Research paper Bangladesh Journal of Ecology

ESTIMATION OF GENETIC VARIABILITY, CORRELATION AND PATH COEFFICIENT ANALYSIS FOR EVALUATION OF SUBMERGENCE TOLERANT RICE GENOTYPES

MU Kulsum[1], KM Iftekharuddaula[1], M Hasan[2], MJ Hasan[1], Al Amin[1], MG Rasul[2] MM Islam[3] and MA Karim[3*]

[1]Bangladesh Rice Research Institute, Joydebpur, Gazipur 1701, Bangladesh, [2]Department of Genetics and Plant Breeding, [3]Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh

Correspondence: M Abdul Karim, Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706, Email: akarim1506@yahoo.com

Received: 12 June 2019, Revised: 26 June 2019, Accepted: 28 June 2019

ABSTRACT

Submergence is a serious environmental condition that causes large loss in rice production in rain fed lowland and flood affected area. Rice (*Oryza sativa* L.) is considered as a submergence-sensitive crop species. Within this species, there are considerable varietal differences in sensitivity to this environmental stress. The experiment was conducted in the exprimental farm of Bangladesh Rice Reserch Insitutute, Gazipur, Bangladesh during 2014-2015 to evaluate 46 submergence tolerant rice genotypes through genetic variability, correlation and path analysis. Most of the charactersof genotypic coefficients of variation (GCV) and phenotypic coefficients of variation (PCV) values were close to each other, which indicated that those characters were controlled by genetic factors. High heritability coupled with high genetic advance as percent of mean was fastened for panicle weight, spikelet fertility percentage, thousand grain weight and grain yield suggesting preponderance of additive gene action in the expression of these characters. Correlation study revealed that significant correlations at both phenotypic and genotypic level exist between yield per plant and panicle weight, spikelete fertility percentage, and thousand grain weight. Path coefficient analysis revealed that panicle weight, spikelet fertility percentage, days to maturity and thousand grain weight had direct positive effect on yield, indicating these are the main contributors to yield. This study reveal that panicle weight, spikelet fertility percentage, days to maturity and thousand grain weight may serve selection criteria for improving genetic potential of rice.

Keywords: Genetic variability, heritability, correlation, path analysis

Introduction

Rice is the main cereal crop in Bangladesh. For meeting the food demand of our increasing population there is no alternative of rice cultivation. In Bangladesh, food security of the vast population is associated with production of rice as it is the staple food of our country. According to BBS, in FY 2013-14, the food grains production stood at around 381.73 lakh metric tons (MT) (BER 2015). Bangladesh possesses six positions among the paddy producing country in the world after China, India, Indonesia, Vietnam, and Thailand (World Top Ten, 2015). Rice alone contributes 12.5 percent of total agricultural Gross Domestic Product (GDP) (BBS 2014).

Rice is grown in a wide range of ecologies ranging from irrigated to uplands, rainfed lowland, deep water and tidal wetlands. The vulnerable effect of climate change has created many natural hazards, which is a great constraint in crop production worldwide. Submergence is a serious problem affecting rice production in rainfed lowlands and flood-prone areas worldwide, and this problem is further worsened with climate change, increasing flood risks especially in areas affected by monsoon rains in Asia. Submergence can be caused by direct rain or overflow of rivers, and sometimes, by tidal inundation (Mohanty and Chaudhary 1986, Sairam *et al.* 2008). Recently, the extent of submergence stress has increased due to extreme weather events such as unexpected heavy rains that have inundated wider areas across many regions in Asia.

Out of 10.6 million ha of rice productionmore than 2 million ha is affected by flash flooding in Bangladesh (Iftekharuddaula *et al.* 2011). Although a number of high yielding submergence tolerant inbred rice varieties have been developed, development of submergence tolerant hybrid rice varieties is not yet been successful in Bangladesh. Moreover, the level of submergence stress tolerance in rice needs to be enhanced, particularly in genotypes with the short duration genetic background.

In order to harness the productivity potential of novel materials, it is important to understand the magnitude and nature of genetic variability and association of various agro-morphological traits with grain yield under normal, sodic as well as flooding environments. Genetic variability is a prerequisite for initiating appropriate breeding procedures in crop improvement programs. Genetic parameters help to understand the gene action, identification of components of genetic variances and finally facilitate the selection of a desirable breeding method. The genotypic variance and phenotypic variance influences the heritability estimates as well as the environmental factors. The heritability and genetic advance are important selection parameters and more helpful in predicting the genetic gain under effective selection (Bisne *et al*. 2009). Correlation coefficients indicate the magnitude of association between or among traits. The correlation coefficients provide information about interrelationship among yield and its components, which is very helpful for the development of efficient selection strategy. Moreover, path coefficient analysis partitions the correlation coefficients into its direct and indirect effects, so that the contribution of each character to yield could be estimated for picking up appropriate traits for indirect selection. The nature and extent of genetic variability and association parameters are expected to be influenced by the genetic material under study and the prevailing environmental factors. Therefore, an attempt has been undertaken to study the genetic parameters of rice to develop the selection criteria for the traits related to crop yield submergence stress.

Materials and Methods

The experiment was conducted at the experimental farm of Bangladesh Rice Research Institute (BRRI), Gazipur during Boro season 2014-2015. The experimental field was of medium high land having well drainage system. Thirty days old seedlings were transplanted on 25 December, 2014 using single seedling per hill at a spacing of 20 cm × 20 cm. Fertilizers were applied with doses of 270-130-120-70-10kg/ha Urea, TSP, MoP, gypsum and $ZnSO_4$, respectively. Whole amount of TSP, two-third of MP, total gypsum and zinc sulphate were applied as basal during final land preparation. Urea was applied in three installments, viz. at 10-15 days after transplanting (DAT), 30-35 DAT and 50-55 DAT. One-third of MoP was top dressed with urea 3rd top dressing. Necessary intercultural operations and protection measures were taken during cropping period for proper growth and development of the plants.The experiment was replicated three times. Following data were recorded from 10 randomly selected plants per plot in each replication at different times as specified- plant height (cm), effective tiller/plant (no.), days to 50% flowering (days), flag leaf length (cm), panicle length (cm), panicle weight (g), spikelet fertility (%), days to maturity (days), thousand grain weight (g), and yield/plant (g). Data were analyzed using MSTAT-C software.

Estimation of genotypic and phenotypic variances: Genotypic and phenotypic variances were estimated according to the formula given by Johnson *et al*. (1955).

Genotypic variance, $\sigma^2_g = \frac{\text{GMS-EMS}}{r}$

Where,

GMS = Genotypic mean square

EMS = Error mean

r = Number of replication

Phenotypic variance, $\sigma^2_p = \sigma^2_g + \text{EMS}$

Where,

σ^2_g = Genotypic variance

EMS = Error mean square

Estimation of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV): Genotypic and phenotypic coefficient of variations were estimated according to Burton (1952), and Singh and Chaudhury (1985).

Genotypic coefficient of variations, $GCV = \frac{\sqrt{\sigma^2 g}}{x} \times 100$

Where,

σ^2_g = Genotypic variance; and

$\overline{X}$ = Population mean

Phenotypic coefficient of variations, $PCV = \frac{\sqrt{\sigma^2 p}}{x} \times 100$

Where,

σ^2_p = Phenotypic variance; and

$\overline{X}$ = Population mean

Estimation of heritability: Heritability in broad sense (h2b) was estimated according to the formula suggested by Johnson *et al*. (1955).

Heritability, $h^2b = \frac{\sigma^2 g}{\sigma^2 p} \times 100$

Where,

h^2_b=Heritability in broad sense

δ^2_g = Genotypic variance; and

δ^2_p = Phenotypic variance

Estimation of genetic advance: Estimation of genetic advance was done following formula given by Johnson *et al.* (1955) and Allard (1960).

Genetic advance, GA = $h^2_b.K.\sigma_p$

Where,

h^2_b = Heritability in broad sense

K = Selection differential, the value of which is 2.06 at 5% selection intensity

σ_p = Phenotypic standard deviation

Results and Discussion

There is a presence of acceptable amount of variability among the genotypes which gives an opportunity for rice breeders to improve those traits through selection and hybridization to improve the desired traits. Phenotypic, genotypic and environmental variances as well as their coefficients of variation are presented in Table 1. The genotypic variance was the highest for plant height (72.68) followed by spikelet fertility (44.20), days to 50% flowering (28.56) and yield (25.29). On the other hand, the lowest genotypic variance was found for effective tiller per plant, flag leaf length, panicle length, panicle weight and thousand grain weights. The phenotypic variance for all the traits were little bit higher but close to the genotypic variance indicating preponderance of additive gene effects for these traits. Phenotypic coefficients of variation (PCV) and genotypic coefficients of variation (GCV) were categorized as low (0-10%), moderate (10-20%) and high (>20%) as indicated by Sivasubramanian and Madhavamenon (1973). Therefore, according to the classification high GCV and PCV values were recorded for yield (25.58, 25.68), panicle weight (20.16, 20.69) and moderate GCV and PCV values were recorded for effective tiller per plant (11.79, 13.32) which suggested the possibility of improving these traits through selection. In general, a high coefficient of variability indicates that there is a scope of selection and improvement of these traits. Low values indicates the need for creation of variability either by hybridization or mutation followed by selection (Tiwari *et al.* 2011).

The narrow magnitude of difference between phenotypic and genotypic coefficient of variations were found for all the studied characters which might be the limited influence

Table 1. Genetic parameters for 46 submergence tolerant lines

Characters	MS	σ^2g	σ^2e	σ^2p	GCV	PCV	h^2_b	GA	GAPM
PH	219.03**	72.68	0.99	73.67	8.47	8.53	98.66	13.38	13.29
ET/P	5.14**	1.57	0.43	2.00	11.79	13.32	78.39	1.75	16.50
50%F	86.10**	28.56	0.42	28.98	4.40	4.43	98.56	8.38	6.89
FLL	12.87**	4.04	0.75	4.79	8.29	9.03	84.23	2.91	12.02
PL	9.98**	3.26	0.2	3.46	7.54	7.76	94.44	2.77	11.58
PW	1.25**	0.41	0.02	0.43	20.16	20.69	94.88	0.98	31.02
SF (%)	137.30**	44.20	4.7	48.90	8.51	8.95	90.39	9.99	12.78
DTM	61.45**	20.23	0.76	20.99	3.01	3.07	96.39	6.98	4.68
TGW	12.99**	4.24	0.26	4.50	8.83	9.08	94.37	3.16	13.55
YLD/P	76.06**	25.29	0.19	25.48	25.58	25.68	99.23	7.91	40.26

** = Significant at 1% level, σ^2g = Genotypic variance, σ^2e = Environmental variance, σ^2p = Phenotypic variance, GCV = Genotypic coefficients of variations, PCV = Phenotypic coefficients of variations, h^2_b = Heritability in broad sense, GA = Genetic advance, GAPM = Genetic advance percent of mean. PH= Plant height (cm), ET/P=Effective tillers per plant, 50%F=Days to 50% flowering, FLL= Flag leaf length (cm), PL=Panicle length (cm), PW= Panicle weight (g), SF(%)=Spikelet fertility percentage, DTM=Days to maturity, TGW= Thousand grain weight (g) and YLD/P= Yield per plant.

of environment in the expression of these characters. The result was in agreement with Idris and Mohamed (2013) who reported small differences between genotypic and phenotypic coefficients of variations for plant height and panicle length. Thus, selection based on phenotypic performance of these characters would be effective to bring about considerable genetic improvement. Heritability was classified as low (below 30%), medium (30-60%) and high (above 60%) as suggested by Johnson *et al.* (1955). Considering this delineation, high heritability values were observed for all the traits in this study. High heritability in broad sense value indicated that the characters under study were less influenced by environment in their expression. In the present findings the genetic advance as percent of mean was ranged from 4.68 for days to maturity to 40.26 for yield. According to Johnson *et al.* (1955) genetic advance as percent of mean classified as low (below 10%), moderate (10-20%) and high (above 20%). Based on this argument, in the present study, traits such as panicle weight (31.02%) and yield (40.26%) gave the high genetic advance as percent of mean while moderate genetic advance as percent of mean was computed for plant height (13.29), effective tiller per plant (16.50), flag leaf length (12.02), panicle length (11.58), spikelet fertility percentage (12.78) and thousand grain weight (13.55). These traits also had high heritability. Therefore, selection based on the above traits with high and moderate genetic advance as percent of mean, high heritability and genotypic coefficient of variation (GCV), result in the improvement of genotypes for the traits. The present finding was in line with the work of Shrivastava *et al.* (2015) for grain yield.

Genotypic and phenotypic correlations coefficientsanalysis result of grain yield and yield related component traits showedboth positive and negative associations (Table 2). Positive correlatedresult indicated that increase of one trait will result in increase of thecorrelated trait and negative association of traits indicated thatincrease of one character will decrease the negatively correlatedcharacter. At genotypic and phenotypic level panicle weight (0.604, 0.591), spikelet fertility percentage (0.790, 0.764) and thousand grain weight (0.748, 0.732) displayed positive and significant association with yield per plant. This result directing that yield of submergence tolerant genotype could be improved by selecting genotypes having higher performance for these traits. The detected positive and significant correlation of yield with these traits indicated

Table 2. Genotypic (r_g) and Phenotypic (r_p) correlation coefficient for 46 Submergence tolerant lines

Character		ET/P	50%F	FLL	PL	PW	SF(%)	DTM	TGW	YLD/P
PH	r_g	0.159	0.076	0.125	0.043	0.111	-0.028	0.013	0.078	0.141
	r_p	0.143	0.077	0.116	0.045	0.106	-0.027	0.014	0.075	0.139
ET/P	r_g		-0.034	0.094	0.233	-0.142	-0.186	-0.258	-0.429	-0.229
	r_p		-0.033	0.087	0.195	-0.132	-0.161	-0.228	-0.386	-0.209
50%F	r_g			-0.174	-0.303	-0.425	-0.221	0.835**	-0.102	-0.007
	r_p			-0.166	-0.296	-0.414	-0.215	0.822**	-0.098	-0.008
FLL	r_g				0.354	0.390	0.374	-0.137	0.381	0.317
	r_p				0.326	0.370	0.333	-0.135	0.349	0.300
PL	r_g					0.190	0.144	-0.378	0.082	0.034
	r_p					0.175	0.135	-0.369	0.080	0.033
PW	r_g						0.752**	-0.288	0.542*	0.604*
	r_p						0.712**	-0.281	0.519*	0.591*
SF(%)	r_g							-0.046	0.608*	0.790**
	r_p							-0.043	0.581*	0.764**
DTM	r_g								0.041	0.211
	r_p								0.042	0.205
TGW	r_g									0.748**
	r_p									0.732**

PH= Plant height (cm), ET/P=Effective tillers per plant, 50%F=Days to 50% flowering, FLL= Flag leaf length (cm), PL=Panicle length (cm), PW= Panicle weight (g), SF(%)=Spikelet fertility percentage, DTM=Days to maturity, TGW= Thousand grain weight (g) and YLD/P= Yield per plant.

that panicle length, spikelet fertility percentage and thousand grain weights simultaneously increased yield. Similar results have been earlier reported by Mulugeta *et al.* (2012) in rain fed upland rice genotypes. Days to 50% flowering (-0.007, -0.008) displayed negative correlation with yield per plant. This result indicated that any increase in days to 50% flowering could result in decrease in yield. Presence of early flowering genotypes is important for climate mitigation as submergence escape mechanism for areas with marginal flash flood. However under a favorable growing condition, too early flowering does not permit production of sufficient assimilates for grain filling and finally ends up with low yield. Therefore, selection for early to medium flowering submergence tolerant rice genotypes could be effective for increasing yield in the respective area. Kampe *et al.* (2018) found negative significant association of days to 50% flowering with grain yield.

Panicle weight showed positive and significant association with spikelet fertility percentage (0.752, 0.712) and thousand grain weight (0.542, 0.519) but with all other yield related traits showed non-significant correlation. Spikelet fertility percentage displayed positive and significant correlation with thousand grain weight (0.608, 0.581). This result suggested that as spikelet fertility increases, thousand grain weight also ultimately increases. Days to 50% flowering exhibited strong positive and significant correlation with days to maturity (0.835, 0.822). This characteristic indicated that increasing of days to 50% flowering would lead to increase in the days to maturity which might be attributed due to pleiotropic gene effects and linkage between genes for these traits. Similar result was reported by Iftekharuddaula *et al.* (2001).

Grain yield per plantof rice was taken as dependent variable and direct and indirect effectsof the other independent variables were computed and have beenshowed in Table 3. Direct positive effect on grain yield of somecharacters indicated that selection of these traits is directly helpful forthe improvement of yield. Negative indirect effects of some characterson grain yield showed that effects of such traits are indirectly affectingthe grain yield in the negative direction. Path analysis revealed that plant height had positive direct effect towards yield. Indirect effect via days to 50% flowering, flag leaf length, panicle length, spikelet fertility percentage showed negative effect on yield. On the other hand Indirect via effective tiller per plant, panicle weight, days to maturity and thousand grain weight exhibit positive effect on yield. Positive correlation between plant height and yield due to direct positive effect and via indirect positive effect of effective tiller per plant, panicle weight, days to maturity and thousand grain weight on yield.

Effective tiller per plant showed positive direct effect on yield. The indirect effect via plant height and days to 50% flowering was positive on yield. Indirect effect via flag leaf length, panicle length, panicle weight, spikelet fertility percentage, days to maturity and thousand grain weight was negative. Effective tiller per plant was negatively correlated with yield due to indirect negative effect via flag leaf length, panicle length, panicle weight, spikelet fertility percentage, days to maturity and thousand grain weight. Highest positive direct effect has been reported

Table 3. Partitioning of genotypic correlation into direct (bold) and indirect effect for 46 Submergence tolerant lines

Characters	Effect through									YLD/P
	PH	ET/P	50%F	FLL	PL	PW	SF (%)	DTM	TGW	
PH	0.106	0.026	-0.015	-0.009	-0.000	0.006	-0.014	0.006	0.036	0.141
ET/P	0.017	0.165	0.007	-0.007	-0.001	-0.007	-0.094	-0.109	-0.199	-0.229
50%F	0.008	-0.006	-0.197	0.013	0.001	-0.021	-0.112	0.354	-0.048	-0.007
FLL	0.013	0.015	0.034	-0.073	-0.001	0.019	0.190	-0.058	0.177	0.317
PL	0.005	0.038	0.060	-0.026	-0.003	0.009	0.073	-0.160	0.038	0.034
PW	0.012	-0.023	0.084	-0.028	-0.001	0.050	0.381	-0.122	0.252	0.604*
SF (%)	-0.003	-0.031	0.043	-0.027	-0.000	0.37	0.507	-0.019	0.282	0.790**
DTM	0.001	-0.042	-0.164	0.010	0.001	-0.014	-0.023	0.424	0.019	0.211
TGW	0.008	-0.071	0.020	-0.028	-0.000	0.027	0.308	0.017	0.465	0.748**

Residual Effect –0.4201, PH= Plant height (cm), ET/P=Effective tillers per plant, 50%F=Days to 50% flowering, FLL= Flag leaf length (cm), PL=Panicle length (cm), PW= Panicle weight (g), SF(%)=Spikelet fertility percentage, DTM=Days to maturity, TGW= Thousand grain weight (g) and YLD/P= Yield per plant.

for number of productive tillers by Rokonuzzaman *et al.* (2008) in rice. Days to 50% flowering displayed negative direct effect on yield and indirect effect via effective tiller per plant, panicle weight, spikelet fertility percentage and thousand grain weights also negative. Negative association between days to 50% flowering and yield due to indirect negative effect via effective tiller per plant, panicle weight, spikelet fertility percentage and thousand grain weight. Days to maturity showed positive indirect effect on yield. It wasinteresting that path coefficient analysis results confirmedthe similarity of the correlation coefficient analysis results. Indirect selection based on days to maturity would be rewarding to get better yield.

Flag leaf length exerted the negative direct effect on yield and indirect effect via panicle length and days to maturity also negative. Flag leaf length positively associated with yield due to indirect positive effect via plant height, effective tiller per plant, days to 50% flowering, panicle weight, spikelet fertility percentage and thousand grain weights. Panicle length was very less and positively associated with yield due to its negative direct effect. Panicle weight had positive and lower direct effects on yield. Indirect effect via effective tiller per plant, flag leaf length, panicle length and days to maturity were negative and almost negligible in magnitude. Whereas via spikelet fertility percentage showed considerable positive indirect effect on yield and the total correlation was significant and positive. So indirect selection via spikelet fertility percentage could be effective for increasing yield.

Spikelet fertility percentage had significant correlation with yield. Among the character used to partitioning the correlation to direct and indirect effect spikelet fertility showed the highest direct effect on yield indicated spikelet fertility percentage was the major character that associated with yield. Direct selection based on this character would be rewarding to get better yield. The highest positive direct effect has been reported for percentage fertile spikelet by Agbo and Obi (2005) in rice. Days to maturity showed positive direct effect with yield. Association between days to maturity and yield is due to mainly positive direct effect. So, days to maturity predominantly contributed to the yield. The highest positive direct effect has been reported for days to maturity by Qamar *et al.* (2005) in rice. Thousand grain weights had direct contribution towards yield predominantly. Positive association between thousand grain weight and yield was due to direct positive contribution of thousand grain weight. Indirect effect via plant height, days to 50% flowering, panicle weight, spikelet fertility percentage and days to maturity also had positive contribution.The residual effect was 0.4201 indicated there was some other characters those contribute 42% to the yield.

Yield per plant was significantly and positively correlated with panicle weight, spikelet fertility percentage and thousand grain weight both at genotypic and phenotypic levels. Path coefficient analysis revealed that spikelet fertility percentage, days to maturity and thousand grain weight had high positive direct effect indicated that direct selection based on these characters would be effective for yield improvement of submergence tolerant breeding lines.

References

Agbo CU and IUObi. 2005. Yield and yield component analysis of twelve upland rice genotypes. Journal of Agriculture, Food, Environment and Extension, *4*: 29-33.

Allard RW. 1960. Principles of Plant Breeding. John Wiley and Sons. Inc., New York.

BBS. 2014. Statistical Pocket Book of Bangladesh 2014, Bangladesh Bureau of Statistics, Ministry of Planning, GoB, Dhaka.

BER. 2015. Bangladesh Economic Review 2014. Economic Adviser's Wing, Finance Division, Ministy of Finance, Government of the Peoples Republic of Bangladesh, Dhaka. Pp. 17-99.

Bisne R, Sarwgi AK and Verulka SB. 2009. Study of heritability, genetic advance and variability for yield contributing characters in rice. Bangladesh Journal of Agricultural Research, *34*: 175-179.

Burton. GW. 1952. Quantitative inheritance in Grasses. Proceedings of the 6th International Grassland Congress, *1*: 277–283.

Idris AE and Mohamed KA. 2013. Estimation of genetic variability and correlationfor grain yieldcomponents in rice (*Oryza sativa* L.). Global Journal of Plant Ecophysiology, *3*: 1-6.

Iftekharuddaula KM, Newaz MA, Salam MA, Ahmed HU, Mahbub MAA, Septiningsih EM, Collard BCY, Sanchez DL, Pamplona AM and Mackill DJ. 2011. Rapid and high-precision marker assisted backcrossing to introgress the SUB1 QTL into BR11, the rain fed lowland rice mega variety of Bangladesh. Euphytica, *178*: 83–97.

Iftekharuddaula KM, Badshah MA, Hassan MS, Bashar MK and Akter K. 2001. Genetic variability, character association and path analysis of yield components in irrigated rice (*Oryza sativa* L.). Bangladesh Journal of Plant Breeding Genetics, *14*: 43-49.

Johnson HW, Robinson HF and Comstock RE. 1955. Estimates of genetic and environmental variability in soybeans. Agronomy Journal, *47*: 314-318.

Kampe AK, Tassew AA and Gezmu AT. 2018. Estimation of phenotypic and genotypic correlation and path coefficients in rain fed up land rice (*Oryza sativa L.*) genotypes at Guraferda, Southwest Ethiopia. Journal of Rice Research, *6*: 195.

Mohanty HK and Chaudhary RC. 1986. Breeding for submergence tolerance in rice in India. In: Maclean J, Banta S (Eds) Progress in rain fed low land rice. Manila, the Philippines: International Rice Research Institute, 191-200.

Mulugeta S, Alamerew S and Bantte K. 2012. Gegetic variability, heritability, correlation coefficient and path analysis for yield and yield related traits in upland rice (*Oryza sativa* L.). Journal of Plant Science, *7*: 13-22.

Qamar ZU, Chemma AA, Ashraf M, Rashid M and Tahir GR. 2005. Association analysis of some yield influencing traits in aromatic and non-aromatic rice. Pakistan Journal of Botany, *37*: 613-627.

Rokonuzzaman M, Zahangir MS and Hussain MI. 2008. Genotypic variability of components and their effects on the rice yield: Correlation and path analysis study. Italian Journal of Agronomy, *2*: 131-134.

Sairam RK, Kumutha D, Ezhilmathi K, Deshmukh PS and Srivastava GC. 2008. Physiology and biochemistry of waterlogging tolerance in plants. Biology of Plant, *52*: 401-412.

Shrivastava A, Mishra DK and Koutu GK. 2015. Estimation of genetic parameters of variability for yield and its attributing traits in parental lines of hybrid rice. Plant Archives, *15*: 571-574.

Singh RK and BD Chaudhary. 1985. Biometrical methods of quantitative genetic analysis. Haryana Journal of Horticultural Science, *12*: 151-156.

Sivasubramanian S and Madhavamenon P. 1973. Genotypic and phenotypic variability in rice. Madras Agricultural Journal, *60*: 1093 -1096.

Tiwari DK, Pandey P, Tripathi S, PGiri S and Dwivedi JL. 2011. Studies on geneticvariability for yield components in rice (*Oryza sativa* L.). Advances in Crop Science and Technology, *3*: 76-81.