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Genetic Variability and Association of Traits in Mutant Lines of Rice (*Oryza sativa* L.) for Submergence Tolerance

Nikita Kumari[1*], Rajesh Kumar[1] and Avinash Kumar[1]

[1]Department of Plant Breeding and Genetics, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar (848125), India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Present investigation was carried out with 240 mutant lines developed from different combination of gamma rays and ethyl methyl sulfonate on three rice varieties *i.e* FR13A, FR13B and Labella along with three untreated checks (FR13A, FR13B and Labella). These were evaluated for their survival percentage under submerged condition and yield potential along with 9 other morpho-physiological traits using Type 2 modified augmented design during *Kharif* season of 2017 in the agroclimatic region of north bihar, India. Analysis of variance revealed highly significant differences among the mutant lines for all morpho-physiological characters under study. Higher magnitude of phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (broad sense) and genetic advance as percentage of mean were observed for number of tillers per plant, number of fertile tillers per plant, relative shoot elongation and survival percentage, indicating that these traits could be used as selection indices for yield improvement and submergence tolerance. Association study revealed that number of tillers per plant and survival percentage had significant positive high

**Corresponding author: E-mail: nikita952527@gmail.com;*
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to moderate direct association with grain yield per plant under submergence condition. Thus, these traits may be used as selection criteria in further crop improvement programmes for submergence tolerance.

Keywords: Correlation coefficient; genetic advance; GCV; heritability; mutant rice; Oryza sativa; path coefficient; PCV.

1. INTRODUCTION

Rice (*Oryza sativa* L., 2n=24) is the most essential and staple food of the world and feeds half of the population. Rice provides nutrition for more people in the world than other crops, especially in developing countries [1]. Flooding is a serious, naturally occurring problem for rice production in the rainfed lowlands of south and south-east Asia during the monsoon season. Rainfed lowlands constitute highly fragile ecosystems, always prone to flash floods (submergence). Submergence stress adversely affects poor farmers living on 15 million ha of rice growing areas in the rainfed lowlands in south and south-east Asia. 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. Among the 42 biotic and abiotic stresses affecting rice production, submergence has been identified as the third most important constraint for higher rice productivity [2]. Scientists have estimated that 4 mt of rice is being lost every year because of flooding (IRRI, 2008). According to an estimate of National Bureau of Soil Survey and Land Use Planning nearly 3.3 mha of land in India is affected by flood of varying degree. Bihar is the India's most flood-prone state, with 76 percent of the population, in the north Bihar living under the recurring threat of flood devastation. The plains of North Bihar have recorded the highest number of floods during the last 30 years [3]. Rice is the only crop suitable for cultivation in the rainfed lowlands of India, where flash floods are frequent. Flash flooding accompanied by submergence during crop growth period is severe constraint to rice production in these areas. Inducible mutation is a suitable source of variations for crop improvement in respect of rice production. To achieve this breeding objective, changes at genetic and molecular level are employed to get those traits that could improve yield and other related traits. The purpose of mutation induction is to enhance mutation rate in short duration in developing new plant varieties. Induced Mutation techniques (physical and chemical) in the field of plant breeding can be used to increase the genetic variation that allows plant breeders to make selection according to desired objectives. Genetic variability is one of the important consideration or aspect in any crop improvement programme which needs to be manifested in detail. Variability is measured by estimation of genotypic and phenotypic variance (σ^2g and σ^2p), genotypic and phenotypic coefficient of variation (GCV and PCV), heritability and genetic advance as percent of mean. These parameters help in the selection of plants for the improvement of desired characters. Correlation is the degree of association of one character with the others and determine how these characteristics vary together or whether there is any relationship between any two such characters so the knowledge of correlation effect is considered to be of paramount importance in any crop improvement programme. The path analysis reveals whether the association of all the studied characters with yield is due to their direct effect on yield or is a consequence of their indirect effects *via* other component characters. In other words, it measures the cause of association between two variables (or traits). Considering the importance of genetic variability and character association in the selection of plant for improvement of desired traits. The present study was conducted on rice mutant lines to identify the traits that contributed towards yield directly and indirectly under submerged conditions.

2. MATERIALS AND METHODS

The field experiment was conducted on 240 mutant lines along with 3 untreated rice varieties (FR13A, FR13B and Labella) as checks at rice research farm of Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, during *Kharif*-2017. The experimental site is situated at 25.59° North latitudes and 85.40° East longitudes with an altitude of 52.18 meter above the mean sea level. Soil of Pusa (Samastipur) is mainly young alluvial and calcareous. Soil is deep, light to heavy in texture having 10-30% $CaCo_3$. This region has subtropical climate with annual rainfall of more than 1100 mm.

The experiment was performed in type 2 modified augmented design (MAD2) for one year. The entire tank area was divided into 10 blocks. Each block accommodated 24 lines and 3 checks. The checks were randomized and replicated as per procedure described by You et al. [4]. Each mutant lines was sown in 5 rows in a plot of 1m^2 with row to row distance of 20cm and plant to plant distance of 15cm. Recommended dose of fertilizer was applied during the crop period. Three random plants were tagged from each block to record the data for yield and its related traits except survival percentage. The phenotypic and genotypic coefficient of variability (PCV and GCV), heritability in broad sense, expected genetic advance at 5 percent selection intensity, phenotypic correlations coefficient and path coefficient analysis were computed by using statistical package WINDOSTAT version 9.2 (INDOSTAT service). The heritability (in broad sense) and Genetic advance as percent of means were adjudged on the basis of criteria given by Robinson et al. (1949) for heritability and the criteria suggested by Johnson et al. [5] was considered for genetic advance as percent of mean (Table 1).

Table 1. The heritability (in broad sense) and Genetic advance as percent of means

Category	Heritability (broad sense)	Genetic advance as percent of mean
High	> 60%	> 20%
Moderate	30-60%	10-20%
Low	<30%	< 10%

3. RESULTS AND DISCUSSION

The analysis of variance revealed that mean sum of square within block (ignoring treatments), within treatment (eliminating blocks) and checks vs. varieties were significant for all the traits showing significant differences among 240 mutant lines (Table 2). This indicated that high significant differences exist in mutant lines of rice screened for submergence tolerance along with yield and yield components namely; days to 50% flowering, plant height (cm), panicle length (cm), number of tillers per plant, number of fertile tillers per plant, total shoot elongation under submergence, relative shoot elongation under submergence, survival percentage, tolerance score, grain yield per plant and leaf senescence. High genetic variability for various traits in rice was also reported by Shobha Rani et al. [6], Pandey and Awasthi [7], Akter et al. [8], Khan et al. [9] and Devi et al. [10].

Wide range of phenotypic variances and genotypic variances were observed in the experimental materials for all the characters studied and it was found that phenotypic variance was slightly higher than the genotypic variance for all the characters investigated. The highest variability (genotypic and phenotypic variance) was recorded for survival percentage followed by plant height and days to 50% flowering (Table 3).

Phenotypic coefficient of variation (PCV) was also higher than genotypic coefficient of variation (GCV) for all the traits under investigation indicating the influence of environment on the manifestation of these characters. The narrow difference between GCV and PCV were recorded for most of the traits. A wide range of GCV was observed for the traits under investigation which ranged from 4.15 (grain yield per plant) to 44.97 (number of fertile tillers per plant). The highest GCV and PCV were recorded for number of fertile tillers per plant followed by number of tillers per plant and total shoot elongation (Table 2). This indicates the existence of wide genetic base among the mutant lines taken for study and possibility of genetic improvement through direct selection for these traits. These results are in accordance with the findings of Bhadru et al. [11] and Dhanwani et al. [12].

High heritability (broad sense) along with high genetic advance as percent of mean was recorded for number of tillers per plant (99.84, 73.52), number of fertile tillers per plant (99.77, 92.54), tolerance score (99.33, 35.64), relative shoot elongation (99.30, 52.57) and survival percentage (99.03, 42.76) indicating the heritability for these traits is due to additive gene effects and selection may be effective. These results were in accordance with the findings of Singh et al. [13] for effective tillers, Dhurai et al. [14] for effective tillers, plant height and yield per plant, Krishnaveni et al. [15] for grain yield per plant and effective tillers. Grain yield per plant showed high heritability coupled with low genetic advance (85.58, 7.93) indicating the favourable influence of environment on expression of the character rather than the genotype and selection for such traits may not be rewarding (Table 2). The high coefficient of variation along with high heritability and genetic advance as per cent of mean was observed for number of fertile tillers per plant and number of tillers per plant indicating the influence of additive gene action on the expression of these character and provide a good scope for improvement through selection of these characters under submerged conditions.

Table 2. Analysis of variance for various morpho-physiological characters in mutant lines of rice under submerged condition

Source of variation	d. f	Days to 50% flowering (Days)	Plant height (cm)	Panicle length (cm)	No. of tillers per plant	No. of fertile tillers per plant	Survival percentage (%)	Total shoot elongation (cm)	Relative shoot elongation (cm)	Tolerance score	Grain yield per plant (g.)	Leaf senescence (SPAD Value)
Block (ignoring Treatments)	9.00	202.26**	2154.27**	40.43**	22.41**	12.54**	149.77**	168.30**	49.71**	1.21**	4.01**	8.44**
Treatment (eliminating Blocks)	242.00	102.90**	81.79*	3.34**	6.18**	4.43**	205.53**	51.24**	32.00**	1.78**	0.99**	7.11**
Checks	2.00	285.23**	1061.28**	0.36	1.43**	14.41**	816.03**	403.57**	222.18**	7.61**	2.61**	13.03**
Varieties	239.00	108.24**	150.96**	4.86**	6.96**	4.75**	186.25**	52.32**	31.16**	1.62**	1.12**	7.29**
Checks vs. Varieties	1.00	226.85**	246.87*	8.21**	31.78**	21.20**	4917.17**	604.45**	297.79**	37.89**	1.35**	24.91**
ERROR	18.00	2.27	33.11	0.11	0.01	0.01	1.66	0.14	0.20	0.02	0.15	0.23
CV		8.41	10.36	9.67	16.71	16.53	22.03	29.24	26.75	18.28	4.54	6.64
CD (5%)		3.83	14.64	0.85	0.25	0.25	3.28	0.95	1.13	0.32	0.97	1.22

*** Significance at 1% level*

** Significance at 5% level*

Table 3. Estimates of genetic parameters for various morpho-physiological characters in mutant lines of rice under submerged condition

Sl. No.	Characters	Mean	$\sigma^2 g$	$\sigma^2 p$	GCV	PCV	h^2 (Broad sense)	Genetic advance as % of mean
1.	DFF (days)	122.086±0.66	97.41	99.68	8.09	8.18	97.72	16.47
2.	PH (cm)	118.89±0.79	108.33	141.44	8.76	10.01	76.59	15.79
3.	PL (cm)	22.53±0.14	4.36	4.48	9.28	9.40	97.32	18.87
4.	NTP	7.09±0.17	6.39	6.40	35.72	35.75	99.84	73.52
5.	NFTP	4.65±0.14	4.36	4.37	44.97	45.02	99.77	92.54
6.	SP (%)	62.62±0.89	169.68	171.34	20.86	20.96	99.03	42.76
7.	TSE (cm)	24.72±0.46	47.96	48.10	28.08	28.12	99.71	14.25
8.	RSE (cm)	20.87±0.36	28.46	28.66	25.61	25.70	99.30	52.57
9.	TS	6.98±0.82	1.48	1.49	17.39	17.48	99.33	35.64
10	GYP (g.)	22.74±0.07	0.89	1.04	4.15	4.48	85.58	7.93
11.	LS (SPAD value)	39.99±0.17	6.49	6.72	6.37	6.48	96.58	12.90

DFF = Days to 50% flowering, PH = Plant height, PL = Panicle length, NTP = No. of tillers per plant, NFTP = No. of fertile tillers per plant, SP = Survival percentage, TSE = Total shoot elongation, RSE = Relative shoot elongation, TS = Tolerance Score, GYP = Grain Yield per Plant, LS = Leaf Senescence

Table 4. Inter-relationship of various morpho-physiological characters in mutant lines of rice at phenotypic level under submerged condition

Sl. No.	Characters		DFF (days)	PH (cm)	PL (cm)	NTP	NFTP	SP (%)	TSE (cm)	RSE (cm)	TS	LS (SPAD Value)	GYP (g.)
1	DFF (days)	P	1.00										
2	PH (cm)	P	0.06	1.00									
3	PL (cm)	P	0.12	0.73**	1.00								
4	NTP	P	-0.06	0.07	0.09	1.00							
5	NFTP	P	-0.07	0.13	0.13	0.90**	1.00						
6	SP (%)	P	-0.06	0.11	0.02	0.72**	0.72**	1.00					
7	TSE (cm)	P	0.07	0.37	0.34	0.08	0.10	0.02	1.00				
8	RSE (cm)	P	0.06	0.02	0.08	0.06	0.06	-0.03	0.93**	1.00			
9	TS	P	0.06	-0.09	0.01	-0.64**	-0.64**	-0.86**	-0.03	0.02	1.00		
10	LS (SPAD Value)	P	-0.09	0.09	0.11	0.13	0.13	0.16	0.10	0.06	-0.15	1.00	
11	GYP (g.)	P	-0.06	0.06	0.03	0.84**	0.81**	0.76**	0.04	0.01	-0.68 **	0.13	1.00

P = Phenotypic
(*) Significant at 5% level
(**) Significant at 1% level

Table 5. Path coefficient analysis of various morpho-physiological characters in mutant lines of rice at phenotypic level under submerged condition

Sl. No.	Characters		DFF (days)	PH (cm)	PL (cm)	NTP	NFTP	SP (%)	TSE (cm)	RSE (cm)	TS	LS (SPAD Value)
1.	DFF (days)	P	**0.00**	0.00	0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00	-0.00
2.	PH (cm)	P	-0.01	**-0.11**	-0.08	-0.01	-0.01	-0.01	-0.04	-0.00	0.01	-0.01
3.	PL (cm)	P	-0.01	-0.03	**-0.05**	-0.00	-0.01	-0.00	-0.02	-0.00	-0.00	-0.01
4.	NTP	P	-0.03	0.03	0.04	**0.46**	0.41	0.33	0.04	0.03	-0.29	0.06
5.	NFTP	P	-0.01	0.03	0.03	0.18	**0.20**	0.14	0.02	0.01	-0.13	0.03
6.	SP (%)	P	-0.02	0.03	0.01	0.20	0.20	**0.27**	0.01	-0.01	-0.23	0.04
7.	TSE (cm)	P	0.02	0.11	0.11	0.02	0.03	0.01	**0.31**	0.29	-0.01	0.03
8.	RSE (cm)	P	-0.02	-0.01	-0.03	-0.02	-0.02	0.01	-0.28	**-0.30**	-0.01	-0.02
9.	TS	P	-0.00	0.00	-0.00	0.01	0.01	0.01	0.00	-0.00	**-0.02**	0.00
10.	LS (SPAD Value)	P	-0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	**0.00**
11.	GYP (g.)	P	**-0.06**	**0.06**	**0.03**	**0.84**	**0.81**	**0.76**	**0.04**	**0.01**	**-0.68**	**0.13**

Phenotypic: RESIDUAL EFFECT- 0.1851, R SQUARE- 0.164

Study of correlation coefficient revealed that phenotypic correlation exhibited significant and positive association of grain yield per plant with number of tillers per plant (0.84), number of fertile tillers per plant (0.81) and survival percentage (0.76). This indicated that all these characters were important for yield improvement under submergence conditions. This was in agreement with the earlier reports of Krishnaveni et al. [15] for effective tillers and Mehetre (1996) for number of tillers per plant. However, grain yield per plant showed significant and negative association with tolerance score (-0.68). Similar result was reported by Kole et al. [16] and Mulugela Seyoum et al. [17] (Table 3).

The phenotypic correlations of grain yield per plant with other quantitative characters were partitioned into their corresponding direct and indirect effects through path coefficient analysis (Table 5). Number of tillers per plant and survival percentage showed significant positive association along with high to moderate direct effect on grain yield per plant indicating that these two traits have significant direct influence on grain yield per plant under submergence stress condition. Number of fertile tillers per plant and survival percentage having significant positive association with yield per plant also showed positive indirect effect *via* number of tillers per plant on grain yield per plant. Similarly tolerance score having significant negative association with grain yield per plant showed moderate negative indirect effect via number of tillers per plant and survival percentage. These results indicating that number of tillers per plant, number of fertile tillers per plant and survival percentage are the characters which have to give importance while selecting the lines for submergence tolerance and grain yield. These results are similar to Zahid et al. [18], Kiami et al. (2012), Kiami and Nemadzadeh [19], Krishnamurthy and Kumar [20], Sudharani et al. [21], Bhatia et al. [22], Lakshmi et al. [23], Gopikannan and Ganesh [24] and Kolom et al. [25] (Table 4).

4. CONCLUSION

Higher magnitude of phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (broad sense) and genetic advance as percent of mean were observed for number of tillers per plant, number of fertile tillers per plant, relative shoot elongation and survival percentage, indicating that these traits could be used as selection indices for yield improvement and submergence tolerance. The highest GCV and PCV were recorded for number of fertile tillers per plant followed by number of tillers per plant and total shoot elongation indicating the existence of wide genetic base among the genotypes taken for study and possibility of genetic improvement through direct selection for these traits. Study of correlation coefficient revealed that phenotypic correlation exhibited significant and positive association of grain yield per plant with number of tillers per plant, number of fertile tillers per plant and survival percentage. This indicated that all these characters were important for yield improvement under submergence condition. Association study revealed that number of tillers per plant and survival percentage had significant positive association along with high to moderate direct effect on grain yield per plant indicating that these two traits have significant and direct influence on grain yield per plant under submergence stress condition. Thus these traits may be used as selection criteria for the improvement of rice crop production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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