31
P-8 × VRO-6	7.57**	13.22	18.24	3.74
Plant height (cm)				
Arka Abhay × GAO-5	15.00**	11.64**	19.56	7.51
GJO-3 × VRO-6	-5.09**	-3.75	11.51	4.82
Phule Utkarsha × GAO-5	8.88**	12.86**	16.47	6.47
P-8 × VRO-6	5.92**	2.38	18.19	8.15
Stem diameter (cm)				
Arka Abhay × GAO-5	-4.82*	-3.52	19.13	4.93
GJO-3 × VRO-6	7.51**	14.53	26.19	8.08
Phule Utkarsha × GAO-5	4.49*	9.36	29.20	7.7
P-8 × VRO-6	-5.20*	3.44	33.23	8.17
Internodal length (cm)				
Arka Abhay × GAO-5	11.70**	9.08	35.78	12.71
GJO-3 × VRO-6	8.20**	9.80	21.77	8.48
Phule Utkarsha × GAO-5	6.96**	10.27*	30.13	12.39
P-8 × VRO-6	11.29**	11.57	31.98	14.1
No. of node at which 1st flower appear				
Arka Abhay × GAO-5	-15.07**	-2.82	42.12	30.45
GJO-3 × VRO-6	-7.69*	-4.58	18.29	10.55
Phule Utkarsha × GAO-5	-21.92**	-12.72	36.33	28.61
P-8 × VRO-6	20.31**	19.81	14.49	8.86
Number of branches per plant				
Arka Abhay × GAO-5	-15.39**	15.00	14.60	9.58
GJO-3 × VRO-6	-12.28*	-5.50	26.04	18.94
Phule Utkarsha × GAO-5	-1.59	25.40	26.70	22.11
P-8 × VRO-6	-22.41**	-23.33	11.18	5.99
Fruit yield per plant (g)				
Arka Abhay × GAO-5	11.02**	46.23**	25.32	33.06
GJO-3 × VRO-6	12.69**	-7.69	23.36	17.36
Phule Utkarsha × GAO-5	24.67**	26.32**	21.34	22.08
P-8 × VRO-6	-15.76**	-11.36	19.25	19.57
Fruit length (cm)				
Arka Abhay × GAO-5	4.96	7.27	17.96	7.32
GJO-3 × VRO-6	-15.64**	-20.77	30.24	11.9
Phule Utkarsha × GAO-5	6.01**	8.80	38.87	14.58
P-8 × VRO-6	2.72	5.21	13.69	5.03
Fruit diameter (cm)				
Arka Abhay × GAO-5	8.88**	17.07**	31.04	8.94

Table 1 : Contd………………

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GJO-3 × VRO-6	9.18**	18.17**	13.30	4.28
Phule Utkarsha × GAO-5	6.93**	11.04*	39.91	10.65
P-8 × VRO-6	-6.58**	4.84	33.26	9.9
Number of fruits per plant				
Arka Abhay × GAO-5	5.76*	33.45**	13.87	5.59
GJO-3 × VRO-6	-2.79	-6.00	20.36	6.92
Phule Utkarsha × GAO-5	10.94**	22.18*	29.14	11.89
P-8 × VRO-6	-5.69*	-14.63	8.16	2.68
No. of seeds per fruit				
Arka Abhay × GAO-5	13.63**	-6.93	19.26	3.74
GJO-3 × VRO-6	21.26**	10.10	29.93	7.66
Phule Utkarsha × GAO-5	9.16**	3.01	22.93	5.04
P-8 × VRO-6	25.43**	9.26	11.58	2.95
100 seed weight				
Arka Abhay × GAO-5	2.31	-8.08	20.52	5.33
GJO-3 × VRO-6	11.60**	9.65	29.82	8.79
Phule Utkarsha × GAO-5	6.08**	4.07	35.09	9.79
P-8 × VRO-6	8.12**	6.50	19.31	5.71

*and ** indicate significance of values at P=0.05 and 0.01, respectively

components like fruit length, fruit diameter, number of fruits per plant, plant height and number of branches per plant also exhibited positive inbreeding depression for fruit yield per plant. This revealed that the expression of heterosis and inbreeding depression for fruit yield per plant was dependent on its attributing traits. The results are matching with the results of Kumar *et al*. (2004); Borgaonkar *et al*. (2005); Kumar *et al*. (2005); Ghai and Arora (2006); Kalpande *et al*. (2009); Khanorkar and Kathiria (2010); Patel *et al*. (2010); Kumar and Pathania (2011); Kumar and Singh (2012); Hazem *et al*. (2013); Pathak and Prabhat (2014) and Katagi *et al.* (2015).

Significant and positive heterosis for fruit yield per plant and its related traits followed by significant inbreeding depression indicated major role of non-additive gene actions in the inheritance of fruit yield per plant and its attributes. These findings are similar to those of Kumar *et al*. (2004).

Heritability and genetic advance :

High broad sense heritability recorded for all traits except number of branches in cross Arka Abhay × GAO-5. Cross GJO-3 × VRO-6 exhibited high broad sense heritability for all characters except for plant height and fruit yield per plant, where it had moderate estimates. Estimates of broad sense heritability were high for all the traits in cross Phule Utkarsha × GAO-5. However, cross P-8 × VRO-6 expressed high broad sense heritability for days to 50 per cent flowering, plant height, stem diameter, internodal length, fruit length, fruit diameter, number of fruits per plant number of seeds per fruit and 100 seed weight.

Moderate narrow sense heritability was observed for days to 50 per cent flowering, internodal length, number of node at which first flower, fruit yield, fruit diameter and 100 seed weight, while low for plant height, stem diameter, number of branches, fruit length, number of fruits per plant and number of seeds per fruit in Arka Abhay × GAO-5. In cross GJO-3 × VRO-6, all the traits had moderate narrow sense heritability except plant height. Similarly, the estimates of moderate narrow sense heritability recorded by all the traits, whereas low for plant height in all cross. In cross P-8 × VRO-6, moderate narrow sense heritability was recorded for stem diameter, internodal length and fruit diameter, while rest of the traits had low narrow sense heritability.

The higher estimates of heritability indicates that these traits were comparatively less affected by environment and their phenotype is good reflection of genotype and thus, possessed paramount importance in making selection of superior genotype on the basis of phenotypic performance of these metric traits but in case of lower heritability, pedigree, sib or progeny test can be employed to improve it.

In the present investigation, low genetic advance was recorded for almost all the traits except fruit yield per plant. However, some crosses revealed moderate to high genetic advance for two or more traits. Low genetic advance was reported for days to 50 per cent flowering, plant height, stem diameter, number of branches per plant, fruit yield, fruit length, fruit diameter, number of fruits per plant, number of seeds per fruit and 100 seed weight in cross Arka Abhay × GAO-5; days to 50 per cent flowering, plant height, stem diameter, internodal length, fruit diameter, number of fruits per plant, number of seeds per fruit and 100 seed weight in GJO-3 × VRO-6; days to 50 per cent flowering, plant height, stem diameter, number of seeds per fruit and 100 seed weight in cross Phule Utkarsha × GAO-5; days to 50 per cent flowering, plant height, stem diameter, number of node at which first flower appear, number of branches per plant, fruit length, fruit diameter, number of fruits per plant, number of seeds per fruit and 100 seed weight in cross P-8 × VRO-6.

Moderate genetic advance was recorded for internodal length in cross Arka Abhay × GAO-5; number of node at which first flower appear, number of branches per plant and fruit length in cross GJO-3 × VRO-6; internodal length, fruit length and fruit diameter in cross Phule Utkarsha × GAO-5; internodal length in cross P-8 ×VRO-6.

High genetic advance was recorded for fruit yield per plant in all four crosses, while number of node at which first flower appear in cross Arka Abhay × GAO-5; number of node at which first flower appear and number of branches per plant in cross Phule Utkarsha × GAO-5. These results are similar to the findings of different scientists *viz*.,Indurani and Veeraragavathatham (2005); Adeniji *et al*. (2007); Kumar *et al*. (2007); Nasit *et al*. (2009); Kumar *et al*. (2012); Kumar and Singh (2012); Khatik *et al*. (2012); Jagan *et al*. (2013) and Krishna *et al*. (2015).

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