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EVALUATION OF WHOLE-PLANT ARCHITECTURE OF AEROBIC RICE (*Oryza sativa* L.) FOR YIELD ATTRIBUTES

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Abstract

Rice (Oryza sativa L.) is the staple food of Asia and this warrants a high production across the region. Breeding for drought tolerance has immense value to the farmers as their livelihood depends on the harvest. The present investigation was conducted to study the whole-plant architecture of aerobic rice by analyzing root and shoot characters for improving the grain yield. In this study, ten genotypes which were highly contrasting in phenotypic characters were grown in field as well as in PVC pipes. Analysis of variance for root morphological traits, yield and yield attributed traits under aerobic condition revealed significant differences among the genotypes for all traits. GCV, PCV, h^2 and genetic advance were high in genotypes for all the traits recorded. For root traits, GCV ranged from 14.42 % for root growth rate by length (RGRL) to 44.76 % for root-shoot weight ratio (RSWR) while vegetative traits recorded relatively lower GCV which ranged from 6.68 % for days to maturity (DTM) to 34.09 % for shoot biomass (SBM). Grain yield showed significant positive correlation with plant height (0.458), panicle length (0.549), shoot biomass (0.771), shoot growth rate by length (0.408) and total plant length (0.446). Path analysis revealed that root length (RL) had the highest positive direct effect on grain yield per plant whereas plant growth rate by wt. (TGRW) had the lowest positive direct effect. The root-shoot ratios were higher for improved accessions as compared to traditional genotypes. .

Keywords: Aerobic, drought, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), correlation

I. INTRODUCTION

Declining water resources for rice cultivation has encouraged research on the development of water efficient aerobic rice varieties by combining the high-yielding traits of lowland varieties with the drought-resistant characteristics of upland varieties. Drought is a major abiotic stress affecting crop growth and yield stability. More than 80% of the Asian regions are drought prone and therefore development of rice cultivars suitable for semi-irrigated cultivation is indispensable.

Grain yield is one single trait that could be considered as a manifestation of drought resistance. As grain yield is a result of a well-grown plant, biomass could be a prerequisite to high yield. Breeding for drought tolerance is usually performed by selecting genotypes for high yield under water limited conditions (Arvind Kumar *et al*., 2008). This yield based selection has further lead to a narrow genetic variability for yield and component traits in recently developed cultivars (Araus *et al*., 2002). Good biomass is a result of adequate quantity of water and nutrients made available at appropriate growth of the plant. This implies a well-endowed root system. While the shoot drives water uptake through a plant, root system size, properties, and distribution ultimately determine plant access to water, and thus, set limits on shoot functioning, similar to an analogy of a horse driving a cart and the cart setting limits on the capacity of the horse (Nardini *et al*., 2002). The measured traits were those that were the most easily observable, such as maximum root length, root thickness, root number, mass of roots at different depths, or root to shoot ratio. Rice genotypes that have deep, coarse roots with a high ability of branching and penetration and higher root to shoot ratio were reported as component traits of drought avoidance (Gowda *et al*., 2011**).** Increased root-shoot ratio (Sharp & Davies, 1989), high total root length (Ingram *et al*., 1994) and high root elongation rates enable plants to maintain relatively high water uptake (rates) underwater stress conditions. Despite ample genetic variation for many root-related parameters, genetic improvement of root characteristics in rice, using conventional selection has been difficult (Ekanayake *et al*., 1985; O'Toole, 1987; Thanh *et al*., 1999) and progress towards improvement of grain yield in rainfed lowlands has been hampered.

Several strategies has been adopted by scientists for phenotyping root traits including, phenotyping in containers (Venuprasad *et al*., 2002), hydroponics (Martinez *et al*., 2004), root imaging (Zhang *et al*., 2005), mini-rhizotrons (Drouet *et al*., 2005), PVC pipes (Shashidhar *et al*., 2012), mini-lysimeters (Udayakumar *et al*., 1994). Finally, all shoot and root characters of the plant, be it morphological, physiological, biochemical, anatomical or responses to environment would provide more opportunities for enhancing drought resistance of the crop. The main objective of the present investigation is to study the whole-plant architecture of aerobic rice by considering both shoot and root traits in order to determine an efficient selection criteria for improving grain yield under drought condition.

II. MATERIALS AND METHODS

A. Experimental site

The experimental material comprised of ten different rice genotypes including traditional and improved accessions. The list of genotypes is given in Table 1**.** The experiment was conducted in field at aerobic rice laboratory, Department of Biotechnology, GKVK, Bengaluru during *Kharif*-2016 representing the eastern dry zone which is located at the latitude of 12^{o} 58' North; longitude 77^{o}35' East and altitude of 930 meters above mean sea level (MSL).

B. Experimental design and layout

The experiment was laid out in a randomized block design (RCBD) with three replications and observations were recorded for various yield related traits. For root studies, all the genotypes were grown in polyvinyl chloride (PVC) pipes of 100 cm length and 18 cm diameter and the experiment was laid in completely randomized design (CRD) with three replications. Uniform soil mixture was prepared with the mix of manure and basal dose of NPK fertilizers and compacted into PVC pipes. Soil was compacted with frequent watering. Direct sowing was done and seeds were germinated in aerobic condition for five days. Ten days after germination, the seedlings were thinned, leaving only one seedling in each pipe. At maturity stage, the shoots were cut at the base and the pipes were filled with water for overnight to loosen the soil. The following day, soil was eased out of the pipes and the roots were thoroughly cleaned with a jet of water and observations were recorded.

Table 1. List of genotypes used in the study

S.No.	Genotype	Origin	Race	Parentage	History
1.	Moroberekan	Republic of Guinea	Tropical japonica	IR-8-24-6 (M307H5)	Traditional
2.	ARB-6	UAS (B), India	Indica	Buddha X IR 64	Improved
3.	AM-65	UAS (B), India	Japonica	Azucena X Moroberekan	Improved
4.	AM-72	UAS (B), India	Japonica	Azucena X Moroberekan	Improved
5.	AM-1	UAS (B),	Japonica	Azucena X	Improved

		India		Moromutant	
6.	Black rice	India	Japonica	-	Traditional
7.	AM-143	UAS (B), India	Japonica	Azucena X Moromutant	Improved
8.	Jeerigesanna	Karnataka	Japonica	Local accession	Traditional
9.	IR-64	Phillipines	Indica	IR 5657-33-2-1/ IR 2061-465-1-5-3	Improved
10.	Azucena	Phillipines	Japonica	-	Traditional

C. Data collection and analysis

Analysis of variance (ANOVA) was carried out for each character, and subsequently ANOVA was used to determine whether there were any differences in the traits studied among rice accessions. Correlation and path analysis were performed using the Indostat ver. 9.2 computer programme.

III. RESULTS AND DISCUSSION

Analysis of variance indicated significant genetic variability in various above and below ground drought tolerance traits among rice germplasm accessions except for harvest index in rice during *Kharif*-2016. The mean squares, character means, phenotypic and genotypic coefficient of variability, heritability and genetic advance for upland rice genotypes are presented in Table 2, 3, 4, 5.

Table 2. Analysis of variance for grain yield and related characters of rice accessions under aerobic condition during Kharif-2016

		Mean sum of squares											
Source of variation	**df**	**PH**	**NT**	**NPT**	**PL**	**DFF**	**DTM**	**SBM**	**HI**	**SGRL**	**SGRW**	**GYP**
Genotype	9	1381.19**	77.59**	69.30**	17.86**	419.87**	237.54**	234.19**	0.17	0.06**	0.01**	102.72**
Error	20	25.66	5.81	9.90	3.13	2.52	2.59	30.64	0.11	0.01	0.002	61.75
CD at 5%		6.14	2.92	3.81	2.14	1.92	1.95	6.95	0.41	0.04	0.05	6.71
CD at 1%		8.41	4.01	5.22	2.94	2.64	2.69	9.01	0.56	0.06	0.07	9.19
CV		6.13	15.06	20.76	9.53	1.71	1.21	20.61	51.58	6.01	21.73	35.31

**: Significant at 1%

Note- PH- Plant height (cm), NT- Number of tillers, NPT- Number of productive tillers, PL- Panicle length (cm), DFF- Days to 50 % flowering, DTM- Days to maturity, SBM- Shoot biomass (g), HI- Harvest index, SGRL- Shoot growth rate by length, SGRW- Shoot growth rate by weight, GYP- Grain yield per plant (g)

Table 3. Analysis of variance for root related characters of rice accessions in PVC pipes during Kharif-2016

		Mean sum of squares												
Source of variation	df	RL	RN	RV	RDW	RFW	RSWR	RSLR	RGRL	TBM	TPL	TGRW	RGRW	TGRL
Genotype	9	212.11**	790.89**	535.95**	36.41**	302.02**	0.48**	0.13**	0.01**	245.48**	1,872.24**	0.01**	0.01**	0.07**
Error	20	12.08	27.76	19.66	7.23	29.54	0.14	0.01	0.01	40.66	35.32	0.05	0.06	0.01
CD at 5%		4.18	6.34	5.34	3.23	6.54	0.45	0.11	0.03	7.68	7.15	0.06	0.02	0.06
CD at 1%		5.71	8.65	7.28	4.41	8.92	0.61	0.15	0.04	10.74	9.76	0.08	0.03	0.08
CV		6.65	8.16	9.62	16.21	10.62	46.71	13.54	6.92	14.91	4.41	15.54	16.35	5.08

**: Significant at 1%

Note- RL- Root length (cm), RN- Root number, RV- Root volume (cm^3), RDW- Root dry wt. (g), RFW- Root fresh wt. (g), RSWR- Root-shoot wt. ratio, RSLR- Root-shoot length ratio, RGRL- Root growth rate by length, TBM- Total biomass (g), TPL- Total plant length (cm), TGRW- Total plant growth rate by wt., RGRW- Root growth rate by wt., TGRL- Total plant growth rate by length

Table 4. Estimates of mean, range and genetic parameters for different traits in rice accessions during Kharif-2016

S.No.	Characters	Mean±SE	Min.	Max.	PCV (%)	GCV (%)	h^2 (%)	GAM (%)
1.	**PH (cm)**	82.58 ± 2.92	45.6	112.8	26.45	25.73	94.6	51.57
2.	**NT**	16.02 ± 1.39	7.4	28.0	34.02	30.52	80.4	56.38
3.	**NPT**	15.16 ± 1.81	6.6	27.2	35.95	29.35	66.6	49.36
4.	**PL (cm)**	18.55 ±1.02	14.2	24.0	15.28	11.94	61.0	19.22
5.	**DFF**	93.16 ± 0.91	72	108	12.77	12.66	98.2	25.84
6.	**DTM**	132.4 ± 0.93	116	145	6.79	6.68	96.9	13.54
7.	**SBM (g)**	33.09 ± 3.13	9.91	47.68	40.96	34.09	69.2	58.46
8.	**HI**	0.60 ± 0.19	0.15	1.16	55.52	20.55	13.7	15.67
9.	**SGRL**	0.62 ±0.022	0.32	0.81	23.29	22.50	93.3	44.79
10.	**SGRW**	0.19 ±0.02	0.07	0.37	36.47	29.29	64.4	48.46
11.	**GYP (g)**	16.58 ±3.19	3.04	43.94	57.09	31.84	31.0	36.57

Note- PCV- Phenotypic coefficient of variation; GCV- Genotypic coefficient of variation; h^2- Broad sense heritability; GAM- Genetic advance as per cent of mean

Table 5. Estimates of mean, range and genetic parameters for different root traits in rice accessions during Kharif-2016

S.No.	Root characters	Mean ±SE	Min.	Max.	PCV (%)	GCV (%)	h^2 (%)	GAM (%)
1.	**RL** (cm)	52.22 ± 1.48	35.2	70.5	16.89	15.69	86.3	30.03
2.	**RN**	64.56 ± 2.86	30.0	94	25.64	24.89	94.2	49.77
3.	**RV** (cm^3)	46.05 ± 2.42	24.6	74.6	29.71	28.66	93.0	56.96
4.	**RDW** (g)	16.58 ± 0.75	10.6	26.54	24.04	19.30	64.4	31.93
5.	**RFW** (g)	51.17 ± 1.95	34.2	72.89	20.68	19.04	84.8	36.13
6.	**RSWR**	0.80 ± 0.09	0.2	1.99	59.01	44.76	57.5	69.95
7.	**RSLR**	0.67 ±0.04	0.3	1.30	32.60	30.58	88.0	59.11
8.	**RGRL**	0.39 ± 0.01	0.24	0.51	16.02	14.42	81.0	26.75
9.	**TBM** (g)	42.77 ±1.88	21.41	58.61	24.12	19.48	65.2	32.43
10.	**TPL** (cm)	134.80 ±4.35	100.1	181.1	18.87	18.35	94.5	36.77
11.	**TGRW**	0.32 ±0.02	0.21	0.49	21.01	15.22	52.4	22.73
12.	**RGRW**	0.12 ±0.01	0.07	0.19	24.61	19.37	61.9	31.39
13.	**TGRL**	1.01 ±0.03	0.75	1.33	16.05	15.34	91.2	30.19

Note- PCV- Phenotypic coefficient of variation; GCV- Genotypic coefficient of variation; h^2- Broad sense heritability; GAM- Genetic advance as per cent of mean

Overall, the analysis of variance showed highly significant differences among the various genotypes for the characters under study. This indicated that the genotypes were possessing inherent genetic variances among themselves with respect to the characters studied (Bekele *et al*., 2013). The mean squares for the characters vary significantly ($p < 0.01$) implying the existence of appreciable variation that could be further exploited for improved trait expression. The phenotypic coefficient of variation (PCV) estimates were much higher than the genotypic coefficient of variation (GCV) and gives indication of some amount of environmental effect harboured by the former. The variability in the cultivation conditions usually contributes to the differences between PCV and GCV. In fact plant breeding uses selection for improving the architecture of a crop by management of available genetic variability (Mehetre *et al*.,1994). For root traits, GCV ranged from 14.42 % for RGRL to 44.76 % for RSWR while vegetative traits recorded relatively lower GCV which ranged from 6.68 % for days to maturity to 34.09 % for shoot dry weight. Heritability estimates ranged from 52.4% for TGRW to 94.5% for TPL. Among vegetative traits, heritability values ranged from 13.7% for HI to 98.2% for DFF. Prabuddha (2008) reported high GCV and PCV values for maximum root length, root volume, root dry weight, number of tillers and shoot dry weight while moderate values for shoot height. Moderate PCV as well as GCV were observed in days to 50% flowering. Low PCV and GCV was observed in days to maturity. These results were in accordance with Akinwale *et al*., (2011).

Heritability in broad sense coupled with genetic advance was higher in most of the characters viz., PH, NPT, GYP, RL, RN, RV, RSLR, RSWR. Similar results were reported by Saidaiah *et al*. (2010) and Keshava Murthy *et al*. (2011). High heritability with low genetic advance was reported by days to 50% flowering, panicle length (cm) suggesting non-additive gene action in controlling these traits. Higher h^2 for root dry weight was obtained by Shashidhar *et al*., (2012). High heritability coupled with high genetic advance as percent mean for the traits indicated that these traits were not much influenced by environmental factors. Hence, these traits are mostly controlled by genetic factors and expected to respond to direct selection for trait improvement.

Table 6 shows the phenotypic correlations among all the characters of rice. Plant height showed significant positive correlation with panicle length. Similar results were obtained by Behera *et al*., (2017). PH, PL, SBN, HI, SGRW, TBM, TGRW had significant positive correlation with grain yield. Sabesan *et al.* (2009) observed that grain yield was positively associated with plant height and productive tillers per plant. NT had significant positive correlation with number of productive tillers. Similar results were obtained by Laxuman *et al.* (2011). Hairmansis *et al*. (2010) reported plant height had negative effect on grain yield while days to maturity and 1000-grain weight had negligible effect on grain yield. Root volume showed positive correlation with RDW and RFW. Root length and root volume positively correlated with grain yield but not significant. Price *et al*. (1997) reported significant positive association of root length with root volume. RL showed significant positive correlation with RN (0.709), RV (0.560), RFW (0.521), RGRL (0.919), TBM (0.547), TPL (0.560) and TGRL (0.544). RSLR showed significant positive correlation with RV (0.531), RDW (0.590), RSWR (0.625) and RGRW (0.622) and significant negative correlation with SBM (-0.446) and SGRW (-0.404).

The significant positive correlation of most of the yield related traits to root characters indicate some useful harmony in selection for drought tolerance and grain yield increases. Direct selection for joint expression of these traits would hopefully be desirable in future breeding programmes.

Path analysis has been used to understand the direct and indirect effects of each character on grain yield and the application of selection pressure in a better way for yield improvement, partitioning of correlation coefficient into direct and indirect effects. The phenotypic correlations coefficients were used for carrying out path coefficient analysis and presented in Table 7. The overall path coefficient analysis in rice revealed that RL (4.00) manifested highest direct contribution to grain yield followed by RSWR (0.843), NPT (0.795), TPL (0.785) and SBM (0.782). These results indicate the importance of root in achieving higher crop yield under water limited conditions. The deeper root system would significantly increase the total biomass as well as yield. Jeena and Mani,

(1990) studied root characters and grain yield on some upland rice varieties and indicated that high root length density and root weight, are important for selecting drought tolerant genotypes. It also revealed that panicle length and harvest index had positive direct effect on yield. Similar results were also reported by Yadav *et al*., (2018).

Table 8. Table showing the relationship between root-shoot and shoot-root ratios

Genotype	Root length (RL)	Plant height (PH)	Root-shoot ratio	Shoot-root ratio	Total plant length (TPL)	% of plant that is inside the soil
ARB-6	45.95	77.9	0.59	1.70	123.85	58.99
AM-65	56.56	122.16	0.46	2.16	178.72	46.30
AM-72	52.21	77.16	0.68	1.48	129.37	67.66
AM-1	49.43	101.66	0.49	2.05	151.19	48.72
AM-143	57.5	70.91	0.81	1.23	128.41	81.09
Mean	**52.35**	**89.96**	**0.61**	**1.72**	**142.31**	**60.55**
Moroberekan	68.8	121.06	0.57	1.76	189.86	56.83
Azucena	57.63	133.96	0.43	2.32	191.59	43.02
Mean	**63.22**	**127.51**	**0.50**	**2.04**	**190.73**	**49.93**
Jeerigesanna	39.48	96.63	0.41	2.45	136.11	40.86
Black rice	48.55	81.7	0.59	1.68	130.25	59.42
Mean	**44.02**	**89.17**	**0.50**	**2.07**	**133.18**	**50.14**
IR-64	51.18	61.83	0.83	1.21	113.01	82.78

The shoot relies on the root for water and nutrients, while the roots depend on the shoot for carbohydrates (Hoad *et al*., 2001). An attempt was made to study the root-shoot ratios which are summarized in Table 8. Breeding for deep root system is one of the strategies for making a plant access a larger volume of soil for water and nutrients. One of the ideal source of deep root character is local germplasm and traditional varieties. In the above table, we can see that the root-shoot ratios are much higher for improved accessions which makes a plant more stronger in drought and access enough nutrients.

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V. CONCLUSION

The analysis of variance was carried out for all the characters which showed significant differences for most of the characters among the selected characters indicating that there is a lot of variability among the genotypes studied. GCV, PCV, h^2 and genetic advance were high in genotypes for all the traits recorded. This is an indirect information indicating strong influence of genetic control and are less intervened by environmental factors. h^2 and genetic advance values were also high which indicate the presence of considerable variation that can be heritable and the character is governed by additive genes. So, the genotypes can be selected based on their phenotype easily. The results suggest that a plant type for increasing grain yield should have higher panicle length, high root length and high harvest index. The root-shoot and shoot-root ratios aids in selection of genotypes with more drought tolerance traits like genotypes with a deeper root system. So, both above ground and below ground traits must be taken into account for improving grain yield and drought tolerance.

BIBLIOGRAPHY

[1] Akinwale, M. G. 2011. Heritability and correlation coefficient analysis for yield and its components in rice. *African J. Plant Science,* **5**(3): 207-212.

[2] Araus, J. L., Slafer, G. A., Reynolds, M. P. and Royo, C. 2002. Plant breeding and drought in C3 cereals: What should we breed for?. *Annals of Botany,* **89**: 925-940.

[3] Behera, M., Monalisa, S. P., Bastia, D. N. and Kulkarni, C. 2017. Correlation and Path Analysis Studies in Aerobic Rice. *Int.J.Curr.Microbiol.App.Sci.,*, **6**(8): 2851-2856.

[4] Bekele, B. D., Rakhi, S., Naveen, G. K., Kundur, P. J. and Shashidhar, H. E. 2013. Estimation of genetic variability and correlation studies for grain zinc concentrations and yield related traits in selected rice (*Oryza sativa* L.) genotypes, *Asian J. Exp. Biol. Sci.,* **4** (3): 345-351.

[5] Drouet, J. L., Pages, L. and Serra, V. 2005. Dynamics of leaf mass per unit eaf area and root mass per unit root volume of young maize plants: implications for growth models. *European J. Agron*., **22**: 185-193.

[6] Gowda, V. R. P., Amelia, H., Akira, Y., Shashidhar, H. E. and Rachid, S. 2001. Root biology and genetic improvement for drought avoidance in rice. *Field crop res.* **122**:1–13.

[7] Hairmansis, A., Kustianto, B. and Suwarno. 2010. Correlation analysis of agronomic characters and grain yield of rice for tidal swamp areas. *Indonesian J. Agric. Sci.* 11(1): 11-15.

[8] Hoad, S.P., Russell, G., Lucas, M.E., and Bingham, I. J. 2001. The management of wheat, 457 barley, and oat root systems. *Adv. Agron*. **74**: 193-246.

[9] Indira, J., Ekanayake**,** D. P., Garrity**,** T. M., Masajo**,** J. C. and O'Toole. 1985. Root pulling resistance in rice: Inheritance and association with drought tolerance. *Euphytica,* **34**(3):905-913.

[10] Ingram, K.T., Bueno, F.D., Namuco, O.S., Yambao, E.B. and Beyrouty, C.A. 1994. Rice root traits for drought resistance and their genetic variation. In G.J.D. Kirk ed., Rice Roots: Nutrient and Water Use. IRRI, Los Banos. 67-77.

[11] Jeena, H. S. and Mani, S. C. 1990. Studies on root characters and grain yield of some upland rice varieties. *Oryza*, **27**(2): 214-216.

[12] Keshava Murthy, B. C., Kumar, A. and Hittalmani. S. 2011. Response of rice (*Oryza sativa* L.) genotypes under aerobic conditions. *Electronic J. Plant Breeding*, **2**(2): 194-199.

[13] Kumar, A., Bernier, J., Verulkar, S., Lafitte, H. R. and Atlin, G. N. 2008. Breeding for drought tolerance: Direct selection for yield, response to selection and use of drought-tolerant donors in upland and lowland-adapted populations. *Field Crops Res*., **107**: 221-231.

[14] Laxuman, P., Salimath, P.M., Shashidhar, H. E., Mohankumar, H. D., Patil, S. S., Vamadevaiah, H. M. and Janagoudar, B. S. 2011.Character association and path coefficient analysis among the backcross inbred lines derived from Indica × NERICA cross for productivity traits in rice (*Oryza sativa* L.). *Kar. J. Agri. Sciences*, **24**(5): 626–8.

[15] Martinez, F., Merino, O., Garcia, M D. amd Merino, J.A. 1998. Belowground structure and production in a Meditarranian shrub community. *Plant and Soil*, **201**: 209-216.

[16] Mehetre, S. S., Mahajan, C. R., Patil, P. A., Lad, S.K. and Dhumal, P.M. 1994. Variability, heritability, correlation, path analysis and genetic divergence studies in upland rice. *The International Rice Research Notes*, **19**(1): 8-9.

[17] Nardini, A., Salleo, S. and Tyree, M. T. 2002. Ecological aspects of water permeability in roots. In: Waisel Y, Eshel A, Kafkafi U (eds) Plant roots: the hidden half. Marcel Dekker, New York, pp: 683-698.

[18] O'Toole, J. C and Bland, W.L. 1987. Genotypic variation in crop plant root systems. *Adv. in Agron*., **41**: 91-145.

[19] Prabuddha, H. R., Manjunatha, K., Venuprasad, R., Vinod, M. S., Jureifa, J. H. and Shashidhar, H. E. 2008. Identification of isogenic lines and near-isogenic lines: an innovative approach, validated for root and shoot morphological characters in a mapping population of rice (*Oryza sativa* L.*). Euphytica*, **160**:357-368.

[20] Price, A. H. and Tomas, A. D. 1997. Genetic dissection of root growth in rice (*Oryza sativa* L.) II: mapping quantitative trait loci using molecular markers. *Theor Appl Genet.,* **95**:143-152.

[21] Sabesan, T., Suresh, R. and Saravanan, K. 2009. Genetic variability and correlation for yield and grain quality characters of rice grown in coastal saline low land of Tamil Nadu. *Electronic J. Plant Breeding*, **1**(1):56-59.

[22] Saidaiah, P., Ramesha, M. S. and Kumar, Sudheer, S. 2010. Line x tester analysis in rice (O*ryza sativa* l.). *Madras Agric.J*., **97**(4-6): 110 -113.

[23] Sharp and Davies, 1989. Regulation of growth and development of plants growing with a restricted supply of water. In: H. G. Jones, T. L. Flowers and M. B. Jones, (eds.) Plants under stress, pp: 72-93. Cambridge University Press.

[24] Shashidhar, H. E., Henry, A. and Bill, H. 2012. Methodologies for root drought studies in rice. IRRI, Los Banos, Philippines, ISBN 978-971-22- 0290-2.

[25] Thanh, N. D., Zheng, H. G., Dong, N. V., Trinh, L. N., Ali, M. L. and Nguyen, H. T. 1999. Genetic variation in root morphology and microsatellite DNA loci in upland rice (*Oryza sativa* L.) from Vietnam. *Euphytica*, **105**(1): 53–62.

[26] Udayakumar, M. and Prasad T.G.1994. 13C isotope discrimination in plants -A potential technique to determine WUE. In: Rao, RCN and Wright, GC. (Eds). Selection for WUE in grain legumes, a report of workshop held at ICRISAT center. Andhra Pradesh, India.pp.42-45.

[27] Yadav, S. and Suresh, B. G. 2018. Path Coefficient Analysis for Yield and Yield Components in Diverse Rice Genotypes, *Int.J.Curr.Microbiol.App.Sci*., **6**: 998-1004.

[28] Zhang, L., Cao,W., Zhang, S. and Zhou, Z. 2005. Characterizing root growth and spatial distribution in cotton. *Acta phytoecological Science*, **29**: 266-273.

[29] Venuprasad, R., Shashidhar, H. E., Hittalmani, S. and Hemamalini, G. S. 2002. Tagging quantitative trait loci associated with grain yield and root morphological traits in rice (*Oryza sativa* L.) under contrasting moisture regimes. *Euphytica,* **128**(3): 293-300.

Table 6. Estimates of phenotypic correlation coefficients for 24 characters in selected rice genotypes during Kharif-2016

	PH	NT	NPT	PL	DFF	DTM	SBM	HI	SGRL	SGRW	RL	RN	RV	RDW	RFW	RSWR	RSLR	RGRL	TBM	TPL	TGRW	RGRW	TGRL	GYP
PH	1.000	-0.629**	-0.605**	0.788**	0.680**	0.533**	0.631**	-0.050NS	0.968**	0.535**	0.239NS	0.333NS	-0.237NS	-0.351NS	-0.178NS	-0.602**	-0.819**	0.030NS	0.538**	0.938**	0.373*	-0.467**	0.868**	0.458*
NT		1.000	0.938**	-0.417*	-0.473**	-0.461*	-0.184NS	0.055NS	-0.574**	-0.095NS	-0.409*	-0.317NS	-0.106NS	-0.100NS	0.047NS	-0.049NS	0.350NS	-0.232NS	-0.244NS	-0.682**	-0.099NS	0.013NS	-0.600**	-0.085NS
NPT			1.000	-0.467**	-0.399*	-0.424*	-0.154NS	-0.009NS	-0.558**	-0.074NS	-0.365*	-0.238NS	-0.110NS	-0.149NS	-0.012NS	-0.093NS	0.350NS	-0.202NS	-0.234NS	-0.646**	-0.102NS	-0.044NS	-0.574**	-0.106NS
PL				1.000	0.568**	0.428*	0.670**	-0.017NS	0.753**	0.592**	0.333NS	0.430*	-0.190NS	-0.296NS	-0.098NS	-0.600**	-0.547**	0.166NS	0.604**	0.791**	0.467**	-0.396*	0.732**	0.549**
DFF					1.000	0.824**	0.447*	0.182NS	0.516**	0.310NS	0.437*	0.399*	0.049NS	-0.132NS	0.318NS	-0.373*	-0.348NS	0.117NS	0.431*	0.736**	0.181NS	-0.350NS	0.503**	0.412*
DTM						1.000	0.204NS	0.312NS	0.305NS	0.036NS	0.243NS	-0.039NS	0.076NS	-0.005NS	0.185NS	-0.112NS	-0.266NS	-0.156NS	0.221NS	0.541**	-0.086NS	-0.276NS	0.208NS	0.322NS
SBM							1.000	-0.061NS	0.642**	0.983**	0.317NS	0.523**	-0.341NS	-0.406*	0.009NS	-0.814**	-0.446*	0.233NS	0.917**	0.651**	0.873**	-0.450*	0.660**	0.771**
HI								1.000	-0.158NS	-0.099NS	-0.166NS	-0.198NS	-0.133NS	-0.110NS	0.112NS	-0.037NS	-0.016NS	-0.306NS	-0.114NS	-0.102NS	-0.199NS	-0.201NS	-0.262NS	0.551**
SGRL									1.000	0.583**	0.201NS	0.380*	-0.267NS	-0.375*	-0.257NS	-0.630**	-0.843**	0.084NS	0.538**	0.897**	0.444*	-0.425*	0.918**	0.408*
SGRW										1.000	0.264NS	0.526**	-0.359NS	-0.407*	-0.015NS	-0.809**	-0.404*	0.248NS	0.898**	0.551**	0.911**	-0.406*	0.614**	0.739**
RL											1.000	0.709**	0.560**	0.461*	0.521**	-0.000NS	0.326NS	0.919**	0.547**	0.560**	0.459*	0.371*	0.544**	0.156NS
RN												1.000	0.228NS	0.107NS	0.296NS	-0.343NS	0.007NS	0.733**	0.618**	0.536**	0.623**	0.105NS	0.628**	0.273NS
RV													1.000	0.820**	0.411*	0.540**	0.531**	0.548**	-0.015NS	-0.003NS	-0.048NS	0.762**	-0.017NS	-0.388*
RDW														1.000	0.528**	0.696**	0.590**	0.475**	-0.008NS	-0.136NS	-0.011NS	0.961**	-0.141NS	-0.374*
RFW															1.000	0.254NS	0.481**	0.456*	0.240NS	0.033NS	0.187NS	0.448*	-0.046NS	0.086NS
RSWR																1.000	0.625**	0.049NS	-0.587**	-0.513**	-0.567**	0.702**	-0.537**	-0.655**
RSLR																	1.000	0.437*	-0.230NS	-0.583**	-0.159NS	0.622**	-0.571**	-0.349NS
RGRL																		1.000	0.462*	0.353NS	0.496**	0.495**	0.473**	0.015NS
TBM																			1.000	0.654**	0.950**	-0.073NS	0.660**	0.680**
TPL																				1.000	0.482**	-0.266NS	0.934**	0.446*
TGRW																					1.000	0.008NS	0.590**	0.603**
RGRW																						1.000	-0.179NS	-0.456*
TGRL																							1.000	0.367*

*: Correlation is significant at 5%, **: Correlation is significant at 1%, NS-Not significant

Table 7. Estimates of direct and indirect effects of yield components on grain yield at phenotypic level in selected rice genotypes during Kharif-2016

	PH	NT	NPT	PL	DFF	DTM	SBM	HI	SGRL	SGRW	RL	RN	RV	RDW	RFW	RSWR	RSLR	RGRL	TBM	TPL	TGRW	RGRW	TGRL
PH	**-1.4360**	0.0990	-0.1590	0.1380	-0.1480	-0.0020	0.4960	-0.0400	-0.6590	-0.4210	1.0410	-0.0410	0.0200	-0.0240	-0.0120	0.6700	0.6410	-0.3780	-0.5470	-0.4320	-0.6520	0.2570	-0.9860
NT	0.1295	**-0.1743**	-0.1634	0.1018	0.0824	0.0798	0.0650	-0.0033	0.1236	0.0500	0.0671	0.0494	0.0105	-0.0037	-0.0302	-0.0272	-0.0811	0.0366	0.0673	0.1336	0.0429	-0.0226	0.1230
NPT	-0.5379	0.7453	**0.7952**	-0.4759	-0.3074	-0.3296	-0.2299	-0.0226	-0.5138	-0.1687	-0.2684	-0.1575	-0.0548	-0.0492	0.0654	0.0417	0.3417	-0.1420	-0.2650	-0.5511	-0.1652	0.0321	-0.5075
PL	0.2932	-0.2150	-0.2204	**0.3682**	0.2295	0.1734	0.2387	-0.0042	0.2781	0.2061	0.1444	0.1879	-0.0556	-0.0868	-0.0066	-0.2074	-0.1967	0.0753	0.2161	0.2997	0.1597	-0.1294	0.2740
DFF	-0.4622	0.3116	0.2549	-0.4111	**-0.6595**	-0.5426	-0.3406	-0.1290	-0.3585	-0.2495	-0.2820	-0.2572	-0.0229	0.1146	-0.2003	0.3117	0.2466	-0.0707	-0.3123	-0.4916	-0.1469	0.2596	-0.3424
DTM	-0.6377	0.5278	0.4782	-0.5431	-0.9491	**-1.1535**	-0.2978	-0.3937	-0.3811	-0.0945	-0.2670	0.0622	-0.0783	0.0427	-0.1971	0.2044	0.3356	0.1938	-0.2977	-0.6353	0.0650	0.3630	-0.2568
SBM	0.5420	0.0490	-0.0680	0.1120	-0.1090	-0.0010	**0.7820**	1.0210	0.4320	0.6780	1.5810	-0.0730	0.0280	-0.0240	0.0080	-0.6480	0.3650	0.4290	0.5320	-0.8340	0.8760	-0.6530	0.8940
HI	-0.0382	0.0118	-0.0179	-0.0072	0.1234	0.2153	-0.0585	**0.6309**	-0.1141	-0.0870	-0.1025	-0.1339	-0.0948	-0.0668	0.0734	-0.0099	-0.0017	-0.1967	-0.0907	-0.0685	-0.1509	-0.1289	-0.1783
SGRL	-0.5610	-0.5670	-0.2860	0.3550	0.7660	0.5770	0.0430	-0.0050	**0.3460**	0.0650	0.5470	0.3450	-0.6540	-0.6780	-0.8740	-0.4500	-0.3260	-0.0650	-0.6710	-0.6520	-0.4360	-0.7660	0.5440
SGRW	-0.5240	0.4520	0.0530	-0.5320	-0.5550	-0.7310	-0.6550	-0.0040	-0.6730	**-0.1110**	-0.4380	-0.5840	-0.0140	-0.0560	-0.4520	-0.0050	-0.2310	-0.5380	-0.5430	-0.2370	-0.3480	-0.0980	-0.0640
RL	2.2120	0.0510	-0.0790	0.0680	-0.0900	-0.0010	0.3090	-0.1070	-0.3240	-0.2430	**4.0000**	-0.0820	-0.0490	0.0310	0.0410	0.2110	-0.5320	-0.8750	-0.5210	-0.9540	-0.4340	-0.3410	-0.6740
NR	-0.0036	0.0029	0.0020	-0.0051	-0.0039	0.0005	-0.0063	0.0021	-0.0042	-0.0065	-0.0071	**-0.0101**	-0.0020	-0.0006	-0.0026	0.0048	0.0002	-0.0074	-0.0069	-0.0056	-0.0071	-0.0006	-0.0066
RV	-0.0060	-0.0016	-0.0018	-0.0040	0.0009	0.0018	-0.0084	-0.0040	-0.0067	-0.0089	0.0146	0.0053	**0.0264**	0.0217	0.0101	0.0142	0.0138	0.0143	0.0004	0.0001	-0.0003	0.0200	-0.0002
RDW	-2.8560	-0.0020	-0.0140	-0.0410	0.0360	0.0001	-0.2660	-0.0700	-0.4760	-0.8430	1.7620	-0.0060	-0.0730	**0.0720**	0.0390	0.6560	0.7620	0.0430	0.2330	0.8620	2.4764	0.3240	-0.3470
RFW	-0.0098	0.0108	0.0051	-0.0011	0.0190	0.0107	0.0069	0.0073	-0.0144	0.0059	0.0317	0.0161	0.0240	0.0303	**0.0625**	0.0095	0.0289	0.0280	0.0203	0.0028	0.0178	0.0253	-0.0015
RSWR	-0.5227	0.1313	0.0442	-0.4745	-0.3983	-0.1493	-0.6640	-0.0132	-0.5348	-0.6540	-0.0644	-0.4015	0.4525	0.5546	0.1284	**0.8426**	0.5253	0.0018	-0.4671	-0.4663	-0.4339	0.5716	-0.4682
RSLR	1.3038	-0.7428	-0.6858	0.8523	0.5968	0.4643	0.6685	0.0044	1.3388	0.5948	-0.4921	0.0335	-0.8351	-0.9175	-0.7382	-0.9950	**-1.5958**	-0.6838	0.3166	0.9332	0.1868	-0.9715	0.9025
RGRL	0.7007	-3.4690	-0.2940	0.3790	0.7760	0.2770	0.4740	0.5150	0.6160	0.1240	0.1840	0.1310	0.1850	0.7140	0.3250	0.0349	0.4360	**0.6540**	0.3630	0.5960	0.9110	0.8080	0.6530
TBM	-0.4210	-0.0320	0.2590	0.4570	0.3680	-0.2060	-0.7190	-0.1160	-0.4320	-0.5430	-0.5430	-0.0950	-0.8360	-0.5180	-0.2140	0.5470	0.5900	-0.1240	**-0.7840**	-0.4390	-0.4360	-0.1780	-0.1320
TPL	-0.2240	0.1020	-0.1630	0.1410	-0.1570	-0.0020	0.5300	-0.0710	0.6530	0.5320	2.2920	-0.0640	-0.0002	-0.0090	0.0030	-0.6750	-0.4320	-0.0120	0.3250	**0.7850**	0.0180	-0.2110	0.1450
TGRW	0.6540	-0.4320	-0.3510	0.7340	0.3770	-0.9550	0.4560	-0.4060	0.7150	0.5210	0.5360	0.1130	-0.2034	0.1450	0.1460	-0.8730	-0.6540	0.9370	0.6570	0.6930	**0.0240**	0.1450	0.8530
RGRW	0.2880	-0.7430	-0.2284	0.1780	0.2220	0.1780	0.2260	0.1150	0.2290	0.1960	0.4310	-0.3500	-0.4890	-0.5420	-0.2830	-0.3840	-0.3940	-0.2840	0.0778	0.1540	-0.4857	**0.5780**	0.9143
TGRL	-0.9460	0.4320	0.6540	-0.3220	-0.2440	-0.1950	-0.5460	0.1560	-0.5320	-0.5740	-0.7210	-0.0150	-0.6530	0.6890	0.1040	0.5320	0.4560	0.2320	-0.4540	-0.5430	-0.7650	0.5370	**-0.9640**
GYP	0.4496	-0.2489	-0.2237	0.5292	0.4737	0.3836	0.7464	0.5537	0.3821	0.7091	0.2169	0.3416	-0.3792	-0.3159	0.1786	-0.6139	-0.3170	0.0488	0.6568	0.4579	0.5643	-0.4162	0.3546
Partial R^2	0.6540	0.0434	-0.1779	0.1949	-0.3124	-0.4425	-0.4790	0.3493	0.7430	-0.5320	-0.3140	-0.0034	-0.0100	-0.3150	0.0112	-0.5172	0.5058	0.4240	-0.5420	0.3210	0.5250	0.2560	-0.6540

Residual effect = 0.104

