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Nature of gene action for important quantitative characters in brinjal (*Solanum melongena* L.)

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Abstract
Generation mean analysis was carried out to asses the presence of inter-allelic interaction and estimate the importance of various gene effects for inheritance of seven horticultural traits *viz.*, days to first flowering, number of flowers per inflorescence, number of primary branches per plant, plant height, total number of fruits per plant, yield per plant and early yield per plant in brinjal. Six generations P_1, P_2, F_1, F_2, B_1 and B_2 of the crosses BARI x Pant Rituraj, BARI x PB-67 and BARI x Pant Samrat were used for the study. Scaling test revealed that all four types of scales (A, B, C, and D) were highly significant for most of the characters which indicated non-allelic interaction of gene effects for all characters. High values of chi-square (χ^2) also supported the non-allelic interaction for all characters. The joint scaling tests also indicated the presence of interaction of gene effects and epistatic effects. Duplicate dominant epistasis was observed in the inheritance of all characters in all families, except early yield per plant in family BARI x Pant Rituraj, where complementary recessive epistasis was of importance.

Keywords: Brinjal, gene action, epistasis, non-allelic interaction, scaling test

Introduction
Brinjal or eggplant botanically known as *Solanum melongena* L. (2n=24), is one of the important vegetable crop grown throughout the country for its tender fruits all-round the year. In India, the productivity of brinjal is very less as compared to China due to lack of suitable cultivars and their susceptibility to pests and diseases. India is the second largest producer of brinjal whereas, China ranks first in the world. Knowledge about the nature of gene effects for productivity and the component characters related to it is always helpful in choice of effective and efficient breeding methods. Therefore, geneticists and breeders are interested in the estimation of gene effects in order to formulate the most advantageous breeding procedures for the improvement of the quantitative characters. Estimation of additive and dominance components is important for the improvement of yield and its components. The present investigation was carried out to generate information on gene action for yield and its component characters using six generations of three families.

Materials and Methods
The experimental material for the present investigation was derived from an 8 x 8 half diallel. Eight promising genotypes *viz.*, *Solanum aethiopicum*, BARI, PB-66, Pant Rituraj, WB-1, PB-67 (PB-6), PB-71 and Pant Samrat were selected as parents for crossing. These eight selected genotypes were used for making crosses in diallel fashion (Griffing's Method II, Model I, fixed effect) and generated a set of 28 F_1 hybrids. Evaluation of all 36 genotypes (8 parents + 28 F_1s) was done in the first year of experiment (2010) and F_2 populations from all F_1 hybrids were generated. Three promising crosses *viz.*, BARI x PR (family-1), BARI x PB-67 (family-2) and BARI x PS (family-3) selected to develop three different families consisted four different genotypes as parents i.e. BARI, Pant Rituraj, PB-67 and Pant Samrat. These three F_1 crosses were backcrossed with both the parents to generate B_1 and B_2, as well as develop F_2 generations and thus each cross along with its parents (P_1, P_2), F_1, F_2 and backcross generations (B_1, B_2) constituted a family of each cross, which were used for the study of generation mean analysis. In the next year (2011) whole sets of experiment consisting of sets of three families were laid out in a randomized complete block design (RCBD) with three replications at Vegetable Research Centre of GBPUA&T, Pantnagar. One month old seedlings were transplanted at the spacing of 75 cm x 60 cm in rows of 6 meter length consisting of 10 plants each row. The parental genotypes and F_1 hybrids were transplanted in single rows (consisting 10 plants) in each replication whereas, F_2 were transplanted in five rows (consisting 50 plants) and backcrosses in three rows (consisting 30 plants) each replication. Recommended package of practices were followed for raising the normal seedlings and crop.

Data were recorded on days to first flowering, number of flowers per inflorescence, number of primary branches per plant, plant height, number of fruits per plant, yield per plant and early yield per plant. Means and variances were calculated for each generation using the data recorded on individual plants in each replication. Data were subjected to individual scaling test as given by Mather (1949) [6] and Hayman and Mather (1955) [3], who devised four simple scaling tests i.e. A, B, C and D, for the detection of presence or absence of epistasis. Cavalli (1952) [2] joint scaling test was used for the precise estimate of different parameters as three parameters were found inadequate due to presence of non-allelic interaction and high values of chi-square (χ^2) at three degree of freedom using the 'Weighted least square technique' of Jinks and Jones (1958) [4], taking the weight as reciprocal of squared standard error of each mean.

Results and Discussion

The family wise results of A, B, C and D scaling test for all the seven characters are presented in the Table-1, Table-2 and Table-3, for family-1 (BARI x PR), family-2 (BARI x PB-67) and family-3 (BARI x PS), respectively. The results showed that all the four scales were highly significant for almost all characters. These results indicated the presence of non-allelic interaction for all the characters studied. The high estimates of chi-square (χ^2) calculated for all characters further indicated the presence of non-allelic interaction and inadequacy of three parameter model. Hence, for all seven characters six parameter models were applicable to estimate the gene effects for all families.

Table 1: Scaling test for cross 1 (BARI x PR)

Characters	A	B	C	D	Chi² at 3 d. f	Adequate Model
Days to 1st flowering	-0.333	0.667*	15.163**	4.333**	1794.868	6
Number of flowers per Inflorescence	2.073**	0.220**	1.813**	-2.393**	19853.18	6
Number of primary branches per plant	-1.233**	-0.840**	0.000**	1.850**	3118.426	6
Plant height (cm)	-19.290**	-16.603**	2.790**	-19.603**	431.278	6
Total number of fruits per plant	-7.243**	-6.820**	0.955**	-0.627*	278.54	6
Total yield per plant (kg)	-1.721**	-2.429**	6.704**	0.731**	3092.427	6
Early yield per plant (kg)	-0.157**	-0.090**	3.152**	-0.029**	1246.417	6

*, **: Significant at 0.05 and 0.01 probability level, respectively.

Table 2: Scaling test for cross 2 (BARI x PB-67)

Characters	A	B	C	D	Chi² at 3 d. f.	Adequate model
Days to 1st flowering	-0.667**	1.333**	-0.667	-0.667**	101.586	6
Number of flowers per Inflorescence	1.220**	-0.820**	-1.760**	-1.080**	7032.854	6
Number of primary branches per plant	-1.973**	-0.273**	3.467**	2.857**	23771.721	6
Plant height (cm)	-32.827**	-5.693**	-78.093**	-19.787**	447.891	6
Total number of fruits per plant	-13.983**	-13.357**	-12.467**	7.437**	1985.022	6
Total yield per plant (kg)	-1.318**	-2.452**	0.137	1.953**	8632.479	6
Early yield per plant (kg)	-0.161**	-0.111**	-0.122**	0.075**	846.353	6

*, **: Significant at 0.05 and 0.01 probability level, respectively.

Table 3: Scaling test for cross 3 (BARI x Pant Samrat)

Characters	A	B	C	D	Chi² at 3 d. f.	Adequate model
Days to 1st flowering	6.667**	5.000**	2.333**	-4.667**	2230.453	6
Number of flowers per Inflorescence	-0.480**	0.760**	-4.960**	-2.620**	14312.18	6
Number of primary branches per plant	-1.820**	-2.120**	1.613**	2.777**	6879.22	6
Plant height (cm)	-26.913**	-20.253**	-48.000**	-0.417	309.347	6
Total number of fruits per plant	-21.683**	-28.720**	-41.177**	4.613**	4355.812	6
Total yield per plant (kg)	-2.371**	-1.634**	-2.404**	0.800**	6476.368	6
Early yield per plant (kg)	-0.001	0.030**	-1.147**	-0.588**	53279.84	6

*, **: Significant at 0.05 and 0.01 probability level, respectively.

Cavalli (1952) [2] joint scaling test was used for the precise estimate of different parameters. The mean analysis was conducted for each character in each cross using six parameter models. The character wise results of joint scaling test are presented in Table-4. The results revealed that the additive, dominance and epistatic gene effects were predominant and in desirable direction for all the characters of interest.

Table 4: Estimates of gene effects and interactions along with standard error and type of epistasis

Characters	Crosses	M	D	H	i	j	l	Type of Epistasis
Days to first flowering	BARI x PR	94.167** ±0.235	3.500** ±0.107	-19.833** ±0.658	-8.667** ±0.209	-1.000** ±0.257	8.333** ±0.604	Duplicate
	BARI x PB-67	86.667** ±0.235	1.000** ±0.107	2.333** ±0.634	1.333** ±0.209	-2.000** ±0.257	-2.000** ±0.492	Duplicate
	BARI x PS	76.500** ±0.251	3.167** ±0.138	26.167** ±0.708	9.333** ±0.209	1.667** ±0.311	-21.000** ±0.628	Duplicate
Number of flowers per inflorescence	BARI x PR	0.887** ±0.047	0.033 ±0.025	12.033** ±0.138	4.787** ±0.040	1.853** ±0.062	-7.080** ±0.096	Duplicate
	BARI x PB-67	1.940** ±0.042	-0.167** ±0.033	3.687** ±0.124	2.160** ±0.027	2.040** ±0.069	-2.560** ±0.088	Duplicate
	BARI x PS	-0.704** ±0.079	-0.567** ±0.025	9.393** ±0.231	5.240** ±0.075	-1.240** ±0.087	-5.520** ±0.156	Duplicate
Number of primary branches per plant	BARI x PR	7.900** ±0.080	0.000 ±0.021	-9.607** ±0.220	-3.700** ±0.077	-0.393** ±0.074	5.773** ±0.165	Duplicate
	BARI x PB-67	9.947** ±0.047	-0.033 ±0.028	-13.840** ±0.132	-5.713** ±0.038	-1.70** ±0.063	7.960** ±0.092	Duplicate
	BARI x PS	9.720** ±0.074	0.033 ±0.023	-15.080** ±0.183	-5.553** ±0.070	0.300** ±0.059	9.493** ±0.140	Duplicate
Plant height (cm)	BARI x PR	47.820** ±3.861	15.760** ±0.513	46.270** ±10.162	39.207** ±3.827	-2.687 ±3.038	-3.313 ±6.780	Duplicate
	BARI x PB-67	47.853** ±4.609	15.36** ±0.77	42.353** ±10.048	39.573** ±4.544	-27.133** ±2.151	-1.053 ±6.070	Duplicate
	BARI x PS	97.560** ±5.803	4.393** ±0.723	-59.520** ±12.665	0.833 ±5.758	-6.660** ±2.535	46.333** ±7.334	Duplicate
Total number of fruits per plant	BARI x PR	13.018** ±0.577	3.852** ±0.199	-8.362** ±1.353	1.253* ±0.542	-0.423 ±0.433	12.810** ±1.073	Duplicate
	BARI x PB-67	34.613** ±0.512	-1.617** ±0.375	-57.993** ±1.577	-14.873** ±0.349	-0.627 ±0.792	42.213** ±1.581	Duplicate
	BARI x PS	36.422** ±0.376	-9.072** ±0.264	-72.785** ±1.087	-9.227** ±0.269	7.037** ±0.558	59.630** ±0.922	Duplicate
Total yield per plant (kg)	BARI x PR	3.524** ±0.071	0.087** ±0.034	-5.615** ±0.173	-1.463** ±0.063	0.708** ±0.073	5.612** ±0.108	Duplicate
	BARI x PB-67	6.266** ±0.057	-0.210** ±0.028	-11.353** ±0.158	-3.907** ±0.050	1.134** ±0.065	7.677** ±0.138	Duplicate
	BARI x PS	3.847** ±0.039	-0.097** ±.033	-6.449** ±0.128	-1.601** ±0.021	-0.737** ±0.069	5.605** ±0.133	Duplicate
Early yield per plant (kg)	BARI x PR	0.219** ±0.006	-0.050** ±0.004	0.026 ±0.015	0.059** ±0.004	-0.067** ±0.008	0.188** ±0.010	Comple.
	BARI x PB-67	0.446** ±0.022	-0.069** ±0.003	-0.416** ±0.046	-0.151** ±0.022	-0.050** ±0.008	0.423** ±0.025	Duplicate
	BARI x PS	-0.737** ±0.008	-0.213** ±0.003	2.293** ±0.024	1.177** ±0.007	-0.031** ±0.009	-1.206** ±0.018	Duplicate

*, ** : Significant at 0.05 and 0.01 probability level, respectively.
Comple: Complementary.

Scaling test in the family 1 indicated that the presence of gene interaction effects for almost all the characters studied. Additive (d), dominance (h), additive x additive (i), additive x dominance (j) and dominance x dominance (l) interaction effects were significant for days to first flowering and total yield per plant. Dominance (h), additive x additive (i), additive x dominance (j) and dominance x dominance (l) interaction effects were found to be significant for number of flowers per inflorescence and number of primary branches per plant. Additive (d), dominance (h) and additive x additive (i) interaction effects were significant for plant height. Additive (d), dominance (h), additive x additive (i) and dominance x dominance (l) interaction effects were significant for total number of fruits per plant. Additive (d), additive x additive (i), additive x dominance (j) and dominance x dominance (l) interaction effects were significant for early yield per plant. The gene effects dominance (h) and dominance x dominance (l) took opposite sign indicating the presence of duplicate dominant epistasis in the inheritance of all characters except early yield per plant, where complementary recessive epistasis was of importance. These results are in agreement with the finding of Thangavel *et al*. (2011) [8].

Scaling test for five characters in the family 2 showed highly significant effects indicating the presence of all five types of gene effects exists *viz.*, additive (d), dominance (h), additive x additive (i), additive x dominance (j) and dominance x dominance (l), except two characters i.e. number of primary branches per plant, where additive (d) gene effects was non significant, and total number of fruits per plant which had non significant effect for additive x dominance (j). The gene effects dominance (h) and dominance x dominance (l) took opposite sign indicating the presence of duplicate dominant epistasis in the inheritance of all characters under studied. These results were similar to the findings of Kathiria *et al.* (1998) [5] and Thangavel *et al*. (2011) [8].

In the family 3 all the type of gene effects were highly significant for five characters *viz.*, days to first flowering, number of flowers per inflorescence, total number of fruits per plant, total yield per plant and early yield per plant which indicated that the inheritance of these characters, the role of main effects (d) and (h) as well as inter-action effects (i), (j) and (l) were important. Whereas, other characters *viz.*, number

of primary branches per plant the main effect (h), interaction effects (i), (j) and (l) and for plant height main effects (d) and (h) and interaction effects (j) and (l) were important. Duplicate dominant type of epistasis played major role for all characters. The results were in general accordance with the reports of Kathiria *et al*. (1998) [5], Singh *et al.* (2002) [7], Babu and Thirumurugan (2001) [1] and Thangavel *et al*. (2011) [8]. The investigation indicated the importance of dominance and epistatic gene effects in the inheritance of different characters under study. Hence, selection in early segregating generations may not give the desirable segregants. Therefore, the selection in the later segregating generations, when dominance and epistasis disappear and to inter-mating among selected individuals through recurrent selection will be more beneficial. Diallel selective mating system could also be an alternative approach for the improvement of these traits in brinjal.

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