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Genetic analysis of some quantitative characters in aromatic rice involving induced mutants

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ABSTRACT

The gene effects for grain yield and its components including grain characters were studied using parental, F_1, F_2, BC_1 and BC_2 generations in five crosses of aromatic rice involving induced mutants and 'basmati' varieties. Epistasis was noticed in the majority of characters for all crosses. Additive and dominance effects had major role in most of the crosses for the expression of plant height, days to flowering, panicle number per plant, panicle length, spikelet fertility per cent, grain length, grain length/breadth ratio, test weight and grain yield per plant. Among interactions, additive × additive and dominance × dominance effects were almost equally important, while additive × dominance was less important than the other genetic effects for the inheritance of traits. Duplicate type of epistasis was observed in most of the traits studied. In general, both additive and non-additive gene action were important for the expression of almost all characters studied. Biparental mating, recurrent selection and diallel selective mating system could be used to obtain desirable recombinations like reduced height high yielding aromatic plants with long slender grains similar to 'basmati' type.

Key words: Gene effects, quantitative characters, induced mutants, aromatic rice.

INTRODUCTION

Aromatic rice, popularly known as 'basmati' rice, has a special place in the world rice markets. The leading traditional 'basmati' varieties are handicapped by poor yield and adaptability to varied agroclimatic conditions. Many of the aromatic varieties do not fulfil the required kernel characteristics due to shorter grain length. To achieve the desired genetic improvement towards the development of better cultivar of aromatic rice, it is essential to gather information about the genetic architecture of quantitative traits including grain yield. The knowledge about the nature and magnitude of gene effects may greatly help the rice breeder in formulating efficient breeding strategy. Partitioning of gene effects through generation mean analysis has not been adequately tested for genetic improvement in aromatic rice. The information on the genetics of grain yield, its components and grain characters of aromatic rice, specially involving induced mutants is limited. Therefore, in the present investigation, an attempt was made to understand the gene effects of ten important quantitative traits in five cross-combinations of aromatic rice involving induced mutants and 'basmati' varieties.

MATERIALS AND METHODS

Six basic generations viz., P_1 (Parent 1), P_2 (Parent 2), F_1 ($P_1 \times P_2$), F_2 (selfing of F_1), BC_1($F_1 \times P_1$) and BC_2 ($F_1 \times P_2$) of five crosses viz., 88-8-3/ Basmati 370, 88-8-3/ Pakistan Basmati, 33-9-15/ Pusa Basmati I, 124-17-4/ Basmati 370 and 124-17-4/ Pusa Basmati I were raised in randomised block design replicated thrice at the Agricultural Farm, Visva-Bharati, West Bengal, India (23°39′ N 87°42′ E, 58.9 msl.). The parents were three induced mutants 88-8-3 and 33-9-15 of Tulaipanja (Basak and Ganguli 1995) and 124-17-4 of Gobindabhog (Ghosh and Ganguli 1990) and three 'basmati' varieties - Basmati 370, Pakistan Basmati and Pusa Basmati I. The mutants retained the characteristic aroma of their parents. Two rows each of P_1, P_2, F_1, BC_1 and BC_2 generations and ten rows of F_2 plants were grown in 3 m long plots with a spacing of 20×30 cm^2. Standard cultural practices along with a fertilizer dose of 60 kg N, 30 kg P_2O_5 and 30 kg K_2O per hectare were applied. Ten plants from each of the parents (P_1 and P_2) and F_1s, twenty-five plants from each of the back cross-generations (BC_1 and BC_2) and fifty plants from each of the F_2s of five crosses were randomly selected from each replication for recording observations on ten important quantitative characters.

The individual scaling tests (Mather 1949 and Hayman and Mather 1955) and joint scaling test (Cavalli 1952) were applied to test the adequacy of additive-dominance model. When the model was adequate the genetic parameters 'm', 'd' and 'h' were estimated following Cavalli (1952). Otherwise six-parameters model (Mather and Jinks 1971) following weighted least square technique was used to estimate the components of different parameters viz., 'm', 'd', 'h', 'i', 'j' and 'l'.

RESULTS AND DISCUSSION

Results of individual scaling test and combined scaling test (Table 1) were non-significant for days to flowering and test weight in 88-8-3/ Basmati 370, spikelet fertility per cent in 88-8-3/ Pakistan Basmati and 124-17-4/ Basmati 370, plant height and grain number per panicle in 33-9-15/ Pusa Basmati I and days to flowering, spikelet fertility per cent, test weight and grain yield per plant in 124-17-4/ Pusa Basmati I, indicating the absence of epistatic interaction. Hence, above mentioned characters in respective crosses showed simple type of inheritance, while epistasis contributed significantly towards the inheritance of remaining characters of all crosses.

The study of gene effects (Table 2) revealed that both additive [d] and dominance [h] genetic effects had significant contributions in the majority of crosses for the expression of plant height, days to flowering, panicle number per plant, panicle length, spikelet fertility percent, grain length, grain length/breadth ratio, test weight and grain yield per plant as reported earlier by Mahamoud *et al.* (1984) for days to flowering and tiller number, Perera *et al.* (1986) for days to flowering and panicle number and Roy and Panwar (1993) for plant height, days to flowering, panicle length, kernel length and grain yield per plant.

Additive [d] and additive × additive [i] gene effects were the only signficant components for the inheritance of plant height (d = 17.94** and i = 22.84*) and grain number per panicle (d = 30.02* and i = 15.44*) in 88-8-3/ Basmati 370, and test weight (d = 6.91** and i = 5.10*) in 124-17-4/ Basmati 370. Additive [d] gene effect alone was significant for the expression of spikelet fertility per cent (d = 7.04**) in 88-8-3/ Pakistan Basmati while additive x additive [i] gene effect was the only significant component for panicle length (d = 4.73*) in 124-17-4/ Basmati 370. These additive [d] and additive x additive [i] gene effects would be fixable in later generations. Hence, these traits in respective crosses offer scope for improvement through phenotypic selection based on pedigree method.

The additive [d] gene effect was more important than dominance [h] gene effect in the inheritance of days to flowering (d = 13.98** > h = 3.53**), panicle length [d = 0.95** but h = -4.20, which is nonsignificant (ns)] and test weight (d =5.21** > h = 0.88**) in 88-8-3/ Basmati 370, and spikelet fertility percent (d = 6.27** but h = 12.01^{ns}) in 33-9-15/ Pusa Basmati I. The importance of additive [d] gene effects over dominance [h] gene effects was also observed for plant height (d = 14.43** but h = 19.02^{ns}), days to flowering (d = 6.79** > h = 3.43**), spikelet fertility per cent (d = 8.80** > h = 8.10**) and test weight (d = 5.98** > h = 0.16*) in 124-17-4/ Pusa Basmati I. The results indicated much scope for improvement of these traits in respective crosses through phenotypic selection. However, the progress of selection will depend on the nature and magnitude of different interaction effects present, in addition to dominance effect. The greater role of additive effect was also reported by Buu and Hanh (1991) for test weight and Chakraborty and Hazarika (1996) for plant height, panicle length and test weight.

The dominance [h] effect was more important than the additive [d] gene effect in the inheritance of panicle number per plant (h = 53.02** > d = 2.40**), spikelet fertility per cent (h = 50.90** > d = 6.52**), grain length (h = 2.33* > d = 1.60**) and grain yield per plant (h = 102.95** > d = 4.85**) in 88-8-3/ Basmati 370. The dominance [h] gene effect was also more important in all ten characters, except spikelet fertility per cent (h being nonsignificant), in two crosses of 88-8-3/ Pakistan Basmati and 33-9-15/ Pusa Basmati-1. The greater importance of dominance [h] gene effect than additive [d] gene effect was also observed for all traits in the two crosses of mutant 124-17-4 with Basmati 370 and Pusa Basmati I, except panicle length (d = 0.02^{ns} and h = 10.53^{ns}), grain number per panicle (d = 75.33** but h = - 32.08^{ns}) and test weight (d = 6.91** but h = 11.51^{ns}) in 124-17-4/ Basmati 370 and plant height (d = 14.43** > h = 19.02^{ns}), days to flowering (d = 6.79** > h = 3.43**), spikelet fertility per cent (d =8.80** but h =8.10**) and test weight (d = 5.98** > h =0.16*) in 124-17-4/ Pusa Basmati I. The important contribution of dominance effect was also explained by Singh *et al.* (1996) for tiller number, grain number, test weight and grain yield per plant and Mishra and Singh (1998) for plant height, panicle number, panicle length, grain number, test weight and grain yield per plant. Development of hybrids in the above mentioned cases would be a useful proposition provided hybrid seed production is relatively simple and economically viable.

The additive × additive [i] type of interaction was also responsible in the majority of crosses for the expression of plant height, panicle number per plant, panicle length, grain length, grain length/breadth ratio and grain yield per plant. The significant additive effect [i] was noticed earlier by Buu and Hanh (1991) for panicle number and Majumdar (1995) for plant height, panicle number per plant, panicle length and grain yield per plant.

Table 1. Scaling tests and joint scaling test for ten quantitatives traits in five crosses of rice

Cross combinations	Scales			Joint scaling test
	A	B	C	χ^2 Value
		Plant height		
88-8-3/Basmati-370	-5.03 ± 8.24	-11.53 ± 3.34**	-39.40 ± 8.43**	28.62**
88-8-3/Pakistan Basmati	-0.43 ± 4.82	0.333 ± 4.58	-80.26 ± 8.37**	92.57**
33-9-15/Pusa Basmati-I	32.42 ± 16.87	5.41 ± 5.23	-1.12 ± 3.96	4.95
124-17-4/Basmati-370	1.39 ± 7.66	-9.91 ± 5.29	-31.62 ± 1.76**	325.54**
124-17-4/Pusa Basmati-I	-22.98 ± 8.20**	-13.03 ± 4.64**	-46.50 ± 6.68**	60.73**
		Days to flowering		
88-8-3/Basmati-370	0.65 ± 1.53	1.75 ± 1.72	3.30 ± 5.39	1.43
88-8-3/Pakistan Basmati	1.59 ± 0.92	-0.22 ± 1.10	-6.67 ± 2.68*	11.16*
33-9-15/Pusa Basmati-I	0.41 ± 1.15	0.68 ± 1.05	10.96 ± 1.66**	45.94**
124-17-4/Basmati-370	3.03 ± 1.13**	3.04 ± 1.00**	2.88 ± 1.48	16.23**
124-17-4/Pusa Basmati-I	0.28 ± 1.16	0.11 ± 0.91	4.80 ± 5.97	0.83
		Panicle number/plant		
88-8-3/Basmati-370	4.47 ± 1.33**	5.79 ± 1.87**	-8.63 ± 2.69**	34.94**
88-8-3/Pakistan Basmati	0.50 ± 1.15	4.99 ± 1.35**	3.62 ± 2.61	14.50**
33-9-15/Pusa Basmati-I	-0.43 ± 1.26	10.02 ± 1.44**	-3.79 ± 3.94	56.85**
124-17-4/Basmati-370	4.24 ± 1.55**	3.32 ± 1.38*	-10.43 ± 1.94**	108.94**
124-17-4/Pusa Basmati-I	3.79 ± 0.86**	7.14 ± 2.65**	2.97 ± 1.97	25.48**
		Panicle length		
88-8-3/Basmati-370	-2.25 ± 0.94*	-1.33 ± 1.55	-2.42 ± 1.18*	10.44*
88-8-3/Pakistan Basmati	-3.10 ± 0.83**	2.25 ± 0.78**	-11.99 ± 1.83**	66.35**
33-9-15/Pusa Basmati-I	2.56 ± 1.17*	4.47 ± 0.73**	1.48 ± 1.00	51.57**
124-17-4/Basmati-370	-0.06 ± 1.72	-1.16 ± 1.30	-5.96 ± 0.82**	52.95**
124-17-4/Pusa Basmati-I	-3.42 ± 1.34*	3.25 ± 1.25**	-5.12 ± 1.82**	24.96**
		Grain number/ panicle		
88-8-3/Basmati-370	-9.69 ± 6.13	1.97 ± 6.77	-23.16 ± 7.85**	10.59**
88-8-3/Pakistan Basmati	-6.38 ± 7.82	-4.64 ± 3.01	-55.29 ± 17.97**	11.75**
33-9-15/Pusa Basmati-I	-8.34 ± 4.91	-16.83 ± 12.70	13.97 ± 20.15	5.13
124-17-4/Basmati-370	-50.61 ± 7.76**	-27.94 ± 6.65**	-103.45 ± 13.67**	113.07**
124-17-4/Pusa Basmati-I	-55.47 ± 10.12**	-35.57 ± 10.52**	-52.62 ± 16.89**	48.76**
		Spikelet fetility per cent		
88-8-3/Basmati-370	0.78 ± 1.63	11.17 ± 2.81**	-4.39 ± 3.37	25.21**
88-8-3/Pakistan Basmati	2.01 ± 3.38	-2.22 ± 3.38	5.45 ± 3.36	4.16
33-9-15/Pusa Basmati-I	-4.17 ± 2.77	7.48 ± 2.22*	10.97 ± 6.04	19.03**
124-17-4/Basmati-370	-0.41 ± 1.70	1.80 ± 3.67	-13.86 ± 9.79	2.49
124-17-4/Pusa Basmati-I	-1.76 ± 1.76	-6.38 ± 3.57	-5.64 ± 3.37	4.89
		Grain length		
88-8-3/Basmati-370	0.08 ± 0.18	-0.47 ± 0.06**	-1.66 ± 0.47**	74.68**
88-8-3/Pakistan Basmati	0.12 ± 0.19	0.01 ± 0.07	-0.67 ± 0.11**	40.26**
33-9-15/Pusa Basmati-I	0.37 ± 0.18*	-0.40 ± 0.29	-1.79 ± 0.19**	97.26**
124-17-4/Basmati-370	0.53 ±0.24*	0.56 ± 0.54	-1.64 ± 0.48**	19.84**
124-17-4/Pusa Basmati-I	0.15 ± 0.12	0.30 ± 0.43	-1.48 ± 0.61*	8.36*
		Grain length/breadth ratio		
88-8-3/Basmati-370	0.09 ± 0.15	-0.21 ± 0.04**	-0.60 ± 0.35	30.89**
88-8-3/Pakistan Basmati	0.30 ± 0.03**	-0.03 ± 0.08	-0.37 ± 0.09**	112.74**
33-9-15/Pusa Basmati-I	0.23 ± 0.14	0.04 ± 0.06	-0.73 ± 0.06**	139.78**
124-17-4/Basmati-370	0.45 ± 0.15**	0.40 ± 0.29	-0.43 ± 0.26	14.86**
124-17-4/Pusa Basmati-I	0.35 ± 0.11**	0.28 ± 0.23	-0.32 ± 0.28	13.93**
		Test weight		
88-8-3/Basmati-370	2.04 ± 1.46	-0.23 ± 0.73	-0.91 ± 1.77	2.35
88-8-3/Pakistan Basmati	2.45 ± 0.93**	2.26 ± 0.23**	3.51 ± 0.44**	143.94**
33-9-15/Pusa Basmati-I	3.33 ± 1.32**	1.64 ± 1.20	0.52 ± 1.52	8.22*
124-17-4/Basmati-370	0.92 ± 0.43*	1.32 ± 2.49	-2.85 ±1.58	3.45*
124-17-4/Pusa Basmati-I	0.51 ± 0.73	2.18 ± 1.68	-2.05 ± 2.10	3.13
		Grain yield/plant		
88-8-3/Basmati-370	7.29 ± 2.38**	6.56 ± 3.72	-21.85 ± 3.27**	117.90**
88-8-3/Pakistan Basmati	4.14 ± 3.17	10.86 ± 3.69**	-6.43 ± 6.84	11.74**
33-9-15/Pusa Basmati-I	4.77 ± 3.26	11.99 ± 4.10**	1.22 ± 5.06	10.18*
124-17-4/Basmati-370	3.27 ± 4.82	-0.53 ± 1.94	-32.68 ± 2.78**	247.97**
124-17-4/Pusa Basmati-I	0.37 ± 3.11	6.50 ± 3.95	-5.33 ± 4.83	4.41

* - Significant at P = 0.05, ** - Significant at P = 0.001

Table 2. Estimates of gene effect for ten quantitative characters in five crosses of aromatic rice

Cross combinations	Gene effect m	d	h	i	j	l	Type of Epistasis
			Plant height				
88-8-3 × Basmati-370	105.70 ± 11.57**	17.94 ± 0.32**	56.34 ± 30.08	22.84 ± 11.56*	-6.51 ± 8.59	-6.31 ± 19.09	
88-8-3 × Pakistan Basmati	51.58 ± 10.39**	21.12 ± 0.56**	189.56 ± 25.34**	80.18 ± 10.37**	0.76 ± 6.55	-80.07 ± 15.38**	Duplicate
33-9-15 × Pusa Basmati-1	107.61 ± 0.43**	4.99 ± 0.44**	44.70 ± 1.04**				
124-17-4 × Basmati-370	120.82 ± 9.30**	2.54 ± 0.34**	58.68 ± 27.82*	23.12 ± 9.29*	-11.30 ± 9.27	-14.65 ± 18.57	
124-17-4 × Pusa Basmati-I	116.47 ± 11.31**	14.43 ± 0.38**	19.02 ± 30.78	10.51 ± 11.31	-9.95 ± 9.35	25.49 ± 12.79*	
			Days to flowering				
88-8-3 × Basmati-370	113.32 ± 0.22**	13.98 ± 0.22**	3.53 ± 0.50**				
88-8-3 × Pakistan Basmati	113.01 ± 2.83**	6.22 ± 0.20**	18.59 ± 6.33**	8.04 ± 2.82**	1.81 ± 1.31	-9.41 ± 3.67**	Duplicate
33-9-15 × Pusa Basmati-1	128.63 ± 1.96**	9.03 ± 0.29**	-15.07 ± 5.02**	-9.87 ± 1.94**	-0.27 ± 1.48	8.78 ± 3.18**	Duplicate
124-17-4 × Basmati-370	107.95 ± 1.88**	11.83 ± 0.21**	14.03 ± 4.89**	3.19 ± 1.87	-0.01 ± 1.44	-9.25 ± 3.12**	Duplicate
124-17-4 × Pusa Basmati-I	116.21 ± 0.21**	6.79 ± 0.21**	3.43 ± 0.43**				
			Panicle number/plant				
88-8-3 × Basmati-370	-3.89 ± 3.35	2.40 ± 0.39**	53.02 ± 8.29**	18.89 ± 3.33**	-1.32 ± 2.28	-29.16 ± 5.06**	Duplicate
88-8-3 × Pakistan Basmati	12.33 ± 2.91**	3.20 ± 0.39**	16.36 ± 6.83*	1.87 ± 2.88	-4.49 ± 1.73**	-7.35 ± 4.05	
33-9-15 × Pusa Basmati-1	4.06 ± 3.89	7.42 ± 0.42**	39.36 ± 8.48**	13.39 ± 3.87**	-10.45 ± 1.65**	-22.98 ± 4.85**	Duplicate
124-17-4 × Basmati-370	-4.85 ± 1.87**	0.53 ± 0.41	49.53 ± 5.27**	17.99 ± 1.82**	0.92 ± 1.78	-25.54 ± 3.70**	Duplicate
124-17-4 × Pusa Basmati-I	3.90 ± 3.19	1.82 ± 0.34**	33.26 ± 8.76**	7.95 ± 3.17*	-3.35 ± 2.75	-18.80 ± 5.67**	Duplicate
			Panicle length				
88-8-3 × Basmati-370	28.32 ± 2.15**	0.95 ± 0.09**	-4.20 ± 5.90	-1.15 ± 2.15	-0.92 ± 1.82	4.72 ± 2.01*	
88-8-3 × Pakistan Basmati	15.62 ± 2.12**	1.36 ± 0.13**	24.02 ± 4.92**	11.14 ± 2.12**	-5.35 ± 1.14**	-10.28 ± 2.87**	Duplicate
33-9-15 × Pusa Basmati-1	16.99 ± 1.41**	1.86 ± 0.34**	25.63 ± 3.95**	5.55 ± 1.37**	1.91 ± 1.37	-12.59 ± 2.57**	Duplicate
124-17-4 × Basmati-370	21.47 ± 2.29**	0.02 ± 0.10	10.53 ± 6.64	4.73 ± 2.29*	-1.10 ± 2.15	-3.50 ± 4.37	
124-17-4 × Pusa Basmati-I	20.18 ± 2.27**	1.06 ± 0.18**	15.37 ± 5.91**	4.95 ± 2.26*	-6.68 ± 1.71**	-4.77 ± 3.80	
			Grain number/panicle				
88-8-3 × Basmati-370	68.15 ± 10.98**	30.02 ± 0.82**	40.68 ± 29.32	15.44 ± 7.54*	-11.66 ± 8.76	-7.72 ± 18.92	
88-8-3 × Pakistan Basmati	49.48 ± 19.54*	19.85 ± 0.77**	88.00 ± 43.12*	44.27 ± 19.53*	-1.74 ± 8.24	-33.26 ± 24.18	
33-9-15 × Pusa Basmati-1	76.80 ± 0.65**	1.25 ± 0.65	17.30 ± 1.34**				
124-17-4 × Basmati-370	103.97 ± 16.82**	75.33 ± 1.01**	-32.08 ± 40.45	24.94 ± 16.79	-22.66 ± 10.20*	53.60 ± 24.22*	
124-17-4 × Pusa Basmati-I	178.34 ± 21.91**	64.31 ± 0.96**	-173.40 ± 54.35**	-38.42 ± 21.89	-19.89 ± 14.46	129.45 ± 33.27**	Duplicate
			Spikelet fertility percent				
88-8-3 × Basmati-370	66.43 ± 3.24**	6.52 ± 1.17**	50.90 ± 8.44**	16.34 ± 3.02**	-10.39 ± 3.15**	-28.29 ± 5.40**	Duplicate
88-8-3 × Pakistan Basmati	83.07 ± 0.76**	7.04 ± 0.88**	1.84 ± 0.97				
33-9-15 × Pusa Basmati-1	87.04 ± 5.57**	6.27 ± 1.08**	12.01 ± 12.44	7.66 ± 5.47	11.65 ± 3.04**	4.35 ± 7.42	
124-17-4 × Basmati-370	82.89 ± 0.92**	6.49 ± 0.93**	9.61 ± 1.03**				
124-17-4 × Pusa Basmati-I	80.28 ± 0.72**	8.80 ± 0.74**	8.10 ± 1.14**				
			Grain length				
88-8-3 × Basmati-370	8.15 ± 0.49**	1.60 ± 0.007**	2.33 ± 1.06*	1.27 ± 0.49**	-0.55 ± 0.17**	-0.87 ± 0.58	
88-8-3 × Pakistan Basmati	8.34 ± 0.22**	1.33 ± 0.009**	1.90 ± 0.63**	0.80 ± 0.22**	-0.11 ± 0.20	-0.93 ± 0.41*	Duplicate
33-9-15 × Pusa Basmati-1	7.47 ± 0.39**	1.46 ± 0.01**	3.32 ± 1.09**	1.76 ± 0.39**	-0.76 ± 0.34*	-1.73 ± 0.71*	Duplicate
124-17-4 × Basmati-370	5.67 ± 0.74**	2.62 ± 0.007**	5.99 ± 1.97**	2.72 ± 0.74**	0.02 ± 0.58	-3.81 ± 1.26**	Duplicate
124-17-4 × Pusa Basmati-I	6.30 ± 0.75**	2.45 ± 0.01**	4.12 ± 1.79*	1.94 ± 0.75**	0.15 ± 0.44	-2.39 ± 1.07*	Duplicate
			Grain length/breadth ratio				
88-8-3 × Basmati-370	3.83 ± 0.38**	0.63 ± 0.007**	0.88 ± 0.83	0.48 ± 0.38	-0.30 ± 0.15*	-0.36 ± 0.46	
88-8-3 × Pakistan Basmati	3.48 ± 0.12**	0.44 ± 0.01**	1.50 ± 0.30**	0.63 ± 0.11**	-0.33 ± 0.09**	-0.90 ± 0.19**	Duplicate
33-9-15 × Pusa Basmati-1	3.32 ± 0.16**	0.57 ± 0.01**	2.05 ± 0.46**	1.01 ± 0.16**	-0.19 ± 0.15	-1.28 ± 0.30**	Duplicate
124-17-4 × Basmati-370	2.41 ± 0.39**	1.25 ± 0.005**	3.13 ± 1.06**	1.27 ± 0.39**	-0.05 ± 0.31	-2.12 ± 0.68**	Duplicate
124-17-4 × Pusa Basmati-I	2.71 ± 0.38**	1.23 ± 0.01**	2.43 ± 0.95*	0.96 ± 0.38*	-0.07 ± 0.26	-1.59 ± 0.58**	Duplicate
			Test weight				
88-8-3 × Basmati-370	18.01 ± 0.06**	5.21 ± 0.06**	0.88 ± 0.14**				
88-8-3 × Pakistan Basmati	15.87 ± 1.03**	4.29 ± 0.05**	9.22 ± 2.95**	1.20 ± 1.03	-0.19 ± 0.95	-5.91 ± 1.94**	Duplicate
33-9-15 × Pusa Basmati-1	12.51 ± 2.33**	4.51 ± 0.06**	14.79 ± 6.13*	4.44 ± 2.33	-1.69 ± 1.78	-9.41 ± 3.87*	Duplicate
124-17-4 × Basmati-370	11.34 ± 2.92**	6.91 ± 0.01**	11.51 ± 8.08	5.10 ± 2.52*	0.39 ± 2.50	-7.33 ± 5.23	
124-17-4 × Pusa Basmati-I	15.50 ± 0.03**	5.98 ± 0.03**	0.16 ± 0.07*				
			Grain yield/plant				
88-8-3 × Basmati-370	-17.01 ± 4.20**	4.85 ± 0.57**	102.95 ± 12.17**	35.71 ± 4.17**	0.73 ± 4.01	-49.56 ± 8.36**	Duplicate
88-8-3 × Pakistan Basmati	-1.92 ± 8.01	4.03 ± 0.67**	79.04 ± 19.16**	21.43 ± 7.98**	-6.71 ± 4.76	-36.43 ± 11.40**	Duplicate
33-9-15 × Pusa Basmati-1	2.78 ± 6.61	3.93 ± 0.61**	62.23 ± 17.21**	15.55 ± 6.58*	-7.22 ± 5.02	-32.31 ± 10.98**	Duplicate
124-17-4 × Basmati-370	-16.11 ± 4.81**	5.46 ± 0.73**	89.59 ± 14.41**	35.42 ± 4.75**	3.81 ± 4.94	-38.17 ± 9.84**	Duplicate
124-17-4 × Pusa Basmati-I	19.50 ± 0.63**	5.01 ± 0.65**	16.97 ± 1.08**				

* - Significant at P = 0.05, ** - Significant at P = 0.01

Significant contribution of additive × dominance [j] gene effect was observed in small number of cases indicating less importance of this type of interaction.

In the study of gene effects, the important role of dominance × dominance [l] type of interaction has been well established in most of the cross-combinations for the inheritance of days to flowering, panicle number per plant, panicle length, grain length, grain length/breadth ratio and grain yield per plant as was also noticed by Dhanakadi and Subramanian (1994) for panicle number per plant and grain yield per plant and Singh *et al.* (1996) for panicle number per plant and panicle length.

Predominance of duplicate type of epistasis as evidenced from opposite sign of [h] and [l] was noticed for the expression of days to flowering, panicle number per plant, grain length, grain length/breadth ratio, test weight and grain yield per plant in majority of the crosses which showed non-allelic interaction. Duplicate type of epistasis was also observed by Perera *et al.* (1986) for days to flowering and panicle number and Buu and Tao (1992) for panicle number and grain yield per plant. This type of epistasis tends to cancel or weaken the effect of each other in hybrid combination and hinders the progress made under selection and therefore, selection would have to be deferred till later generations of segregation where dominance effects are dissipated.

Thus, both additive and nonadditive gene effects were important for the inheritance of almost all the characters studied. The use of population improvement concept may become an amenable solution. Frey (1975) explained the use of this technique in highly autogamous crop. Biparental mating, recurrent selection and diallel selective mating system (Jenson, 1970) might be profitable in exploiting both additive and nonadditive gene action to obtain desirable recombinants having the characteristics of reduced height high yielding aromatic plants with long slender grains similar to 'basmati' type.

The conclusions drawn from the gene effects for different characters are based on digenic interaction model only. However, possibilities of trigenic or higher order interactions and /or linkages among the interacting genes cannot be ruled out.

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REFERENCES

Basak AK, Ganguli PK and Lodh SB 1995 Eating and cooking quality in induced mutants of a scented traditional cultivar Tulaipanja. In: Proceedings of National Symposium on Sustainable Agriculture in Sub-humid Zone held at Visva-Bharati, Palli Siksha Bhavana, Sriniketan, India. pp. 215-218.

Buu BC and Hanh TT 1991 Some quantitative characters of rice *Oryza sativa* L. studied by triple cross analysis. In: Rice Genetics, IRRI, Manila, Philippines. pp. 766-767.

Buu BC and Tao PB 1992 Genetic nature of some agronomic traits in two elite lines of rice. Int. Rice Res. Newsl. 17: 11.

Cavalli LL 1952 An analysis of linkage in quantitative inheritance. In: Reeve ECR and Waddington CH (eds.) Quantitative inheritance. HMSO, London. pp. 135-144.

Chakraborty S and Hazarika GN 1996 Gene action for some quantitative traits in rice. Oryza. 33 : 136-137.

Dhanakodi CV and Subramanian M 1994 Genetics of quantitative characters in short duration rice (*Oryza sativa* L.). Madras Agric. J. 81: 414-415.

Frey KJ 1975 Breeding concepts and techniques for self-pollinated crops. In: International Workshop on Grain Legumes, ICRISAT, Hyderabad, India. pp. 257-258.

Ghosh SC and Ganguli PK 1990 Gamma-ray induced mutants in a traditional rice cultivar in M_3 generation. In: Proceedings of National Seminar on Agroecosystem Management held at Visva-Bharati, Palli Siksha Bhavana, Sriniketan, India. pp. 134-139.

Hayman BI and Mather K 1955 The description of genetic interaction in continuous variation. Biometrics. 11: 69-82.

Jensen NF 1970 A diallel selective mating system for cereal breeding. Crop Sci. 10: 629-635.

Mahmoud AA, Sayyed SMA, Fayed AH, Latif MAA and Ismail MA 1984 Genetic consequences of the transfer of induced mutations in rice *Oryza sativa* L. II. Days to heading and tillering capacity. Indian J. Genet. 44: 533-537.

Majumdar ND 1995 Inheritance of phosphorus uptake and agronomic characters in rice. Oryza. 32 : 83-86.

Mather K (ed.) 1949 Biometrical Genetics. 1st Edn. Methuen, London.

Mather K and Jinks JL (ed.) 1971 Biometrical Genetics. 2nd Edn. Chapman and Hall, London.

Mishra DK and Singh CB 1998 Gene action for seed yield and its components in rice under different environments. Oryza. 35: 325-328.

Perera ALT, Senadhira D and Lawrence MJ 1986 Genetic architecture of economically important characters and prediction of performance of recombinant inbred lines in rice. In: Rice Genetics, IRRI, Manila, Philippines. pp. 565-568.

Roy A and Panwar DVS 1993 Nature of gene interaction in the inheritance of quantitative characters in rice. Ann. Agric. Res. 14: 286-291.

Singh D, Katoch PC and Kaushik RP 1996 Genetics of yield and yield components in rice. Oryza. 33: 174-177.