Biological Forum – An International Journal **13(1): 446-451(2021)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Genetic Variability and Character Associations in Rice Cultivars of North Bank Plain Zone of Assam for Traits Associated with Adaptation under Moisture Stress and Grain Yield

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(Received 14 February 2021, Accepted 03 May, 2021)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Breeding rice varieties for tolerance to moisture stress along with high yield potential is a challenging task. Considering the wide diversity of rice growing environment including various degrees of moisture stress conditions, the rice germplasm of North Bank Plain Zone (NBPZ) of Assam appears to be important for their studies on genetic architecture with respect to traits associated with grain yield and moisture stress tolerance. Thus, the present study was conducted to elucidate the genetic variability and character association for traits related to tolerance towards moisture stress and grain yield in a set of 54 rice varieties of the region. The genotypes were evaluated by growing them in PVC pipes. The study revealed highest genotypic coefficient of variation for root volume, followed by root dry weight, root length density and grain yield. Considerably high amount of variation was also exhibited by filled grains per panicle, shoot dry weight, root length and root-shoot ratio. Out of all the traits studied, high heritability along with high genetic advance was recorded for root dry weight, root volume, root length density, root-shoot ratio, root length and grain yield per plant. As such, there exists ample scope for selection in order to obtain genetic gain on the above root parameters and grain yield. Correlation studies revealed a positive and significant association of plant height, filled grains per panicle, shoot dry weight, chlorophyll stability index and total chlorophyll with grain yield per plant. Indirect selection for these traits would bring about improvement in grain yield. The non-significant association of grain yield with the important root traits related to adaptation under moisture stress, despite their scope for gain in selection, indicated a further necessity of recombination breeding to combine good root traits with higher grain yield.

Keywords: Genetic variability, Correlation, Rice, North Bank Plain Zone of Assam, Grain Yield and Moisture stress tolerance

INTRODUCTION

The cultivated rice (*Oryza sativa* L.) is a noble crop feeding almost half of the global population. Rice is the staple food of almost the entire South East Asian countries including India. In fact, 'Rice is life' for the people of South-East Asia (Khush and Virk, 2000). Amongst the major challenges in the entire rice growing countries, the most important one is the water crisis. Thus, recent thrust of rice breeding is to search for genotypes adapted for water limiting environment. It is estimated that 5000 litres of water is needed to produce one kilogram of rice (Sarma *et al*, 2014). Being part of a mega biodiversity hot spot, the Northeast India including the state of Assam is the important reservoir of a plethora of rice germplasm having a wide range of climatic as well as seasonal adaptation. It is thus felt imperative to evaluate the rice genotypes of the North-Eastern region under moisture stress (aerobic) environment. Successful evidences are there indicating that rice varieties could be bred by incorporating root characteristics of upland genotypes that saved up to 60 % of water (Sarma *et al.*, 2014). A total of 1003 upland adapted rice germplasm are known to exist and are being conserved in the state of Assam (Das and Ahmed, 1995). However, in view of their low yield potential, it is necessary to exploit the variability in rice germplasm for further improvement of upland rice genotypes with tolerance to moisture stress.

Tolerance to moisture stress or drought is a complex phenotype associated with various morpho-physiological and biochemical traits. Plenty of reports are available indicating considerable diversity in rice genotypes for various traits related to adaptation under moisture stress. Plants, during this long run in evolution, have evolved numerous adaptive mechanisms to escape, avoid or tolerate moisture deficiencies. Among such mechanisms, the root system of plant forms one of the best drought resistance components (Passioura, 1982; Price *et al*., 1997).

Thus, keeping in view of need to improve tolerance to moisture stress and the possibility to explore the available diversity in rice germplasm of North East India, the native rice cultivars of one of the zones having rich in rice diversity *i.e.* the North Bank Plain Zone of Assam were studied for their variability and character association with respect to traits associated with grain yield and tolerance to moisture stress.

MATERIALS AND METHODS

A set of 54 rice cultivars comprising 51 winter rice varieties from farmers' fields of North Bank Plain Zone of Assam representing all the administrative blocks of the zone along with three hill rice genotypes formed the materials for the investigation. The investigation was conducted at the experimental field of Biswanath College of Agriculture, Biswanath Chariali, represented by the latitude of 26°15′N, 27°45′N, the longitude of 92°42′E, 95°30′E and altitude of 104 m MSL. The crop was raised during the *Kharif* season of 2019. The experiment was carried out using PVC (Poly Vinyl Chloride) tubes of 1m length and 20 cm in diameter. The experiment was conducted following a Completely Randomized Design (CRD) with two replications. To ensure the homogeneity of the experimental units, the same soil media was used thought the experimental units (PVC tubes). Five to six seeds were directly sown into each PVC pipes. Upon germination and seedling establishment, three well-spaced seedlings were retained and others were discarded. The experiment was carried out under rainfed condition to impose natural moisture stress upon the crop. To quantify and understand the genetic variability, observations were recorded for 15 quantitative traits *viz*., days to 50 *per cent* flowering, days to maturity, plant height (cm), effective tillers per plant, filled grains per panicle, root length (cm), root dry weight (g), root volume (cm^3), shoot dry weight (g), root-shoot ratio, total chlorophyll content, chlorophyll stability index, root length density, proline content and grain yield per plant. The data obtained were subjected to analysis of variance following the standard protocol given by Panse and Sukhatme (1967).

The mean sum of squares obtained from the analysis of variance (ANOVA) was subjected to estimation of genetic parameters of variation following Singh & Choudhury (1988). Genetic variability parameters, heritability and genetic advance were estimated using standard methods of Burton and Devane (1953), Lush (1945) and Johnson *et al.*, (1955). The correlation coefficients were calculated to determine the degree of association between the characters and yield. Both phenotypic and genotypic correlation coefficients between all pairs of characters were determined using variance and covariance components as suggested by Al-Jibouri *et al.*, (1958).

RESULTS AND DISCUSSION

The analysis of variance revealed the presence of significant variation for all the 15 quantitative traits which indicated scope of selection in the set of genotypes under study for traits related to yield and adaptation under moisture stress. Many workers in the past reported the presence of wide variability in rice germplasm for different quantitative and qualitative traits (Dhurai *et al*., 2014; Lingaiah *et al*., 2020). A high magnitude of variability in the set of genotypes under study might be due to the diverse types of cultivars representing diverse ecological situations of the zone as well as representing the cultivars from different ethnic communities and preferences. Thus, further dissection of the nature and magnitude of this variation in genetic terms would be meaningful. The estimates of different genetic parameters of variation are presented in Table 1.

The highest genotypic and phenotypic coefficient of variance (GCV and PCV) was observed for root volume followed by root dry weight, root length density and grain yield per plant. Ganapathy *et al.,* (2010) reported similar results for traits *viz*., root length, root dry weight, root length density, root volume and root-shoot ratio. However, moderate estimates of GCV and PCV were observed for traits *viz*., plant height, and effective tillers per plant, proline content, days to 50 *per cent* flowering and days to maturity. Nithya *et al*., (2020) reported similar results for plant height, effective tiller number, days to 50 *per cent* flowering and relative water content. Total chlorophyll content and chlorophyll stability index on the other hand showed low estimates of GCV and PCV which partially corresponds to the findings of Khriedinuo *et al.*, (2011). The magnitude of PCV was observed to be higher than that of GCV for all the characters under study which also corresponded to findings reported by Das *et al*. (2001) and Pandey *et al*., (2012).

Mere presence of variation is not sufficient to set the selection criteria unless heritable fraction of variation is not known (Burton, 1952). Here lies the essence of heritability estimation. Moreover, it is also important to predict the genetic gain under selection. Therefore, heritability and genetic advance serve as the reliable estimate to arrive at a morereliable conclusion about selection (Sarma and Richharia, 1995). When heritability and genetic advance are considered together, the prediction of the resultant effect of selection on phenotypic expression would be far better (Johnson *et al*., 1955). In the present investigation, high heritability coupled with high genetic advance as *per cent* mean was observed for traits *viz*., root dry weight, root volume, root length density, root-shoot ratio, root length and grain yield per plant. Similar results were also recorded by Hemamalini (1997) for root number, root volume and dry root weight and Perween *et al*., (2020) for traits *viz*., proline content, root biomass and grain yield per plant. A preponderance of additive gene action in the expression of these traits might be suggested based on these observations.

Table 1: Genetic parameters of variation for 15 quantitative traits in rice under moisture stress situation.

Character	Mean	Range	GV	PV	EV	GCV (%)	PCV (%)	H_{bs}	GA (%)
Days to 50 *per cent* flowering	114.537	69 - 144	223.82	225.69	1.87	13.06	13.12	99.17	26.80
Days to maturity	146.787	102 - 174	222.91	226.48	3.56	10.17	10.25	98.43	20.79
Plant Height	114.662	64.28 - 161.94	508.95	514.96	6.01	19.68	19.79	98.83	40.29
Effective tillers per plant	9.503	4 - 16	3.42	4.96	1.54	19.47	23.44	69.03	33.33
Filled grains per panicle	84.111	22 - 182	1018.07	1134.79	116.72	37.93	40.05	89.71	74.02
Root length	37.402	15.44 - 63.42	109.66	119.55	9.88	28.00	29.23	91.73	55.24
Root volume	23.905	6.5 - 59.5	157.98	165.83	7.85	52.58	53.87	95.27	105.72
Root dry weight	14.562	4.18 - 30.36	42.95	44.04	1.09	45.01	45.57	97.53	91.56
Shoot dry weight	44.295	15.94 - 83.74	232.55	236.98	4.43	34.43	34.75	98.13	70.25
Root-Shoot ratio	0.325	0.19 - 0.52	0.01	0.01	0.00	26.98	27.82	94.07	53.91
Total Chlorophyll content	1.688	1.24 - 1.87	0.01	0.01	0.01	4.66	6.65	49.17	6.74
Chlorophyll Stability Index	76.269	66.92 - 83.62	7.46	11.02	3.56	3.58	4.35	67.72	6.07
Root length density	0.139	0.04 - 0.29	0.00	0.00	0.00	45.01	45.57	97.53	91.56
Proline content	52.611	32.00 - 97.95	85.78	91.78	6.00	17.60	18.21	93.46	35.06
Grain yield per plant	13.625	3.69 - 34.69	36.39	41.28	4.89	44.28	47.16	88.16	85.64

Where,

GV-Genotypic Variance, PV-Phenotypic Variance, EV-Environmental Variance, GCV-Genotypic Coefficient of Variance, PCV-Phenotypic Coefficient of Variance, H_{bs}-Heritability in Broad Sense, GA-Genetic Advance as per cent mean

High heritability associated with moderate genetic advancement as *per cent* mean was recorded for the traits *viz*., days to 50 *per cent* flowering and days to maturity. Islam *et al.* (2015) and Sabesan *et al.* (2009) reported similar results indicating a possibility of obtaining a reasonable response to selection in these traits having high transmissibility (Osman *et al*., 2012 and Kumar *et al.*, 2001). Madhan Mohan *et al*. (2000) opined that high chlorophyll stability indices act as a reliable component for stress tolerance in rice. Plants tend to adapt through better availability of chlorophyll corresponding to an increased photosynthesis (Li *et al*., 2018). In the present study, chlorophyll stability index exhibited moderate heritability with low genetic advance indicating the non-additive gene action governing the trait. Hence, direct selection would not be effective for chlorophyll stability index in the group of cultivars under study.

The ultimate objective of any breeding programme is to obtain a high grain yield. Yield being a complex trait contributed by various yield attributing traits, it is important to elucidate the relationship of different yield attributing traits on grain yield. This is very useful for building an efficient breeding strategy for evolving high yielding varieties (Edukondalu, 2017). In this respect, the correlation coefficient of component traits with grain yield provides themeasure of their degree of association which helps us in understanding the nature and magnitude of relationship among various components and yield (Kumar *et al*., 2017). Apart from the normal yield components, consideration of various root traits contributing to drought could serve as a reliable criterion for improving yield in water-limited environments. Therefore, phenotypic and genotypic correlations were worked out for all the 15 quantitative characters to understand the nature of association among root traits, yield attributing characters and grain yield (Table 2 and Table 3).

A significant positive association was recorded for grain yield with plant height, filled grains per panicle, shoot dry weight and total chlorophyll at both phenotypic level and genotypic level. This corroborates with the findings of Saravanan and Sabesan (2009). Chlorophyll stability index exhibited a positive and significant association with grain yield at genotypic level only. Similar findings were reported by Nahakpam *et al*., (2017). Hence, direct selection of the above yield components showing a positive significant association with grain yield would improve on grain yield.

Amongst the yield components, positive significant correlation was observed between days to 50 *per cent* flowering and days to maturity; plant height with root length, shoot dry weight and total chlorophyll content; effective tiller number with root and shoot dry weight; filled grains per panicle with shoot dry weight, total chlorophyll content, and chlorophyll stability index. These results were in conformity with the result of Rao and Shrivastav (1999). It was revealed that the root-shoot ratio showed a significant negative association with grain yield as well as filled grains per panicle and chlorophyll stability index *i.e.* with an increase in the shoot in comparison to root, there is a corresponding increase in grain yield and also filled grains per panicle and chlorophyll stability index. Days to flowering exhibited a negative association with total chlorophyll content, while effective tillers showed a negative association with chlorophyll stability index.

Table 2: Estimates of phenotypic correlation for yield and root related traits under low-moisture stress condition.

Traits	DF	DM	PH	ETN	FG	RL	RV	RDW	SDW	RS	TC	CSI	RLD	PC
DF	1													
DM	0.9902	1												
PH	-0.0943	-0.1177	1											
ETN	0.0519	0.0599	0.1854	1										
FG	-0.1799	-0.203	0.2241	-0.0741	1									
RL	-0.0311	-0.0213	0.268	0.0482	-0.0961	1								
RV	-0.0813	-0.0756	0.0698	0.1609	-0.1758	0.4873	1							
RDW	-0.2128	-0.1951	0.2622	0.2754	0.0072	0.6301	0.7747	1						
SDW	-0.2283	-0.2204	0.3813	0.3229	0.3144	0.3819	0.4751	0.7647	1					
RS	-0.067	-0.0441	-0.0849	0.0202	-0.3644	0.5414	0.7006	0.6861	0.0925	1				
TC	-0.3294	-0.3409	0.2143	-0.0708	0.3339	0.1171	0.1699	0.1729	0.2141	0.0245	1			
CSI	-0.1147	-0.1286	0.1034	-0.217	0.2043	-0.0363	-0.0372	-0.1203	0.0143	-0.2266	0.469	1		
RLD	-0.2139	-0.1958	0.2665	0.2741	0.0013	0.6315	0.7719	0.9989	0.7654	0.6826	0.1716	-0.1259	1	
PC	-0.0914	-0.0789	0.2456	-0.1702	0.0671	0.1812	-0.1208	0.041	0.1668	-0.0923	-0.0216	-0.0015	0.0479	1
GY	-0.2055	-0.2138	0.3815	0.2053	0.628	-0.1334	-0.1532	0.0673	0.4021	-0.384	0.2923	0.2178	0.0653	0.0776

	Significant at 5%		Significant at both 1% & 5%

Where,

DF-Days to 50per cent flowering, DM-Days to maturity, PH-Plant height, ETN-Effective tillers per plant, FG-Filled grains per panicle, RL-Root length, RV-Root volume, RDW-Root dry weight, SDW-Shoot dry weight, RS-Root-shoot ratio, TC-Total Chlorophyll content, CSI-Chlorophyll Stability Index, RLD-Root Length Density, PC-Proline content, GY-Grain yield per plant

Table 3: Estimates of Genotypic correlation for yield and root related traits under low-moisture stress condition.

Traits	DF	DM	PH	ETN	FG	RL	RV	RDW	SDW	RS	TC	CSI	RLD	PC
DF	1													
DM	0.9936	1												
PH	-0.0965	-0.1205	1											
ETN	0.0696	0.0836	0.2162	1										
FG	-0.1968	-0.2206	0.2425	0.0128	1									
RL	-0.0306	-0.0174	0.2889	0.1115	-0.1081	1								
RV	-0.0839	-0.0788	0.0726	0.1973	-0.1859	0.5114	1							
RDW	-0.2169	-0.196	0.2687	0.3651	-0.0002	0.6429	0.7998	1						
SDW	-0.2357	-0.228	0.3914	0.4119	0.3177	0.3935	0.4922	0.7759	1					
RS	-0.0683	-0.0407	-0.0904	0.0502	-0.3928	0.558	0.731	0.6839	0.1041	1				
TC	-0.4795	-0.4931	0.3036	-0.2151	0.5592	0.1339	0.2229	0.2174	0.3147	0.0072	1			
CSI	-0.1372	-0.1612	0.1219	-0.3656	0.2861	-0.0221	-0.0642	-0.1462	0.01	-0.2751	0.626	1		
RLD	-0.2172	-0.1966	0.273	0.3588	-0.0031	0.6421	0.7976	1.0003	0.7781	0.6812	0.2105	-0.1502	1	
PC	-0.0978	-0.0817	0.2522	-0.1946	0.0631	0.1943	-0.1075	0.0385	0.1717	-0.1025	-0.0298	-0.0018	0.0471	1
GY	-0.2248	-0.2351	0.4074	0.2229	0.7337	-0.166	-0.1676	0.0693	0.4232	-0.4244	0.429	0.2797	0.0673	0.1271

	Significant at 5%		Significant at both 1% & 5%

Where,

DF-Days to 50per cent flowering, DM-Days to maturity, PH-Plant height, ETN-Effective tillers per plant, FG-Filled grains per panicle, RL-Root length, RV-Root volume, RDW-Root dry weight, SDW-Shoot dry weight, RS-Root-shoot ratio, TC-Total Chlorophyll content,CSI-Chlorophyll Stability Index, RLD-Root Length Density, PC-Proline content, GY-Grain yield per plant

Recombination breeding is an effective tool to break the undesirable negative association between important traits contributing to grain yield. Negative association like days to flowering with chlorophyll content, is however, desirable which indicate higher content of chlorophyll and therefore, photosynthesis, in the relatively early maturing genotypes.

Although grain yield is the primary trait for selection under stress condition, its low heritability often creates a necessity for choosing an alternative approach such as selection for secondary and putative traits. For simultaneous improvement of various traits associated with drought-tolerant, a thorough knowledge of the interrelationship between the traits is very important for the breeder to decide upon the direction and intensity of selection pressure to be imposed on related traits (Siddi, 2020). In the present study, important drought adaptive root traits *viz*., root length, root volume, root dry weight and root length density did not show significant association with grain yield despite their significant variation present in the set of germplasm. However, significant association amongst the root traits were prominent. Root length was positively and significantly correlated with root volume, root dry weight, shoot dry weight, root-shoot ratio and root length density. Likewise, root volume with root dry weight, shoot dry weight, root shoot ratio and root length density; root dry weight with shoot dry weight, root shoot ratio and root length density; shoot dry weight with root length density and grain yield per plant; root shoot ratio with root length density. Similar findings were also reported by Yogameenakshi *et al*., (2004). The *inter se* positive association of these drought adaptive traits are indicative of their scope for simultaneous selection. However, their non-significant association with grain yield indicates that direct selection for them will not favour grain yield improvement. It is thus, inferred that the breeding approach would be to combine the good root traits with good yield components through a recombination breeding approach. Further analysis of genetic diversity and efficient hybridization programme involving diverse genotypes with good root traits and good yield traits are necessary for the improvement of grain yield and traits for moisture stress adaptation.

In the light of the above discussion, it may be suggested that selection of characters such as plant height, filled grains per panicle, shoot dry weight, total chlorophyll and chlorophyll stability index would be very effective as they expressed positive and significant correlation with grain yield and would be highly fruitful in developing varieties having higher yield.

CONCLUSION

The present study indicated that direct selection for the traits *viz*., filled grains per panicle, root volume, root dry weight, shoot dry weight, root length density and grain yield per plant would be effective. From the association studies it was obvious that root traits which play a vital role in conferring drought tolerance exhibit little direct correlation with yield and other yield components. Therefore, all the root traits associated with drought adaptation needs to be selected separately. For simultaneous improvement genotypes for drought tolerance and higher yield, two separate yet parallel selection schemes need to be formulated, one for root traits and the other for yield related traits. This should be followed by further genetic divergence and combining ability studies and hybridization between genotypes to obtain segregants with combination of desirable root traits and yield attributes. Thus, it appears that judicious manipulation of the existing variability in the set of genotypes under the present study, would yield more efficient varieties with higher yield and adaptation under moisture stress.

ACKNOWLEDGEMENT

Authors are thankful to Advanced Level Biotech Hub and Department of Plant Breeding and Genetics, B N College of Agriculture, Assam Agricultural University, Biswanath Chariali, 784176, India.

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How to cite this article: Ahmed, A.S.N., Sarma, M.K., Bhuyan, J., Deka, S.D., Choudhury, H. Zaman, S. and Sharma, A.A. (2021). Genetic Variability and Character Associations in Rice Cultivars of North Bank Plain Zone of Assam for Traits Associated with Adaptation under Moisture Stress and Grain Yield. *Biological Forum – An International Journal*, **13**(1): 446-451.