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Effect of water deficit and salinity stress on morphological traits in early duration rice (*Oryza sativa* L.) genotypes

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Abstract

The drought and salinity affects plant growth and productivity in rice and considered as severe threat to sustainable rice production across the world. Hence, this experiment was aimed at assessment of extant tolerance against both stresses and genetic diversity amongst 24 early duration rice lines for further breeding invigoration. The results revealed substantial reduction in Plant height, number ear bearing tillers, leaf dry weight, root dry weight and chlorophyll content when plants were exposed to reduced moisture and salinity. The effects of drought and salinity are generally apparent as a reduction in growth and photosynthesis. From the current research, it was observed that both stresses affected plant growth stages especially in panicle initiation stage.

Keywords: drought, salinity, genetic diversity, morphology, *Oryza sativa*

Introduction

Impeding climatic scenario and depleting soil resources threatens rice (*Oryza sativa* L.) crop sustainability throughout the world. Water deficit and salinity are the two most damaging factors limiting rice production in rainfed ecosystem (Sekar and Pal 2012) [20]. Both of the stresses causes diminution in water uptake ability of plants which affect the sustainability *per se* productivity (Munns 2002, Hazmana *et al*. 2016) [8, 15]. Rice, a staple food crop, directly linked to the livelihood and economy of most of the Asian states (Rout *et al*., 2020) [18], is very prone to several environmental challenges like drought, salinity and heavy metal (Khush GS, 2005) [12]. In rainfed rice ecosystem, owing to uneven rainfall distribution and frequency, drought, salinity, chilling, freezing and high temperature stresses are general, creates adversity to sustain rice crop and hampers their production and productivity, significantly. Drought (osmotic stress) is found to be most deleterious for rice crop as all growth stages are prone to this stress but reproductive stage is more crucial, susceptible genotypes suffers substantially, (Suriyan *et al*. 2010, Pirdashti *et al*. 2004) [16, 21]. Drought or osmotic stress during the plant developmental stage delayed growth, narrowed leaf area and partitioning (Islam *et al*. 2010) [9, 10, 17, 24].

These stresses cause substantial changes in root and shoot structure thus disturb plant growth (Chaves *et al*. 2003) [2, 3]. Both the stresses cause reduced stomatal conductance which adversely affects the photosynthesis most important metabolic process led plant growth and even plant death at extreme (Yusuf *et al*. 2010, Krasensky *et al*. 2012, Chen *et al*. 2013) [4, 13, 23]. Canopy's stomatal closure under drought causes reduction in transpiration and degradation in chlorophyll content (Chaves *et al*. 2004, Cattivelli *et al*. 2008, Tuna *et al*. 2010) [1-3, 22]. Whereas, salinity induces salt movement in root which is associated with transpiration flux, thus, unregulated transpiration causes ion toxicity in areal part of the plant. Increased ionic concentration in plants affects ion homeostasis which interferes with internal solute balance. Under salinity, increased Na^+ accumulation in plant inhibits the K^+ which disrupts the K^+/Na^+ ratio of cells thus cell injury (Ma *et al*. 2014) [14, 23, 24].

The susceptibility of rice to water deficit and salinity are varies, it depends on extent of stress, stress factors, genotypes and species and developmental stages (Ashraf *et al*. 2009) [22]. Nonetheless, many research works towards various aspects of drought and salinity has been carried out across the world (Demirevska *et al*. 2010, Zubayer *et al*. 2007, Ishlam *et al*. 2001) [5, 24] but to make rice crop more sustainable and substantial under fragile climatic and depleting soil condition, this research study 'Effect of Water Deficit and Salinity Stress on morphological traits in early duration rice (*Oryza sativa* L.) genotypes' was taken up to investigate the crucial stage based on morphological traits and their suitability for further rice breeding invigoration against abiotic stresses.

Experimental plan

This research was laid out with 24 rice genotypes *viz*., Taramon, Nedu, IR91167-31-3-1-33, IR91167-99-1-1-1-3, IR91171-66-3-2-1-3, IR92953-49-1-3, NUD3, NDRK5088, NUD2, NDR359, CSR30, IR 29, IR64, CSR13, IR28, Sarjoo52, Ayaar, Amker, FL478, NDRK2008, Nageena 22, NDR 1, Baranideep and Sushk Samrat at NDUA&T, Kumarganj, Ayodhya, Faizabad. The experiment was grown in a Complete Randomized Design (CRD) with 03 replications. Drought was screened at control (100% FC) and drought (40% FC) were imposed on 24 rice genotypes at two growth stages, maximum tillering and panicle initiation stages; whereas, salinity was screened by following IRRI standard protocol (Gregorio *et al*., 1997). Water stress application was started at 42 and 50 days after transplanting when plants were attained at maximum tillering and PI stage. Data on plant height (cm), flag leaf length (cm), ear bearing tillers, per hill root dry weight, shoot dry weight (g) and Chlorophyll content at all two stages for both the stresses. The collected data were analyzed by Duncan's Multiple Range Test (DMRT) adjudged the treatment means (Gomez *et al*. 1984).

The genetic diversity analysis was completed with 26 polymorphic SSR markers in 24 rice genotypes. The genomic DNA from the leaf sample of each plant (20-22 days old seedling) was extracted and purified using CTAB protocol (Doyle and Doyle, 1987) [6]. The genetic diversity was analyzed using Graphical Genotyper (GGT2.0) software.

Results

Evaluation of rice lines under drought and salinity stresses

The frequent occurring of drought and salinity during growing period causes drastic yield reduction in rice. In this study, altogether 24 early duration rice genotypes were evaluated under imposed drought and salinity AT and PI growth stage showed significant differences at 5% level of probability. The PI stage showed the highest plant height under both stresses (drought and salinity) among two stages imposed. The rice line NDR1 was recorded highest height (110.7 cm) under drought and NDR 359 with 106.9cm under salinity (Table 2). Similarly, the maximum flag leaf length was observed at PI stage under both stresses where, IR91167-31-3-1-33 recorded longest flag leaf (36.3) under drought and Amker (38.7 cm) under salinity stress. The ear bearing tiller which is mean yield determinant in rice was recorded maximum at PI stage under both stresses, where IR28 recorded maximum number of ears bearing tillers under drought stress and NUD3 was found with maximum tillering under salinity stress. Same trend was also recorded for root and shoot dry weight as maximum values were recorded at PI stage under both conditions. Rice line, Nagina 22 was recorded highest root weight under drought and NUD2 under salinity. Shoot weight on the other hand one of the important morphological marker depicting yielding ability in rice was recorded highest in Sarjoo 52 under drought and in NUD3 under salinity. Besides, chlorophyll content which is basis for rice sustainability was recorded highest at PI stage under both stresses, NUD3 is found to have maximum chlorophyll content under drought and NUD2 has maximum under salinity condition. Result of this study revealed that all genotypes exerts reduced expression for all studied traits under both stresses. Water deficit and salinity significantly reduced root dry weight in all the stages and genotypes.

Genetic diversity amongst rice genotypes

Genetic diversity amongst 24 early duration rice lines were assessed utilizing 82 STMS markers of rice genome. Of those, 26 are found informative, amplified a total of 75 alleliec forms with a range of 2 to 5 allele per markers (average of 2.88) (Table 1). The PIC (polymorphism information content) value was recorded to range from 0.231 to 0.507 for the markers RM12233and RM20810, respectively. The RM24412 found to have highest resolving power (RP) i.e. 1.996, whereas, marker RM 11258 sowed highest marker index (MI) (Table 1).

The genetic coefficients (Jaccard's coefficient) was analysed using 26 markers data, results revealed variable range of genetic similarity. Owing to diversified morphology and pedigree of rice genotypes subjected under the study, Jaccard's similarity coefficient was recorded with a range of 0.02 to 0.89 (Figure-1). Dendrogram showed a clear-cut distinction amongst 24 genotypes. All 26 markers could distinguish 24 rice genotypes into two major groups. The resultant dendrogram grouped all genotypes under two major groups. The group-I contained only one genotype i.e. Nedu, whereas, Group II is found with maximum number of genotypes (total 23), Taramon, IR91167-31-3-1-33, IR91167-99-1-1-1-3, IR91171-66-3-2-1-3, IR92953-49-1-3, NUD3, NDRK5088, NUD2, NDR359, CSR30, IR 29, IR64, CSR13, IR28, Sarjoo52, Ayaar, Amker, FL478, NDRK2008, Nageena 22, NDR 1, Baranideep, Sushk Samrat. (With 0.65-0.96 Jaccard's similarity coefficient). The group-II has major diversity, again categorizes into subgroups (02) where Sub-group-IIA contain 06 genotypes i.e. CSR13, Sarjoo52, Ayaar, Baranideep, Sushk Samrat and IR 28 (0.96 similarity coefficient). Whereas, sub-group-IIB distributed with 17 genotypes where IR29, NUD2, Amker, FL 478, NDR 359, IR 64 and NDR 1 were more genetically similar. Based on the result Nendu has more genetic distance with other genotypes. Thus, genetically diverse lines can be utilised for heterosis exploitation whereas closely related lines are suitable for MAS based trait improvement strategies for enhancement of sustainability of rice under abiotic stresses.

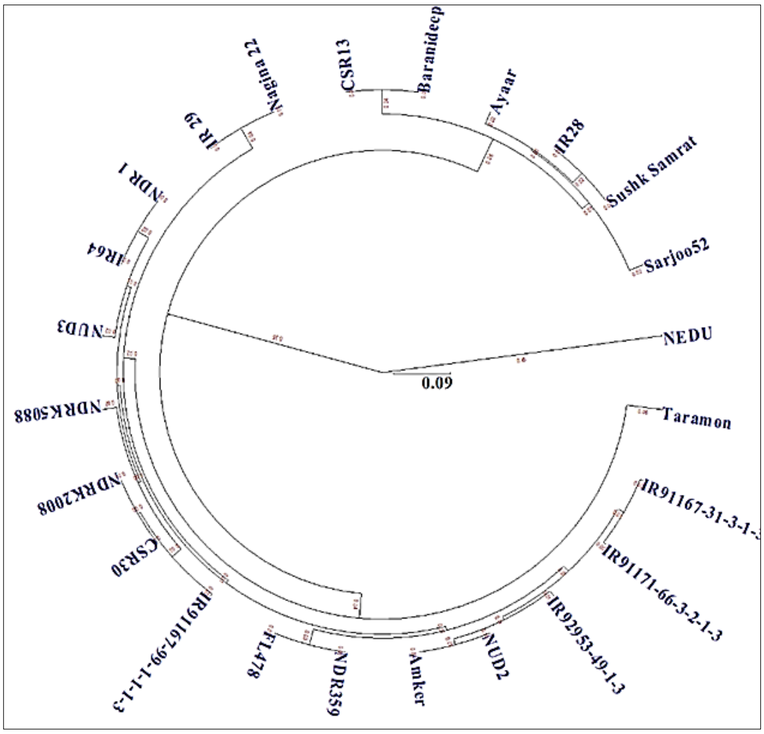

Fig 1: UPGMA dendrogram depicting extant of genetic diversity among 24 rice genotypes

Discussion

The effects of drought and salinity are usually caused decreases in growth and photosynthesis. The results obtained from the present work clearly demonstrated that the rice genotypes displayed distinct variation in drought and salinity stresses during vegetative growth stage. In this study, PI stage found to be crucial affecting various morphological attributes. This reduction in growth might be due to low osmotic potential as well as a decrease in wall extensibility and cellular expansion (Kamoshita *et al*. 2004) [11]. Reduction of fresh and dry biomass production was observed in our study (Table 1). A common adverse effect of water stress on crop plant is reduction in fresh and dry biomass production in different growth stages was also observed (Khush GS, 2005) [12]. Water deficit and salinity stress at maximum tillering and panicle initiation stages decreased shoot dry weight, plant height, tiller number, and root dry weight. Decrease shoot dry matter under lower soil moisture might be due to reduction of leaf area and photosynthesis (Flexas *et al*. 2006) [7]. Kumar and Sharma (2009) reported that drought decreased leaf water status, rates of photosynthesis and altered dry matter partitioning in different plant parts. Response of different rice cultivars towards drought stress particularly at maximum tillering and panicle initiation stages varied, might be due to genetic variation. Drought stress at maximum tillering stage due to disturbed physiological, biochemical processes and adverse effect on enzymatic activities. Water stress directly affects rates of photosynthesis due to the decreased CO_2 availability resulted from stomatal closure (Rahman *et al*. 2002) [17]. The occurrence of soil moisture stress affects many of the physiological processes such as photosynthesis and transpiration resulting in reduced growth (Sadeghi *et al*. 2011) [19].

Table 1: Details of molecular markers utilized for genetic diversity analysis of 24 rice genotypes

Markers	Chrom.	Motif	Number of repeat	Size range (bp)	Allele	PIC	RP	MI
RM7075	1	ACAT	13	370	4	0.294	1.534	1.137
RM12233	1	AGG	8	85	3	0.231	0.765	0.664
RM23	1	(GA)15	-	140	2	0.353	0.919	0.687
RM 11258	1	AAT	9	165	5	0.289	1.842	1.397
RM 13902	2	AGC	10	195	2	0.270	0.611	0.522
RM 13781	2	AG	18	190	5	0.251	1.534	1.208
RM 15981	3	AG	46	260	3	0.412	1.842	1.208
RM 14811	3	AG	19	330	3	0.381	1.688	1.113
RM17034	4	AG	15	270	4	0.264	1.381	1.019
RM18004	5	AAG	15	190	3	0.373	1.534	1.090
RM 18336	5	AT	34	255	2	0.424	1.227	0.829
RM 20522	6	AG	23	125	3	0.397	1.688	1.161
RM 19456	6	AAT	20	185	3	0.381	1.688	1.113
RM 21395	7	AG	13	90	3	0.428	1.842	1.255
RM 21427	7	AAG	8	190	3	0.412	1.842	1.208
RM 20810	7	AT	34	200	2	0.507	1.842	0.995
RM23107	8	AG	14	100	2	0.270	0.611	0.522
RM22230	8	AG	34	290	3	0.318	1.227	0.924
RM 22914	8	AG	29	0	3	0.333	1.381	0.971
RM23528	8	AGG	8	105	3	0.326	1.227	0.948

RM24412	9	AG	11	290	3	0.436	1.996	1.279
RM2456 0	9	GCG	7	420	2	0.495	1.688	0.971
RM24878	10	AAT	19	445	2	0.436	1.227	0.853
RM224	11	AAG	7	165	3	0.404	1.842	1.184
RM27235	11	AC	12	265	2	0.270	0.611	0.522
RM27644	12	AG	11	280	2	0.436	1.381	0.853
					75(2.88)	0.34	1.41	0.97

Table 2: Agro-morphological traits of 24 rice lines under imposed drought (40% FC) and salinity stresses

Treatments	PH (cm)	Flag leaf length (cm)	EBT	Root dry wt (g)	Shoot dry wt (g)	Chlorophyll content	PH (cm)	Flag leaf length (cm)	EBT	Root dry wt (g)	Shoot dry wt (g)	Chlorophyll content
Drought condition (40% FC)							**Salinity condition (Gregorio *et al*., 1997)**					
Maximum tillering	110.2 a	35.00 a	28.75 b	8.40 b	9.64 b	44.6a	103.6a	36.2a	28.2a	21.5b	14.6b	46.7a
Panicle initiation	110.7 a	36.3a	31.64 a	20.22 a	12.47 a	45.15b	105.2a	37.5b	28.9a	21.7b	15.2c	47.8b
Genotype												
Taramon	104.5 b	18.17 c-e	28.56 ab	11.26 a	9.35ad	43.93 ab	88.7b	28.6c	14.50 de	4.62 gh	4.53 ik	43.93 ab
NEDU	106.3 a	25.33 b	26.17 bc	10.64 a	8.59bc	45.20 a	82.8dc	19.5ab	13.50 df	8.11 eg	11.38 bd	45.20 a
IR91167-31-3-1-33	103.8 ab	35.00 a	29.67 a	11.67 a	9.35eg	42.58 ad	102.4ab	37.5a	20.83 c	21.06 ac	12.15 ac	42.58 ad
IR91167-99-1-1-1-3	103.9 ab	22.50 bc	28.67 ab	12.11 a	9.11dc	41.40 ad	88.6eg	29.5a	12.67 df	5.44 fh	6.01 hj	41.40 ad
IR91171-66-3-2-1-3	105.7 a	31.83 a	25.50 c	12.32 a	9.27a	44.15 ab	106.3ik	35.8bc	14.00 df	7.91 eg	7.70 gh	44.15 ab
IR92953-49-1-3	89.61 c	34.67 a	18.89 d	10.71 a	8.49i	39.33 cd	101.5ab	28.5ac	21.33 c	18.57 cd	12.07 ac	39.33 cd
NUD3	109.6 a	30.33 bd	27.00 de	21.62 gh	14.53 ik	46.42 cd	100.5a	35.5b	32.67 df	23.19 eg	16.36 hi	42.42 cd
NDRK5088	98.4ac	31.50 a	34.00 a	8.11 a	11.38 bd	40.92 ad	86.7a	36.3b	15.33 de	7.45 eh	9.57 ef	40.92 ad
NUD2	106.2a	36.17 a	34.67 a	21.06 a	12.15 ac	42.42 d	104.6bc	34.6d	28.83 bc	29.35 bd	12.13 ac	48.42 d
NDR359	110.6ab	13.17 e	28.17 ce	20.44 fh	12.01 hj	42.27 ad	106.9bc	28.6ab	29.83 f	25.45 fh	14.56 jk	42.27 ad
CSR30	101.7a	33.17 a	25.33 b	7.91 eg	7.70 gh	43.60 abc	81.7eg	18.2c	15.33 de	8.59 ef	9.81 df	43.60 abc
IR 29	98.4ab	19.5ab	35.00 a	18.57 cd	12.07 ac	41.72 ad	87.2a	28.5c	26.50 ab	22.29 ab	12.95 ab	41.72 ad
IR64	99.33 ab	15.8c	22.50 bc	8.19 eg	6.36 hi	41.73 ad	103.2cd	23.7ac	13.83 df	4.19 h	3.65 k	41.73 ad
CSR13	88.17 cd	28.5e	31.83 a	7.45 eh	9.57 ef	43.28 abc	82.5a	14.8ab	16.50 d	9.52 e	10.71 ce	43.28 abc
IR28	104.50 a-d	15.5dc	34.67 a	19.35bd	12.13 ac	45.27 bcd	105.6ab	29.2b	32.50 a	23.35 a	13.45 a	40.27 bcd
Sarjoo52	99.17 ab	36.3eg	30.33 bd	22.45 fh	14.56 jk	41.95 ad	100.0a	33.9cd	31.50 ef	26.59 eg	14.74 ik	41.95 ad
Ayaar	98.33 ab	14.6ac	31.50 a	8.59 ef	9.81 df	42.15 ad	100.2bc	16.5bc	11.33 ef	8.83 ef	8.65 fg	42.15 ad
Amker	102.17 a	18.6dc	34.17 a	22.29 ab	12.95 ab	43.93 ab	65cd	38.7ab	23.00 bc	16.72 d	12.08 ac	43.93 ab
FL478	98.67 cd	18.2b	13.17 e	4.19 h	3.65 k	45.20 a	104.6a	15.7a	14.50 de	4.62 gh	4.53 ik	45.20 a
NDRK2008	92.17 bd	18.5ab	33.17 a	9.52 e	10.71 ce	42.58 ad	85ab	33.9a	13.50 df	8.11 eg	11.38 bd	42.58 ad
Nagina 22	110.17 ab	33.7ac	30.17 a	23.35 a	13.45 a	41.40 ad	99.5dc	36.4a	30.83 c	21.06 ac	12.15 ac	41.40 ad
NDR 1	110.7 d	34.8b	31.83 cd	22.59 eg	4.74 ik	44.15 ab	84dc	26.5b	12.67 c	5.44 fh	6.01 hj	44.15 ab
Baranideep	88.67 cd	29.2b	16.67 de	8.83 ef	8.65 fg	39.33 cd	98.6dc	35.6b	14.00 d	7.91 eg	7.70 gh	39.33 cd
Sushk Samrat	102.42a	21.33 c	21.17 b-d	16.72 d	12.08 ac	39.42 cd	90.7b	17.5b	21.33 c	18.57 cd	12.07 ac	39.42 cd

Values under each factor having common letter(s) in a column do not differ significantly at $P \leq 0.05$ as per DMRT

Conclusion

Among all studied rice lines, genotypes like NUD1, NUD2, IR 28, NDR 359, Sarjoo 52, Nagina-22, Nendu were found to have substantial adaptive flexibility under both stresses might be due to balanced physio-chemical indexes. This finding suggests that among the stages, panicle initiation stage showed the highest interaction effect among the growth stages. So, this stage is crucial because significant reduction was observed in morpho-physiology of different parts due to drought and salinity stresses in this stage hence; at this growth stage needs intensive research intervention to make this entity be more sustainable under impeding climatic scenario.

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