

RESEARCH ARTICLE

# Variability and Character Association in Different Classes of Rice (*Oryza sativa* L.) of Assam for Root and Yield Attributing Traits

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## Abstract

Root and yield-attributing traits for plant selection in rice have been major breeding objectives for the development of varieties with higher yield and stress tolerance. Therefore, the present investigation was conducted for a comparative study of root and yield attributing traits in different classes of rice in Assam. The study revealed the presence of genetic variability among the genotypes for all the traits. Bao varieties showed maximum root development throughout its growth period up to maturity. The highest phenotypic and genotypic coefficient of variation was observed for the root length, root volume and root: shoot ratio. Similarly, in yield attributing traits number of spikelets per panicle showed maximum PCV and GCV followed by total tillers per plant and Days to 50% flowering. The correlation coefficient revealed a positive association of fresh root weight, root: shoot ratio, total tillers per plant, and effective tillers per plant with grain yield per plant, respectively at the genotypic level. A higher genotypic correlation coefficient indicates less influence of environmental effects on traits.

**Keywords:** Root traits, Assam rice, Yield attributing traits, Moisture stress.

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## Introduction

Rice is one of the most widely consumed cereals and is the primary food source for about two-thirds of the global population (Pirdashti *et al.*, 2009). For approximately 100 million Indian families, rice serves as their main source of carbohydrates and minerals. The most significant food crop in Northeast India is rice, including Assam, which is widely grown on 72% of the total cultivated land in upland, lowland, and deepwater conditions (Singh *et al.*, 2006). About 5.2 million tonnes of rice are produced on 2.5 million hectares of paddy land in Assam. Although the crop is mainly cultivated in rainfed conditions, the production of rice is impacted by the climatic fluctuation of the region.

In rainfed conditions, water scarcity is the major limiting factor for the growth and productivity of rice crops. In addition to that climatic variation due to global warming contributed more towards moisture stress in rice production. According to Babu *et al.* (2003), moisture stress is the primary obstacle to rice production and yield stability in rainfed ecosystems, resulting in a yield that is less than one-third of the global average. It is imperative to identify or develop rice cultivars that can withstand such threats during this critical period to address the increasing global food crisis.

Due to its extreme difficulty studies on root traits in the field condition is very limited. In Assam, a few attempts have been undertaken to study root traits in rice besides yield attributing

traits, which are confined to the shoot portion only. Roots are the principal organ for the uptake of nutrients and water from soil. Besides the uptake of water and nutrients, it provides mechanical anchorage to the plant. The root system serves as vital in situations of stress since it is the first organ to encounter different abiotic stimuli. The current study aims to find genotypes that possess desirable root and yield-attributing traits that could impact rice productivity and production.

## Materials and Methods

The experimental materials consisted 23 genotypes that belong to three diverse traditional rice classes of Assam, namely *Bao*, *Ahu*, *Sali* and two high-yielding varieties were also included (Table 1). These genotypes were collected in pure form from Assam Agricultural University Zonal Agricultural Research Station, Lakhimpur, Assam. The experiment was conducted during *Sali* season (June–November) of 2020 at Instructional cum Research Farm, Department of Plant Breeding and Genetics, Assam Agricultural University, Jorhat. The material was planted in a randomized block design with three replications in PVC pipes with dimensions of 11 cm diameter and 1 m length placed in 30 cm depth and filled with a mixture of soil

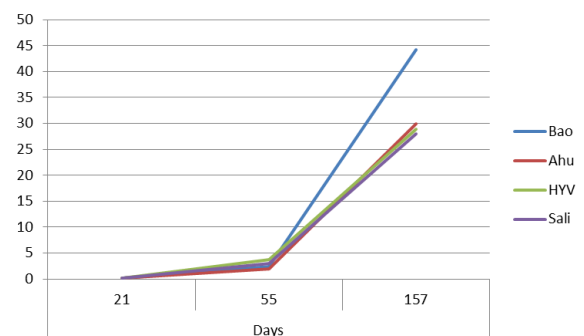
**Table 1:** Details of rice genotypes used in the experiment

S No.	Genotypes	Class	Type of cultivar
1	Panindra	Bao	Improved
2	Sunmoti 2	Bao	Traditional
3	Negheri	Bao	Traditional
4	Amona	Bao	Traditional
5	Pachanan	Bao	Improved
6	Kekuwa	Bao	Traditional
7	Ahina	Bao	Traditional
8	Betguti 1	Ahu	Traditional
9	Lahi Ahu	Ahu	Traditional
10	Kola Ahu	Ahu	Traditional
11	Bengungutia Ahu	Ahu	Traditional
12	Kopougutia Ahu	Ahu	Traditional
13	Disang	Ahu	HYV
14	Luit	Ahu	HYV
15	Arize Bold	Sali	Hybrid
16	Arize Diamond	Sali	Hybrid
17	Kola Pakhi	Sali	Traditional
18	Ranjit	Sali	HYV
19	Gitesh	Sali	HYV
20	Bor Aijung	Sali	Traditional
21	Solpona	Sali	Traditional
22	Bordubi 3	Sali	Traditional
23	Chakua	Sali	Traditional

and farm yard manure in the ratio of 10:1. The spacing for the tubes was 50 x 50 cm. Altogether 15 parameters were recorded. Different root traits considered were root and shoot weight (g), maximum root length (cm), root volume (cc) and root: shoot ratio. Root sampling was done at 21 and 55 days and at maturity in the month of November. At the time of sowing, five seeds per pipe were sown, but at 21 days of sowing, one seedling from each pipe was uprooted to record the root weight of the seedlings. Similarly, root sampling was done at 55 days for recording root weight, allowing only one plant per pipe to grow from then onwards. A suitable growing condition was maintained so that less possible extraneous effect is shown on the phenotypic expression of the characters. The PVC pipes were removed carefully and soaked in water to loosen the soil. Roots were cleaned thoroughly and carefully under running water. The intact root system of each plant was collected and stored. Root fresh weights were recorded after sampling, root dry weights were recorded by drying in room temperature (25°C) for one week and dry weights (g) were recorded. Maximum root length (cm) was measured from the base of the plant (collar region) to the tip of the longest root. Root volume (cubic centimeter; cc) was measured based on the water displacement method. A graduated measuring cylinder was filled with water and the initial volume was recorded. Then, the root system was immersed in the measuring cylinder and the final volume was noted down after the proportionate water displacement occurred. The difference between the two readings gave root volume (cc). Root: shoot ratio was computed by dividing the root dry weight of a sample plant by the respective shoot dry weight. Data were collected and subjected to analysis of variance (ANOVA) for all the traits following the standard protocols. Genetic parameters of variation, heritability and genetic advance were estimated following Burton and Devane (1953). Genotypic and phenotypic correlation coefficients were determined by following Singh and Choudhury (1985).

## Result and Discussion

The analysis of variance revealed significant variation among the genotypes for root and yield attributing traits, which



**Fig 1:** Rate of change of root development (root weight) of different classes of rice

**Table 2 (a):** Analysis of Variance for root traits of rice genotypes

Source of variation	df	Mean square						
		Root Fresh Weight (g)	Root Dry Weight (g)	Shoot Fresh Weight (g)	Shoot Dry Weight (g)	Root Length (cm)	Root Volume (cc)	Root: Shoot Ratio
Replication	2	110.88**	15.84	13.5	33.46	15.79	37.96	0.02
Genotype	22	310.74**	291.18**	402.17**	330.97**	503.47**	900.92**	0.20**
Error	44	12.02	10.56	25.19	28.16	5.92	18.75	0.01
CD (%)		5.71	5.88	8.27	8.76	4.02	7.15	0.18
CV		7.38	10.61	5.95	9.77	6.30	9.05	16.71

**Table 2 (b):** Analysis of Variance for yield attributing traits of rice genotypes

Source of variation	df	Mean square							
		Days to 50% Flowering	Plant Height(cm)	Total Tillers per Plant	Effective Tillers per Plant	Panicle Length(cm)	Number of Spikelet per Panicle	1000-Grain Weight(g)	Grain yield per plant (g)
Replication	2	127.14	0.23	0.91	8.74**	4.52	376.41	4.15	30.13*
Genotype	22	879.32**	1016.61**	42.03**	6.30**	32.55**	4577.49**	26.43**	34.80**
Error	44	40.27	16.54	4.08	1.41	1.73	219.25	2.22	7.91
CD (%)		10.48	6.72	3.34	3.34	2.17	24.45	2.46	4.65
CV		6.78	3.61	11.33	14.82	5.59	9.98	8.03	12.21

\*Significant at 5%; \*\*significant at 1%

might be due to diverse sources (*Ahu, Sali, Bao*, Modern cultivars) amongst the experimental material (Table 2(a) &(b)). Similar findings were reported by many workers in the past, which revealed the presence of wide genetic variability among root traits and for different quantitative traits (Anbumalarmathi *et al.*, (2008); Courtois *et al.*, (2013)). The rate of change of root weight was computed graphically (Fig.1) based on the observations made at 21, 55 and 157 (maturity) days after sowing (DAS) for *Bao, Ahu, Sali* and the hybrid group. The mean root weight of all the classes of rice exhibited a similar trend up to 55 DAS. The mean root weight increased at a faster rate in the case of *Bao* varieties up to 40 g at maturity, while in all other classes, the rate of increase was similar (30 g). *Bao* or deepwater rice exhibited the highest root growth as compared to other rice classes. Since *Bao* or deepwater rice encounters drought in the early vegetative stage and prolonged submergence in the later part of the life cycle, it is likely to show higher root growth than the others. Varietal differences were obtained from genetic parameters calculated for all the characters presented in Table 3(a) & (b). Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV) were recorded as highest for root: shoot ratio followed by root volume root length. Similarly, for yield attributing traits number of spikelets per panicle recorded maximum PCV and GCV followed by total tillers per plant and Days to 50% flowering. Minimum differences between GCV and PCV were recorded, which depicts the minimum role of the environment in the expression of these characters. These

findings concurred with Roy *et al.*, (2009) and Hijam *et al.*, (2012).

The presence of high magnitude of variation is not sufficient for the selection to become effective unless a heritable fraction of variation is not known (Burton, 1952). Hence it becomes imperative to estimate the heritable variation. In addition, it is also important to find out genetic gain under selection along with heritability to reach a more reliable conclusion. In the present investigation, heritability estimates were observed to be highest for root length, followed by root volume, root fresh weight and root dry weight. Genetic advance as a percentage of the mean was observed to be highest for root shoot ratio, followed by root volume, root length, root fresh weight, and root dry weight. Similarly, in yield attributing traits maximum heritability was observed for plant height followed by days to 50% flowering and panicle length. Genetic advance as a percent of mean was found to be the maximum for the number of spikelets per panicle, followed by total tillers per plant and days to 50% flowering. Similar findings were reported by Hijam *et al.*, (2012); Phung *et al.*, (2016). High heritability, along with high genetic gain, indicated the presence of additive gene action. Both high heritability coupled with high genetic advance together serve as a better indication for the efficiency of selection than considering alone (Johnson *et al.*, 1955). Based on the above observations, root traits such as root volume, root fresh weight, and root dry weight can be considered for further investigation in the present germplasm under study.

The mean value of root fresh weight was 47 g, with a

**Table 3 (a):** Estimate of range, general mean, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability in broad sense, genetic advance as percentage of mean for root traits:

Traits	Range	MEAN $\pm$ Sem	PCV (%)	GCV (%)	Heritability (bs) (%)	GA as % of mean
Root Fresh Weight(g)	28–62.33	46.9 9 $\pm$ 2.00	22.48	21.23	89.22	41.32
Root Dry Weight (g)	19–50.67	33.64 $\pm$ 2.06	30.54	28.64	87.93	55.32
Shoot Fresh Weight (g)	60.67–104	84.40 $\pm$ 2.90	14.55	13.28	83.30	24.97
Shoot Dry Weight (g)	38.67–79.83	54.35 $\pm$ 3.06	20.90	18.48	78.18	33.67
Root Length (cm)	22.5–73.67	38.62 $\pm$ 1.405	33.94	33.35	96.55	67.50
Root Volume (cc)	9.17–80.33	47.87 $\pm$ 2.50	36.94	35.82	94.00	71.54
Root: Shoot Ratio	0.31–1.33	0.65 $\pm$ 0.06	2.52	39.10	84.56	74.07

**Table 3 (b):** Estimates of range, general mean, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability in broad sense, genetic advance as percentage of mean for yield attributing traits

Traits	Range	MEAN $\pm$ Sem	PCV (%)	GCV (%)	Heritability (%)	GA as % of mean
Days to 50% Flowering	70–124	93.55 $\pm$ 3.66	19.12	17.87	87.41	34.43
Plant Height(cm)	86.33-161	112.54 $\pm$ 2.35	16.62	16.22	95.27	32.62
Total Tillers per Plant	9.67–23	17.83 $\pm$ 1.17	22.94	19.95	75.61	35.73
Effective Tillers per Plant	5.33–10	8.00 $\pm$ 0.69	21.78	15.97	53.72	24.11
Panicle Length(cm)	17.73–29.33	23.53 $\pm$ 0.76	14.72	13.62	85.57	25.95
Number of Spikelet per Plant	92–216	148.42 $\pm$ 8.55	27.55	25.68	86.88	49.31
1000-Grain Weight(g)	10.83–22.4	18.56 $\pm$ 0.86	17.28	15.30	78.42	27.91
Grain Yield per Plant(g)	14.17–27.46	23.03 $\pm$ 1.62	17.83	12.99	53.10	19.51

range of 28 g in *Lahi Ahu* (Fig. 2: Plate no. 5) to 62.33 g in *Pachanan* (Fig. 2: Plate no. 1) (Tables 3 (a and b) & 4). Similarly, dry root weight varied from 19 g in *Lahi Ahu* to 50.67 g in *Sunmoti 2* (Fig 2; Plate no. 2) with a mean value of 55.33 g. The wide range of variation for root weight revealed the scope for the selection of desirable genotypes having high root weight. Genetic variation for root biomass was also reported by Hijam *et al.*, (2012). Considerable genetic variations in root biomass were also reported by various authors (Ingram *et al.*, 1994 and Kato *et al.*, 2009). Shoot fresh weight varied from 60.67 in *Bordubi 3* to 104 g in *Kekua*, with a mean value of 84 g. Similarly, the mean value for the shoot dry weight was recorded to be 54 g, with a range of 38.67 g in *Solpona* to 79.83 g in *Kola Pakhi*. Root length significantly varied from 22.5 cm in *Bor Aijung* (Fig 2: Plate no.1) to 73.67 cm in *Chakua* (Fig 2: Plate no. 5) with a mean value of 39 cm. The mean value for root volume was 48 cc with a range of 9.17 cc in *Betguti 1* (Fig 2; Plate no. 2) to 80.33 cc in *Negheri* (Fig2: Plate no.5) Similarly, root: shoot ratio varied from 0.31 in *Lahi Ahu* to 1.33 in *Sunmoti 2* with mean value of 1. *Bao* varieties are significantly superior to all other genotypes for root fresh weight, root dry weight, shoot fresh weight, root volume, and root: shoot ratio, which indicates scope for selection from this class of rice. Wang *et al.*, (2006) have also reported that the characters, viz., root volume, root: shoot ratio, root distribution pattern, have various functional significance.

In the present investigation, apart from estimating the correlation coefficient for yield and yield-attributing traits,

the effect of root traits on grain yield was also estimated (Table 5), which could serve as a reliable criterion for improving the adaptation of rice crops under water-limiting conditions.

A significant positive association was recorded for grain yield with root fresh weight, root: shoot ratio, and effective tillers per plant at the genotypic level. At the phenotypic level, the traits showed a non-significant association with grain yield. These findings were in agreement with Yogameenkashi & Vivekananda (2010); and Pushpam *et al.* (2017). Root fresh weight was found to have a significant positive correlation at phenotypic and genotypic levels with root dry weight, shoot fresh weight, root: shoot ratio and days to 50% flowering. These findings were in conformity with Hijam *et al.*, (2012); Nassir *et al.*, (2017). This strong inter-correlation among the traits indicates the scope for simultaneous selection and improvement of these traits along with grain yield

Similarly, root length showed a significant positive association with panicle length at phenotypic and genotypic levels. This was in agreement with the findings of Armenta-Soto *et al.*, (1983); Toorchi *et al.*, (2003). Therefore, selection for root length may simultaneously improve the panicle length, which is an important yield-attributing trait.

Total tillers per plant and 1000-grain weight recorded a positive association with grain yield at both phenotypic and genotypic levels. Also, total tiller per plant recorded a positive correlation with root volume, indicating the scope

Table 4: Mean performance of the genotypes for root traits

Genotypes	Mean ± Standard Deviation						
	Root Fresh Weight(g)	Root Dry Weight(g)	Shoot Fresh Weight(g)	Shoot Dry Weight(g)	Root Length(cm)	Root Volume(cc)	Root: Shoot Ratio
Panindra	60 ± 2.71	48.00 ± 2.99	93.33 ± 1.86	61.17 ± 1.42	32.33 ± 1.31	40.67 ± 1.50	0.79 ± 0.03
Sunmoti 2	61.33 ± 2.99	50.67 ± 3.55	77.33 ± 1.47	38.17 ± 3.37	28.33 ± 2.14	40.50 ± 1.54	1.33 ± 0.14
Negheri	60 ± 2.71	44.33 ± 2.23	76.33 ± 1.68	42.50 ± 2.47	42.00 ± 0.71	80.33 ± 6.77	1.05 ± 0.08
Amona	45.66 ± 0.27	32.00 ± 0.34	95.67 ± 2.35	62.50 ± 1.70	31.33 ± 1.52	35.33 ± 2.61	0.51 ± 0.03
Pachanan	62.33 ± 3.20	44.67 ± 2.30	91.67 ± 1.52	55.50 ± 0.24	30.00 ± 1.80	78.67 ± 6.42	0.81 ± 0.03
Kekuwa	61 ± 2.92	46.67 ± 2.72	104.00 ± 4.09	62.33 ± 1.66	62.33 ± 4.95	44.00 ± 0.81	0.75 ± 0.02
Ahina	52.33 ± 1.12	43.33 ± 2.02	85.00 ± 0.13	51.50 ± 0.59	59.83 ± 4.42	41.00 ± 1.43	0.85 ± 0.04
Betguti 1	38 ± 1.87	27.67 ± 1.24	67.67 ± 3.49	52.00 ± 0.49	33.33 ± 1.10	9.17 ± 8.07	0.53 ± 0.03
Lahi Ahu	28 ± 3.96	19.00 ± 3.05	84.67 ± 0.06	62.00 ± 1.60	42.67 ± 0.84	64.00 ± 3.36	0.31 ± 0.07
Kola Ahu	38.33 ± 1.80	24.33 ± 1.94	75.33 ± 1.89	53.67 ± 0.14	51.67 ± 2.72	45.00 ± 0.60	0.45 ± 0.04
Bengungutia Ahu	47.33 ± 0.07	31.67 ± 0.41	84.67 ± 0.06	42.33 ± 2.51	40.33 ± 0.36	14.67 ± 6.92	0.75 ± 0.02
Kopougutia Ahu	55.66 ± 1.81	45.00 ± 2.37	79.67 ± 0.99	41.67 ± 2.64	41.00 ± 0.50	56.67 ± 1.83	1.08 ± 0.09
Disang	52.33 ± 1.12	39.67 ± 1.26	83.17 ± 0.26	50.67 ± 0.77	30.00 ± 1.80	45.33 ± 0.53	0.80 ± 0.03
Luit	37.66 ± 1.94	22.67 ± 2.29	61.33 ± 4.81	49.87 ± 0.93	26.33 ± 2.56	66.67 ± 3.92	0.46 ± 0.04
Arize Bold	55.33 ± 1.74	32.00 ± 0.34	98.00 ± 2.84	63.67 ± 1.94	33.00 ± 1.17	65.67 ± 3.71	0.51 ± 0.03
Arize Diamond	41 ± 1.25	25.67 ± 1.66	83.67 ± 0.15	67.33 ± 2.71	45.00 ± 1.33	48.33 ± 0.10	0.38 ± 0.06
Kola Pakhi	44 ± 0.62	34.33 ± 0.14	102.67 ± 3.81	79.83 ± 5.31	44.33 ± 1.19	58.67 ± 2.25	0.43 ± 0.05
Ranjit	36.33 ± 2.22	24.33 ± 1.94	87.67 ± 0.68	56.17 ± 0.38	30.33 ± 1.73	45.00 ± 0.60	0.43 ± 0.05
Gitesh	35 ± 2.50	20.67 ± 2.70	96.33 ± 2.49	64.50 ± 2.12	30.83 ± 1.62	37.33 ± 2.20	0.33 ± 0.07
Bor Aijung	44.33 ± 0.55	30.33 ± 0.69	89.00 ± 0.96	57.00 ± 0.55	22.50 ± 3.36	30.00 ± 3.73	0.54 ± 0.02
Solpona	33.66 ± 2.78	20.33 ± 2.77	81.33 ± 0.64	38.67 ± 3.27	31.67 ± 1.45	50.67 ± 0.58	0.53 ± 0.03
Bordubi 3	44 ± 0.62	33.67 ± 0.01	60.67 ± 4.95	41.33 ± 2.71	25.33 ± 2.77	46.00 ± 0.39	0.86 ± 0.04
Chakua	47 ± 0.003	32.67 ± 0.20	82.00 ± 0.50	55.67 ± 0.27	73.67 ± 7.31	57.33 ± 1.97	0.59 ± 0.01

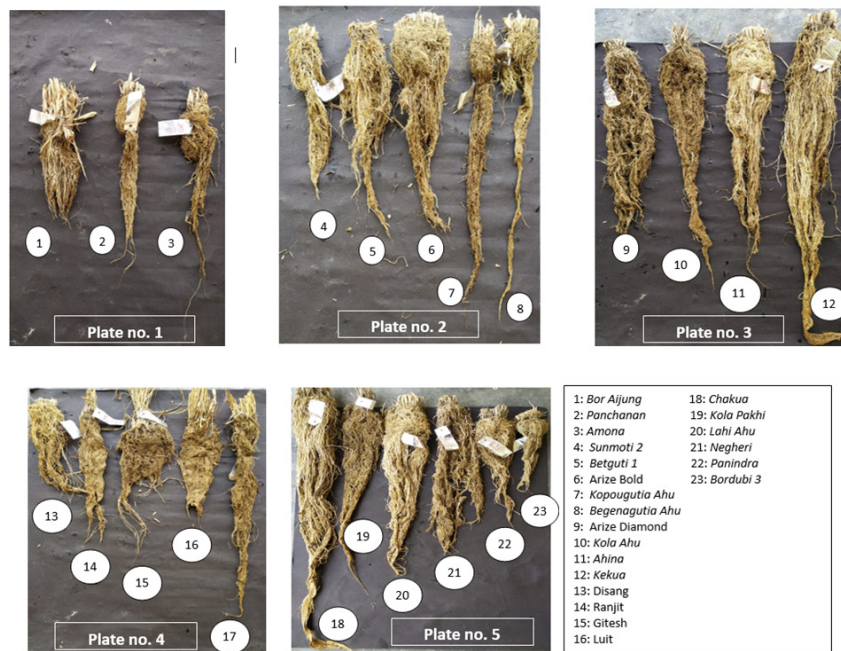


Fig 2: Root traits of different rice genotypes

Table 5: Correlation coefficient at genotypic level (upper diagonal) and phenotypic level (lower diagonal)

	RFW	RDW	SFW	SDW	RL	RV	RSR	DFF	PH	TTP	ETP	PL	NSP	TGW	GYP
RFW															
RDW	0.973**														
SFW	0.265*	0.179													
SDW	-0.176	-0.212	0.721**												
RL	0.121	0.154	0.210	0.084											
RV	0.228	0.140	0.035	0.103	0.058										
RSR	0.811**	0.863**	-0.233	0.089	0.164	0.066									
DFF	0.293*	0.358**	0.370**	-0.054	0.221	0.333**	0.371**								
PH	-0.011	0.044	0.190	0.275*	0.068	0.023	-0.151	-0.212							
TTP	0.113	0.106	0.096	0.189	-0.057	-0.035	-0.172	0.609**	0.114						
ETP	0.257*	0.228	0.102	0.222	0.191	0.918**	-0.277*	-0.195	0.200	0.119					
PL	-0.425**	-0.412**	0.045	0.258*	0.304*	0.283*	-0.379**	0.066	-0.104	0.139	0.119				
NSP	0.167	0.183	-0.152	-0.033	0.494**	0.165	-0.182	0.060	-0.168	0.060	0.119	0.245*			
TGW	0.200	0.124	-0.024	-0.170	-0.090	0.207	-0.117	0.259*	-0.263*	0.060	0.119	0.245*	0.622**		
GYP	0.310**	0.172	0.012	-0.267*	0.241*	0.057	-0.013	0.403**	0.024	0.060	0.119	0.245*	0.622**	0.796**	

\*Significant at 5%; \*\*significant at 1%

for selection of root volume, which may improve total tiller per plant and eventually improve the grain yield due to a strong positive correlation between grain yield and total tiller plant.

However, a negative significant association of panicle length with total tillers per plant later having a positive association with grain yield might affect the grain yield negatively. Therefore, to break this negative association, recombination breeding can be adopted.

From the above discussion, it can be inferred that direct selection for root fresh weight, root: shoot ratio, and effective tillers per plant can be advocated to improve grain yield. Drought adaptive traits such as root length, root volume, and root: shoot ratio did not show any significant association with grain yield; hence, direct selection for these traits will not be effective. However, their inter-correlation with other yield-attributing traits indicated the scope for simultaneous improvement of these traits. The breeding approach would be combining good root traits with good yield attributing traits through recombination breeding.

## Conclusion

From the present investigation, we can conclude that root traits such as root volume, root: shoot ratio, root fresh weight and yield attributing traits such as total tillers per plant, days to 50% flowering, number of spikelets per panicle can be used as a reliable criterion for improving grain yield. Simultaneous improvement of root traits along with yield attributing traits might contribute to the grain yield along with adaptation of rice genotypes in moisture stress growing conditions. The findings from the above investigation can be followed by studying genetic divergence, combining ability and hybridization among the genotypes to obtain cultivars with desirable traits adapted to moisture stress growing conditions. Although in the present investigation, drought stress, submergence, and other abiotic stress were not studied, further study with the inclusion of stress tolerance may be useful.

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