World Journal of Agricultural Sciences 15 (4): 269-277, 2019
ISSN 1817-3047

DOI: 10.5829/idosi.wjas.2019.269.277

Genetic Diversity in Rice (*Oryza sativa* L.) For Tolerance Against Drought and Salinity Stresses at Germination Stage

[1]*Muhammad Safyan*, [2]*Qasim Raza and* [1]*Iqra Parveen*

[1]Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan
[2]Rice Research Institute, Kala Shah Kaku, Pakistan

Abstract: Rice (*Oryza sativa* L.) is a staple food for more than half of the world's population. Globally, rice is grown on 158 million hectares, with an average annual production of 700 million tons. Drought and salinity are two major abiotic determinants due to high magnitude of their impact and wide occurrence. In the present study rice genotypes were analyzed to determine the stress tolerance of water and salt at the germination stage. Seeds of ten rice genotypes (Super basmati (Control), PK-9533-9-6-1-1, Shaheen Basmati (Control), PK-8892-4-1-3-1, PK-9194, RRI 3, PKBB 15-1, PKBB 15-6, PKPB-8 and PK 10683) were collected and maintained under four water stress and four salt stress levels. Seed germination, root length, shoot length, root / shoot ratio and other parameters were recorded. The results showed that with increasing water stress, germination of all varieties was delayed and decreased from the control level to the highest stress level (-8 bar). Root length, shoot length and root / shoot ratio decreased in all rice genotypes with increasing water stress. PK BB 15-1, PK-9433-9-6-1-1, RRI 3, PK 10683 showed a better response while Shaheen basmati was very sensitive to germination in all levels of water stress. The increase in salt stress also reduced every measured trait significantly in all genotypes. Among the ten rice genotypes PKBB 15-1, RRI 3, PK-9433-9-6-1-1 and PK 10683 showed better performance against salt stress. In response to drought stress PKBB 15-1, PK-9433-9-6-1-1, RRI 3 and PK 10683 showed better performance. Seed germination decreased from control to highest (16 dS / m) salt stress level. The maximum percentage of germination was observed in PK BB 15-1, RRI 3, PK-9433-9-6-1-1 and PK 10683 under all levels of salt stress. These results could be helpful for identification of the tolerant genotypes (PKBB-15) that can be studied further and exploited economically.

Key words: Salt Stress · *Oryza sativa* · Water Stress · Seed Germination · Root Length · Shoot Length · Root/Shoot Ratio

INTRODUCTION

Rice is the most widely consumed staple food at the global level and is an excellent source of compound carbohydrates. Rice provides the major source of dietary fiber and protein that is 27 and 20, respectively to the people of developing countries [1]. It has cultivated under diverse ecologies like irrigated to rain fed and upland to lowland to deep water system. Pakistan ranks as 11th largest producer of rice in the world. Rice remains a major source of foreign exchange earnings and ranks second as staple food grain crop in Pakistan. It is export crop in agriculture economy of Pakistan. It is an important crop of Kharif season. From 2016-17, Pakistan has produced about 6.7 million tons of rice, out of which round about 4 million were exported, mainly to the countries, like Middle East and Africa. In the fertile lands of Sindh and Punjab, rice has grown and millions of farmers depend on rice cultivation because it is their major source of employment. Basmati which is among the most famous varieties grown in Pakistan is known for its flavor and quality.

Abiotic stresses can directly or indirectly affect the physiological status of an organism by altering its metabolism, growth and development and adversely affect agricultural productivity [2, 3]. In addition, abiotic stresses are the major cause of crop failure, decreasing average yield for major crops by more than 50% and

Corresponding Author: Muhammad Safyan, Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan.

threatening the sustainability of the agricultural industry [4]. Processes such as seed germination, seedling growth and vigor, vegetative growth, flowering and fruit set are adversely affected by high salt and water stress, ultimately causing diminished economic yield and also quality of produce. Many plant species naturally accumulate protein and proline as major organic osmolytes when subjected to different abiotic stresses. These compounds are considered to play adaptive role in mediating osmotic adjustment and protecting sub- cellular structures in stressed plants.

Drought is considered one of the main constraints that limit rice yield in rain-fed and poorly irrigated areas. At least 23 million hectares of rain-fed rice area in Asia are estimated to be drought prone and drought is becoming an increasing problem even in traditionally irrigated areas [5]. It is an ever-growing problem that harshly limits the crop production and result in important agricultural losses especially in arid and semiarid areas.

The identification or development of rice cultivars that could resist to drought stress and produce economic yields is imperative in order to alleviate that increasing food crisis. Most improved cultivars grown in drought prone rain fed lowlands were originally bred for irrigated conditions and were never selected for drought tolerance [6].

Traditional as well as high yielding varieties of the eastern region are also highly susceptible to drought, particularly at reproductive stage. Degree and duration of drought stress during the reproductive stage in rain fed lowland rice is in need of development of drought tolerant rice cultivars [7] which must survive under water deficit stress at reproductive stage, quickly recover and grow rapidly upon renewed availability of soil moisture.

If drought stress occur during reproductive stage grain yield would drastically reduced. Rice plants respond to water deficit conditions through changing in their morphological, physiological and metabolic behavior. Hence, traits which are related to improved performance under drought conditions or survivals to extremely low water conditions are diverse [8].

The maintenance of osmotic pressure, more than plant functions, controls crop performance under drought.

Under drought stress leaf rolling is the most prominent physiological response of plant. It is an adaptive response plant to water stress which helps in maintaining favorable osmotic balance within plant tissues with resultant benefit to plants under water stress.

The important traits contributing to enhance stress tolerance, root characters are considered to be an important component of dehydration postponement mechanism because they contribute to regulation of plant growth and extraction of water and nutrients from deeper layer of soil.

Several components of root morphology contributing to drought tolerance have been identified which are root diameter root length etc. A deep root system has the ability to extract water from the depth and respond to evaporative demand; this is the most consensual of the traits contributing to drought avoidance at least in upland conditions [9].

Hence the present study was undertaken to identity the rice genotypes which perform better under drought conditions, having high yield potential and remains stable under drought stress.

Therefore present study was undertaken to identify rice genotypes having high yield potential and stability under drought stress conditions by analyzing drought tolerance indices at reproductive stage under rainfed condition of eastern India particularly in Bihar.

Salinity is a major factor reducing plant growth and productivity throughout the world. Approximately 10% of the world's arable land surface consist of saline or sodic soils. The percentage of cultivated land affected by salts is even greater. Of the cultivated lands, 23% are considered saline and another 37% are sodic and it has been estimated that one-half of all irrigated lands are seriously affected by salinity and water logging [10]. This problem is more serious in the agriculture of south and southeast Asia, which accounts for more than 90% of world rice production are worstly affected by salinity (320 mha) [11]. Rice is rated as a salt sensitive crop [12]. Although, salinity affects all stages of the growth and development of rice plant and the crop responses to salinity varies with growth stages, concentration and duration of exposure to salt. In the most commonly cultivated rice young seedlings were very sensitive to salinity [13]. There are other reports where grain yield is much more depressed by salt than the vegetative growth (Other than that of very young seedlings). Yield is a very complex character which comprise of many components and these yield components are related to final grain yield which are also severely affected by salinity. Panicle length, spikelet's per panicle and 1000-grain weight are significantly affected by salinity [14,15]. Inspite of these extensive studies of salinity on rice, our knowledge of the quantitative effect of salinity on rice seedling growth and yield components and interrelationship among yield components is limited. The present study was therefore, undertaken to determine the effects of salt levels and stress duration on seedling growth to analyze the salt sensitivity of different yield components and to identify the most important yield component(s) responsible for reduction in grain yield of rice crop.

MATERIAL AND METHODS

Germination Test for Salinity: In this study factorial experiments under a complete randomized design (CRD) were conduct at five different levels of (0, 4, 8, 12 and 16 dS/m) and distilled water serve as the control. In 1dsm^{-1} solution requires 640 mg (Salt) in 1000 ml distilled water. So we were used 5.11g salt (NaCl) and 1000 ml distilled water for this experiment. Seeds of ten advanced rice genotypes (Super basmati (check), PK-9533-9-6-1-1, Shaheen Basmati (check), PK-8892-4-1-3-1, PK-9194, RRI 3, PKBB 15-1, PKBB 15-6, PKPB-8 and PK 10683) were obtain from Rice research institute Kala shah kaku and were sterilized with 1g of Copper Hydroxide fungicides solution. The seeds were placed in petri dishes (9 cm diameter) lined with tissue paper and 11 ml of distilled water were added into petri dishes. There were twenty (20) seeds in per petri dish. Germination test were conducted under control condition of 14h light/ 10h dark cycle with 30°C temperature where 25°C minimum and 35°C maximum temperature and 90% relative humidity. A seed was considered germinated when radicle was 2 mm long. The germination percentage was determined counting the number of germinated seeds every day. The root and shoot length were measured on the 12th day. Statistical analysis was performed using Statistix version 8.1.

Drought Tolerant Experiment: In drought experiment, after initial studies related to germination percentage in PEG initiated drought and the whole plant behavior then subsequently only ten traditional genotypes were screened for their response to osmolyte production under physiological drought condition simulated by PEG 6000. PEG-6000 were used for simulation of physiological drought. Seeds of the experimental rice genotypes were also treat with 1g copper hydroxide fungicide solutions. The experiment was also conduct in a (CRD). Twenty healthy seeds each of the 10 different genotypes were presoaked in distilled water for 12 h. Ninety clean and sterilized petri plates were used for the experiment. The presoaked seeds were first air-dried to eliminate the surface water. They were then place over tissue paper in the petri. Deionized water were used for the control and applied similarly. Drought stress were simulate at five different concentrations namely 0, -2.0, -4.0, - 6 and -8 bars of water potential created by dissolving 15.3, 31.36, 37.6 and 46.24 grams of PEG 6000 respectively in 1000 ml of distilled water [16]. One liter distilled water which is used for experiment total 130.5 g PEG6000 were be used. A control (0.0 bar) were maintained using distilled water. So we used total 130.5 g PEG6000 and 5 liter distilled water for this experiment. A seed was considered germinated when radicle was 2 mm long. The germination percentage was determined counting the number of germinated seeds every day. The root and shoot length were measured on the 12th day. Statistical analysis was performed using Statistix version 8.1.

Fig. 1: Fungicide solution (Copper hydroxide)

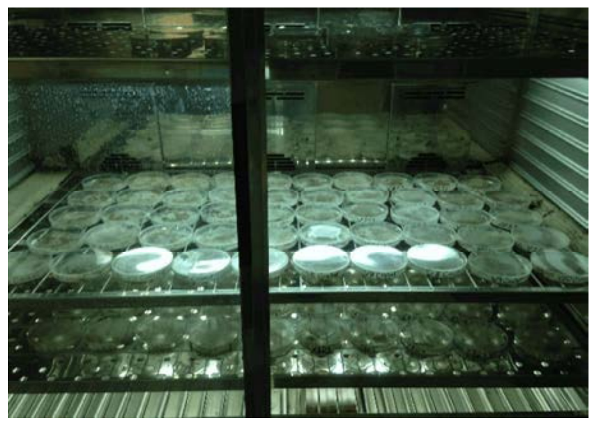


Fig. 2: Incubator containing petri dishes

In Fig 2.Ten genotypes of rice were incubated in petri dishes for germination. In Fig 3. These solutions were prepared to check salinity and drought, containing one control solution while others containing different levels of NaCl and PEG 6000 (Polyethylene glycol).

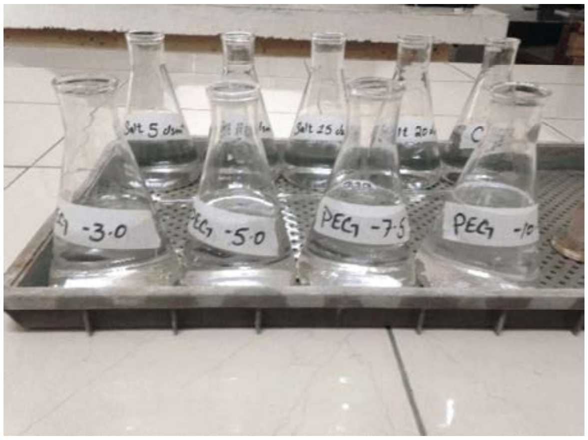


Fig. 3: Solutions

RESULTS

Germination and seedling growth of rice seeds was significantly influenced by salt and drought stress levels. Physiological parameters decreased with increasing water and salt stress (Table 1, 2, 3, 4). At -6 and -8 bar levels germination was low in all the varieties. Among the ten genotypes, shaheen basmati was very sensitive to drought and salt stress as compared to other genotypes as in this genotype germination was completely inhibited at the water stress (-6,-8) levels. Among the ten rice genotypes PKBB 15-1, RRI 3, PK-9433-9-6-1-1 and PK 10683 showed better performance against salt stress. In response to drought stress PKBB 15-1, PK-9433-9-6-1-1, RRI 3 and PK 10683 showed better performance. In the present investigation drought and salt affects seed germination, but the response intensity and adverse effect of stress depend on the variety. Among the genotypes, PKBB 15-1 showed the highest seed germination while shaheen basmati showed the lowest germination percentage.

DISCUSSION

Germination percentage of rice genotypes under stress was calculated. Best germination percentage was calculated in case of G7. Root length, shoot length and root/shoot ratio of these genotypes was measured under stress (salinity and drought) using meter rod. Mean comparison and all pairwise comparison using software statistix 8.1 were applied to all genotypes to check the tolerant genotype under stress conditions.

Table 1: Germination Percentage of rice genotypes

Genotypes	No. of plants	Germination (%) Control	S1 (4dS/m)	S2 (8dS/m)	S3 (12dS/m)	S4 (16dS/m)	D1 (-2.0)	D2 (-4.0)	D3 (-6.0)	D4 (-8.0)
G1	20	80	70	60	10	0	75	50	40	30
G2	20	100	90	80	65	55	85	70	65	55
G3	20	30	25	10	5	0	25	10	5	0
G4	20	90	70	30	23	5	70	40	20	5
G5	20	90	85	80	50	5	70	55	30	20
G6	20	100	95	80	65	60	85	75	45	30
G7	20	100	85	80	70	65	95	90	80	75
G8	20	95	90	85	45	10	80	20	15	5
G9	20	75	65	60	55	50	65	55	35	25
G10	20	95	90	65	55	50	85	75	45	20

In this table, G1, G2, G3,……,G10 represent rice genotypes. S1, S2, S3, S4 represent different levels of salinity. D1, D2, D3, D4 represent different levels of drought.

Table 2: Measured Root length (mm) of rice genotypes

	Genotypes	No. of Plants	Control	S1 (4dS/m)	S2 (8dS/m)	S3 (12dS/m)	S4 (16dS/m)	D1 (-2.0)	D2 (-4.0)	D3 (-6.0)	D4 (-8.0)
Root Length	G1	10	9.5	9.0	8.5	6.4	3.9	7.9	7.2	6.5	4.5
	G2	10	9.6	6.9	6.5	5.1	3.9	6.5	5.3	3.8	3.1
	G3	10	5.6	4.0	3.2	0.0	0.0	3.9	3.2	2.6	0.0
	G4	10	7.7	7.0	5.7	5.3	4.6	5.4	4.3	3.1	2.3
	G5	10	8.2	5.2	4.9	3.9	2.4	5.6	5.2	5.0	2.6
	G6	10	8.5	6.5	3.8	3.1	2.9	4.8	4.2	3.3	2.9
	G7	10	9.5	8.5	6.8	4.8	2.4	6.9	5.6	5.1	3.9
	G8	10	6.4	5.7	3.4	2.3	2.0	5.2	3.6	2.5	2.1
	G9	10	6.5	5.2	4.5	4.0	2.2	5.1	3.8	2.2	1.9
	G10	10	5.4	4.3	3.5	3.3	2.9	4.8	4.6	3.9	3.0

In this table, G1, G2, G3,……,G10 represent rice genotypes. S1, S2, S3, S4 represent different levels of salinity. D1, D2, D3, D4 represent different levels of drought.

Table 3: Measured Shoot length (mm) of rice genotypes

	Genotypes	No. of Plants	Control	S1 (4dS/m)	S2 (8dS/m)	S3 (12dS/m)	S4 (16dS/m)	D1 (-2.0)	D2 (-4.0)	D3 (-6.0)	D4 (-8.0)
Shoot length	G1	10	30.7	24.1	19.4	6.6	2.3	17.8	15.2	14.2	13.1
	G2	10	25.9	19.9	17.9	3.3	2.6	19.3	15.8	11.7	7.7
	G3	10	18.2	15.8	11.5	0.0	0.0	12.2	7.0	6.3	0.0
	G4	10	32.2	19.6	15.4	11.2	9.1	19.1	15.2	14.2	7.3
	G5	10	33.4	19.3	17.5	10.1	7.0	19.9	12.4	11.9	10.7
	G6	10	30.0	20.7	9.6	6.1	6.0	15.1	13.6	7.2	4.6
	G7	10	39.4	35.2	24.2	20.8	6.3	30.0	15.3	12.2	6.9
	G8	10	30.5	20.2	14.3	10.6	8.7	19.5	8.5	7.3	4.9
	G9	10	40.4	16.4	12.5	7.6	4.4	14.4	7.6	6.9	5.1
	G10	10	37.8	18.2	15.5	13.1	3.5	18.2	12.8	8.2	5.6

In this table, G1, G2, G3,……,G10 represent rice genotypes. S1, S2, S3, S4 represent different levels of salinity. D1, D2, D3, D4 represent different levels of drought.

Table 4: Root/shoot ratio of rice genotypes:

		Control	S1 (4dS/m)	S2 (8dS/m)	S3 (12dS/m)	S4 (16dS/m)	D1 (-2.0)	D2 (-4.0)	D3 (-6.0)	D4 (-8.0)
Root/Shoot ratio	G1	0.31	0.37	0.44	0.41	0.38	0.44	0.47	0.46	0.34
	G2	0.37	0.35	0.36	0.39	0.37	0.34	0.34	0.32	0.40
	G3	0.31	0.25	0.28	0.00	0.00	0.32	0.46	0.41	0.00
	G4	0.24	0.36	0.37	0.47	0.48	0.28	0.28	0.22	0.31
	G5	0.25	0.27	0.28	0.39	0.34	0.28	0.42	0.42	0.24
	G6	0.28	0.31	0.40	0.50	0.49	0.32	0.31	0.46	0.38
	G7	0.24	0.24	0.28	0.23	0.38	0.23	0.37	0.42	0.45
	G8	0.21	0.28	0.24	0.21	0.23	0.27	0.42	0.34	0.43
	G9	0.16	0.32	0.36	0.49	0.49	0.35	0.50	0.32	0.37
	G10	0.14	0.24	0.23	0.25	0.32	0.26	0.36	0.48	0.47

In this table, G1, G2, G3,……,G10 represent rice genotypes. S1, S2, S3, S4 represent different levels of salinity. D1, D2, D3, D4 represent different levels of drought.

Table 5: All-pairwise comparison test of root for rice genotypes

Genotypes	Mean	Homogeneous Groups
G1	7.2056	A
G7	6.0556	AB
G2	5.6167	ABC
G6	5.4722	BC
G4	5.0556	BCD
G5	4.7778	BCD
G9	4.0611	CDE
G10	3.9611	CDE
G8	3.4333	DE
G3	2.9222	E

Means of these ten genotypes were calculated using software statistix 8.1 and genotypes in this table are arranged such that G1 has maximum mean value and G3 has lowest mean value.

Table 6: All-pairwise comparison test of root/shoot ratio for genotypes

Genotypes	Mean	Homogeneous Groups
G1	0.6350	A
G2	0.6167	A
G6	0.4778	B
G9	0.3944	BC
G10	0.3667	BCD
G4	0.3383	CD
G5	0.3300	CD
G7	0.361	CD
G3	0.300	CD
G8	0.2656	D

Means of these ten genotypes were calculated using software statistix 8.1 and genotypes in this table are arranged such that G1 has maximum mean value and G8 has lowest mean value regarding root/shoot ratio.

Table 7: All-pairwise comparison test of shoot for genotypes

Genotypes	Mean	Homogeneous group
G7	22.011	A
G4	16.078	B
G1	16.056	B
G5	15.800	B
G10	14.767	BC
G2	13.783	CD
G8	13.606	CD
G9	12.811	D
G6	12.539	D
G3	7.383	E

Means of these ten genotypes were calculated using software statistix 8.1 and genotypes in this table are arranged such that G7 has maximum mean value and G3 has lowest mean value.

Table 8: Relative Values of Root length, Shoot length and Root/shoot Ratio

	Genotypes	S1 (4 dS/m)	S2 (8dS/m)	S3 (12dS/m)	S4 (16dS/m)	D1 (-2.0)	D2 (-4.0)	D3 (-6.0)	D4 (-8.0)
Relative Value of Root length	G1	1.23	1.25	0.87	0.53	1.08	1.23	1.08	0.62
	G2	0.72	0.68	0.53	0.41	0.68	0.55	0.40	0.32
	G3	0.71	0.71	0.00	0.00	0.70	0.75	0.82	0.00
	G4	1.07	0.79	0.73	0.64	0.75	0.60	0.43	0.31
	G5	0.63	0.60	0.48	0.29	0.68	0.63	0.61	0.32
	G6	1.99	0.51	0.41	0.45	0.64	0.75	0.44	0.39
	G7	1.00	0.72	0.51	0.25	0.73	0.59	0.54	0.41
	G8	0.89	0.53	0.35	0.31	0.81	0.21	0.39	0.33
	G9	1.11	1.05	0.73	0.39	0.93	0.69	0.40	0.35
	G10	0.80	0.65	0.61	0.53	0.89	0.85	0.72	0.56
Relative value of Shoot Length	G1	0.79	0.63	0.21	0.07	0.58	0.37	0.55	0.50
	G2	0.77	0.69	0.13	0.10	0.75	0.61	0.45	0.30
	G3	1.10	0.80	0.00	0.00	0.85	0.49	0.44	0.00
	G4	0.61	0.48	0.35	0.28	0.64	0.47	0.44	0.23
	G5	0.58	0.52	0.30	0.21	0.60	0.37	0.36	0.32
	G6	0.69	0.32	0.20	0.20	0.50	0.45	0.24	0.15
	G7	1.09	0.61	0.53	0.16	0.76	0.39	0.31	0.18
	G8	0.66	0.47	0.35	0.29	0.64	0.21	0.24	0.16
	G9	0.41	0.31	0.19	0.11	0.36	0.19	0.17	0.13
	G10	0.48	0.41	0.35	0.09	0.48	0.34	0.22	0.15
Relative value of Root/shoot Ratio	G1	1.58	1.96	4.04	7.06	1.87	3.31	1.95	1.27
	G2	0.95	0.97	4.09	4.09	0.91	0.90	0.88	1.06
	G3	0.63	0.90	0.00	0.00	0.84	1.50	1.81	0.00
	G4	1.76	1.66	2.10	2.27	1.20	1.27	0.98	1.39
	G5	1.10	1.15	1.61	1.49	1.15	1.75	1.87	1.00
	G6	3.03	1.58	2.07	2.29	1.29	1.62	1.84	2.54
	G7	0.91	1.16	0.95	1.58	0.95	1.52	1.71	2.34
	G8	1.34	1.12	1.02	1.10	1.27	0.87	1.64	2.04
	G9	2.70	3.39	3.84	3.56	2.59	3.73	2.34	2.75
	G10	1.66	1.58	1.78	5.75	1.86	2.53	3.35	3.77

In this table, G1, G2, G3,……,G10 represent rice genotypes. S1, S2, S3, S4 represent different levels of salinity. D1, D2, D3, D4 represent different levels of drought.

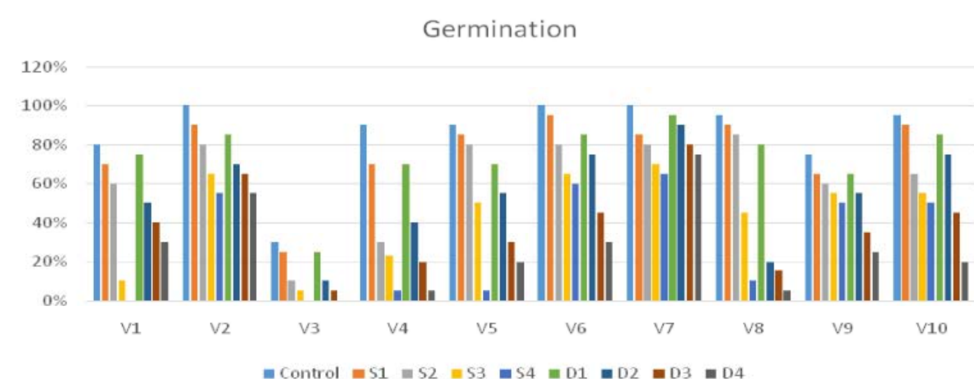


Fig. 4: Graphical representation of germination percentage of rice genotypes under NaCl and PEG6000

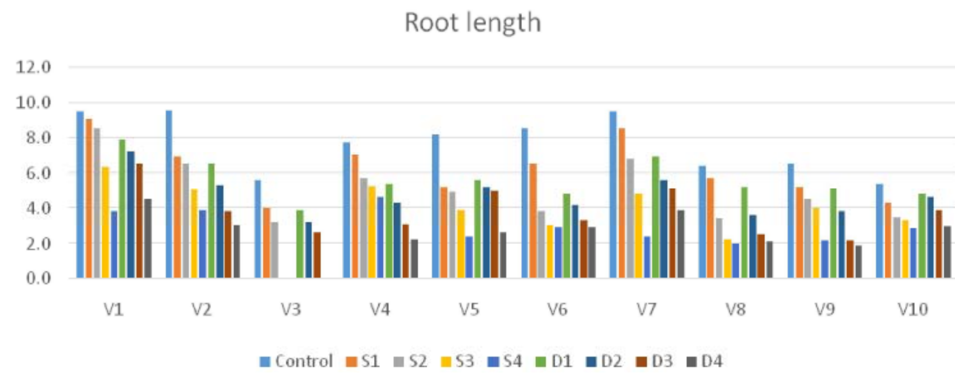


Fig. 5: Graphical representation of root length (mm) of rice genotypes under NaCl and PEG6000

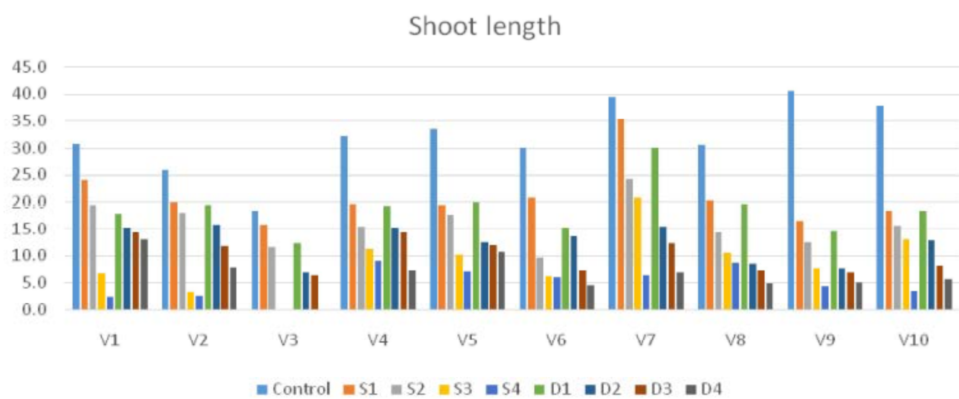


Fig. 6: Graphical representation of shoot length (mm) of rice genotypes under NaCl andPEG6000

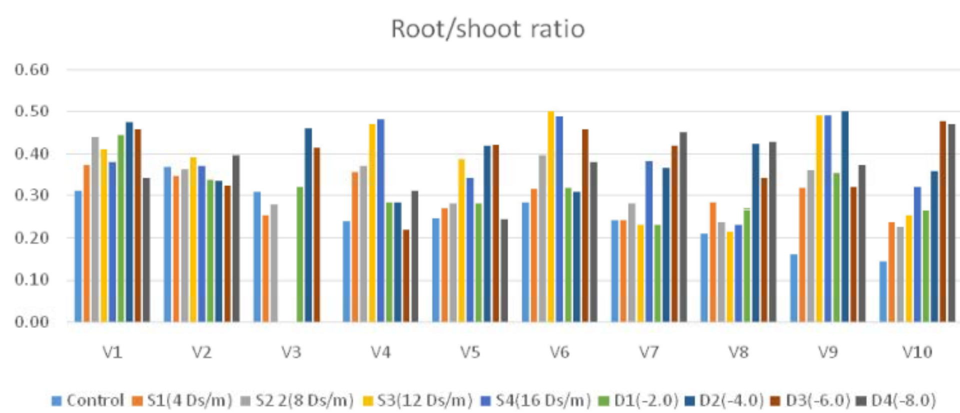


Fig. 7: Graphical representation of root/shoot ratio of rice varieties under NaCl and PEG6000

CONCLUSION

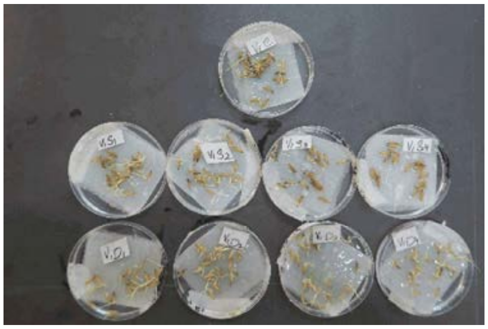
Rice genotypes were very sensitive to drought and salinity stress. With increasing levels of water and salt stress, seed germination and early seedling growth were adversely affected in all rice genotypes. However, for the physiological parameters like germination percentage, root length, shoot length and root/shoot ratio varietal differences were recorded and the difference was maximum towards higher stress levels.

ACKNOWLEDGMENT

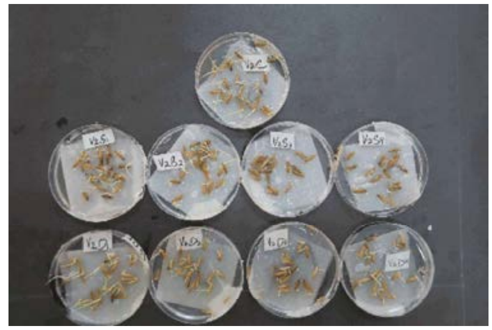
We would like to thanks Dr. Muhammad Sabar (Director, Rice Research Institute, Kala Sha Kaku) for providing necessary lab facilities to conduct the research are gratefully acknowledged.

Genotypes:

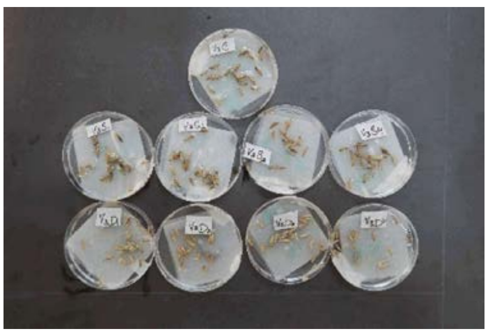
Super Basmati (Check)



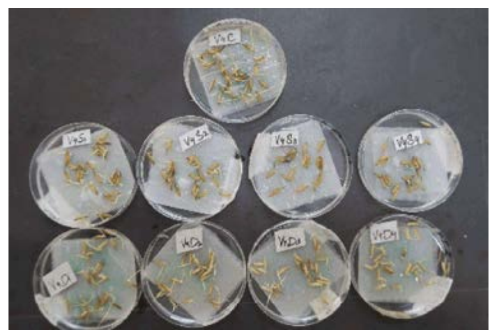
PK-9433-9-6-1-1



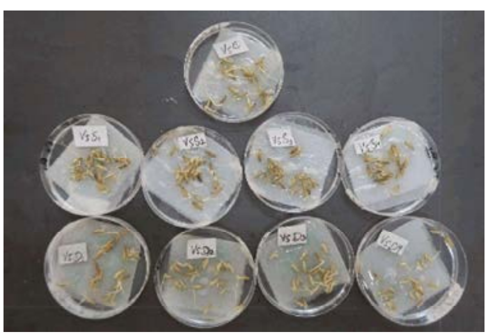
Shaheen Basmati (check)



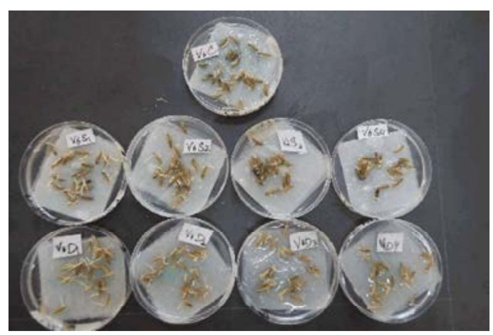
PK-8892-4-1-3-1



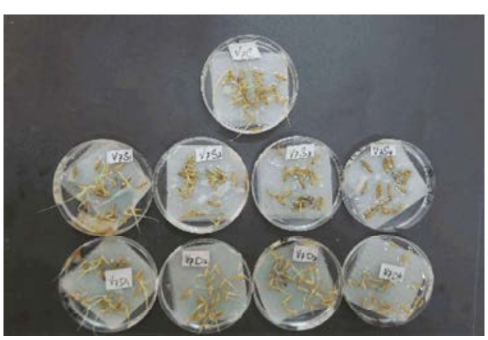
PK-9194



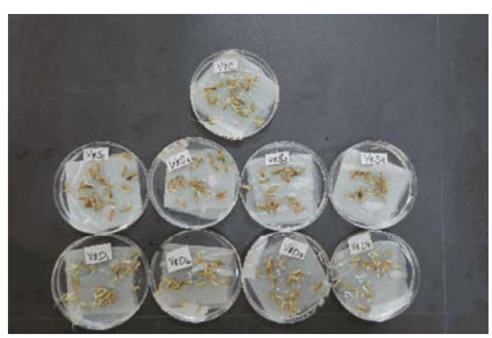
RRI 3



PKBB 15-1

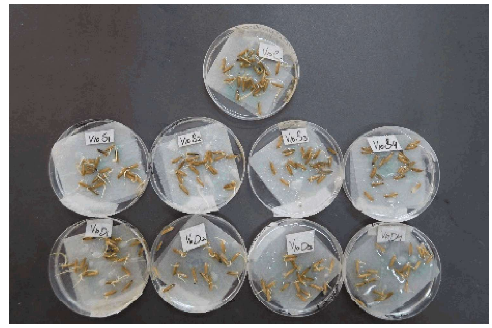


PKBB 15-6



PKPB-8

PK 10683



REFERENCES

1. Singh, A.K. and L. Singh, 2007. Role of thermal time in rice phenology. Envi. and Ecol, (1): 46-49.
2. Bartels, D. and R. Sunkar, 2005. Drought and salt tolerance in plants. Critical Reviews in Plant Science, 24: 23-58.
3. Chutia, J. and S. Borah, 2012. Water stress effects on leaf growth and chlorophyll content but not the grain yield in traditional rice (*Oryza sativa* L.) genotypes of Assam, India. II. Protein and proline status in eedlingsunder PEG induced water stress. American Journal of Plant Sciences, 3(7): 971-80.
4. Mahajan, S. and N. Tuteja, 2005. Cold, salinity and drought stresses: an overview. Archives of Biochemistry and Biophysics 444(2): 139-58.
5. Pandey, S., H. Bhandari, R. Sharan, D. Naik, S.K. Taunk and A. Sastri, 2005. Economic Costs of Drought and Rainfed Rice Farmers' Coping Mechanisms in Eastern India. Final Project Report. International Rice Research Institute, Los Banos, Philippines.
6. Cui, H., Y. Takeoka and T. Wada, 1995. Effect of sodium chloride on the panicle and spikelet morphogenesis in rice. Jpn. J. Crop Sci., 64: 593-600.
7. Kumar, A., J. Bernier, S.B. Verullkar, H.R. Lafittee and G.N. Atlin, 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 Crop Res., 107: 221-231.
8. Slafer, G.A., J.L. Araus, C. Roya and D.L.F. Moral, 2005. Promising eco-physiological traits for genetic improvement of cereals in Mediterranean environments. Ann. App. Biol., 146: 61-70.
9. Nakata, N.K., Y. Inukai, L.J. Wadw, D.L.C. Siopongco and A.Yamauchi, 2011. Root Development, Water Uptake and Shoot Dry Matter Production under Water Deficit Conditions in Two CSSLs of Rice. J. Plant. Sci., 14(4): 307-317.
10. Francois, L.E. and E.V. Maas,1999. Crop response and management of salt affected soils. In: Hand Book of Plant and Crop Stress. (Eds.): M. Pessarakli. Marcel Dekker, Inc., New York, pp: 169-201.
11. Aslam, M., R.H. Qureshi and N. Ahmed, 1993. A rapid screening technique for salt tolerance in rice (*Oryza sativa* L.). Plant and Soil, 150: 99-107.
12. Mass, E.V. and G.J. Hoffman, 1977. Cropsalttolerance - Currentassessment. J. Irrig., Drain. Div., ASCE, 103(IR2): 115-134.
13. Flowers, T.J. and A.R. Yeo, 1981. Variability in the resistance of sodium chloride salinity within rice (*Oryza sativa* L.) varieties. New Phytol., 88: 363-373.
14. Kumar, A., J. Bernier, S.B. Verullkar, H.R. Lafittee and G.N. Atlin, 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 Crop Res., 107: 221-231.
15. Slafer, G.A., J.L. Araus, C. Roya and D.L.F. Moral, 2005. Promising eco-physiological traits for genetic improvement of cereals in Mediterranean environments. Ann. App. Biol, 146: 61-70.
16. Hadas, A., 1976. Water uptake and germination of leguminous seeds under changing external water potential in osmoticum solution,? J. Exp. Bot., 27: 480-489.