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Screening and Variability Studies in Rice Genotypes for Drought Tolerance and Yield

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Abstract

In the present investigation, laboratory and field screening of nine rice genotypes, namely, TM 12061, TM 12077, TM 12012, TM 14035, TM 16017, Senthuram, Vandhana, TKM 12 and Anna (R) 4 was taken up to assess their drought tolerance potential. For laboratory screening, the effect of different levels of PEG concentration namely*, -0.2, -0.4, -0.6* and *-1.0* MPa on germination, shoot length and root length were studied. There was a considerable decrease in the germination potential among all the genotypes with increase in PEG concentration. The culture, TM 12077 showed higher level of tolerance to PEG induced drought stress showing 30.8% germination with 3.2 cm and 8.85 cm shoot and root length, respectively at higher level of PEG concentration (1.0 MPa). In field screening under managed stress condition, the cultures, TM 12077 and TM 12012 showed higher accumulation of proline (4.15 mg/g). Chlorophyll stability index was more than 80% in the genotypes, TM 12012, TM 12077, and TM 12061. The culture TM 14035, the varieties Anna (R) 4 and Vandhana matured early in 115 days. Plant height was found to be moderate in Vandhana (103.3 cm), TM 12077(105.4 cm), TM 12061 (108.2 cm) and TM 12012 (110.5 cm) under managed stress condition. The number of tillers per plant, number of panicles/sqm and yield/hectare were maximum in the culture, TM 12077 under managed stress condition. Based on laboratory and field screening, the cultures TM 12077, TM 12012, and TM 12061 were found promising for water stress environment and can be utilized as donors in the breeding programs for drought tolerance in rice. High heritability coupled with moderate to high GA as per cent of mean was recorded for plant height, tillers per plant, chlorophyll Stability index and total chlorophyll content indicating the presence of additive gene effects and scope for their improvement through direct selection.

Keywords: Rice, drought tolerance, screening, variability

Introduction

Rice is the most important and widely cultivated food crop. Drought is one of the most challenging abiotic stresses that severely impairs rice production. Climate change increases the frequency and severity of drought (Wassmann *et al*., 2009). Global warming and unpredictable rainfall patterns in recent years have led to excessive drought spells causing severe yield losses. Drought stress can occur at any growth stage and can cause a significant yield reduction. Most of the improved rice varieties grown in drought prone areas were originally bred for irrigated conditions and were never selected for drought tolerance (Kumar *et al*., 2008). Development of drought tolerant rice varieties is an important strategy to minimize rice yield losses in drought prone areas. The complex nature and polygenic control of drought tolerant traits, however, is a major bottleneck for the current research in drought tolerance and maintenance of yield in rice under drought conditions is a multifaceted phenomenon controlled by the cumulative effects of several traits.

The ability of rice genotype to adapt against drought stress during seedling stage is important when early-season drought occurs. The germination and seedling growth stage are the most sensitive stages to drought stress, implying the importance of the plant's tolerance to drought in the early growth stages (Wolny *et al*., 2018, Reddy *et al*., 2021). Drought affects growth and development, pigment content, photosynthetic activities, membrane integrity and osmotic adjustment apart from yield loss. Understanding the morphological, biochemical, and physiological mechanisms involved in rice under drought will play a very important role in breeding drought-tolerant cultivars. Hence, the present investigation aims to assess the drought tolerance potential of different rice genotypes by studying the impact of water stress on germination and early growth in addition to the effect on different morphological, biochemical, physiological and yield traits along with yield under induced water stress conditions. Since, a critical analysis of the genetic variability is a prerequisite for any crop improvement programme and for adopting of appropriate selection techniques, the present study also aims to assess the extent of genetic variability available for yield and drought tolerant traits in the experimental material.

Materials and Methods

Laboratory screening

Laboratory studies for assessing the drought tolerance in nine rice genotypes *viz*., TM 12061, TM 12077, TM 12012, TM 14035, TM 16017, Senthuram, Vandhana, TKM 12 and Anna (R) 4 was carried out at Agricultural College and Research Institute, Eachangkottai during 2020 using different concentrations of PEG for creating water stress. Seed materials were collected from Rice Research Station, Tirur and Tiruvallur, Tamil Nadu. Seeds of each genotype were surface sterilized with 70% ethanol for five minutes and washed thoroughly with sterilized distilled water. Seed germination test was performed by evenly distributing the seeds on a 10 cm diameter sterilized Petri dish with layers of germination paper. Distilled water was used as a control (0 MPa) and osmotic potentials of -0.2, -0.4, -0.6 and -1.0 MPa were created by adding PEG 6000 at 4, 8, 10 and 14 g per 100 ml distilled water. Each Petri dish was moistened with 10 ml distilled water (control) and different concentrations of PEG. Observations on germination, shoot and root length of the seedlings under different levels of PEG induced water stress were recorded on seventh day. The experiment was laid out in Complete Randomized Block Design (CRBD) with four levels of drought stress and four replications.

Field screening

Field experiment was conducted at Rice Research Station, Tirur during *kharif*, 2020. Nine rice genotypes TM 12061, TM 12077, TM 12012, TM 14035, TM 16017, Senthuram, Vandhana, TKM 12 and Anna (R) 4 were raised in the nursery and the twenty-five days old seedlings were transplanted in the main field in RBD with three replications adopting the spacing of 20 x 15 cm. Irrigation was stopped and water stress was imposed for 15 days from 60 DAS. Effect of water stress on physiological parameters such as proline content, chlorophyll stability index and total chlorophyll content were studied at the end of stress period *i.e.,* 75 DAS. Observations on days to maturity, plant height, number of tillers per plant, number of panicles per square meter, root length (cm), root volume (cc) and grain yield (recorded on plot basis and expressed as kg/ha) were also recorded at the time of harvest and the mean was used for analysis.

Variability studies were carried out for nine traits, namely, days to maturity, plant height, number of tillers per plant, number of panicles per square meter, root length (cm), chlorophyll Stability Index, Proline content, Total chlorophyll content and plot yield. The estimates on phenotypic variability, genotypic variability, phenotypic coefficient of variation, genotypic coefficient of variation, heritability, genetic advance as per cent of mean were estimated for yield and drought parameters as per the procedures described by Johnson *et al*., (1955).

Results and Discussion

Effect of different levels of PEG concentration on germination, shoot length and root length is presented in **Table 1.** In the present study, germination percentage varied from 97% to 100% in control and there was a considerable decrease in the germination potential among all the genotypes with increase in PEG concentration from 0.2 MPa to 1.0 MPa. Elevated drought stress was noticed to slow down water uptake by seeds, thereby inhibiting their germination, shoot and root elongation. However, differential tolerance was observed among the rice genotypes studied. The culture, TM 12077 showed higher level of tolerance to PEG-induced drought stress showing 30.8% germination with 3.2 cm and 8.85 cm shoot and root length, respectively at higher level of PEG concentration (1.0 MPa), when compared to Anna (R) 4, which was found to be moderate in drought tolerance with 14.8% germination at the same level of PEG concentration. TKM 12 showed poor ability to cope up with tolerance reaction to drought even at 0.6 MPa and showed considerable reduction in germination (21.4%) and shoot (2.3 cm) and root length (5.0 cm). The decrease in germination percentage and seedling growth as a result of the decrease in osmotic potentials has been reported by several authors (Pirdashti *et al*., 2003, Vibhuti *et al.*, 2015, Ishlam *et al.,* 2018).

Understanding of biochemical and physiological mechanism which enables plants to adapt to water stress could help in the selection of tolerant genotypes (Zaharieva *et al.,* 2001). Under water-deficit conditions, plants have developed osmotic adjustment, one of the fundamental mechanisms of drought adaptation. Osmotic adjustment helps in the maintenance of turgor and cell volume during drought and has been emphasized in the context of drought tolerance of crops. Accumulation of osmo-protectants, such as proline, glycine, betaine and

Table 1: Germination Percentage, Shoot length (cm), Root length (cm) of different rice genotypes under varied PEG levels

Genotypes	Germination Percentage (%)					Shoot length (cm)					Root length (cm)				
	Control	0.2 MPa	0.4 MPa	0.6 MPa	1.0 MPa	Control	0.2 MPa	0.4 MPa	0.6 MPa	1.0 MPa	Control	0.2 MPa	0.4 MPa	0.6 MPa	1.0 MPa
TM 12061	100.0	88.4	84.9	55.4	28.4	12.8	10.0	8.0	6.7	2.5	20.45	17.45	15.73	11.00	8.23
TM 12077	100.0	91.8	85.4	60.7	30.8	14.9	10.4	8.7	7.2	3.2	19.6	17.25	15.50	11.20	8.85
TM 12012	100.0	90.5	84.7	48.0	24.1	14.1	10.4	8.1	6.8	2.3	23.70	18.20	16.70	8.85	7.60
TM 14035	100.0	89.4	83.9	41.4	26.7	14.0	10.6	8.2	7.0	2.8	16.80	13.40	11.90	9.00	7.25
TM 16017	100.0	89.7	81.4	43.6	27.0	13.4	9.0	8.2	6.5	2.5	22.50	17.50	15.45	8.15	7.10
TKM (R)12	98.0	80.5	71.4	21.4	0.0	11.4	8.5	5.5	2.3	0.0	12.40	10.95	9.85	5.00	0.00
Anna (R)4	97.0	84.6	79.4	38.9	14.8	11.2	10.1	6.7	4.2	1.9	19.75	17.80	16.25	11.80	8.25
Senthuram	98.0	88.7	79.4	45.8	18.4	12.7	10.4	6.6	4.7	1.0	12.70	10.40	9.75	7.95	7.50
Vandhana	98.0	89.1	79.0	37.4	15.7	12.0	10.0	6.1	5.6	0.6	18.75	16.80	10.25	7.80	7.25
SEd	0.44	0.42	0.39	0.36	0.34	0.20	0.18	0.16	0.14	0.13	0.18	0.185	0.12	0.114	0.11
CD (0.05)	0.92	0.88	0.85	0.82	0.81	0.40	0.37	0.35	0.30	0.28	0.37	0.34	0.26	0.22	0.20

soluble sugar, provides osmotic adjustments for the plants. Proline content can act as a biochemical marker under drought screening of plants (Pandey and Shukla, 2015), since higher accumulation of proline is usually associated with drought tolerance. Among the nine genotypes that were subjected to managed water stress under field condition and analyzed for proline content (mg/g), the rice cultures, TM 12077 and TM 12012 showed higher accumulation of proline (4.15 mg/g) followed by TM 12061 (4.13 mg/g) **(Figure 1).**

Figure 1: Effect of water stress on Proline content of different rice genotypes

Chlorophyll stability index (CSI) is an indication of the stress tolerance capacity of plants. Plants with high CSI tend to stay green even under stress which is very important for photosynthetic activity. Chlorophyll stability index was recorded to be higher in the genotype, TM 12012 (80.76%) followed by TM 12077 (80.34%) and TM 12061 (80.23%) **(Figure 2).** A higher CSI helps the plants to withstand stress through better availability of chlorophyll which leads to increased photosynthetic activity, more dry matter production, and higher productivity (Madan Mohan *et. al.,* 2000). CSI is an indicative of the maintenance of photosynthetic pigments under drought and is a more dependent parameter for drought tolerance than chlorophyll content. High total chlorophyll content of 1.50 g was recorded in TM 12061, TM 12077 and TM 16017 and it was minimum (1.21 mg/g) in the variety, TKM (R) 12. Madan Mohan *et al*., (2000) reported that drought tolerant plants possess high value of total chlorophyll, while Gowri (2005) observed decrease in chlorophyll content under water scarcity situation than irrigated environment.

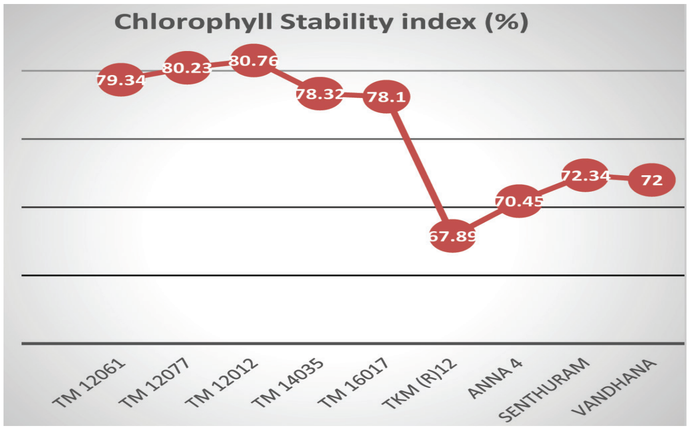

Figure 2: Effect of water stress on Chlorophyll stability index of different rice genotypes

Rice genotypes reacted to drought stress with reductions in height, leaf area and biomass production, tiller abortion, changes in rooting patterns, and a delay in development. The effect on the plant depended on the severity of the stress. Under managed stress conditions, the culture TM 14035 and the varieties, Anna (R) 4 and Vandhana matured in 115 days. Plant height was found to be moderate in Vandhana (103.3cm), TM 12077(105.4 cm), TM 12061 (108.2 cm) and TM 12012 (110.5 cm) under stress condition. The number of tillers and number of panicles/sqm was maximum in TM 12077 (14 and 302 respectively) whereas the variety Anna(R) 4 recorded minimum number of tillers (8.00) and number of panicles/sqm (226). Under managed stress condition, maximum yield was recorded by the culture TM 12077 (4692 kg/ha) followed by TM 12061 (4563 kg/ha).

Root characteristics of the plants are the vital attributes for enhancing production under drought stress. Rice

Table 2: Effect of water stress on physiological parameters of different rice genotypes under managed stress condition

Genotypes	Proline Content	Chlorophyll Stability Index	Total Chlorophyll content
TM 12061	4.13	80.23	1.50
TM 12077	4.15	80.34	1.50
TM 12012	4.15	80.76	1.48
TM 14035	4.10	78.32	1.48
TM 16017	4.05	78.10	1.50
TKM (R)12	3.52	67.89	1.21
Anna (R) 4	3.78	70.45	1.29
Senthuram	4.02	72.34	1.38
Vandhana	4.00	72.00	1.37
Mean	3.97	75.6	1.41
SEd	0.07	1.02	0.13
CD (0.05)	0.14	2.09	0.37

production under water stress can be predicted by considering root mass (dry) and length into account (Comas *et al*., 2013). Generally, rice varieties with profound and prolific root system show better adaptability to drought (Mishra *et al*., 2019, Kim *et al*., 2020). Plants with longer roots have access to extract water from deeper layers of soil which is important especially when the water recedes to lower strata due to drought, while higher root volume directly relates to more root hairs and better availability of water to plants when the water level is reduced below field capacity. Hence, root characters are primary traits of drought tolerance and show the inherent potential of genotypes to withstand drought. Varieties bred for dry / semi-dry conditions should therefore, possess better root architecture than lowland varieties. Root length (cm) was found to be higher in TM 12077 (17.8 cm) followed by TM 12061 (17.5 cm) and Vandana (16.9 cm). Root volume was maximum in TM 12061 (60 cc) followed by TM 12077 (59 cc), among the genotypes studied under managed stress condition **(Table 3).** Drought resistant entries had recorded higher root volume and root length than the susceptible genotypes. This is also in accordance with the findings of Yogameenakshi *et. al.,* (2003) and Sheeba *et. al.,* (2010).

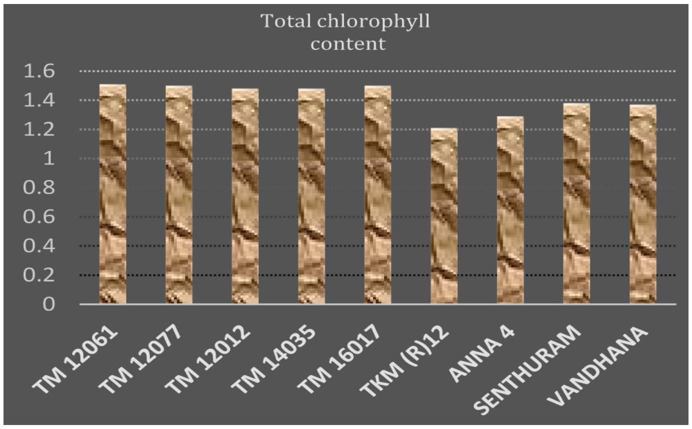

Figure 3: Effect of water stress on total chlorophyll content of different rice genotypes

Genetic Variability Studies

The available variability in a population can be partitioned into genetic parameters such as coefficients of variation, heritability, and genetic advance to serve as basis for selection of desirable genotypes. The genotypic coefficient of variation estimates the heritable variability, while phenotypic component measures the role of environment on genotype. PCV and GCV estimates are classified as low (0-10%), moderate (10%-20%) and high (>20%) according to Johnson *et al.,* (1955). The magnitude of difference between phenotypic coefficient of variance (PCV) and genotypic coefficient of variance (GCV) was less for the traits, namely, days to maturity, plant height, chlorophyll Stability Index, proline content and total chlorophyll content indicating little influence of environment. Relatively more difference between PCV and GCV was observed for number of panicles per square meter, root length and plot yield indicating the sensitive nature of these traits to environmental fluctuations. Similar conclusions were drawn by Prajapati *et al.,* (2011) and Mohan *et al.,* (2015). None of the traits recorded higher magnitude of PCV and GCV, whereas PCV was moderate for the traits, namely, plant height (15.40), tillers per plant (14.92), number of panicles / sqm (11.39%), root length (14.20%) and plot yield (13.85%). GCV was also moderate for the traits, namely, plant height (15.11%) and tillers per plant (11.69%) indicating the presence of variability in these traits for the genotypes and hence, the possibility of improving these characters through selection. Moderate PCV and low GCV was recorded by the traits, namely, number of panicles per square meter, root length and plot yield **(Table 4)** which indicated excessive effect of environment in their expression.

Genotypic coefficient of variation measures the extent of genetic variability present for a trait, but it is not sufficient for determination of the amount of heritable variability. In addition, estimation of heritability and genetic Advance as per cent of mean is also needed to assess the heritable portion of total variation and extent of genetic gain expected for effective selection. According to Johnson *et al.,* (1955), broad sense heritability was classified as low

Table 3: Effect of water stress on biometrical / agronomical parameters of different rice genotypes under managed stress condition

Genotypes	Days to Maturity	Plant height (cm)	No. of tillers / Plant	No. of panicles/sqm	Root Length (cm)	Root volume (cc)	Yield (kg/ha)
TM 12061	119	108.2	14.0	296	17.5	60	4563
TM 12077	117	105.4	14.0	302	17.8	59	4692
TM 12012	122	110.5	12.0	270	15.4	53	4277
TM 14035	115	91.0	10.0	256	14.8	49	4402
TM 16017	117	95.4	10.0	262	14.2	51	4025
TKM (R)12	122	115.0	10.0	242	16.2	39	3744
Anna (R) 4	115	96.0	8.00	226	15.5	42	3900
Senthuram	123	93.6	11.0	232	14.0	36	3060
Vandhana	115	103.3	10.0	250	16.9	55	4157
SE	11.20	11.46	11.11	8.48	0.66	1.58	49.33
C.D. (5%)	31.05	31.77	30.81	23.50	1.83	4.39	136.74
CV (%)	10.73	11.95	22.86	6.66	7.25	5.56	2.06

Table 4: Components of genetic parameters for yield and yield attributing traits in rice

Characters	PCV	GCV	Heritability in broad sense (%)	Genetic advance as per cent of mean
Days to maturity	4.48	4.33	93.24	8.61
Plant Height	15.40	15.11	96.20	30.53
Tillers per plant	14.92	11.69	61.69	18.86
No. of Panicles / sqm	11.39	8.72	58.51	13.74
Root Length	14.20	8.33	34.47	10.08
Chlorophyll Stability Index	6.89	6.71	94.90	13.46
Proline content	4.31	4.06	89.07	7.89
Total Chlorophyll content	6.35	6.21	95.71	12.52
Plot Yield	13.85	9.28	44.93	12.81

(<30%), medium (30% to 60%) and high (>60%). In the present study, high heritability was recorded for the traits, namely, days to maturity (93.2%), plant height (96.2%), tillers per plant (61.7%), chlorophyll Stability index (94.9%), proline content (89.07%) and total chlorophyll content (95.7%). The presence of high heritability indicates that these characters are least influenced by the environment. This serves as an index of transmissibility of traits from parents to their offspring. However, character exhibiting high heritability may not necessarily give high genetic advance (Gandhi *et al.*, 1964) because of involvement of non-additive gene action. Thus, selection for the characters should be based on high heritability as well as high genetic advance (Johnson *et al.*, 1955). The range of genetic advance as per cent of mean was classified as low (0-10%), moderate (10-20%) and high (>20%) by Johnson *et al.,* (1955). The genetic advance as per cent of mean was high for plant height (30.5) and moderate for tillers per plant (18.9), number of panicles per sqm (13.7), root length (10.1), chlorophyll stability index (13.5), total chlorophyll content (12.5) and plot yield (12.8). Presence of high/ moderate heritability along with genetic advance as per cent of mean for the traits plant height, tillers per plant, number of panicles per sqm, root length, chlorophyll stability index, total chlorophyll content and plot yield indicated that these characters were attributable to additive gene effects which are fixable revealing that improvement in these characters would be possible through direct selection.

Based on laboratory and field screening, the cultures, TM 12077, TM 12012 and TM 12061 were found promising for water stress environment and can be tested for yield performance before variety release and /or utilized as donors in the breeding programs for drought tolerance in rice. The characters, plant height, tillers per plant, chlorophyll Stability index and total chlorophyll content registered high heritability coupled with moderate to high GA as per cent of mean indicating the role of additive gene action in governing these traits and their potential for improvement through direct selection.

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