The Pharma Innovation Journal 2022; 11(12): 5758-5762

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(12): 5758-5762

www.thepharmajournal.com
Received: 01-09-2022
Accepted: 05-11-2022

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Generation Mean analysis in Okra [*Abelmoschus esculentus* L. Moench]

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Abstract

The goal of the current investigation was to study generation mean analysis of three crosses each having P_1, P_2, F_1, F_2, BC_1 and BC_2 generations in a Randomized block design with two replications at the experimental research farm of the Department of Horticulture, College of Agriculture Latur, during the *summer* of 2021 (crossing) and *kharif* of 2021 (evaluation). Epistatic gene interaction was present, as shown by the scaling test. In all three crosses, the duplicate epistasis was seen in the plant height, nodal length, number of nodes per plant, number of branches per plant, and node at which the first flower appeared. Arka Abhay x Varsha Uphar showed duplicate epistasis for days to 50% flowering, number of fruits per plant, length of fruit, and diameter of fruits in cross. This suggests that in order to take advantage of the population under study, a specific breeding procedure, such as intermating the most desirable segregants, selfing, and selecting superior genotypes along with progeny testing, is required. Gene actions that are both additive and non-additive were found in all characters that contribute to yield. When additive effects are greater than non-additive ones, selection in the early generation would be effective. The development of the character requires extensive selection through subsequent generations if the non-additive portions are greater than the additive ones.

Keywords: Gene action, Additive, Dominance, Epistasis, Fruit yield, Scaling test, Okra

Introduction

An economically significant crop, okra (*Abelmoschus esculentus* [L.] Moench) is grown primarily in tropical and subtropical regions of the world. It is also referred to as the lady's finger or Bhendi. Despite having originated in tropical Africa, okra is a highly prized vegetable in India. In Southeast Asia, the distributions of closely related wild species and cultivated okra are the same. The variety of okra is also known to exist in West Africa and India. Because of its delicate pods, it is a popular fruit vegetable in India. It can be grown as a garden crop or in industrial farms. The second-largest producer of vegetables in the world is India. Okra is a member of the malvaceae family and the genus Abelmoschus.

Okra is very nutrient-dense, especially the edible fruit, which has high concentrations of iron (0.35 mg/100g), calcium (0.35 mg/100g), and vitamin C (66 mg/100g). Aproximate humidity levels of 88%, 7.7% carbohydrate, 1.1% fibre, 0.7% mineral, 0.08% phosphorus, and calorific content of 41 (kcal) are also high. Vitamin B is 0.06 mg, Nicotinic acid is 0.06 mg, Riboflavin is 0.06 mg, and Vitamin A is 58 IU. The tender fruits are consumed as a cooked vegetable, frequently fresh but frequently soaked and frozen. Other domestic and medical uses were also made of it (Chavan *et al*., 2021) [5]

Okra yield levels have been successfully increased through intensive and coordinated breeding efforts, and further yield improvements appear to be more challenging, necessitating the use of cutting-edge breeding techniques. Determining the type of breeding procedure requires estimating the type of gene effects in the plant population. Applying the generation mean, the most common tool, directly aids in the estimation of gene effects and genetic variance components. The mode of gene action for quantitative traits, specifically its yield components, can be assessed using generation mean analysis (Sargar *et al.*, 2021) [1]. In order to further improve the crop, plant breeders must understand the genetic diversity and relationships among breeding materials.

Materials and Methods

The current investigation of Generation mean analysis in Okra (*Abelmoschus esculentus* L. Moench) was undertaken in the period from *Summer*- 2021 to *Kharif*- 2021 at Instructional-Cum-Research Farm, Department of Horticulture, College of Agriculture, Latur, Vasantrao

Naik Marathwada Krishi Vidyapeeth, Parbhani. The experimental material comprised of six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2) derived from three crosses *viz*., Phule Vimukta x Arka Abhay, Kashi Pragati x Varsha Uphar and Kashi Pragati x Arka Abhay. From the above three hybrids, three F_2 (F_2 generation), three first backcrosses generation (BC_1 generation) and three second back crosses generation (BC_2 generation) were developed. During the *Kharif* season 2021, these materials were tested using a Randomized Block Design with two replications. 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 six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2).

For all of the metric characters under investigation, the analysis of variance for Randomized Block Design (RBD) was conducted in accordance with the instructions provided by Panse and Sukhatme (1985) [2] to test the significance of differences between treatments. Crosses with notable variations in the character's entries (progenies) were subjected to generation mean analysis and gene effect estimation using the six parameter models suggested by Hayman (1958) [3] and the three-parameter model provided by Jinks and Jones (1958) [4]. Scaling tests were used to determine whether the additive-dominance model in each cross was adequate, as described by Hayman and Mather in 1955. Two requirements, namely the additive nature of gene effects and the independence of the heritable component from the non-heritable, must be met for the scale to be adequate. The first condition's test reveals whether there are gene interactions present or not. Tests A, B, C and D were computed by calculating their values and variances. The joint scaling test (Cavalli, 1952) [6] was used to detect epistasis for all traits measured.

Result and discussion

For fifteen traits of three crosses, genetic analysis of the mean values of all six generations, P_1, P_2, F_1, F_2, BC_1 and BC_2 was performed. Since most estimations of the additive and dominance components of variance are made under the assumption that gene interaction is not present, the test of scale adequacy is crucial. For the purpose of identifying epistasis, Cavalli's (1952) [6] joint scaling test and Mather's (1949) [7] simple scaling test of A, B, C, and D were applied. Scaling tests were significant for all of three crosses under study suggesting the presence of digenic interaction in the inheritance of these characters. The individual scaling tests A, B, C and D revealed the presence of epistasis for most of the traits in all the crosses.

The results of the individual scaling tests A, B, C, and D showed that all of the traits in both crosses had epistasis. Three digenic interaction parameters from Hayman's 1958 six-parameter model were used to calculate the generation means. For the character plant height, the scaling tests A, C, and D were significant for the crosses Phule Vimukta x Arka Abhay and Kashi Pragati x Varsha Uphar. For the scaling tests A, C, and D for the characters, internodal length, number of nodes per plant, days needed for 50% flowering, and fruit weight, it was determined that the cross between Kashi Pragati and Arka Abhay was significant. For characteristics, fruit yield per plant, fruit yield per plot, and fruit yield per hectare, Phule Vimukta x Arka Abhay and Kashi Pragati x Arka Abhay were found to be significantly different in all scaling tests A, B, C, and D. For the four scaling tests for traits, including the number of fruits per plant, the cross Kashi Pragati x Arka Abhay was found to be significant. All four scaling tests for the cross Phule Vimukta x Arka Abhay found that the cross Kashi Pragati x Varsha Uphar was significant for the character length of fruit and for the trait days required for 50% flowering. Khanorkar *et al*., (2010), Mistry (2013), and Mahajan *et al.*, (2017) [8, 10] discovered similar findings.

In the cross between Kashi Pragati and Varsha Uphar, the scaling tests A, B, and C were found to be significant for the traits of number of branches per plant, fruit yield per plant, fruit yield per plot, and fruit yield per hectare, and for the trait of fruit length in the cross between Phule Vimukta and Arka Abhay. For the trait diameter of fruits, the scaling tests B, C, and D were significant for the crosses Kashi Pragati x Arka Abhay and Kashi Pragati x Varsha Uphar. The significant value of chi square for plant height in all the crosses indicated that, three parameter model did not adequately explain the genetic variability for this trait. The insufficiency of the model also designated the presence of epistasis (non-allelic gene interaction), which was also deduced from the generation means. As the three-parameter model did not satisfactorily explain the genetic variability for plant height, therefore, a six-parameter model was applied to accommodate epistatic interactions. The similar results were found by, Soher *et al*., (2013 and Mahajan *et al*., (2017) [11, 8, 10].

The highly significant mean values from the generation mean analysis in three crosses demonstrated that the studied traits are all quantitatively inherited and that the six generations varied from one another presented in table 1. Both the cross between Kashi Pragati and Arka Abhay and the cross between Kashi Pragati and Varsha Uphar showed a significant and positive additive (d) effect for internodal length. In the cross between Kashi Pragati and Arka Abhay as well as the trait of number of branches per plant in the cross between Kashi Pragati and Varsha Uphar, the additive (d) effect was found to be positively significant for fruit and shoot borer infestation. In all three crosses, Phule Vimukta x Arka Abhay, Kashi Pragati x Arka Abhay, and Kashi Pragati x Varsha Uphar, the additive (d) effect was significant and negative for fruit length, diameter, weight, yield per plant, yield per plot, and yield per hectare. The additive (d) effect was found to be negatively significant in the crosses between Phule Vimukta and Arka Abhay and Kashi Pragati and Arka Abhay for the number of nodes per plant and the number of fruits per plant. Simple pedigree selection can be used to take advantage of the additive component of variation.

The hybrids Phule Vimukta x Arka Abhay, Kashi Pragati x Arka Abhay, and Kashi Pragati x Varsha Uphar showed positive and significant dominance (h) effects for number of nodes per plant, fruit yield per plant, fruit yield per plot, and fruit yield per hectare. Kashi Pragati x Arka Abhay and Kashi Pragati x Varsha Uphar also showed positive and significant dominance (h) gene effect for number of fruits per plant in crosses, as did Phule Vimukta x Arka Abhay and Kashi Pragati x Arka Abhay for fruit diameter and weight. Phule Vimukta x Arka Abhay demonstrated positively significant dominance (h) gene effect for the traits, plant heights, internodal length, and fruit and shoot borer infestation cross. The hybrid shows negetive and significant dominance (h) effects for number of plant height, internodal length, node as first flower appeared, length of fruit and yellow vein mosaic virus infestation was observed in cross, Kashi Pragati x Varsha Uphar. For days required for 50% flowering of cross, Kashi Pragati x Arka Abhay and Phule Vimukta x Arka Abhay exhibited negetive and significant dominance (h) gene effect. These results are harmony with previous findings by Patel *et al*. (2010) [13], Wakode *et al.* (2015) [12] and Mahajan et al. (2017) [8, 10].

By estimating the magnitude of the dominance (h) component, which was higher than that of the additive (d) gene effect, it was determined that the dominance effect played a greater role in the expression of all the studied traits. (Table 1) It is possible to use an unconventional breeding method to take advantage of the dominance effect. Epistasis gene effects are known to play a significant role in the variation in a person's genetic make-up, which exhibits higher estimates of dominance effects. In the current investigation, significant epistasis interaction was linked to high estimates of dominance (h) effect for the aforementioned traits in the corresponding crosses. The hybrid showing positive and significant additive x additive (i) effects for number of nodes per plant, fruit yield per plant, fruit yield per plot and fruit yield per hectare was observed in crosses, Phule Vimukta x Arka Abhay and Kashi Pragati x Arka Abhay. For number of branches per plant, length of fruit, diameter of fruit, number of fruits per plant and fruit weight of cross, Kashi Pragati x Arka Abhay, also, for plant height in cross, Phule Vimukta x Arka Abhay exhibited positive and significant additive x additive (i) gene effect. For the trait, diameter of fruit, cross, Kashi Pragati x Varsha Uphar exhibited positively significant additive x additive (i) gene effect. For days required for 50% flowering for additive x additive (i) gene effect found significant and negative in all three cross, Phule Vimukta x Arka Abhay, Kashi Pragati x Arka Abhay and Kashi Pragati x Varsha Uphar. For plant height, internodal length, length of fruits, yellow vein mosaic virus infestation, and number of fruits per plant, additive x additive (i) gene effect found negatively significant in cross, Kashi Pragati x Varsha Uphar.

For fruit yield per plant, fruit yield per plot and fruit yield per hectare for additive x dominance (j) gene effect found significant and negative in all three cross, Phule Vimukta x Arka Abhay, Kashi Pragati x Arka Abhay and Kashi Pragati x Varsha Uphar. For plant height and number of branches per plant, additive x dominance (j) gene effect found negatively significant in cross, Phule Vimukta x Arka Abhay. Also, for node at which first flower appeared and fruit weight, additive x dominance (j) gene effect found negatively significant in cross, Kashi Pragati x Arka Abhay. The sign of dominance x dominance (l) effects were negative for fruit yield per plant, fruit yield per plot and fruit yield per hectare, in cross, Phule Vimukta x Arka Abhay and Kashi Pragati x Varsha Uphar and for diameter of fruit and weight of fruit in cross, Kashi Pragati x Arka Abhay indicating their reducing effect in the expression of these characters.

The sign of dominance x dominance (l) effects were found positively significant in plant height, internodal length, number of fruits per plant and yellow vein mosaic virus infestation which indicates their enhancing effect in cross, Kashi Pragati x Varsha Uphar. The sign of dominance x dominance (l) component was positive in the other character indicating their enhancing effect in the expression of that character. The sign of dominance (h) and dominance x dominance (l) parameter being opposite indicates involvement of duplicate type of epistasis in the inheritance of a trait. Such type of gene action also observed for various traits in the present investigation.

Duplicate epistasis would hinder rapid development and make it challenging to fix genotypes with higher levels of character manifestation because one parameter's opposite effect would be counterbalanced by another's detrimental effect. In all three crosses—Phule Vimukta x Arka Abhay, Kashi Pragati x Arka Abhay, and Kashi Pragati x Varsha Uphar—the duplicate epistasis was seen in the plant height, internodal length, number of nodes per plant, number of branches per plant, node at which the first flower appeared, and yellow vein mosaic virus infestation. Duplicate epistasis was found in the crosses Kashi Pragati x Arka Abhay and Kashi Pragati x Varsha Uphar for traits like fruit length, fruit diameter, and fruit and shoot borer infestation. In cross, Kashi Pragati x Arka Abhay, duplicate epistatis was observed for trait fruit weight.

The involvement of complementary epistasis in the expression of a trait indicated by the similar sign of dominance (h) and dominance x dominance (l) parameter. Complementary epistasis were observed for fruit yield per plant, fruit yield per plot and fruit yield per hecatre in cross, Phule Vimukta x Arka Abhay, Kashi Pragati x Arka Abhay and Kashi Pragati x Varsha Uphar and for days to 50% flowering and number of fruits per plant, in cross, Phule Vimukta x Arka Abhay and Kashi Pragati x Arka Abhay. For fruit weight, complementary epistatis was observed in crosses Phule Vimukta x Arka Abhay and Kashi Pragati x Varsha Uphar. In crosses, Phule Vimukta x Arka Abhay, Kashi Pragati x Arka Abhay and Kashi Pragati x Varsha Uphar for some characters main gene effect and duplicate epistasis were involved. This suggests the need of specific breeding procedure such as intermating of most desirable segregants followed by selfing and selecting superior genotypes coupled with progeny testing to exploit the population under study. When additive effects are larger than non-additive ones, selection in early generation would be effective, while if the non-additive portions are larger than additive one, the improvement of the character need intensive selection through later generation. These results are in agreement with the Akthar *et al.,* (2010) [14], Singh *et al.,* (2012) [15] and Wakode *et al*., (2015) [12].

Table 1: Estimates of gene effects in three crosses for 15 characters in okra.

Crosses	*m*	*d*	*h*	*i*	*j*	*l*	Types of Epistasis
Plant height (cm)							
Phule Vimukta x Arka Abhay	40.515**±0.034	-14.9**±0.113	43.665**±0.307	32.94**±0.265	-9.025**±0.13	-12.59*±0.566	Duplicate
Kashi Pragati x Arka Abhay	50.465**±0.003	-3.510±0.031	-1.735±0.011	-12.480±0.004	4.185±0.075	37.810*±0.211	Duplicate
Kashi Pragati x Varsha Uphar	52.015**±0.002	3.020±0.028	-28.54**±0.055	-34.02**±0.05	1.540±0.028	69.02**±0.111	Duplicate
Internodal length (cm)							

Phule Vimukta x Arka Abhay	5.460**±0.005	-0.52±0.011	2.073*±0.079	1.560±0.028	-0.272±0.045	-0.785±0.155	Duplicate
Kashi Pragati x Arka Abhay	8.570**±0.061	1.30**±0.050	-5.75**±0.264	-5.28**±0.263	1.920**±0.054	3.900±0.319	Duplicate
Kashi Pragati x Varsha Uphar	7.205*±0.001	1.025**±0.089	-7.477**±0.183	-5.81**±0.177	0.158±0.098	5.775**±0.366	Duplicate
No. of nodes per plant							
Phule Vimukta x Arka Abhay	6.850**±0.002	-1.70**±0.065	6.385**±0.164	4.61**±0.130	-0.830±0.117	-3.170±0.327	Duplicate
Kashi Pragati x Arka Abhay	5.400**±0.00	-1.6**±0.047	3.900**±0.101	2.800*±0.094	-0.850±0.050	-1.100±0.203	Duplicate
Kashi Pragati x Varsha Uphar	6.935**±0.002	-0.840±0.033	5.165**±0.070	2.580±0.067	0.265±0.036	-0.070±0.139	Duplicate

Table 1: Continued…

Crosses	*m*	*d*	*h*	*i*	*j*	*l*	Types of Epistasis
No. of branches per plant							
Phule Vimukta x Arka Abhay	1.400**±0.000	-0.450*±0.037	-0.250±0.077	-0.500±0.006	-0.50*±0.002	1.500±0.155	Duplicate
Kashi Pragati x Arka Abhay	1.250**±0.008	-0.250±0.037	1.225*±0.082	0.900*±0.081	-0.125±0.038	-1.050±0.153	Duplicate
Kashi Pragati x Varsha Uphar	1.600**±0.00	0.600**±0.033	-0.400±0.067	-0.800±0.067	0.7**±0.033	0.400±0.133	Duplicate
Node at which first flower appeared							
Phule Vimukta x Arka Abhay	2.500**±0.016	0.100±0.075	-1.65*±0.176	-1.00±0.162	-0.050±0.076	0.500±0.334	Duplicate
Kashi Pragati x Arka Abhay	1.900**±0.016	-0.90**±0.033	-0.700±0.101	-0.600±0.092	-1.2**±0.041	0.600±0.169	Duplicate
Kashi Pragati x Varsha Uphar	2.290**±0.010	-0.200±0.00	-1.960*±0.056	-1.560±0.038	-0.350±0.037	0.160±0.090	Duplicate
Length of fruit (cm)							
Phule Vimukta x Arka Abhay	10.065**±0.025	-0.975**±0.133	0.532±0.295	-1.510±0.285	0.05±0.134	4.975**±0.565	Complementary
Kashi Pragati x Arka Abhay	8.150**±0.00	-0.965**±0.025	10.795**±0.051	9.13**±0.049	0.310±0.026	-9.03**±0.102	Duplicate
Kashi Pragati x Varsha Uphar	16.370**±0.035	-4.120**±0.085	-13.488**±0.22	-18.04**±0.22	-0.823±0.085	26.975**±0.368	Duplicate

Table 1: Continued…

Crosses	*m*	*d*	*h*	*i*	*j*	*l*	Types of Epistasis
Diameter of fruit (mm)							
Phule Vimukta x Arka Abhay	13.99**±0.019	-2.565**±0.079	0.163±0.191	-1.470±0.176	-0.468±0.080	3.835±0.358	Complementary
Kashi Pragati x Arka Abhay	11.52**±0.011	-2.825**±0.048	12.22**±0.108	9.190**±0.107	-0.712±0.051	-9.325**±0.20	Duplicate
Kashi Pragati x Varsha Uphar	13.025**±0.02	-3.315**±0.088	7.740**±0.194	5.270**±0.194	-1.580±0.089	-6.080±0.363	Duplicate
Days required for 50% flowering							
Phule Vimukta x Arka Abhay	62.25**±0.152	-0.050±0.277	-11.375**±0.87	-9.30**±0.823	0.875±0.282	-2.850±1.390	Complementary
Kashi Pragati x Arka Abhay	69.215**±0.03	1.050±0.248	-11.26*±0.517	-10.78*±0.513	-0.410±0.248	-6.340±1.009	Complementary
Kashi Pragati x Varsha Uphar	58.39**±0.008	0.850±0.037	-4.385±0.172	-6.56**±0.081	-0.495±0.130	5.510±0.3397	Duplicate
No. of fruits per plant							
Phule Vimukta x Arka Abhay	7.55**±0.008	-2.3**±0.075	3.450**±0.232	1.200±0.152	-1.050±0.180	0.900±0.461	Complementary
Kashi Pragati x Arka Abhay	6.005**±0.012	-0.90**±0.047	3.580**±0.109	2.180*±0.106	0.200±0.054	2.820±0.202	Complementary
Kashi Pragati x Varsha Uphar	7.40**±0.016	-0.700±0.120	-1.150±0.252	-2.200*±0.249	0.150±0.126	4.700*±0.491	Duplicate

Table 1: Continued…

Crosses	*m*	*d*	*h*	*I*	*j*	*l*	Types of Epistasis
Fruit weight (g)							
Phule Vimukta x Arka Abhay	9.590*±0.011	-1.02**±0.192	1.410±0.393	-0.280±0.387	-0.330±0.194	1.540±0.782	Complementary
Kashi Pragati x Arka Abhay	7.85**±0.005	-2.37**±0.347	9.163**±0.696	7.740**±0.694	-1.348**±0.347	-4.805*±1.39	Duplicate
Kashi Pragati x Varsha Uphar	11.26**±0.08	-4.40**±0.174	6.978**±0.488	2.970±0.482	-1.563±0.191	3.905±0.788	Complementary
Fruit yield per plant (kg)							
Phule Vimuktax Arka Abhay	72.33**±0.022	-30.69**±0.10	45.155**±0.235	10.020*±0.225	-14.45**±0.115	25.07**±0.4	Complementary
Kashi Pragati x Arka Abhay	46.64**±0.072	-22.47**±0.04	91.505**±0.317	65.10**±0.299	-5.69**±0.108	7.410±0.391	Complementary
Kashi Pragati x Varsha Uphar	83.32**±0.011	-37.04**±0.07	49.355**±0.170	7.360±0.154	-6.590**±0.103	74.29**±0.3	Complementary
Fruit yield per plot (kg)							
Phule Vimukta x Arka Abhay	1.440**±0.002	-0.600**±0.00	0.905**±0.007	0.20**±0.006	-0.27**±0.001	0.53**±0.08	Complementary
Kashi Pragati x Arka Abhay	0.930**±0.002	-0.44**±0.002	1.838**±0.008	1.31**±0.007	-0.108**±0.03	0.145±0.011	Complementary
Kashi Pragati x Varsha Uphar	1.670**±0.00	-0.74**±0.002	0.980**±0.005	0.140±0.005	-0.13**±0.003	1.480**±0.01	Complementary

Table 1: Continued…

Crosses	*m*	*d*	*h*	*I*	*j*	*l*	Types of Epistasis
Fruit yield per hectare (q)							
Phule Vimukta x Arka Abhay	80.365**±0.02	-34.1**±0.113	50.17**±0.257	11.14**±0.248	-16.05**±0.12	27.83**±0.484	Complementary
Kashi Pragati x Arka Abhay	53.47**±0.344	-24.9**±0.025	95.153**±1.384	65.86**±1.378	-6.292**±0.12	14.655±1.404	Complementary
Kashi Pragati x Varsha Uphar	92.25**±0.012	-48.155**±2.4	40.850**±4.812	-5.830±4.811	-14.325*±2.40	110.58**±9.62	Complementary
Fruit and shoot borer (%)							
Phule Vimukta x Arka Abhay	1.400**±0.00	-1.890±0.267	0.00**±0.00	-1.60**±0.267	0.110±0.133	1.380±0.533	Complementary
Kashi Pragati x Arka Abhay	2.095**±0.01	1.100**±0.075	-0.980±0.155	-0.580±0.149	0.900**±0.078	0.380±0.309	Duplicate
Kashi Pragati x Varsha Uphar	0.70**±0.008	-0.90**±0.033	1.100±0.084	1.400±0.074	-0.800*±0.041	-1.400±0.160	Duplicate
Yellow vein mosaic virus (%)							
Phule Vimukta x Arka Abhay	3.075**±0.004	-0.075±0.042	4.100±0.098	3.050±0.085	0.075±0.056	-7.300±0.195	Duplicate
Kashi Pragati x Arka Abhay	4.475**±0.036	-0.200±0.047	-2.550±0.176	-2.700*±0.172	-0.450±0.060	5.600*±0.249	Duplicate
Kashi Pragati x Varsha Uphar	1.375**±0.012	-0.400±0.047	-3.500**±0.108	-2.70**±0.106	-0.300±0.053	4.700**±0.200	Duplicate

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

Conclusion

For some characters, duplicate epistasis was present in crosses. This suggests that in order to take advantage of the population under study, a specific breeding procedure, such as intermating the most desirable segregants, selfing, and selecting superior genotypes along with progeny testing, is required. Additionally, these traits could be enhanced by recurrent selection in biparental offspring, which would aid in the utilisation of the duplicate type of non-allelic interaction, permit recombination and concentration of genes with cumulative effects in populations, and aid in the dissociation of unfavourable linkage. Early generation selection would be effective when additive effects outweighed non-additive ones, whereas character improvement would require intensive selection through later generations if non-additive effects outweighed additive ones. The yield contributing characters in cross, Arka Abhay x Varsha Uphar are controlled by additive gene effect can be improved by most appropriate method of breeding would be pedigree method of selection. In contrast to it, other growth-related characters in cross, Phule Vimukta x Arka Abhay were controlled by non- additive gene effects in different crosses, hence those could be successfully improved by heterosis breeding or hybridization.

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