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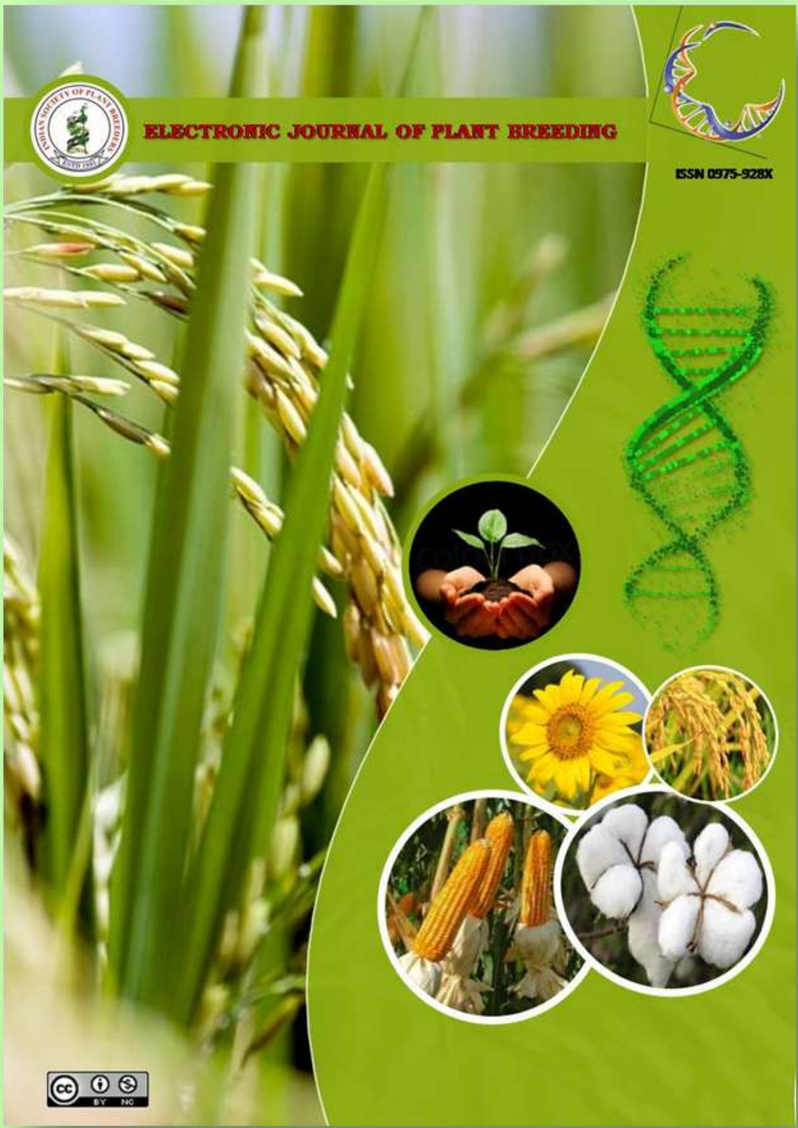

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Research Article

Evaluation of rice genotypes for seedling and reproductive stage drought tolerance

A. Ambikabathy[1], S. Banumathy[1], R. P.Gnanamalar[1], P. Arunchalam[1], P. Jeyaprakash[2], R. Amutha[2] and N.S.Venkatraman[3]

[1] Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Madurai
[2]Department of Plant Breeding and Genetics, Anbil Dharmalingam Agricultural College and Research Institute, Trichy
[2] Department of Seed Science and Technology, Agricultural College and Research Institute, Madurai
[3] Department of Agronomy, Agricultural College and Research Institute, Madurai
E-Mail: banumathysiva2004@gmail.com

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Abstract

The present investigation was undertaken to evaluate 25 drought tolerant genotypes for seedling stage and reproductive stage drought tolerance. The genotypes were evaluated under gravimetric method at three moisture levels *viz.*, i) control at 100 % field capacity (FC) ii) water - deficit stress at 80 % Field capacity (80 % FC) and iii) water - deficit stress at 60 % Field capacity (60 % FC) for seedling stage drought tolerance. Observations were recorded on six morphological traits *viz.*, seedling height, root length, shoot length, dry weight, leaf rolling and leaf drying and three physiological traits *viz.*, chlorophyll stability index, proline content and nitrate reductase activity. The variety, APO and landraces *viz.*, Kuliyadichan, Kattanur and Sivappuchithiraikar were identified with all desirable drought tolerant seedling traits and these genotypes also had high stress tolerance index (STI) for all the morphological traits. For reproductive stage drought tolerance, the moisture stress was imposed under field condition. Yield characters *viz.*, number of days to maturity, panicle length, spikelet fertility and single plant yield and three physiological traits *viz.*, chlorophyll stability index, proline content and nitrate reductase activity were recorded. Based on stress tolerance index (STI) and high mean performance, varieties *viz.*, Anna (R) 4 and APO and landraces *viz.*, Kattanur, Kuliyadichan and Sivappuchithiraikar were identified as drought tolerant lines for reproductive stage drought tolerance. From this study, APO, Kattanur, Kuliyadichan and Sivappuchithiraikar were identified as drought tolerant lines for seedling stage as well as reproductive stage. Therefore, these genotypes can be used as potential donors in the development of new drought tolerant varieties in rice.

Keywords

Rice, Drought tolerance, seedling traits, biochemical traits, Stress Tolerance Index

Introduction

Rice (*Oryza sativa* L.) is one of the major cereal food crops for more than 50 per cent of the world population. It is cultivated over 167 million hectares with the production of 780 million tonnes (FAO STAT, 2017). Rice is grown under varying environments ranging from flooded condition to upland rainfed ecosystem. About 42 per cent of cultivable land area in India is facing drought. Drought is the most widespread constraint in rice production affecting grain yield and quality.Valuable differences exist in grain yield between drought-prone rice production systems (uplands and rainfed lowlands) and irrigated ones. For example, drought-prone systems represent over half of the world area dedicated to grow rice, but represent only 25% of the total world rice production (Venuprasad *et al.*, 2007).

In lowland irrigated systems, high yielding varieties have reached an average productivity of 3 to 4 t ha^{-1}, while in rainfed systems, adapted varieties produce hardly around 1 t ha^{-1} (Prasad, 2011). Additionally, water scarcity is becoming a serious problem with global climate changes, which is a potential risk for rice productivity and food security (Li *et al.*, 2011). It is estimated that by 2025, 15 million hectares of traditionally irrigated land will suffer physical water scarcity and 22 million hectares will be under economic water scarcity (Prasad, 2011).

The development of new rice genotypes tolerant to drought stress will increase and stabilize yield and could save water. The availability of landraces represents a powerful source of adapted drought tolerance genes/ donors for breeding (Kumar *et al.*, 2009). Unfortunately, these genotypes normally have many undesirable agronomic traits and low yield potential. Thus, the challenge for rice breeders is to combine robust drought tolerant traits with high yielding traits. Screening techniques, such as gravimetric method, provide useful tools for the identification of drought tolerant genotypes. Root

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system plays an important role under drought conditions. The nature and extent of root characteristics are considered to be major factors affecting plant response to water stress. Among the root morphological traits, root length is found to be associated with drought resistance in upland condition. Selection and breeding for desirable root characteristics associated with drought resistance have been reported in rice (Chang *et al.*, 1972).

Chlorophyll being the most important photosynthetic pigments plays vital role in regulating crops yield. However chlorophyll is quite delicate, not very stable and easily affected by abiotic stresses. The reduction in chlorophyll content may occur due to stress- induced impairment in pigment biosynthetic pathways or in pigment degradation, loss of chloroplast membrane and increased lipid peroxidation thus resulting in generation of reactive oxygen species (ROS) which are potentially harmful under drought stress condition (Reddy *et al*.,2014). Hence chlorophyll stability index (CSI) is important index for screening of genotypes for abiotic stresses.

All plants are capable of perceiving and responding to stress. To overcome the effect of stress, plants have evolved adaptive mechanisms. One mechanism utilized by the plants to overcome the water stress effects might be *via* accumulation of compatible osmolytes, such as proline and soluble sugars. Production and accumulation of free amino acids, especially proline by plant tissue during drought and salt stress is an adaptive response. Proline has been proposed to act as a compatible solute that adjusts the osmotic potential in the cytoplasm. Thus, proline can be used as a metabolic marker in relation to stress (Bohnert *et al*., 1995).

Stress Tolerance Index (STI) is defined as a useful tool for determining high yield and stress tolerance potential of genotypes. Fernandez (1992) has suggested to use STI for identification of high tolerance genotypes based on the ratio of means under non-stress to the moderate and severe stress. The higher value of stress tolerant index indicates superiority of genotypes combining both higher yield potential and stress tolerance. The relative yield performance of genotypes in drought-stressed and non-stressed environments can be used as an indicator to identify drought-resistant varieties for drought-prone environments. Several drought indices have been suggested on the basis of a mathematical relationship between yield under drought conditions and non-stressed conditions. These indices are based on either drought resistance or drought susceptibility of genotypes (Kumar *et al*. 2009).Keeping the above points in view, the present study was conducted to evaluate the rice genotypes under seedling and reproductive stages moisture stress to identify the genotypes which possess both seedling and reproductive stages drought tolerance along with high STI.

Materials and Methods

The present investigation was carried out in glass house for seedling stage stress and under field condition for reproductive stage stress at Agricultural College and Research Institute, Madurai during *Kharif*, 2017. The experimental materials consisted of 25 genotypes which included land races and high yielding varieties (Table 1).

All 25 genotypes were grown in glass house under controlled environment. The experiment was laid out in Completely Randomized Design (CRD) with two replications. Seeds were sown in pots and each pot was filled with a mixture of 10 kg sand and vermicompost. Each entry was maintained in two pots per replication. Moisture content was maintained at three levels *viz.,* i) control at 100 % field capacity (100 % FC) that is the maximum soil moisture content after drainage of excess water, ii) water –deficit stress at 80 field capacity (80 % FC) and iii) 60 % field capacity (60 % FC). Water stress was imposed at seedling stage *i.e.* 15 days after sowing and continued upto 45 days (30 days of stress period). A standardized gravimetric method of daily pot weighing was followed to ascertain the FC of 80 and 60 % and thereafter maintained at the same level until the end of experiment. Pot weight was recorded for 30 consecutive days of stress period. Measured quantity of water was added daily to bring the moisture content to the desired target in each pot to compensate the weight loss due to transpiration. The observations were recorded 45 days after sowing individually on randomly selected five plants / replication. The observations *viz.*, seedling height (cm), root length (cm), shoot length (cm) and dry weight (g) was measured. Scoring of leaf rolling and leaf drying was done as per SES IRRI. Nitrate reductase activity ($NO_2g^{-1}h^{-1}$), proline content (mg/g) and chlorophyll stability index (%) was done by Murthy and Majumdar (1962), Bates *et al*. (1973) and Nicholas *et al.* (1976) respectively.

Same twenty five genotypes were raised in nursery and 25 days old seedlings were planted in the main field. The trial was laid out in Randomized Block Design (RBD) with two replications under both irrigated and water stress condition. Normal irrigation was given to both conditions upto 45 days after transplanting. For drought stress condition, the stress was imposed at 70 days after sowing for a period 15 days. Observations *viz.,* leaf rolling and leaf drying were recorded on 85th day in each one of the genotypes under moisture stress condition. The observations *viz.*, panicle length, spikelet fertility, days to maturity and grain yield were recorded at the time of maturity under both conditions.

Results and Discussion

The choice of parents is very important for developing high yielding varieties in any breeding programme. The phenotypic mean performance is taken as the sole criterion for choosing the parents. The parents with high mean performance would result in good performing offspring. So, the parents with significant mean performance over the grand mean for the drought related traits are preferred. The mean performance of 25 genotypes for seedling characters recorded during seedling traits is presented in Table 1. Analysis of variance has revealed significant difference among the genotypes for all four quantitative traits *viz.*, seedling height, root length, shoot length and dry weight (Table 2). Among the twenty five genotypes, ten genotypes recorded significantly higher seedling height at 60 % field capacity. APO showed the highest seedling height with an average of 60 cm under 60 % field capacity followed by Kattanur (49.7 cm). The variety Vandana had exhibited drastic reduction from 51 cm to 26.7 cm between 100 and 60 % FC for seedling height. The genotypes *viz.*, Kattanur and APO were less affected by water stress for seedling height.

Under 60% field capacity six genotypes had recorded significantly higher root length. APO and Kattanur showed very less reduction in root length between 100 and 60 % FC. This showed the stability of APO and Kattanur under water stress condition. Poongar recorded 8 and 7 cm for root length under 100 and 80 % FC respectively, but the root length was drastically reduced (3.7 cm) when the plant was subjected to 60 % field capacity. This indicates Poongar is having less seedling stage drought tolerance. For shoot length, 11 genotypes have recorded significantly higher values at 60 % FC. APO had recorded highest shoot length (47 cm) at 60 % FC and Vandana displayed shoot length reduction at 60 % field capacity. Seven genotypes had registered significantly higher dry weight at 60 % field capacity (Table 1). Ganapathy *et al.* (2010) has recorded high mean value for root length, root volume, total number of roots, root thickness and root dry weight among parents and their hybrids for drought tolerance under controlled (PVC pipes) condition. Vengatesh and Govindarasu (2017) reported that six genotypes *viz.*, PMK 2, PMK 4 (Anna (R) 4), MAS 946, Annada , KMP 175 and Vandana had significant mean values for most of the root traits *viz.*, root length, root number, root volume, root density, root thickness and root weight under polythene bag. Anandhan *et al.* (2015) reported significantly high mean values for root traits for drought tolerance under gravimetric method.

Four genotypes *viz.*, APO, Kuliyadichan, Kattanur and Sivappuchithiraikar recorded significant mean values for four traits *viz.*, seedling height, root length, shoot length and dry weight. These genotypes also recorded healthy leaves with no symptoms of leaf drying under 60 % field capacity (Table 1) which indicates the tolerant nature of these genotypes. Swapna and Shylaraj (2017) identified two rice varieties *viz.*, Swarnapraha and Kattamodan with less leaf rolling, better drought recovery ability as well as relative water content, increased membrane stability index, osmolyte accumulation and antioxidant enzymes activities pointed towards the degree of drought tolerance to drought stress. With regard to nitrate reductase activity, seven genotypes had significant mean performance under 60 % FC. High significant values for proline content at 60 % field capacity were observed in nine genotypes (Table 3). Kamarudin *et al.* (2018) found that proline content increased significantly in drought-tolerant rice genotypes and the highest proline content was obtained MR219-4 followed by MR219-9 under drought stress.

Two genotypes *viz.*, APO and Kuliyadichan recorded significantly high chlorophyll stability index under 60 % field capacity. Swapna and Shylaraj (2017) identified two rice varieties *viz.*, Swarnapraha and Kattamodan with increased membrane stability index pointed towards the degree of drought tolerance to drought stress. The genotypes *viz.*, APO and Kuliyadichan recorded significant mean value for all the physiological traits.

Under seedling stage drought tolerance study, the genotypes APO, Kattanur, Kuliyadichan and Sivappuchithiraikar registered high stress tolerance index (STI) for all the traits *viz.*, seedling height, root length, shoot length and dry weight (Table 1). The variety APO produced seedlings with more height compared to all other genotype and also recorded minimum reduction in seedling height under 60 % moisture stress. Hence, APO variety recorded high stress tolerance index of 2.31 for this trait. The higher value of stress tolerant index indicates superiority of genotypes in terms of stress tolerance. Bhattacharya (2017) has found that the STI and yield index (YI) were superior in genotypes RAU-1421-12-1-7-4-3, RAU-1397-25-8-1-2-5-4, RAU-1428- 6-7-3-6 and RAU-1451-35-7-6-9-5-1 indicating that these indices can be used as tools to select drought tolerant genotypes with high yield performance under both irrigated and stress conditions.

Among the 25 entries, two genotypes *viz.,* APO and Kuliyadichan had higher mean values for seven traits. In addition, Kattanur and Sivappuchithirakar had high significant mean values for all the traits except chlorophyll stability index. The mean performance of 25 genotypes for yield characters recorded during maturity stage under reproductive stage moisture stress is presented in Table 4. Analysis of variance revealed significant difference among the genotypes for the traits *viz*., panicle length, days to maturity, spikelet fertility and grain yield (Table 5). The maturity period for 20 cultivars was delayed which ranged from 3 to 20 days. Dikshit *et al*. (1987) reported that the severe drought stress prolonged the maturity period of 20 early maturing rice varieties by 2 to 27 days. Kumar *et al.* (2014) reported slight delay (2-5 days) in 50% flowering under stress. Significant values for spikelet fertility were observed in seven genotypes (Table 4). Five genotypes *viz.,* Anna (R) 4, APO, Kuliyadichan, Kattanur and Sivappuchithiraikar recorded significantly high grain yield under water stress (Table 4). Three genotypes *viz.,*Anna (R) 4, APO and Vellaichithiraikar also recorded significant mean value for traits *viz.*, days to maturity and spikelet fertility. Kumar *et al*. (2015) revealed that significant yield decline was observed in all rice genotypes under water stress condition compared to irrigation condition. Out of these 12 rice genotypes, IR88964-24-2-1-4, IR 88966-43-1-1-4 and IR88964-11-2-2-3 showed superiority in terms of grain yield and yield attributes.

Six genotypes *viz.,* APO, Anna (R) 4, PMK (R) 3, Kuliyadichan, Kattanur, and Sivappuchithiraikar registered significantly high values for physiological traits *viz.,* nitrate reductase activity, proline and chlorophyll stability index (Table 6). Chlorophyll stability index (CSI) is the indicative of maintenance of photosynthetic pigments under drought and is more dependent parameter for drought tolerance. Sareeta Nahakpam (2017) reported that the genotypes BRR-0028 showed the highest CSI with higher yield irrespective of chlorophyll content. Bunnag and Pongthai (2013) revealed that proline accumulation in plants is a result of drought stress.

The lines APO, Anna (R) 4, Kattanur, Kuliyadichan and Sivappuchithiraikar had also exhibited higher values of STI under reproductive stage moisture stress (Table 4). The higher value of STI indicates superiority of genotypes having both higher yield potential and stress tolerance. Garg and Bhattacharya (2017) reported that the stress susceptibility index (SSI), Tolerance Index (TOL) and yield stability index (YSI) were superior in the genotypes *viz.,* Rasi, Vandana, RAU-1428-31-5-4-3-2-2-2, RAU-1421-15-3-2-5-7-3 and RAU-1428-31-5-4 indicated that SSI, TOL and YSI can be used to screen drought resistant genotypes under reproductive stage drought condition. Banumathy *et al*. (2018) reported that the lines *viz.*, BIL 108, BIL 752, BIL 1101, BIL 1079, BIL 1094 and BIL 1095 had exhibited higher values of stress tolerance index under salinity.

Among the 25 genotypes Anna (R) 4, APO, Kattanur, Kuliyadichan and Sivappuchithiraikar had significant mean values days to maturity, spikelet fertility, grain yield, nitrate reductase activity, proline content and chlorophyll stability index along with high STI (Table 6).From the above study, the variety APO and landraces *viz*., Kattanur, Kuliyadichan and Sivappuchithiraikar were identified with significant mean values and high STI for seedling stage and reproductive stage drought tolerance. Hence these above genotypes can be used as parents for the development of drought tolerant varieties. These genotypes may be crossed with high yielding varieties to develop segregants combining the drought tolerance along with high yield.

References

Anadhan, T., Ninteen, K., Jagadish, K., Raveendran, S.V and Ushakumari, R. 2015 . Variability of Root Anatomical Traits in Rice Germplasm Trends in Biosciences 8(17), Print: ISSN 0974-8431, 4630-4634.

Banumathy, S., Veni, K., Anandhababu, R., Arunachalam, P., Raveendran, M and Vanniarajan, C. 2018. Character association and stress indices for yield components in *Saltol* introgressed backcross inbred lines of rice (*Oryza sativa* L.). *Indian J. Agric. Res.,* **52** (1):28-33.

Bates LS, Waldren RP, Teare ID (1973) Rapid determination of free proline for water stress studies. *Plant Soil* **39**: 205-207.

Bohnert, H.J., Nelson, D.E. and Jensen, R.G. 1995. Adaptations to environmental stresses. *Plant Cell* 7, 1099-1111.

Bunnag, S and Pongthai, P. (2013) Selection of Rice (*Oryza sativa* L.) Cultivars Tolerant to Drought Stress at the Vegetative Stage under Field Conditions. *American Journal of Plant Sciences*, 4, 1701-1708

Chang, T.T., Loresto, G.C. and Tagumpay, O. 1972. Agronomic and growth characteristics of upland and lowland varieties. In: Rice Breeding, IRRI, Los Banos, Philippines, 648-661.

Dikshit, U.N., Parida, D. and Satpathy, D. 1987. Response of short duration rice cultivars to drought stress. IRRI Newsl. **12**(6): 14-15.

FAO.2017.FAOSTAT.Availableathttp://faostat3.fao.org/faostatgateway/go/to/download/Q/QC/E. FAO, Rome, Italy.

Fernandez,G 1992. Effective selection criteria for assessing plant stress tolerance. In: Proceedings of the International Symposium on Adaptation of Vegetables and other Food Crops in Temperature and Water Stress, Taiwan; 257-270.

Ganapathy, S., S.K. Ganesh, P. Shanmugasundram and R. Chandra Babu,2010. Studies on root traits for drought tolerance in rice (*Oryza staiva* L.) under controlled (PVC pipes) condition. *Electron J of plant Breed.*, **1**(4): 1016-1020.

Garg, H,S.and Bhattacharya, C.2017. Drought Tolerance Indices For Screening Some Of Rice Genotypes. *IJABR*, VOL.**7** (4) :671-674.

IRRI. 2014. Standard Evaluation System for Rice. 5th edn. Los Banos, the Philippines: International Rice Research Institute.

Kamarudin, Z,F., Mohd Rafii Yusop, M, R., Mahmud Mohamed, T,M., Ismail, M,R., and Abdul Rahim Harun, A, R. 2018. Growth Performance and Antioxidant Enzyme Activities of Advanced Mutant Rice Genotypes under Drought Stress Condition. *Agronomy* , 8, 279.

Kumar A, Bernier J, Verulkar S, Lafitte HR, Atlin GN. 2009. 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 Research* 107, 221–231.

Kumar S, Dwivedi, S.K., Singh, S.S., Jha, S.K., Lekshmy, S., Elanchezhian,R., Singh, O.N., and Bhatt, B.P. 2014. Identification of drought tolerant rice genotypes by analyzing drought tolerance indices and morpho-physiological traits. *SABRAO Journal of Breeding and Genetics* **46**(2) 217-230.

Kumar A, Dixit S, Henry A. 2015. Marker-assisted introgression of major QTLs for grain yield under drought in rice. In: Varshney RK, Tuberosa R, eds. *Translational genomics for crop breeding: abiotic stress, yield and quality*, Vol. **2**. Chichester, UK: Wiley, 47.

Li, X., S. Waddington, J. Dixon, A. Joshi, and M. de Vicente. 2011. “The Relative Importance of Drought and Other Water-related Constraints for Major Food Crops in South Asian Farming Systems.” *Food Security* **3**(1): 19-33.

Murthy, K.S.and Mujumdha R, S. K., 1962, Modification of the technique for determination of chlorophyll stability index in relation to studies of drought resistance in rice. *Current Science*, **3**1(11) :470- 471.

Nahakpam, S. (2017) .Chlorophyll Stability: A Better Trait for Grain Yield in Rice under Drought. *Indian Journal of Ecology* (Special Issue-4): 77-82.

Nicholas, J.C.; Harper, J.E. and Hageman, R.H. 1976. Nitrate reductase activity in soybeans (*Glycine max* [L] Merr.): 1. Effects of light and temperature. *Plant Physiology*, v.**58**, p.731-735.

Prasad, R. 2011. “Aerobic Rice Systems.” *Advances in Agronomy*, **111**: 207-247.

Reddy A R, Chaitanya K V, Vivekanandan M. 2014. Drought induced responses of photosynthesis and antioxidant metabolism in higher plants. *J Plant Physiol*, **161**(11): 1189–1202..

Swapna, S and Shylaraj, S. 2017. Screening for Osmotic Stress Responses in Rice Varieties under Drought Condition. Rice Science, **24**(5): 253-263.

Vengatesh, M and Govindarasu, R. 2017. Studies on root traits for drought tolerance in aerobic rice (*Oryza sativa* L.) using polythene bags. *Electronic J of plant Breed.*, **8**(2): 708-711.

Venuprasad, R., H. R. Lafitte, and G. N. Atlin. 2007. “Response to Direct Selection for Grain Yield under Drought Stress in Rice.” *Crop Science*, **47**(1): 285-293.

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Table 1. Mean performance of seedling traits under varied level of moisture stress in 25 rice genotypes

Genotypes/Traits	Seedling height (cm)				Root length (cm)				Shoot length (cm)				Dry weight (g)				Leaf drying		Leaf rolling	
	100% FC	80 % FC	60 % FC	STI	100 % FC	80 % FC	60 % FC	STI	100 % FC	80% FC	60 %FC	STI	100% FC	80% FC	60% FC	STI	80 % FC	60 % FC	80% FC	60% FC
PMK 1	50.6	46.3*	41.2*	1.21	4.2	3.5	3.2	0.39	46.4*	42.8	38.0	0.50	2.1	1.8	1.5	0.69	3	3	3	3
PMK 2	66.7*	52.2*	45.2*	1.68	6.2*	4.9*	4.1	0.74	60.5*	47.3*	41.1*	1.37	2.2	1.8	1.4	0.67	0	1	1	1
PMK (R) 3	45.7	39.8	31.8	0.81	4.1	3.2	2.8	0.33	41.6	36.6*	29.0	0.64	2.1	2.0	1.6	0.73	1	1	1	1
Anna (R) 4	41.1	37.8	30.4	0.69	6.3*	4.7	4.4*	0.81	34.8	33.1	26.0	0.47	2.1	1.9	1.7	0.78	1	1	1	1
APO	69.3*	62.3*	60*	2.31	7.6*	7.3*	6.7*	1.50	61.7*	55*	47.0*	1.60	2.4*	2.3*	2.2*	1.15	0	0	0	0
Anjali	41.9	36.1	34.5	0.84	5.4	4.4	4.0	0.63	36.5	31.7	30.5	0.61	2.2	2.2	1.7	0.81	3	3	1	3
RMD (R) 1	31.7	26.1	25.5	0.45	4.7	3.0	2.5	0.32	27.0	23.1	23.0	0.33	2.1	1.8	1.2	0.55	1	3	1	3
Govind	46.7	41.2	23.1	0.59	6.7*	3.9	3.3	0.65	40.0	37.1	19.8	0.43	2.1	2.0	1.8	0.82	3	5	1	3
Vandana	50.2*	24.9	22.0	0.61	5.1	4.0	3.3	0.49	45.1*	20.9	18.5	0.46	2.0	2.1	1.7	0.74	1	3	1	3
Sahabagidhan	36.9	21.6	19.8	0.41	5.1	3.5	3.0	0.45	31.8	18.1	16.8	0.29	2.0	1.7	1.2	0.52	5	7	5	7
Tulasi	34.5	36.2	31.5	0.49	7.1*	4.4	3.5	0.73	27.4	31.8	28.0	0.48	2.1	2.1	2.0	0.92	3	3	1	3
Aruvatham kuruvai	50.1*	35.3	25.6	0.73	7.2*	5.1*	3.6	0.76	42.9*	30.2	22.0	0.52	2.1	2.0	1.7	0.78	3	3	1	3
Sivappuchithiraikar	59.7*	56.4*	51.2*	1.68	6.3*	5.5*	5.1*	0.94	53.4*	50.9*	46.1*	1.35	2.2	2.0	2.0*	0.96	0	0	0	0
Kuruvaikalanjiyam	57.0*	50.2	39.6*	1.26	6.8*	6.5*	3.4	0.68	50.2*	43.7*	36.2*	1.00	2.2	1.9	1.5	0.72	1	1	1	1
Norungan	50.6*	46.8*	38.7*	1.09	5.6	5.0	4.1	0.67	45.0*	41.8*	34.6*	0.85	2.3*	2.1	1.7	0.85	3	3	1	3
Poongar	58.9*	55.3*	44.6*	1.23	8.0*	7.0*	3.7	0.87	50.9*	48.3*	40.9*	1.14	2.1	2.1	1.4	0.64	1	1	0	1
Kuliyadichan	50.3*	49.1*	47.2*	1.32	7.2*	6.6*	6.0*	1.27	43.1*	42.5*	41.2*	0.98	2.1	2.0	2.2*	1.05	0	0	0	0
Kattanur	64.2*	50.4*	49.8*	1.78	7.0*	6.4*	6.1*	1.25	57.2*	44.0*	43.7*	1.38	2.1	2.1	2.0*	0.92	0	0	0	0
Mattaikar	47.5	37.1	30.3	0.80	5.0	4.3	3.2	0.47	42.5*	32.8	27.1	0.63	2.0	2.0	1.7	0.74	0	1	1	1
Chithiraikar	41.6	35.4	27.0	0.62	4.3	3.2	2.5	0.31	37.3	32.2	24.5	0.50	2.2	1.9	1.5	0.72	3	3	1	3
Varalu	23.8	19.3	20.5	0.27	5.1	4.2	4.0	0.60	18.7	15.1	16.5	0.15	2.1	1.8	1.4	0.64	1	3	1	3
Chandikar	29.5	27.4	32.0	0.72	5.1	4.3	3.9	0.58	24.4	23.1	28.1	0.46	2.1	2.0	1.5	0.69	1	1	1	1
Kallurundaikar	42.0	38.4	35.0	0.82	6.0	5	4.0	0.70	36.0	33.4	31.0	0.61	2.1	2.0	1.8	0.82	3	3	1	3
Nootripathu	28.8	28.0	27.2	0.41	4.3	3.7	3.5	0.44	24.5	24.3	23.7	0.34	2.1	1.6	1.2	0.55	3	5	3	5
Vellaichithiraikar	42.4	38.7	35.6	0.81	5.5	4.7	4.3*	0.69	36.9	34	31.3	0.63	2.1	2.1	2*	0.92	1	1	1	1
Mean	46.46	39.69	34.77		5.8	4.73	3.9		40.5	33.9	29.9		2.1	2.1	1.7					
SE	1.08	0.83	0.76		0.13	0.18	0.16		0.58	0.93	0.71		0.09	0.09	0.09					
CD	2.16	1.67	1.53		0.27	0.36	0.32		1.17	1.87	1.42		0.182	0.181	0.180					

*Significant at 5 percent level

Note: Leaf rolling: 0- Leaves healthy, 1-Leaves start to fold (shallow), 3-Leaf folding (deep V-shape), 5- Leaves fully cupped (U-Shape), 7- Leaf margin touching (o-shape), 9-Leaf death
Leaf drying :0- No symptoms, 1- Slight tip drying, 3- Tip drying , 5- One fourth to ½ of all leaves dried, 7-More than 2/3 of all leaves fully dried, 9- All plants apparently dead

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Table 2. ANOVA for seedling traits at different moisture stress in rice

Source of variation	Df	Mean squares											
		Seedling height			Root length			Shoot length			Dry matter		
		100 % FC	80 % FC	60 % FC	100 % FC	80 %FC	60 %FC	100 %FC	80%FC	60%FC	100%FC	80%FC	60%FC
Between groups (Genotypes)	24	424.99**	358.23**	304.29**	4.07**	4.44**	3.43**	393.33**	356.22**	258.19**	0.02**	0.52	0.25**
Within groups (Error)	50	1.74	1.03	0.87	0.02	0.04	0.03	0.50	1.30	0.752	0.01	0.49	0.01

****Significant at 1% level**
FC-Field Capacity

Table 3. Mean performance of various physiological traits under seedling stage moisture stress in 25 rice genotypes

Genotypes/Traits	Nitrate reductase activity (NO_2 /g/h)			Proline (mg/g)			Chlorophyll stability index (%)		
	100 % FC	80 % FC	60 % FC	100 % FC	80 % FC	60 %FC	100% FC	80 % FC	60 % FC
PMK1	184.00	177.00	171.66	112.43*	114.00	121.66*	82.16	77.50	75.26
PMK 2	184.33	178.00*	176.66*	113.56*	117.76*	125.00*	82.56	79.66*	75.50
PMK (R) 3	183.00	179.66	176.00	115.23*	122.23*	127.33*	83.50	80.43	76.26
Anna (R) 4	194.00*	187.76*	179.00*	121.10*	125.33*	129.66*	82.43	80.00	77.00
APO	207.00*	204.00*	193.00*	120.23*	128.33*	136.00*	85.10*	82.33*	80.66*
Anjali	184.00	183.56*	172.66	106.33	109.23	114.33	84.26	80.90	76.06
RMD (R) 1	181.00	173.33	172.00	107.66	110.33	116.00	80.00	77.66	75.33
Govind	180.00	172.76	169.00	90.00	96.00	100.43	82.06	78.83	74.76
Vandana	181.66	177.00	175.33	113.33*	116.43*	117.23	81.76	79.73	74.90
Sahabagidhan	182.43	179.76*	178.00*	96.00	102.66	107.76	81.43	76.40	73.06
Tulasi	171.33	168.56	167.33	96.10	107.56	109.90	82.26	77.33	74.43
Aruvatham kuruvai	173.00	167.33	161.66	93.23	99.66	108.76	84.00	77.56	73.90
Sivappuchithiraikar	191.00*	183.00	181.00*	116.66*	124.43*	127.56*	82.43	79.43	76.00
Kuruvaikalanjiyam	180.66	177.33	173.00	108.10	113.23	115.43	81.60	80.33	76.06
Norungan	179.33	175.66*	172.33	106.33	112.00	117.00	81.00	76.66	72.66
Poongar	182.00	176.66	168.00	108.66	115.00	116.90	82.30	80.16	76.06*
Kuliyadichan	183.66	183.56*	178.33*	122.56*	123.66*	130.33*	82.90*	80.66	79.06*
Kattanur	192.00*	189.66*	180.00*	116.23*	122.33*	129.33*	81.06	80.06	77.16*
Mattaikar	173.33	170.90	170.33	105.10	111.76	119.33	82.06	79.46	75.10
Chithiraikar	180.33	175.23	171.33	105.66	111.10	116.00	82.06	78.40	75.40
Varalu	176.60	172.00	170.00	94.33	98.56	106.00	82.40	77.73	73.40
Chandikar	175.66	169.76	166.66	98.16	97.10	106.00	82.33	77.43	74.26
Kallurundaikar	171.33	166.33	165.00	107.33	110.00	116.00	81.00	77.00	73.66
Nootripathu	174.00	170.00	166.33	97.00	104.43	112.00	82.76	78.93	74.16
Vellaichithiraikar	182.33	175.10	171.66	115.23*	119.23*	127.00*	83.33	81.40*	75.50
Mean	181.92	177.36	173.05	107.46	112.49	118.12	82.35	79.04	75.42
SE	1.62	1.87	1.58	1.46	1.70	1.62	1.07	1.13	1.06
CD	3.25	3.74	3.16	2.92	3.40	3.24	2.14	2.27	2.13

*Significant at 5 percent level

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Table 4. Mean performance of rice genotypes under reproductive stage moisture stress

Genotypes/Traits	Mean performance under drought				STI			
	Days to maturity	Panicle length	Spikelet fertility	Grain yield	Days to maturity	Panicle length	Spikelet fertility	Grain yield
PMK 1	120	21.50	92.00	30.76	1.01	0.98	0.99	0.88
PMK 2	120	21.55	89.00*	31.54	1.17	0.94	0.95	0.91
PMK (R) 3	113	20.88	84.00	32.00	1.01	0.93	0.88	0.98
Anna (R) 4	110*	22.00	93.00*	34.45*	0.98	1.01	1.00	1.11
APO	110*	23.00	92.00*	36.00*	0.98	1.08	0.99	1.16
Anjali	105*	21.50	81.00	31.00	0.85	0.97	0.86	0.94
RMD (R) 1	105*	21.50	65.00	32.00	0.94	0.98	0.67	0.98
Govind	120	20.50	70.00	29.56	1.12	0.90	0.74	0.88
Vandana	105*	21.00	84.00	30.00	0.85	0.92	0.90	0.87
Sahabagidhan	110*	20.00	76.00	28.56	0.98	0.87	0.77	0.78
Tulasi	120	21.45	82.00	28.56	1.17	0.98	0.84	0.79
Aruvatham kuruvai	95*	19.56	65.00	27.78	0.89	0.82	0.68	0.77
Sivappuchithiraikar	115	22.67	86.00*	35.56	1.08	1.04	0.90	1.16
Kuruvaikalanjiyam	110*	19.45	81.00	30.55	1.08	0.83	0.86	0.90
Norungan	114	20.88	82.00	31.33	1.07	0.93	0.86	0.95
Poongar	100*	21.85	84.00	32.05	0.94	0.98	0.87	0.98
Kuliyadichan	117	22.89	90.00*	34.56*	1.03	1.05	0.96	1.06
Kattanur	115	22.50	89.00*	35.00*	1.08	1.05	0.96	1.11
Mattaikar	117	21.00	80.00	29.66	1.15	0.92	0.83	0.83
Chithiraikar	115	21.50	83.00	30.50	1.08	0.96	0.88	0.86
Varalu	105*	20.77	74.00	28.67	0.94	0.89	0.77	0.75
Chandikar	116	20.50	85.00	29.00	1.09	0.88	0.89	0.81
Kallurundaikar	120	21.50	75.00	31.75	1.17	0.96	0.80	0.94
Nootripathu	120	20.50	80.00	30.55	1.02	0.88	0.82	0.88
Vellaichithiraikar	105*	21.67	86.00*	32.00	1.03	0.95	0.92	0.93
Mean	**111.65**	**21.28**	**81.92**	**31.3356**				
SE	**1.93**	**1.63**	**1.63**	**1.40**				
CD	**3.89**	**3.27**	**3.27**	**2.81**				

*Significant at 5 percent level

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Table 5. ANOVA for yield traits at reproductive stage moisture stress in Rice

Source of variation	Degrees of freedom	Mean squares			
		Panicle length	**Spikelet fertility**	**Days to maturity**	**Grain yield**
Replication	2	70.56	6.24	17.85	14.22
Genotypes	24	2.60**	171.07**	138.15**	10.20**
Error	48	1.22	3.90	5.61	1.42

****Significant at 1% level**

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Table 6. Mean performance of physiological traits for 25 rice genotype under reproductive stage moisture stress

	Nitrate reductase activity (NO_2 /g/h)		Proline (mg/g)		Chlorophyll stability index (%)	
Genotypes/Traits	IRRIGATED	STRESS	IRRIGATED	STRESS	IRRIGATED	STRESS
PMK1	189.66*	168.33	114.33*	123.00	83.00	76.00*
PMK 2	186.33	176.33*	114.66*	122.00	83.67	75.33
PMK (R)3	186.00	179.00*	117.00*	129.33*	85.00*	76.00*
Anna (R) 4	196.00*	180.00*	123.00	132.67*	84.00	78.00*
APO	208.33*	199.67*	123.66*	137.67*	85.00*	77.00*
Anjali	185.00	173.67	107.66	115.33	83.33	72.33
RMD (R) 1	185.00	169.00	115.33*	121.67	82.00	71.00
Govind	185.33	166.33	95.33	107.67	83.67	72.00
Vandana	181.66	173.33	115.66*	122.00	82.67	71.33
Sahabagidhan	185.00	168.33	97.66	106.33	82.00	73.33
Tulasi	173.33	165.33	99.00	107.67	83.00*	71.33
Aruvatham kuruvai	177.00	163.33	96.33	109.33	82.67	71.00
Sivappuchithiraikar	193.00*	186.67*	119.00*	132.00*	83.33	77.00*
Kuruvaikalanjiyam	182.33	171.00	111.00	118.33	82.00	71.00
Norungan	182.66	172.33	109.00	117.00	81.00	72.00
Poongar	185.00	174.33	111.66	122.00	82.00	71.00
Kuliyadichan	186.00	181.00*	122.66*	135.00*	83.67	77.67*
Kattanur	191.66*	185.00*	119.00*	129.33*	82.00	77.33*
Mattaikar	175.00	165.00	112.33	120.67	82.33	73.33
Chithiraikar	183.00	174.33	107.00	114.33	81.67	72.00
Varalu	179.33	164.33	96.66	111.00	83.33	71.00
Chandikar	178.00	163.67	101.66	108.00	82.33	71.00
Kallurundaikar	174.33	163.33	110.00	119.33	82.00	73.67
Nootripathu	175.66	166.33	99.33	112.33	82.00	73.67
Vellaichithiraikar	183.33	174.33	116.66*	125.00*	83.67	75.67
Mean	184.32	172.97	110.22	119.96	82.85	73.64
SE	1.16	1.39	1.31	1.82	0.80	1.11
CD	2.32	2.78	2.63	3.65	1.61	2.22

*Significant at 5 percent level

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