Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2320-7051.6055

ISSN: 2320 – 7051

Int. J. Pure App. Biosci. **5 (6):** 870-878 (2017)

Research Article

International Journal of Pure & Applied Bioscience

OPEN ACCESS

Generation Mean Analysis for Yield and Quality Traits in Aromatic Genotypes of Rice (*Oryza sativa* L.)

Dilruba A. Bano[1*], Sheo P. Singh[1] and Showkat A. Waza[2]

[1]Department of Genetics and Plant Breeding, Institute of Agricultural Sciences, BHU, Varanasi-221005

[2]Division of Genetics and Plant Breeding, MRCFC Khudwani, SKUAST-Kashmir

*Corresponding Author E-mail: dabgpb@gmail.com

Received: 1.12.2017 | Revised: 26.12.2017 | Accepted: 29.12.2017

ABSTRACT

The present investigation in aromatic rice (Oryza sativa L.) was undertaken for studying the magnitude of gene action in three cross combination for eight yield and nine quality traits deploying generation mean analysis following six parameter model for parents (P1 and P2), F1, F2, BC1 and BC2 generations during three crop season. The results of the scaling tests revealed that the additive-dominance model was inadequate for all of the characters evaluated in all of the three crosses, suggested the existence of epistasis in the inheritance of these characters. Mean values of all the crosses revealed significant. Additive gene effect [d] had significant contribution in all the crosses except Pusa Sugandh-5 × Type-3 for days to maturity and main panicle length where as dominance [h] genetic effects was significant for all of the characters in three crosses except Kasturi Basmati × Type-3 for main panicle length and amylose content. Major contribution of duplicate epistasis was revealed by all the three crosses, for most of the character. Few crosses revealed complementary epistasis for the traits. The present study demonstrates the importance of additive, dominance and epistatic gene effects for the inheritance of almost all the yield as well as quality characters studied.

Key words: *Rice, Scaling test, Generation mean, Quality traits*

INTRODUCTION

Rice is one of the most crucial food crops in the world. As more than 50 per cent of the world population depends on rice for their staple diet. It is cultivated in 114 countries across the globe, but 90 percent of world's rice is grown and consumed in Asia. Nowadays, the quality considerations assume enhanced importance, especially in the countries which are self-sufficient in their production. As per capita income increases the consumption preference of common man is shifting towards quality rice. Aromatic rices constitute a small but special group of rices which are considered best in quality. Among the quality rices, Basmati is the unique aromatic quality rice. It is a nature's gift to Indian sub-continent. As living standards are improving steadily, human demand for high quality rice is continuously on an increase. This entails in incorporation of preferred grain quality features as the most important objective next to yield enhancement.

Cite this article: Bano, D.A., Singh, S.P. and Waza, S.A., Generation Mean Analysis for Yield and Quality Traits in Aromatic Genotypes of Rice (*Oryza sativa* L.), *Int. J. Pure App. Biosci.* **5(6):** 870-878 (2017). doi: http://dx.doi.org/10.18782/2320-7051.6055

Based on the survey of 11 major rice growing countries, Juliano and Duff[8] concluded that grain quality is second only to yield as the major breeding objective. In the future, improvement of grain quality traits will be even more enhanced as once the very poor, many of whom depend largely on rice for their staple food become better off and begin to demand higher quality rice[24].

Genetic improvement for rice has thoroughly been studied worldwide. To achieve genetic improvement of yield and quality traits, it is imperative to have knowledge about the nature of gene interactions for different characters. The generation mean analysis has been considered to be one of the best methods for estimating the different components of genetic variance and presence or absence of epistasis. Therefore, the study of genetics of yield and quality traits is important to formulate a breeding programme to improve yield while maintaining the quality of rice. Keeping in view the above mentioned facts, present investigation was formulated to study to the gene action for yield and quality traits in aromatic genotypes of rice.

MATERIALS AND METHODS

The material for the present investigation comprised of three crosses among five aromatic genotypes of rice. Six generations viz., (P1 and P2), F1, F2, BC1 and BC2 generations of three crosses were raised in a Compact Family Randomized Block Design with three replications at Institute of Agricultural Sciences, Banaras Hindu University during *Kharif* -2016. The site of study is situated at 25^0 18´ N latitude and 83^0 03´ E longitudes, at an elevation of 80.71 m above mean sea level .Three rows of each parent, F1 and backcrosses and 10 rows of F2 of 5m each were transplanted following a spacing of 15 x 20 cm within and between rows. The recommended package of practices was followed to raise a good crop. Observations were recorded on eight yield and nine quality traits viz., days to 50% flowering, days to maturity, plant height (cm), main panicle length (cm), effective tillers/plant, filled spikelet per panicle, 100 grain weight (g) and grain yield/plant (g) on 10 selected plants from parental generation and F1's, 30 plants each from B1 and B2 generations and 75 plants from each F2, from each replication. However, in case of quality traits, observation was estimated for kernel length before cooking (mm), kernel breadth before cooking (mm), kernel length after cooking and kernel breadth after cooking (mm), kernel length/breadth ratio before cooking, kernel length/breadth ratio after cooking, kernel elongation ratio, alkali spread value and amylose content. The observations for various traits were recorded as per the standard evaluation system of IRRI[5]. Kernel dimensional analysis was done with the help of graph paper and small millimeter scale. Alkali digestion was estimated by the test devised by Little *et al*[12]. The simplified calorimetric method described by Juliano[9] was followed for the estimation of amylose content. Characters estimated in ratios were first converted to arc sine values for analysis. Generation mean analysis was conducted using six generations viz. parental (P1 and P2), F1, F2, and backcrosses (BC1 and BC2) of three selected crosses involving five diverse parents. Average values were subjected to scaling test[3,13]. The joint scaling test as proposed by Cavalli[1] was also applied to test the adequacy of additive-dominance model because the joint scaling test combines, very effectively, several scaling tests into one and offers a more general and informative approach.

RESULTS AND DISCUSSION

In the present investigation, all the four scaling tests (A, B, C and D) were highly significant for majority of the characters under study, indicating inadequacy of additive-dominance model to explain the inheritance of yield and quality characters. The values for individual scaling tests and estimates of mean ($\hat{m}$), additive gene effect ($\hat{d}$), dominance gene effect ($\hat{h}$) and epistatic interactions *viz.*, additive x additive ($\hat{i}$), additive x dominance ($\hat{j}$) and dominance x dominance ($\hat{l}$) interactions are presented in tables 1 and 2 respectively.

For days to 50% flowering and days to maturity, all the three crosses exhibited significant additive [d] and additive x additive [i] gene effects. The dominance [h] and dominance x dominance [l] effects were significant and in opposite direction for all the crosses indicating duplicate type of epistasis. Though, additive and dominance effect both are significant, but the magnitude of dominant effect is higher than additive effect. In such case, Single plant selection can be postponed and biparental mating should be followed. Similar finding were also presented by Murugan and Ganesan[14], Nayak *et. al.*[16] and Srivastava *et al.*[20].

For the trait plant height and main panicle length, all the six gene effect [m], [d], [h], [i], [j] and [l] revealed significant for cross, Ranbir Basmati × Pusa Basmati-1, with exhibiting complementary epistasis. For such gene effect simple pedigree methods might be helpful for the crop improvement. Prabhu *et al.* [18] reported complementary epistasis for in their study. However, for the cross, Pusa Sugandh-5 × Type-3, additive gene effect played important role for both the traits. Verma *et al.*[23], Thirugnanakumar *et.al.* [21] and Srivastava *et al.*[20] also reported additive gene effect for the traits. However, Crosses Kasturi Basmati × Type-3 exhibited duplicate type of epistasis, as the signs of dominant [h] and dominance x dominance [l] gene effects were in opposite direction. In such crosses, selection should be delayed in advanced generation, so that heterozygosity will be reduced and thereby reducing dominance gene effects.

The estimates of additive and dominant component of gene effects were significant in almost all the crosses for effective tillers per plants. All the non-allelic interactions, [i], [j] and [l] were significant for cross, Pusa Sugandh-5 × Type-3. In all the three crosses, dominant type of epistasis interaction was revealed. Selection for this trait likely confuses. Hence, selection has to postponed to later generations by reduction of heterozygosity and there by reducing dominance gene effects. Similar reports were studied by Murugan and Ganeshan[14], Jhansi Rani *et al.*[19] and Prabhu *et.al*[18].

For the character filled spikelet per panicle analysis of all types of gene effects i.e. [m], [d], [h], [i], [j] and [l] revealed significant for crosses, Pusa Sugandh-5 × Type-3 and Ranbir Basmati × Pusa Basmati-1. Duplicate type of epistasis was evident for Ranbir Basmati × Pusa Basmati-1 whereas, complementary type makes its existence in two cross, Pusa Sugandh-5 × Type-3 and Kasturi Basmati × Type-3 for the same trait. This result was in agreement with, Murugan and Ganeshan[14], Kumar *et al.*[11], Jhansi Rani *et al.*[19] and Prabhu *et al*[18].

For 100 grain weight, epistatic interactions is concerned that additive × additive [i] and dominant × dominant [l] appeared to play an important role for the inheritance of this important trait as they were highly significant in almost all the crosses. However, additive × dominance could be visualized significant in crosses, Pusa Sugandh-5 × Type-3 and Ranbir Basmati × Pusa Basmati-1 for the trait. Only duplicate type of epistasis was exhibited by all the crosses for this one of the important yield traits. Similar results were recorded by Verma *et.al.*[23], Murugan and Ganeshan[14] and Srivastava *et al*[20].

For grain yield per plant, the additive [d] and dominant [h] gene components were significant in all the crosses, while, the magnitude of dominance component was higher than additive component. Additive × additive [i] and dominant × dominant [l] component revealed significance in all the crosses. Positive and highly significant [h] and [l] component in cross viz., Pusa Sugandh-5 × Type-3 indicates complementary epistasis and suggestions for selection in early generation might be effective. Moreover, two cross revealed duplicate epistasis. These results were in agreement by Nayak *et al.*[15], Srivastava *et al.*[20], Kumar *et al.*[11] and Prabhu *et al*[18].

ABCD scaling tests were significant for trait kernel length before cooking. The additive [d] and dominance [h] gene effects were positively significant in all crosses except cross *i.e* Kasturi Basmati × Type-3) for kernel length before cooking. Moreover, non-allelic gene interactions were concerned, additive × additive [i] gene effects were positively significant in crosses Pusa Sugandh-5 × Type-3 and Ranbir Basmati × Pusa Basmati-1, while negatively significant in cross Kasturi Basmati × Type-3. All the six components of gene effects were observed to be significant in cross viz., Pusa Sugandh-5 × Type-3 and Ranbir Basmati × Pusa Basmati-1. Moreover, duplicate type of epistasis makes its existence in all the crosses for this trait. Predominant non additive gene action coupled with duplicate epistasis restricts the scope for further improvement through direct selection. Nayak[16] and Kumar *et al.*[11], P. Satheesh Kumar *et al*.[10] also observed all three types of interactions.

For the trait kernel breadth before cooking, the scaling tests were revealed significant. Among main gene effect, additive [d] and dominant [h] components were significant in all crosses except in Ranbir Basmati × Pusa Basmati-1. The dominant gene action was more predominant than additive type indicating that selection in early segregating generations is ineffective. All three types of interactions were significant in all crosses which indicated the complex nature of inheritance of this trait. The additive [d] type of gene effects was negative and significant, which are desirable for selection of slender grain types. Complementary epistasis was observed in all crosses as the [h] and [l] were in same direction which was in conformity with Kumar *et.al.*[11] and P. Satheesh Kumar *et al*[10].

Kernel L/B ratio is an important quality parameter as it denotes shape and size of the grain. Generally consumers prefer slender grain varieties. In the present study, for L/B ratio significance of scaling tests suggested presence of non allelic interactions. Analysis of all types of gene effects i.e. [m], [d], [h], [i], [j] and [l] revealed significant for Kasturi Basmati × Type-3 whereas additive × additive gene effect is nonsignificant for first cross viz., Pusa Sugandh-5 × Type-3 for this trait. Complementary type of epistasis was evident for Ranbir Basmati × Pusa Basmati-1, whereas, duplicate type makes its existence in crosses, Pusa Sugandh-5 × Type-3 and Kasturi Basmati × Type-3 for this trait as [h] and [l] components were opposite in direction. Duplicate type of epistasis was also reported by Nayak *et. al*.[16], Kumar *et.al.*[11] and P. Satheesh Kumar *et al*[10].

Significance of scaling tests indicated the presence of inter allelic interactions for kernel length after cooking. The additive and dominance components were significant for all the crosses. The additive x additive [i] component was positive and significant in all crosses, which gives the indication of simple mass selection that should be effective for further crop improvement programme. Dominance × dominance gene action revealed highly significant for Ranbir Basmati × Pusa Basmati-1 and Kasturi Basmati × Type-3. Existence of duplicate epistasis revealed by Ranbir Basmati × Pusa Basmati-1 and Kasturi Basmati × Type-3. The duplicate type of epistasis can be effectively utilized in pedigree breeding by delaying the selection and it is easier to exploit duplicate type than the complementary type of epistasis. Nayak *et al.*[16] and Chamundeswari[2] reported predominant role of additive gene effects.

Dominant[h] and additive [d] gene effect for kernel breadth after cooking revealed highly significant for all the crosses, and magnitude of dominance component were higher than additive component. The additive x dominance [j] and dominance x dominance

[l] components were negative and significant while additive x additive [i] was positive and significant in Kasturi Basmati × Type-3. Existence of duplicate epistasis revealed in Pusa Sugandh-5 × Type-3 and Kasturi Basmati × Type-3 as the sign of [h] and [l] are in opposite direction. As both additive and non additive gene actions need to be exploited, reciprocal recurrent selection and bi-parental mating in early segregating generations would be more rewarding.

Scaling test revealed significant for kernel L/B ratio after cooking. Among main gene effects, additive and dominance gene effect were highly significant in all the crosses respectively. The dominant gene action was more predominant than additive type indicating that selection in early segregating generations is ineffective All the epistatic interactions [i], [j] and [l] revealed highly significant and making the trait very complex for crop improvement programme. Moreover, duplicate type of epistasis existed by all the three crosses studied.

Generally higher kernel elongation ratio of grains is desirable. In the present study, all the scaling tests were significant except A in Kasturi Basmati × Type-3 , indicating that additive dominance model was inadequate to draw valid inferences on genetic effects governing elongation ratio. Both additive[d] and dominance[h] components were positively and negatively significant in all the crosses. Among non allelic interactions, [i], [j] and [l] components were significant in all crosses. In two crosses additive x additive [i] effects were predominant and positive indicating their importance in the inheritance of kernel elongation ratio which can be further utilized through simple crop improvement programme like mass selection. [h] and [l] are in opposite direction in Ranbir Basmati × Pusa Basmati-1 and Kasturi Basmati × Type-3 indicating duplicate type of epistasis. These finding were in agreement with Nayak *et al*[16].

All three scaling tests were significant in all crosses indicating that additive dominance model was inadequate for alkali spreading value. Among genetic components additive [d] and dominance [h] were significance and opposite in direction in Ranbir Basmati × Pusa Basmati-1 and Kasturi Basmati × Type-3. Prabhu *et al*.[20] reported duplicate epistasis for this trait in their study. All three types of inter allelic interactions were significant in Pusa Sugandh-5 × Type-3. The [h] and [l] effects were in opposite direction indicating duplicate type of epistasis which controls the trait ASV scores. It clearly states that selection in early segregating generations was in effective. Tomar and Nanda [22] reported duplicate epistasis for gelatinization temperature.

Amylose content is an important quality trait which determines the cooking quality of rice. For amylose content also additive dominance model was inadequate to explain its inheritance. Both additive [d] and dominance [h] effects were significant, except for the dominance effect in cross Kasturi Basmati × Type-3 and significance were in same direction in Ranbir Basmati × Pusa Basmati-1 while in opposite direction in Pusa Sugandh-5 × Type-3. All epistatic interactions were significant in all crosses except additive x dominance [j] effect in Pusa Sugandh-5 × Type-3 and also suggested the importance of both additive x additive [i] and dominance x dominance [l] interactions. The genetic components [h] and [l] took opposite signs for this trait in two crosses, which indicated the presence of duplicate dominance epistasis. These findings were in agreement with Prabhu *et al*[20].

Table 1: Test of significance of A, B, C and D scale for yield and quality characteristics

Crosses/Parameters	A	B	C	D
DAYS TO 50% FLOWERING				
Pusa Sugandh-5 × Type-3	2.78**	10.43**	-38.70**	-20.46**
Ranbir Basmati × Pusa Basmati-1	5.16**	16.16**	-59.80**	-40.07**
Kasturi Basmati × Type-3	-0.63	-6.86**	-52.10**	-22.30**
DAYS TO MATURITY				
Pusa Sugandh-5 × Type-3	-3.50**	-3.56	-36.31**	-16.12**
Ranbir Basmati × Pusa Basmati-1	5.64**	17.43**	-58.33**	-40.70**
Kasturi Basmati × Type-3	3.43**	-5.83**	-45.60**	-21.60**
PLANT HEIGHT(cm)				
Pusa Sugandh-5 × Type-3	-1.00	-9.30**	-29.60**	-11.15**
Ranbir Basmati × Pusa Basmati-1	-8.49**	10.56**	-64.14**	-33.10**
Kasturi Basmati × Type-3	-3.06**	-8.63**	-68.75**	-29.52**
MAIN PANICLE LENGTH (cm)				
Pusa Sugandh-5 × Type-3	7.66**	11.00**	-12.53**	-9.10**
Ranbir Basmati × Pusa Basmati-1	-4.06**	-12.89**	-17.99**	-1.52**
Kasturi Basmati × Type-3	-16.50**	-10.33**	-26.63**	0.10
EFFECTIVE TILLERS/ PLANT				
Pusa Sugandh-5 × Type-3	2.26**	-2.56**	-7.90**	-3.80*
Ranbir Basmati × Pusa Basmati-1	-0.93	-1.49*	-10.87**	-4.22**
Kasturi Basmati × Type-3	-9.40**	-5.09**	-2.34	6.07**
FILLED SPIKELETS PER PANICLE				
Pusa Sugandh-5 × Type-3	-5.20**	-5.00**	21.30**	12.25*
Ranbir Basmati × Pusa Basmati-1	6.56**	11.79**	-62.30**	-37.83**
Kasturi Basmati × Type-3	-9.13**	-8.46**	-23.80**	-13.10**
100 GRAIN WEIGHT (g)				
Pusa Sugandh-5 × Type-3	-0.59**	-0.66**	-0.23*	0.48**
Ranbir Basmati × Pusa Basmati-1	-0.67**	-0.81**	0.37*	0.38**
Kasturi Basmati × Type-3	-0.07	-0.04	-0.62**	-0.96**
GRAIN YIELD PER PLANT (g)				
Pusa Sugandh-5 × Type-3	-6.56**	-6.70	-8.16**	2.55*
Ranbir Basmati × Pusa Basmati-1	-0.94**	0.78**	-18.43**	-9.14**
Kasturi Basmati × Type-3	-12.17**	-7.56**	-11.13**	4.30

*Significant at $P \leq 0.05$, **Significant at $P \leq 0.01$

CROSSES/PARAMETERS	A	B	C	D
KERNEL LENGTH BEFORE COOKING (mm)				
Pusa Sugandh-5 × Type-3	-0.29**	0.82**	-0.12	-0.43*
Ranbir Basmati × Pusa Basmati-1	-0.27**	-0.18**	-0.82**	-0.28**
Kasturi Basmati × Type-3	-0.29**	-0.68**	-0.40	0.29**
KERNEL BREADTH BEFORE COOKING (mm)				
Pusa Sugandh-5 × Type-3	-0.20**	-0.18**	-0.46**	-0.03
Ranbir Basmati × Pusa Basmati-1	-0.24**	-0.21**	-0.76**	-0.14**
Kasturi Basmati × Type-3	-0.12	-0.12*	-0.44**	-0.10*
L/B RATIO BEFORE COOKING				
Pusa Sugandh-5 × Type-3	0.49**	0.87**	1.06**	-0.15
Ranbir Basmati × Pusa Basmati-1	0.61*	0.41*	1.63**	0.30*
Kasturi Basmati × Type-3	0.43**	-0.18	0.71*	0.38*
KERNEL LENGTH AFTER COOKING(mm)				
Pusa Sugandh-5 × Type-3	-1.34**	0.63**	-1.91**	-0.28
Ranbir Basmati × Pusa Basmati-1	0.96**	-0.23**	-3.77**	-2.22**
Kasturi Basmati × Type-3	-0.28**	-0.56**	-2.78**	-1.02**
KERNEL BREADTH AFTER COOKING(mm)				
Pusa Sugandh-5 × Type-3	-0.40**	-0.09	-0.78**	0.47**
Ranbir Basmati × Pusa Basmati-1	-0.13	-0.56**	-0.47**	-0.44**
Kasturi Basmati × Type-3	-0.24**	0.37**	-1.33**	-0.68**
L/B RATIO AFTER COOKING				
Pusa Sugandh-5 × Type-3	0.37*	1.31**	3.12**	-0.28
Ranbir Basmati × Pusa Basmati-1	0.53**	0.07	-0.88**	-0.59*
Kasturi Basmati × Type-3	-0.003	-0.40**	2.06**	1.23**
ELONGATION RATIO (ER)				
Pusa Sugandh-5 × Type-3	-0.17**	-0.20**	-1.25**	0.06
Ranbir Basmati × Pusa Basmati-1	0.12*	0.02*	-0.32**	-0.23**
Kasturi Basmati × Type-3	0.04	0.09**	-0.31**	-0.23**
ALKALI SPREAD VALUE				
Pusa Sugandh-5 × Type-3	0.70**	2.06**	-1.68**	-2.22**
Ranbir Basmati × Pusa Basmati-1	-1.21**	-2.36**	-2.55**	0.51*
Kasturi Basmati × Type-3	-0.44*	0.86**	-2.60**	-1.51**
AMYLOSE CONTENT				
Pusa Sugandh-5 × Type-3	-0.28	1.02*	18.18**	8.72**
Ranbir Basmati × Pusa Basmati-1	0.90*	-1.10*	-14.35**	-7.07**
Kasturi Basmati × Type-3	1.15**	1.72*	-0.50	-1.69**

*Significant at $P \leq 0.05$, **Significant at $P \leq 0.01$

Table 2: Estimation of gene effect of yield and quality traits through generation mean analysis

CROSSES/ PARAMETERS	$[\hat{m}]$	$[\hat{d}]$	$[\hat{h}]$	$[\hat{i}]$	$[\hat{j}]$	$[\hat{l}]$	EPISTASIS
DAYS TO 50% FLOWERING							
Pusa Sugandh-5 × Type-3	103.30**	-4.14*	41.50**	40.92**	4.61**	-43.14**	D
Ranbir Basmati × Pusa Basmati-1	86.23**	-24.47**	78.77**	80.14**	-60.00**	-100.47**	D
Kasturi Basmati × Type-3	89.25**	-14.21**	48.38**	44.60**	24.51**	-37.10**	D
DAYS TO MATURITY							
Pusa Sugandh-5 × Type-3	133.84**	-3.40	32.95**	32.25**	21.53**	-28.18*	D
Ranbir Basmati × Pusa Basmati-1	116.63**	-11.24**	80.00**	81.41**	-40.89**	-104.49**	D
Kasturi Basmati × Type-3	120.20**	-13.20**	47.07**	43.20**	4.63	-40.80**	D
PLANT HEIGHT(cm)							
Pusa Sugandh-5 × Type-3	125.63**	-28.80**	22.25**	22.30	2.65	-15.00	-
Ranbir Basmati × Pusa Basmati-1	117.59**	15.59**	70.09**	66.21**	-9.53**	+68.29**	C
Kasturi Basmati × Type-3	128.84**	-17.60**	64.87**	59.05**	6.78	-49.35**	D
MAIN PANICLE LENGTH (cm)							
Pusa Sugandh-5 × Type-3	30.25**	-2.40	18.97**	18.20**	6.83**	23.87**	C
Ranbir Basmati × Pusa Basmati-1	28.76**	7.20**	13.72**	12.04**	4.41**	15.92**	C
Kasturi Basmati × Type-3	28.05**	-6.00**	1.58	-0.20	-3.08	27.03**	-
EFFECTIVE TILLERS/ PLANT							
Pusa Sugandh-5 × Type-3	10.50**	3.20**	10.92**	7.60**	2.42**	-7.30**	D
Ranbir Basmati × Pusa Basmati-1	11.57**	3.10**	10.21**	8.44**	0.28	-6.01*	D
Kasturi Basmati × Type-3	11.19**	-4.50**	-17.97**	-12.16**	-2.15	26.65**	D
FILLED SPIKELETS PER PANICLE							
Pusa Sugandh-5 × Type-3	136.62**	-19.00**	30.33**	-24.50*	22.32**	27.70**	C
Ranbir Basmati × Pusa Basmati-1	118.64**	-11.90**	52.99**	75.66**	-10.11**	-89.03**	D
Kasturi Basmati × Type-3	128.65**	-12.80**	20.14*	6.20	-5.33	11.40**	C
100 GRAIN WEIGHT (g)							
Pusa Sugandh-5 × Type-3	2.30**	0.18**	-1.08**	-0.39**	-0.24**	2.95**	D
Ranbir Basmati × Pusa Basmati-1	2.25**	-0.03	-0.60**	-0.76**	0.33**	1.15**	D
Kasturi Basmati × Type-3	1.97**	0.15**	0.90**	0.49**	-0.02	-3.10**	D
YIELD PER PLANT (g)							
Pusa Sugandh-5 × Type-3	28.87**	-5.20**	5.73**	-15.10**	0.06	18.36**	C
Ranbir Basmati × Pusa Basmati-1	33.50**	-5.81**	22.05**	18.27**	-16.47**	-18.12**	D
Kasturi Basmati × Type-3	26.38**	-6.08**	-11.26**	-8.60**	-6.30**	28.34**	D
KERNEL LENGTH BEFORE COOKING(mm)							
Pusa Sugandh-5 × Type-3	7.91**	0.20**	2.05**	0.87**	-0.44**	-1.62**	D
Ranbir Basmati × Pusa Basmati-1	7.16**	0.25**	0.46**	0.58*	0.70**	-1.42**	D
Kasturi Basmati × Type-3	6.98**	0.39**	-0.64	-0.58*	0.20	1.56**	D
KERNEL BREADTH (mm)							
Pusa Sugandh-5 × Type-3	1.70**	-0.11*	0.20**	0.09**	-0.03	0.33**	C
Ranbir Basmati × Pusa Basmati-1	1.52**	-0.02	0.30**	0.29**	-0.12**	0.17	-
Kasturi Basmati × Type-3	1.62**	-0.19**	0.23**	0.22**	0.10**	0.21**	C
L/B RATIO BEFORE COOKING							
Pusa Sugandh-5 × Type-3	4.67**	0.41**	1.20**	0.32	-0.20**	-1.69*	D
Ranbir Basmati × Pusa Basmati-1	4.75**	0.23**	-0.90**	-0.60*	0.10	-0.42**	C
Kasturi Basmati × Type-3	4.31**	0.70**	-0.78**	-0.78**	0.16**	0.84**	D
KERNEL LENGTH AFTER COOKING(mm)							
Pusa Sugandh-5 × Type-3	12.68**	0.36**	0.65**	0.67**	-1.68**	0.78	-
Ranbir Basmati × Pusa Basmati-1	12.68**	-0.64*	5.60**	4.46**	0.53	-5.13**	D
Kasturi Basmati × Type-3	11.66**	0.22**	1.99**	2.03**	1.20**	-1.29**	D
KERNEL BREADTH AFTER COOKING(mm)							
Pusa Sugandh-5 × Type-3	2.24**	0.20**	-0.19*	-0.16	0.07	1.10**	D
Ranbir Basmati × Pusa Basmati-1	2.28**	0.10**	0.10**	0.29	-0.04	-0.10	-
Kasturi Basmati × Type-3	2.03**	0.90**	1.17**	1.38**	-0.09**	-1.40**	D
L/B RATIO AFTER COOKING							
Pusa Sugandh-5 × Type-3	5.72**	-0.20**	1.48**	1.57**	-0.58**	-2.25*	D
Ranbir Basmati × Pusa Basmati-1	5.56**	-0.48*	2.15**	2.20**	0.34**	-1.80**	D
Kasturi Basmati × Type-3	5.72**	0.10*	-2.03**	-2.48**	0.50**	2.89**	D
ELONGATION RATIO (ER)							
Pusa Sugandh-5 × Type-3	1.62**	-0.38	1.93**	-0.32**	0.20**	0.70**	C
Ranbir Basmati × Pusa Basmati-1	1.78**	-0.12**	0.66**	0.48**	0.25**	-0.62**	D
Kasturi Basmati × Type-3	1.68**	-0.07**	0.39**	0.46**	-0.37**	-0.60**	D
ALKALI SPREAD VALUE							
Pusa Sugandh-5 × Type-3	5.44**	0.70**	5.33**	4.45**	-5.68**	-7.22**	D
Ranbir Basmati × Pusa Basmati-1	5.24**	-1.05**	2.36**	-0.33	4.57**	4.62**	C
Kasturi Basmati × Type-3	2.85**	-1.24**	3.07**	3.02**	-1.65	-3.44**	D
AMYLOSE CONTENT							
Pusa Sugandh-5 × Type-3	26.57**	14.08**	-16.49**	-17.45**	-1.65	16.72**	D
Ranbir Basmati × Pusa Basmati-1	19.67**	10.40**	14.39**	14.16**	5.00**	-13.96**	D
Kasturi Basmati × Type-3	16.97**	-11.32**	-2.05	3.39**	-3.29**	-6.27**	-

*Significant at P ≤ 0.05, **Significant at P ≤ 0.01 C= complementary, D = duplicate type of epistasis

CONCLUSIONS

Generation mean analysis was carried out by evaluating six basic populations (P_1, P_2, F_1, F_2, B_1 and B_2) of three cross combinations viz., (Pusa Sugandh-5 × Type-3, Ranbir Basmati × Pusa Basmati-1, Kasturi Basmati × Type-3) for yield and quality traits. All the 3 crosses were subjected to A, B, C and D scaling tests to sort out the model (interacting crosses) for the characters concerned were further subjected to six parameter models to estimate the main gene effects; [m], [d] and [h] and their interactions [i], [j] and [l] involved in the cross for the expression of respective trait under study. Scaling test (A, B, C and D) was applied to test the inadequacy of additive-dominance model. Significant deviation of the scale (s) from zero indicates the presence of epistatic interaction in respective crosses. It is interesting to note that all the three crosses scored significant values for all the six components of gene effect for yield and quality traits. Considering the seed yield and its components, cross combination, Ranbir Basmati × Pusa Basmati-1 scored significant values for all the components of gene effects. Whereas, cross combination, Pusa Sugandh-5 × Type-3 scored significant values for all the component of gene effect in six yield characters, out of eight yield characters studied. However, cross combination, Kasturi Basmati × Type-3 revealed significant values for all six components in two yield traits. Both duplicate as well as complementary type of epitasis noticed in three crosses for yield trait. Considering quality traits, cross combination, Kasturi Basmati × Type-3 scored significant values for all the component of gene effect in five quality characters, out of nine quality characters studied. However, Pusa Sugandh-5 × Type-3 and Ranbir Basmati × Pusa Basmati-1 scored significant values for all the component of gene effect in five quality characters, out of nine characters studied. Since, the sign of dominance (h) and dominance × dominance (l) for almost all of the quality related traits of these three crosses was opposite, therefore, the nature of epistasis was identified as duplicate in these crosses. Duplicate epistasis as observed may postponed single plant selection and biparental mating or diallel selective mating could be followed where in few cycles of crossing of promising segregants in F_2 and onward generations that might help in the incorporation of desirable genes into a single genetic background. In other words, 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 differed till later generations of segregation where dominance effects are dissipated[17]. However, the crosses showing complementary interactions might be exploited in the form of pedigree methods. Biparental mating, recurrent selection and diallel selective mating system[6] might be profitable in exploiting both additive and non additive gene action to obtain desirable recombinants.

Acknowledgement

The first author is grateful to the University Grant Commission (UGC), New Delhi India, for awarding Maulana Azad National Fellowship as financial assistance and Department of Genetics and Plant Breeding, BHU for providing facilities for conducting of experiments during the course of present study.

REFERENCES

1. Cavalli, L.L., An analysis of linkage in quantitative inheritance. HMSO, London: 135-144 (1952).
2. Chamundeshwari, N., Genetic studies on quality traits in rice (*Oryza sativa L.*). PhD. *Thesis Submitted to the Acharya N.G. Ranga Agricultural University*, Hyderabad (2010).
3. Hayman, B.I. and Mather, K., The description of genetic interactions in continuous variation. *Biometrics* **11:** 69-82 (1955).
4. Hayman, B.I., The separation of epistatic from additive and dominance variation in generation means. *Heredity* **12:** 371-390 (1958)

5. IRRI. Standard evaluation system for rice. International Rice Research Institute, Los Banos, Manila, Philippines. **35p** (1988)
6. Jenson, N.E., A diallel selective mating system for cereal breeding. *Crop Sci*., **10:** 629-35 (1970).
7. Jinks, J. L. and Jones, R. M., Estimation of components of heterosis. *Genetics* **43:** 223-234 (1958)
8. Juliano, B. O. and Duff, B., Rice grain quality as an emerging priority in national breeding programs. *In:* Rice Grain Marketing and Quality Issues. International Rice Research Institute, Los Banos, Philippines, pp. 55-64, (1991)
9. Juliano, B. O., A simplified assay for milled rice amylose. *Cereal Sci. Today,* **16:** 334-338, 340, 360 (1971).
10. Kumar, P. S., Saravanan, K. and Sabesan, T., Generation mean analysis for yield and grain quality characters in rice (*Oryza sativa L.*) *Plant Archives* Vol. 17 No. 1, pp. 557-560, (2017).
11. Kumar. A, Singh, N. K., Kumar, R., Sharma, V. K., Rai, B. and Dayaram, Estimation of genetic components for yield in rice using generation mean analysis. *Oryza* **52(4):** 284-291, (2015).
12. Little, R. R., Hilder, G. B. and Dawson, E. H., Differential effect of dilute alkali on 25 varieties of milled white rice. *Cereal Chem.*, **35:** 111-126, (1958).
13. Mather, K., Biometrical Genetics: The study of continuous variation. Metheun and Co. Ltd. London, (1949).
14. Murugan, S. and Ganesan, J., Generation mean analysis in rice (*Oryza sativa* L.) crosses utilizing 'WA' cytosteriles. *Plant Archives* **6(1):** 165-167 (2006).
15. Nayak, A. R., Chaudhary, D. and Reddy, J. N., Genetics of yield and yield components in scented rice. *Oryza* **44(3):** 227-230, (2007).
16. Nayak, A. R., Genetic architecture of quality characters in scented rice. *Agriculture Science Digest* **27(2):** 103-106 (2007).
17. Perera, A.L.T., Senadhira, D. and Lawrence, M.J., Genetic architecture of economicall important characters and prediction of performance of recombinant inbred lines in rice. In: *Rice Genetics,* IRRI, Manila, Philippines. p. 565-568. (1986)
18. Prabhu, S.M., Ganesan, N.M., Jeyaprakash, P., Selvakumar, R. and Prabhakaran, N.K., Generation Mean Analysis for Yield and Its Contributing Characters in F2 Populations of Rice (*Oryza sativa L.*), *Int. J. Pure App. Biosci.* **5(4):** 373-380 (2017).
19. Rani, P. J., Satyanarayana, P.V., Chamundeswari, N., Lal Ahamed, M., Rani, Y. A. & Srinivasa Rao, V. S., Genetic effect of grain yield and yield component in rice using generation mean analysis. *Int. J. Of Tr. Agri*. Serials Publications, ISSN: 0254-8755(2015).
20. Srivastava,A.K., Jaiswal, H.K., Agrawal, R.K. and Singh, R.P., Genetic Architecture of Yield and Yield Components in Indigenous Aromatic Rice (*Oryza sativa L.*). *Vegetos,* **25 (1):** 146-150 (2012).
21. Thirugnana kumar, S., Narasimman, R., Senthil kumar, N., Eswaran, R and Praveen Sampath kumar, C., Gene effects for grain yield and its component characters in rice (*Oryza sativa L.*). *Crop Improvement*. **34 (1):** 19-23 (2007).
22. Tomar, J. B. and Nanda, J. S., Genetics of gelatinization temperature and its association with protein in rice. *Zeitschrift fur Pflanzenzuchtung* **94(2):** 89-100 (1985a).
23. Verma, R.S., Yadav, R.D.S and Giri, S.P., Genetics of yield and its important components in rice (*Oryza sativa L.*). *Crop Research*. **31 (1):** 142-146 (2006).
24. Welch, R. M. and Graham, R. D., Breeding crops for enhanced micronutrient content. *Plant Soil,* **245(1):** 205-214 (2002).