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IMPACT OF WATER STRESS ON MORPHO-PHYSIOLOGICAL AND BIOCHEMICAL TRAITS IN RICE GENOTYPES

A Sheeba*, C Tamil Selvi[1], P Yogameenakshi[2], M Bhaskaran[3] and S Banumathy[2]

Agricultural Research Station, Kovilpatti -628 501, Tamil Nadu, India

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Abstract

Laboratory and field screening were performed in nine rice genotypes *i.e.*, TM 12061, TM 12077, TM 12012, TM 14035, TM 16017, Senthuram, Vandhana, TKM 12 and Anna (R) 4 to assess their drought tolerant potential. For laboratory screening, the effect of different levels of Poly Ethylene Glycol (PEG) concentration *viz*., -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 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 concentration (1.0 MPa). In the field screening under managed stress condition, 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 genotype TM 14035, the varieties Anna (R) 4 and Vandhana matured early in 115 days. Number of tillers per plant, number of panicles/sqm and yield/hectare were maximum in TM 12077. While considering both laboratory and field screening, the genotypes TM 12077, TM 12012 and TM 12061 were found promising for water stress environment and can be utilized as donors in the drought tolerance breeding programs. High heritability coupled with moderate to high GA as per cent of mean recorded for plant height, tillers per plant, chlorophyll stability Index and total chlorophyll content indicates the presence of additive gene effects and their improvement through direct selection.

Introduction

Drought is one of the most challenging abiotic stress 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 spell causing severe yield losses. 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. Maintenance of yield in rice under drought conditions is a multifaceted phenomenon controlled by the cumulative effects of several traits.

The germination and seedling growth stage are the most sensitive stages in plant development, implying the importance of the plant's tolerance to drought in the early growth stage (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 against 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, early growth as well as morphological,

*Author for correspondence: <sheebateddy@gmail.com>. [1]Agricultural College and Research Institute, Echengkottai, Thanjavur, Tamil Nadu, India. [2]Rice Research Station, Tirur-602025, Tamil Nadu, India. [3]Vels Institute of Science and Technology and Advanced Studies, Chennai, Tamil Nadu, India.

biochemical, physiological traits and yield under induced water stress conditions. Since, a critical analysis of the genetic variability is a prerequisite for any crop improvement programme, the present study also aims to assess the extent of genetic variability for yield and drought tolerant traits.

Materials and Methods

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 Poly Ethylene Glycol for creating water stress. Seed materials were collected from Rice Research Station, Tirur, Tiruvallur, Tamil Nadu. Seeds of each genotypes were surface sterilized with 70% ethanol for five minutes and washed thoroughly with sterilized distilled water. Seed germination test was performed in sterilized petri dishes with the layers of germination paper. Distilled water was used as a control (0 MPa) and osmotic potentials -0.2, -0.4,-0.6 and -1.0 MPa were created by adding Poly Ethylene Glycol 6000 at 4,8,10 and 14 g per 100 ml distilled water. Each perti dish was moistened with 10 ml distilled water (control) and different concentrations of Poly Ethylene Glycol. The experiment was laid out in Complete Randomized Block Design (CRBD) with four levels of drought stress and four replications. Observations on germination, shoot and root length of the seedlings were recorded on seventh day.

Field experiment was conducted at Rice Research Station, Tirur during *kharif*, 2020. The nine rice genotypes *viz*., 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 RBD with three replication adopting the spacing of 20 x 15 cm. Irrigation was stopped and water stress was imposed for fifteen days from 60 days after sowing. Effect of water stress on physiological parameters such as proline content, chlorophyll stability index and total chlorophyll content was studied on 75th day after sowing. 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 were recorded at the time of harvest and the mean was used for analysis. Variability studies was done as per Johnson *et al*. (1955).

Results and Discussion

Effect of different levels of Poly Ethylene Glycol (PEG) concentration on germination, shoot and root length is presented in Table 1. There was a considerable decrease in the germination potential with increase in PEG concentration from 0.2 MPa to 1.0 MPa. Elevated drought stress slows down the water uptake by seeds, thereby inhibiting their germination, shoot and root elongation. However, differential tolerance was observed among the rice genotypes studied. 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 1.0 MPa of Poly Ethylene Glycol concentration. Anna (R) 4 was found to be moderate in drought tolerance (14.8% germination) at the same 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 also 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, Islam *et al.* 2018).

Among the nine genotypes, TM 12077 and TM 12012 showed higher accumulation of proline (4.15 mg/g) followed by TM 12061 (4.13 mg/g) (Fig. 1). Chlorophyll stability index was recorded higher in the genotype TM 12012 (80.76%) followed by TM 12077 (80.34 %) and TM 12061

(80.23%) (Fig. 1). A higher CSI helps plants to withstand stress through better availability of chlorophyll which leads to increased photosynthetic rate and higher productivity (Madan Mohan *et. al.* 2000). High total chlorophyll content of 1.50 g was recorded in TM 12061, TM 12077 and TM 16017 and these genotypes are considered as drought tolerant which was in accordance with the findings of Madan Mohan *et. al.* (2000).

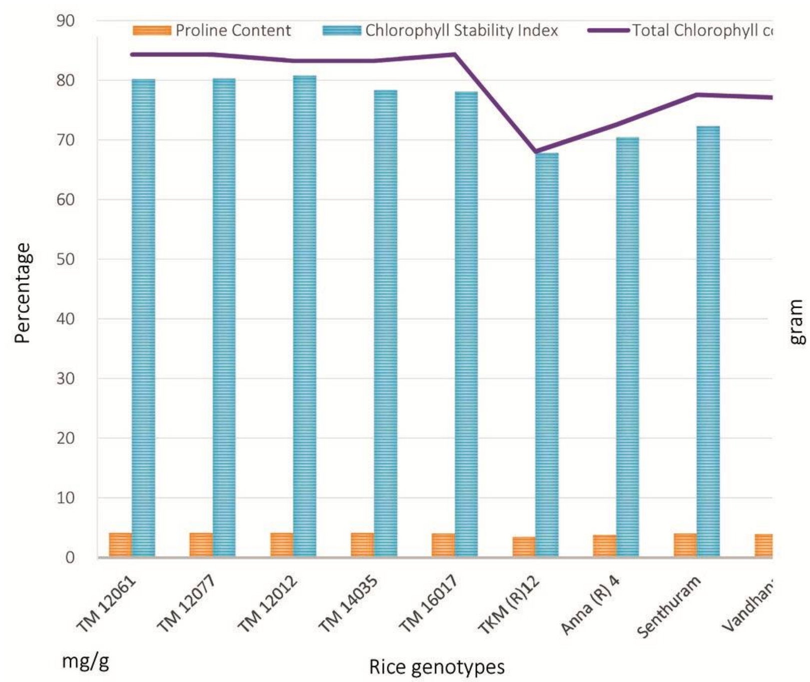

Fig. 1. Effects of water stress on proline content (mg/g), chlorophyll stability index (%) and total chlorophyll content (g) in rice genotypes

Under managed stress conditions, TM 14035, 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). The number of tillers per plant and panicles/sqm was maximum in TM 12077(14 and 302, respectively). Maximum yield was recorded by TM 12077 (4692 kg/ha) followed by TM 12061 (4563 kg/ha) (Table 2).

Root length 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) (Table 2). Drought resistant entries had recorded higher root volume and root length. This was also in accordance with the findings of Yogameenakshi *et.al.* (2003) and Sheeba *et. al.* (2010).

The magnitude of difference between phenotypic coefficient of variance (PCV) and genotypic coefficient of variance (GCV) was less for the traits days to maturity, plant height, chlorophyll stability index, proline content and total chlorophyll content indicating little influence of environment which was in consonance with the findings of Sudeepthi *et al.* (2020) and Akshay *et al.* (2022). Relatively more difference between PCV and GCV observed in number of panicles per square meter, root length and plot yield indicated the sensitive nature of these traits to

Table 1. Germination percentage, shoot length and root length of different rice genotypes under varied Poly Ethylene Glycol 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

MPa = Mega Pascal

Table 2. Effects of water stress on agronomical parameters of different rice genotypes under managed stress condition.

Genotypes	Days to maturity	Plant height (cm)	Number of tillers/Plant	Number 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

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. GCV was moderate for plant height (15.11%) and tillers per plant (11.69 %) indicated the presence of considerable level of variability in these traits among the genotypes and suggested possibility of improving these characters through selection. Similar finding was reported earlier by Mani and Kumar (2018) for plant height and Gautam *et al.* (2016) and Nithya *et al.* (2020) for productive tillers per plant. Moderate PCV and low GCV was recorded by the traits number of panicles per square meter, root length and plot yield which indicated excessive effect on environment in its expression (Table 3).

Table 3. Genetic parameters for yield and yield attributing traits in rice.

Characters	Phenotypic co-efficient of variation	Genotypic co-efficient of variation	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
Number 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

In the present study, high heritability was recorded by the traits *i.e.*, 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 indicated that these characters were least influenced by the environment. However, character exhibiting high heritability may not necessarily give high genetic advance 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 GA as percent 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) (Table 3). Presence of high/ moderate heritability along with genetic advance as per cent indicated that these characters were attributable to additive gene effects revealing that improvement in these characters would be possible through direct selection.

Based on laboratory and field screening, 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.

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