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Effect of Salinity on Emergence and Early Growth Stages of Aromatic and Non-Aromatic Rice (*Oryza sativa* L.) Genotypes

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Abstract. Salinity hampers the production of many field crops in the region including rice (*Oryza sativa* L.), while commonly classified as salt sensitive within the same species, the level of sensitivity varies between genotypes. This study investigated the salinity tolerance of 28 rice genotypes, including 9 aromatics and 19 non-aromatics. Sixty seeds of each genotype were initially sown in trays (24×18 inches) during the 1st week of June, by of using four salt treatments (0, 40, 80 and 120 mM NaCl+$CaCl_2$ @ 20:1). The experiment was laid down in a completely randomized design with four replicates in laboratory conditions, at Shah Abdul Latif University Khairpur, Sindh, for the period of twenty-five days. A significant reduction in agro-morphological parameters was observed against all salinity levels. Based on reduction in dry matter yield, all rice genotypes were found tolerant at 40 mM. Eleven rice genotypes were found tolerant, fourteen were moderately tolerant, one was moderately sensitive and remaining two genotypes were found sensitive at 80 mM salinity level. Furthermore, none of the genotypes were able to with stand 120 mM of salinity. The genotypes Khushboo, DR-83 and Mahek performed meager and showed more than 50% reduction over control and categorised as sensitive, with the genotypes Latifee, DR-67 and DR-92, DR-51 and IR-6 are categorised as tolerant with a reduction of less than 20% over control based on dry matter yield reduction against all salinity treatments at the early seedling stage. However, these genotypes cannot be justified as tolerant only on the basis of their improved performance at early growth stage. Hence, these genotypes are suggested to be studied further at other advanced growth stages up to maturity to evaluate their response under a saline environment.

Keywords: salinity tolerance, aromatic and non-aromatic rice, genotypes, germination, survival percentage, dry matter yield

Introduction

Rice, a major export commodity, for export, play a key role in Pakistan agrarian based economy. The country earned 26.5 million US$ during 2017 through its export (PBS, 2018). It is the third largest crop in terms of area, cultivating over 9,050,000 hectares and second principal food grain crop of Pakistan, produced 26,500,000 tonnes during 2017-18. Punjab and Sindh are the major rice producing provinces of Pakistan, contributing approximately 90% of the overall rice production (PBS, 2018). Rice is one of the nutritionally imperious grain crops feeding more than three billion people around the world (Ghosh *et al*., 2016; Mohammadi-Nejad *et al*., 2010). A 100 g of rice provide 345 Kcal energy, 78.2 g of carbohydrates, 6.8 g of protein and a significant amount of suggested Zinc and Niacin (Ali *et al*., 2014; Gopalan *et al*., 2007). Rice varieties with some special traits such as fragrance, better taste and higher cooking quality also provide extra value in socio-economic aspects.

Salinity is one of the ecological challenges after drought, reducing crop production over 800 million hectares throughout the world (Islam *et al*., 2013). Generally, the Na^+ and Cl^- ions resulting from NaCl, are the major cause of salinity. A high concentration of such ions may affect the functioning of plant cell, resulting in reduced growth and lessen yield (Läuchli and Grattan, 2007). High salinity in the flooded soil is one of the main factors that depress water availability to root cells of rice plants due to reduced osmotic potential, consequently, inhibiting growth, development and grain yield of rice (Ganie *et al*., 2016; Molla *et al*., 2015). Salinity causes oxidative stress and disparity in nutrition, due

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to high concentration of specific ions unbalancing osmotic regulation (Ashraf, 2010; Noreen *et al*., 2010). This further inhabits germination, affects the growth of seedlings, and crush leaf enlargement, subsequently providing small leaf blade for photosynthetic activities and less dry matter of plant (Ahmad *et al.*, 2010; Ashraf, 2010).

During the early seedling (2-3 leaf) stage, rice remains very sensitive studied by (Mondal and Borromeo, 2016). Salinity reduces seedling survival and results in low crop standing (Pushpam and Rangasamy, 2000). Salinity reduces the weight of the shoot, the number of leaves, shoot and root length and the surface area of the roots (Meloni *et al*., 2001). Some high concentrations of Na^+ and/or Cl^- in plants cause wilting of leaf tips and necrosis (Zafar *et al*., 2015). Salinity stressed suppress development can be distinguished by measuring effects immediately upon salt exposure or after several days to weeks (Roy *et al*., 2014). Soil salinity is one of many factors that poses a major challenge to sustainable agriculture in Pakistan (Hussain *et al*., 2012). Most of the saline soils have originated from various natural processes, such as rocks weathering movement of salt traces through irrigation water (Munns and Tester, 2008).

In Asia, salinity has affected more than twenty million hectares of arable land and loss about half of the predictable fertile land (Huyen *et al*., 2013; Nazar *et al*., 2011). Moreover, the human population around the globe is increasing rapidly. Either cropping area or production is to be increased to feed this growing population of the world. The supply of agricultural land availability is slowly declining with speed as population grows, as much of the land is being converted into residential and commercial areas for community. On the other hand, agriculture is suffering from serious damage of biotic and abiotic stresses. Scientists around the globe are putting their best efforts to improve genotypes to combat stress affected environments and meet the challenges of the present era (Sankar *et al*., 2011). The screening of salt tolerant species is a reliable method to cope the salinity and produce a better production (Shannon *et al*., 1998). Therefore, this study was conducted to screen out the salt-tolerant rice genotypes at early seedling stages and to test their salt tolerance levels in saline environment.

Materials and Methods

In the 1st week of June 2016, the experiment was conducted at Department of Botany, Shah Abdul University Khairpur, Sindh, Pakistan. Twenty eight rice genotypes were selected, including 09 aromatic (Mahek, Khushboo, DR-61, DR-62, DR-63, DR-66, DR-67, Super Basmati and Lateefi), and 19 non-aromatic (Kanwal-95, Shahkar, Sarshar, Sada Hayat, Shadab, Shandar, NIA-19-A, NIA-625, DR-50, DR-51, DR-52, DR-57, DR-59, DR-82, DR-83, DR-92, IR-6, IR-8 and Shua-92 was used as salt-tolerant check variety) for analysis. The seeds of genotypes were sourced from RRI Dokri, Sindh, Pakistan and NIA Tandojam, Sindh, Pakistan. The seeds were sterilized for 30 min on the surface with 1% industrial bleach and washed four times with distilled water. After rinsing, sixty seeds of each genotype were sown in 10 Kg air dried soil filled trays (24×18 inches). The soil was analyzed before experiments (Table 1). The trays were arranged in completely randomized design (CRD) with four repeats and four salt treatments (0, 40, 80 and 120 mM, $NaCl+CaCl_2$ @ 20:1) were applied. The salt solution was prepared by following method. For the conversion of molar into mM following formula was used:

$$\text{mM} = \frac{\text{Molar weight of NaCl}}{1000} \times \text{salt treatments}$$

The resulting weight of salt is added in distilled water per liter to make a salt solution. The temperature of the laboratory was maintained at 28 °C.

Emergence percentage was measured at interval of one week of sowing. Twenty five days old seedlings were harvested and washed with distilled water. Survival percentage, shoot height and root length (cm), shoot and root dry weight (g), shoot/root ratio and dry matter yield (g) were recorded at the time of seedlings harvest**.** Seedlings were wrapped in paper bag and kept in an

Table 1. Physico-chemical properties of soil used in experiment

Soil properties	Value
Texture	
Sand	25.2%
Silt	41.3%
Clay	33.5%
Textural class	Clay loam
Electrical conductivity (1:5)	2.2 d/Sm
pH (1:5)	7.4
Organic matter	0.75%
$CaCO_3$	6.0%

oven at 65 °C for 24 h to a constant dry weight. The germination percentage (GP) and survival percentage (SP) was calculated using the formula suggested by Raun *et al*. (2002). Whereas, percent reduction over control (PROC) was computed using the formula suggested by Ali *et al*. (2014), as following:

$$GP = \frac{\text{Total number of germinated seeds}}{\text{Total number of germinated seedling}} \times 100$$

$$SP = \frac{\text{Total number of survival seedling}}{\text{Total number of germinated seedling}} \times 100$$

$$PROC = \frac{\text{Volume in control - Value in saline environment}}{\text{Value in control}} \times 100$$

Genotypes were categorised as tolerant (T) having 0-20% reduction, moderately tolerant (MT) and moderately sensitive (MS), having 21-40% and 41-60% reduction respectively while, sensitive (S) more than 60% reduction of their aggregate dry material (shoot and root) at various levels of salinity stress (Ologundudu *et al*., 2014; Hakim *et al*., 2010). The data were analyzed by performing two-way ANOVA (P<0.05) and means were compared by least significant difference (LSD) using statistical software namely "Statistix version 8.1".

Results and Discussion

Germination percentage (GP). The germination of all aromatic and non-aromatic rice genotypes significantly decreased when exposed to salinity treatments (Table 2). A negligible effect of salinity was observed at 40 mM salinity with least (14.6) average PROC of all genotypes (Fig.1a). However, genotype DR-63 showed maximum (37.77) PROC even at this level of salinity. The most severe effect of salinity was observed at 120 mM salt concentration, where maximum (47.86) average PROC of all genotypes was recorded. The genotypes DR-92, DR-51 and Latifee performed better, both showed least (≤ 16.51) average PROC at all salinity levels, whereas genotypes DR-63, DR-61 and Sada Hayat germinated poorly in saline environment and showed maximum (>50) average PROC as compared to other genotypes. Generally, PROC increases with the rise in salinity level (Fig.1a).

Survival percentage (SP). Increased salinity levels significantly decreased the survival percentage of all rice genotypes (Table 2) as compared to control salinity treatment. Salinity level 120 mM showed most harmful effects on seedling survival, where more than 60% reduction was observed as compared to control (Fig. 1b). Genotypes DR-83 and Khushboo could not with stand the hazardous effect of salinity and completely died at 80 mM salinity. Genotypes DR-92, DR-51 and IR-6 remained successful with least average (≤ 21) PROC.

Shoot height and root length. Shoot height of all aromatic and non-aromatic rice genotypes was reduced when exposed to salt stress (Table 3). Mild effect of salinity was observed at 40 mM salinity, where on an average less than ten PROC was recorded. The most significant effect of salinity was noted at 120 mM salinity treatment, where on an average 56.62 PROC was observed. The maximum (68.98, 68.73 and 41.67) average PROC was observed in genotypes Khusboo, DR-83 and DR-57 respectively, whereas minimum average (<20) PROC was recoded in genotypes Latifee, DR-92 and DR-51 (Fig.1c). Similarly, root length was also decreased with increased levels of salinity (Table 4). The minimum (11.24) average PROC in root length was observed at 40 mM salinity which raised to maximum (61.91) average PROC at maximum (120 mM) salinity level. The genotypes DR-92, NIA-19A and Super Basmati showed minimum (≤ 26) average PROC in root length at all salinity levels, whereas maximum (69.07, 68.49 and 50.37) average PROC for same trait at all salinity treatments was recorded in genotypes Khushboo, DR-83 and DR-52, respectively (Fig.1d).

Shoot and root dry weight. Shoot dry weight of all rice genotypes was significantly reduced with higher salinity levels as compared to control (Table 3). All genotypes performed well with a least PROC (<9%) at 40 mM salinity treatment (Fig.1e). DR-92, Latifee and DR-51 showed better response with minimum (18.82, 22.64 and 22.75) average PROC, whereas Khushboo, DR-83 and Mahek performed meager and showed maximum average PROC at all salinity levels (Fig.1e). Similarly, root dry weight of all genotypes was also decreased with increased salinity levels (Table 4), on average, at 40, 80 and 120 mM salinity, root dry weight of all genotypes reduced (8.24, 24.54 and 51.48%) respectively as compared to control.

The lowest (14.18, 16.99 and 17.39%) reduction on average at all salinity levels were observed in genotypes DR-67, DR-92 and DR-51 respectively, whereas highest (68.69, 67.50 and 50.45%) average reduction at all salinity levels in root dry weight were recorded in genotypes Khushboo, DR-83 and Mahek respectively as compared to control (Fig.1f).

Shoot/root ratio. In all genotypes, shoot/root ratio was significantly decreased with increased salinity levels (Table 5). The highest (2.51, 2.44 and 2.42) shoot/root ratio at all salinity levels were observed in genotypes DR-92, DR-51 and Latifee respectively, whereas lowest (0.94, 1.27 and 1.28) shoot/root ratios were recorded in genotypes DR-83, IR-8 and DR-52, respectively. The more average PROC (>60) was observed in genotypes Khushboo, DR-83 and Shandar respectively, while mild average PROC (≤ 13.5) was recorded in genotypes DR-92, DR-51 and IR-6 (Fig.1g).

Classification of genotypes. All genotypes were classified as tolerant (T), medium tolerant (MT), medium sensitive (MS), and sensitive (S) on the basis of dry matter production at different salinity levels (Table 5). All rice genotypes fall in the category of T at 40 mM. Eleven rice genotypes fall in the category of T, fourteen in the category of MT, one in the category of MS and remaining two genotypes fall in the category of S at 80 mM salinity level. No any rice genotype could qualify for T category at 120 mM salinity.

Table 2. Effect of salinity on germination and survival percentages of aromatic and non-aromatic rice genotypes grown in solution culture. The number shows the mean germination and survival under various salinity treatments. (NaCl + $CaCl_2$ @ 20:1 salt concentrations (mM))

Genotypes	Germination percentage (GP)					Survival percentage (SP)				
	T1	T2	T3	T4	Genotype mean	T1	T2	T3	T4	Genotype mean
Sarshar	85.0	75.4	70.5	53.0	71.0	94.1	93.0	76.9	34.3	74.6
Shadab	82.3	75.0	55.0	30.0	60.6	94.0	84.4	69.0	34.4	70.5
Shandar	86.6	78.4	71.3	48.0	71.1	89.8	85.7	51.1	34.1	65.2
Shua-92	87.2	81.4	75.2	70.0	78.5	96.3	93.2	83.2	67.5	85.0
NIA-19A	86.0	76.6	70.1	65.0	74.4	94.4	89.1	73.1	54.0	77.7
NIA-625	86.6	70.0	50.4	30.0	59.3	85.0	71.3	56.6	27.5	60.1
DR-50	85.0	70.5	50.3	35.0	60.2	95.3	76.1	72.9	20.6	66.2
DR-57	86.0	73.4	70.0	46.1	68.9	88.4	73.5	55.9	0.0	54.4
DR-83	85.0	68.3	40.0	30.0	55.8	90.8	76.4	0.0	0.0	41.8
DR-52	86.0	75.0	70.1	44.8	69.0	88.0	80.0	69.4	0.0	59.3
DR-51	87.0	83.5	76.4	60.3	76.8	94.1	91.2	74.3	57.6	79.3
DR-82	85.0	66.2	45.0	30.1	56.6	84.7	76.6	64.2	30.3	63.9
DR-92	88.1	81.6	73.0	71.1	78.4	94.4	91.4	68.4	66.7	80.2
IR-6	87.0	76.1	73.3	68.0	76.1	94.3	90.5	82.1	50.0	79.2
IR-8	85.0	76.0	50.5	30.0	60.4	88.6	71.2	65.6	28.5	63.5
Sada Hayat	85.0	61.6	38.0	24.8	52.4	86.3	75.0	62.9	29.0	63.3
Kanwal-95	85.0	70.0	39.9	34.6	57.4	90.6	75.0	66.1	29.0	65.2
Shahkar	86.4	73.1	70.0	64.6	73.5	94.0	80.8	76.1	52.2	75.8
DR-59	82.0	70.4	59.6	45.0	64.2	88.2	75.0	62.2	35.0	65.1
Mahek	78.0	71.6	68.3	24.8	60.7	87.0	77.0	64.9	0.0	57.2
Khushboo	81.2	65.0	45.0	25.0	54.1	87.0	77.1	0.0	0.0	41.0
DR-62	84.0	74.5	60.1	51.3	67.5	87.0	78.2	67.6	30.0	65.7
DR-66	94.0	85.1	81.5	50.0	77.7	94.0	85.1	81.5	50.0	77.7
DR-67	85.0	76.8	74.6	60.1	74.1	94.0	79.2	76.1	62.0	77.8
DR-63	80.4	50.0	35.1	28.0	48.4	95.3	72.7	52.2	28.0	62.1
Super Basmati	86.0	81.0	70.0	36.5	68.4	94.3	88.2	74.3	52.6	77.4
DR-61	76.2	50.0	35.3	25.2	46.7	94.5	72.7	54.8	37.4	64.8
Latifee	85.0	76.2	71.7	65.0	74.5	94.2	88.0	73.0	60.0	78.8
Treatment mean	84.85	72.59	60.	44.5		91.4	81.0	63.4	34.7	
	Genotype (G)		**Salinity**	**G X S**		**Genotype (G)**		**Salinity**	**G X S**	
S.E.D	0.62		0.23	1.25		0.48		0.18	0.96	
L.S.D (0.05%)	1.23***		0.46***	2.47***		0.94***		0.35	1.89***	

Although eight genotypes were found successful for MT, eleven for MS and remaining nine were categorised as S at 120 mM salinity.

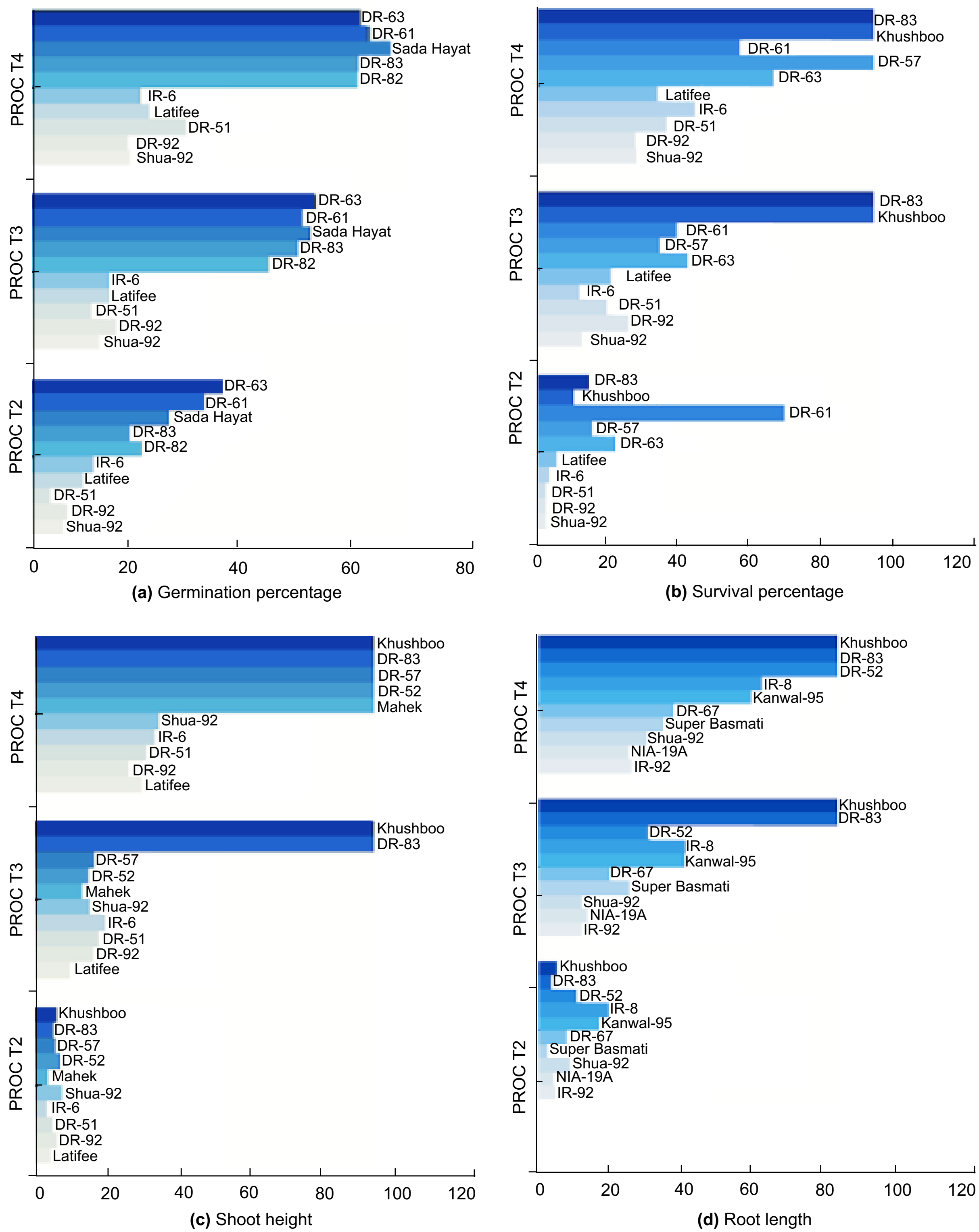
In Pakistan, agriculture is facing plenty of problems and issues regarding crop production (Muzaffar *et al*., 2015; Rao *et al*., 2013). Several approaches are being attempted to cope against those problems and issues (Awan *et al*., 2015; Nasir *et al*., 2014). Soil salinity, an abiotic stress is also one of the major problems which not only reduce the crop growing area but also its yield throughout the world (Kronzucker *et al*., 2008). Rice is susceptible to salt-stress, especially during the period of seedling growth (Zafar *et al*., 2015). It is therefore, vital to screen out the best genotypes that produce better yield in saline conditions (Zeng and Shannon, 2002).

In present study, the influence of salinity remained adverse on emergence, survival and early growth of aromatic and non-aromatic rice genotypes. Results showed a significant reduction in almost all agronomic parameters. However, the rate of reduction varied in both aromatic and non-aromatic rice genotypes. The symptoms of salt injury could be visualized physically.

Table 3. Effect of salinity on shoot height and shoot dry weight of aromatic and non-aromatic rice genotypes grown in solution culture. The number shows the mean shoot height (cm) and shoot dry weight (g) under various salinity treatments. (NaCl + $CaCl_2$ @ 20:1 salt concentrations (mM))

Genotypes	Shoot height (cm)					Shoot dry weight (g)				
	T1	T2	T3	T4	Genotype mean	T1	T2	T3	T4	Genotype mean
Sarshar	15.1	13.4	11.9	5.9	11.6	0.089	0.08	0.066	0.027	0.066
Shadab	16.0	12.6	11.1	7.9	11.9	0.097	0.082	0.068	0.023	0.068
Shandar	15.5	12.6	11.4	9.0	12.1	0.088	0.076	0.067	0.033	0.066
Shua-92	16.2	14.8	13.5	10.2	13.7	0.131	0.123	0.111	0.061	0.107
NIA-19A	16.7	15.4	12.5	10.7	13.8	0.089	0.081	0.074	0.049	0.073
NIA-625	15.7	13.7	12.9	8.4	12.7	0.084	0.078	0.06	0.027	0.062
DR-50	15.7	14.5	12.7	7.0	12.5	0.076	0.072	0.058	0.028	0.059
DR-57	14.9	13.9	12.2	0.0	10.3	0.081	0.077	0.063	0	0.055
DR-83	13.2	12.4	0.0	0.0	6.4	0.074	0.071	0	0	0.036
DR-52	14.9	13.7	12.4	0.0	10.3	0.083	0.073	0.058	0	0.054
DR-51	15.7	14.8	12.7	10.5	13.4	0.126	0.115	0.102	0.075	0.105
DR-82	16.2	15.0	12.4	9.6	13.3	0.081	0.07	0.06	0.045	0.064
DR-92	16.8	15.6	13.8	12.1	14.6	0.124	0.121	0.102	0.079	0.107
IR-6	16.1	15.5	12.7	10.4	13.7	0.116	0.106	0.081	0.07	0.093
IR-8	17.8	14.7	13.1	7.1	13.2	0.077	0.068	0.06	0.035	0.06
Sada Hayat	16.2	14.5	12.4	7.9	12.8	0.082	0.078	0.06	0.041	0.065
Kanwal-95	19.0	15.2	14.8	9.9	14.7	0.077	0.065	0.058	0.045	0.061
Shahkar	15.8	14.7	14.1	8.7	13.3	0.117	0.109	0.081	0.07	0.094
DR-59	14.6	13.3	12.3	7.6	11.9	0.076	0.07	0.057	0.037	0.06
Mahek	14.7	14.0	12.5	0.0	10.3	0.106	0.099	0.047	0	0.063
Khushboo	14.4	13.4	0.0	0.0	7.0	0.101	0.091	0	0	0.048
DR-62	17.1	16.3	13.9	5.4	13.2	0.084	0.076	0.062	0.03	0.063
DR-66	17.7	16.3	14.3	6.4	13.7	0.081	0.072	0.066	0.038	0.064
DR-67	23.1	20.5	16.0	13.5	18.3	0.108	0.095	0.08	0.07	0.088
DR-63	17.2	13.2	12.3	8.3	12.8	0.079	0.074	0.062	0.025	0.06
Super Basmati	18.1	16.5	12.9	9.5	14.3	0.096	0.086	0.075	0.055	0.078
DR-61	16.5	15.1	12.5	6.4	12.6	0.081	0.078	0.06	0.038	0.064
Latifee	15.7	14.9	14.0	10.7	13.8	0.106	0.102	0.085	0.059	0.088
Treatment mean	16.3	14.7	12.04	7.24		0.093	0.085	0.065	0.038	
		Genotype (G)		**Salinity**	**G X S**		**Genotype (G)**		**Salinity (S)**	**G X S**
S.E.D		0.42		0.15	0.84		1.90		7.20	3.81
L.S.D (0.05%)		0.82***		0.31***	0.65***		3.75***		14.42***	7.51***

Burning of older leaf tips were noticed at initial stage which led to completely dying of leaf. Germination of all rice genotypes including aromatics and non-aromatics were affected by salinity. Reduction in their germination percentage increased with the increasing intensity of salinity. This may have resulted from the imbalance of osmotic pressure caused by the concentration of salts (Anbumalarmathi and Mehta, 2013). Other studies



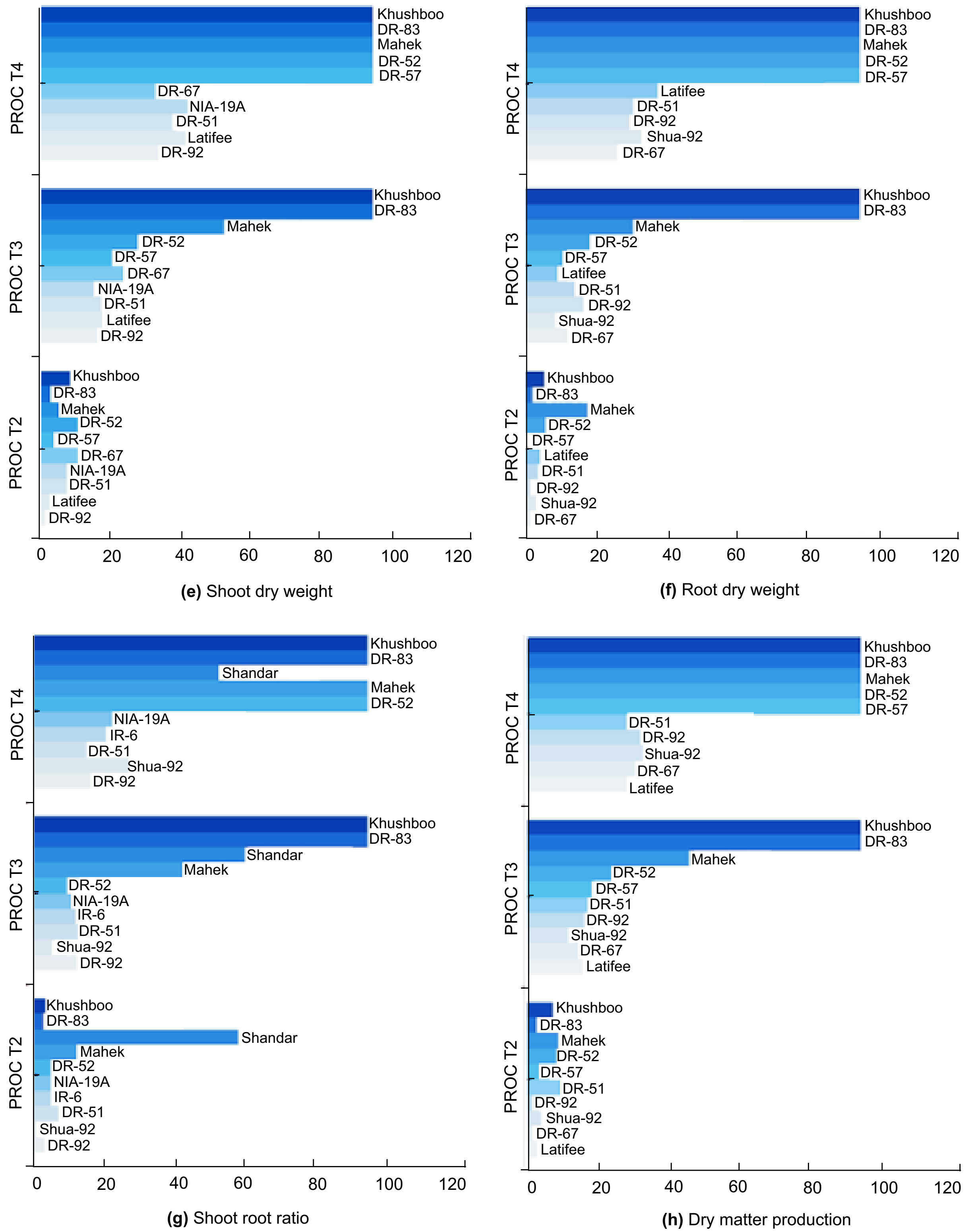


Fig. 1. Reduction (PROC) in the agro-morphological parameters of rice genotypes at three salinity treatment. (a) Germination percentage, (b) Survival percentage, (c) Shoot height, (d) Root length, (e) Shoot weight, (f) Root dry weight, (g) Shoot root ratio and (h) Dry matter production. Only ten genotypes having the highest and lowest impact of salinity are plotted in the figure for the clarity.

(Hakim *et al*., 2010; Zafar *et al*., 2015) have also reported rice genotypes susceptible for germination percentage against salinity stress particularly in salt sensitive varieties. Germination percentage is among many other parameters that are considered to identify salt-tolerant genotypes. However, a single trait cannot be relied for evaluating salt tolerance because germination depends upon various other factors studied by Ashraf *et al*. (2006).

Salinity also showed harmful effect on the survival percentage of all aromatic and non-aromatic rice genotypes in present experiment. At all salinity treatments, genotypes DR-92, DR-51 and IR-6 performed better and showed the lowest PROC, whereas the genotypes Khushboo, DR-83, DR-50, DR-52 and Mahek performed meager and showed the highest PROC. Intense reduction in seedling survival and growth is associated with saline environment (Puvanitha and Mahenderan, 2017; Zeng and Shannon, 2000). Roots can be an important trait for the identification of salt tolerant genotypes as these are directly affected by salt concentration (Khan *et al*., 2007).

In this study the root length decreased in all genotypes when exposed to higher salinity levels. The maximum PROC regarding root length was observed in genotypes

Table 4. Effect of salinity on root length and root dry weight of aromatic and non-aromatic rice genotypes grown in solution culture ($NaCl + CaCl_2$ @ 20:1 salt concentrations (mM)

Genotypes	Root length (cm)					Root dry weight (g)				
	T1	T2	T3	T4	Genotype mean	T1	T2	T3	T4	Genotype mean
Sarshar	3.7	3.3	2.8	1.1	2.7	0.043	0.037	0.033	0.023	0.034
Shadab	3.7	3.4	2.9	1.3	2.8	0.035	0.032	0.028	0.023	0.030
Shandar	3.3	3.0	2.5	1.5	2.6	0.025	0.023	0.020	0.012	0.020
Shua-92	3.5	3.1	3.0	2.2	2.9	0.054	0.052	0.049	0.035	0.048
NIA-19A	3.3	3.1	2.7	2.3	2.8	0.048	0.043	0.039	0.035	0.041
NIA-625	3.6	3.3	2.6	1.5	2.7	0.043	0.038	0.033	0.028	0.036
DR-50	2.8	2.5	2.1	1.2	2.2	0.039	0.033	0.028	0.017	0.029
DR-57	3.7	3.1	2.8	0.0	2.4	0.034	0.034	0.030	0.000	0.025
DR-83	3.3	3.1	0.0	0.0	1.6	0.040	0.039	0.000	0.000	0.020
DR-52	3.7	3.2	2.3	0.0	2.3	0.046	0.043	0.037	0.000	0.032
DR-51	3.9	3.5	2.7	2.3	3.1	0.046	0.044	0.039	0.031	0.040
DR-82	3.8	3.7	2.3	1.8	2.9	0.037	0.032	0.029	0.022	0.030
DR-92	4.1	3.8	3.5	2.8	3.5	0.051	0.050	0.042	0.035	0.045
IR-6	3.8	3.7	2.3	2.0	2.9	0.045	0.043	0.037	0.028	0.038
IR-8	5.0	3.8	2.5	1.2	3.1	0.047	0.040	0.039	0.025	0.038
Sada Hayat	3.9	3.5	2.6	1.6	2.9	0.034	0.030	0.027	0.021	0.028
Kanwal-95	5.0	4.0	2.6	1.4	3.2	0.040	0.038	0.036	0.021	0.034
Shahkar	4.0	3.6	2.5	1.8	3.0	0.047	0.044	0.039	0.032	0.041
DR-59	4.0	3.9	2.8	1.5	3.1	0.034	0.031	0.027	0.022	0.029
Mahek	2.6	2.4	2.1	0.0	1.8	0.037	0.030	0.025	0.000	0.023
Khushboo	2.8	2.6	0.0	0.0	1.3	0.033	0.031	0.000	0.000	0.016
DR-62	3.2	2.5	2.0	1.0	2.2	0.041	0.040	0.037	0.017	0.034
DR-66	3.9	3.3	2.8	1.9	3.0	0.045	0.043	0.039	0.024	0.038
DR-67	3.1	2.8	2.4	1.7	2.5	0.047	0.046	0.041	0.034	0.042
DR-63	2.7	2.2	2.2	1.2	2.1	0.046	0.040	0.036	0.024	0.037
Super Basmati	3.2	3.1	2.2	1.9	2.6	0.048	0.042	0.035	0.027	0.038
DR-61	3.7	3.0	2.5	1.4	2.6	0.035	0.030	0.025	0.018	0.027
Latifee	5.1	4.4	3.5	2.9	4.0	0.040	0.038	0.036	0.024	0.035
Treatment Mean	3.66	3.24	2.39	1.41		0.041	0.038	0.032	0.021	
		Genotype (G)		**Salinity**	**G X S**		**Genotype (G)**		**Salinity**	**G X S**
S.E.D		0.11		0.04	0.22		1.47		5.58	2.95
L.S.D (0.05%)		0.22***		0.08***	0.44***		2.91***		11.17***	5.82***

Khushboo, DR-83 and DR-52, whereas minimum PROC was recorded in genotypes DR-92, NIA-19A and Super Basmati. Puvanitha and Mahenderan (2017) has also reported the decrease in root length under saline environment in rice. The reduction in root length with increase in salt-stress might be due to the inhibitory effect of sodium chloride salt (Rahman *et al*., 2001). Similarly, the significant effect of salinity regarding shoot height was observed in all genotypes. A reduction of seedling is a general phenomenon of various crops in saline environment (Hakim *et al*., 2010). Puvanitha and Mahenderan (2017) also proved the hazardous influence of salinity on shoot height in rice crop especially in salt susceptible varieties. Results from the present experiments showed reduction in shoot and root dry weights of rice significantly with increased salinity treatments. The highest reduction in shoot and root was observed at 120 mM salinity, whereas the lowest reduction was recorded at 40 mM salinity as compared to control treatment. Hakim *et al*. (2014) reported that the reduction in shoot and root dry weight due to decreased per unit photosynthesis leaf area. This

Table 5. Effect of salinity on root shoot ratio and total dry matter production of aromatic and non-aromatic rice genotypes grown in solution culture. The rice genotypes against salinity tolerance on the basis of total dry matter production (g/10 plants)

Genotypes	Root shoot ratio					Total dry matter production				Tolerance at salinity level		
	T1	T2	T3	T4	Genotype mean	T1	T2	T3	T4	T2	T2	T3
Sarshar	2.10	2.03	1.69	1.00	1.70	0.121	0.115	0.105	0.054	T	T	MS
Shadab	2.77	2.40	2.16	0.91	2.06	0.133	0.117	0.100	0.049	T	MT	S
Shandar	3.53	1.35	1.29	1.56	1.93	0.132	0.113	0.088	0.055	T	MT	MS
Shua-92	2.41	2.38	2.26	1.72	2.19	0.185	0.176	0.161	0.12	T	T	MT
NIA-19A	1.96	1.85	1.73	1.49	1.76	0.14	0.125	0.112	0.084	T	T	MT
NIA-625	1.94	1.87	1.80	0.84	1.61	0.128	0.114	0.093	0.082	T	MT	MT
DR-50	2.16	2.02	1.65	1.55	1.84	0.115	0.106	0.086	0.046	T	MT	MS
DR-57	2.34	2.25	2.14	0.00	1.68	0.116	0.111	0.093	0.000	T	T	S
DR-83	1.91	1.84	0.00	0.00	0.94	0.114	0.110	0.000	0.000	T	S	S
DR-52	1.80	1.70	1.62	0.00	1.28	0.129	0.117	0.096	0.000	T	MT	S
DR-51	2.70	2.49	2.33	2.26	2.44	0.172	0.154	0.140	0.120	T	T	MT
DR-82	2.22	2.02	1.85	1.62	1.93	0.118	0.105	0.090	0.060	T	MT	MS
DR-92	2.75	2.65	2.38	2.27	2.51	0.175	0.171	0.144	0.115	T	T	MT
IR-6	2.58	2.43	2.24	2.01	2.31	0.162	0.150	0.118	0.109	T	MT	MT
IR-8	1.65	1.54	1.15	0.73	1.27	0.125	0.114	0.091	0.056	T	MT	MS
Sada Hayat	2.40	2.22	2.08	1.59	2.07	0.116	0.111	0.087	0.067	T	MT	MS
Kanwal-95	2.21	1.95	1.89	1.68	1.93	0.118	0.105	0.097	0.060	T	T	MS
Shahkar	2.50	2.44	1.95	1.88	2.19	0.164	0.154	0.127	0.095	T	MT	MS
DR-59	2.22	2.02	1.85	1.58	1.92	0.11	0.101	0.087	0.055	T	T	MS
Mahek	3.37	2.92	1.86	0.00	2.04	0.143	0.129	0.073	0.000	T	MS	S
Khushboo	3.08	2.96	0.00	0.00	1.51	0.134	0.123	0.000	0.000	T	S	S
DR-62	2.10	1.93	1.68	1.50	1.80	0.125	0.112	0.082	0.047	T	MT	S
DR-66	2.41	1.76	1.66	1.23	1.76	0.153	0.137	0.116	0.088	T	MT	MS
DR-67	2.22	2.10	1.90	1.70	1.98	0.128	0.125	0.108	0.086	T	T	MT
DR-63	1.71	1.64	1.59	1.06	1.50	0.126	0.120	0.102	0.049	T	T	S
Super Basmati	1.74	1.65	1.50	1.30	1.55	0.146	0.130	0.113	0.073	T	MT	MS
DR-61	1.74	1.68	1.53	1.15	1.52	0.117	0.113	0.091	0.045	T	MT	S
Latifee	2.70	2.66	2.45	1.86	2.42	0.146	0.141	0.121	0.102	T	T	MT
Treatment mean	2.33	2.10	1.72	1.23								
		Genotype (G)			Salinity		G X S					
S.E.D		0.07 (Genotype)			0.02 (Salinity)		0.15 (GXS)					
L.S.D (0.05%)		0.15***			0.05*		0.30***					

Note: T = Tolerant; MT = Moderately tolerant; MS = Moderately sensitive; S = Sensitive result in inadequate supply of starch needed for shoot growth and decreased turgor, resulting in lower water potential and imbalance supply of nutrients in saline environment.

The shoot/root ratio may also be a good criterion for screening of salt-tolerant crop species. In the current study, a significant difference was observed amongst all genotypes under saline environment as compared to control and this ratio was decreased with increased treatment of salinity. Our findings are in consensus with the findings of Pradheeban *et al.* (2017) that salinity significantly reduces shoot/root ratio due to toxic effects of NaCl salt.

Conclusion

The conclusion is that, the higher concentration of salts inhabited the germination of seeds and effects also on growth of seedlings in various rice genotypes. The dry shoots and roots, ratio yields of all aromatic and non-aromatic genotypes were significantly decreased with increased salinity levels. Compared to other genotypes the DR-92, DR-51, IR-6, Latifee and DR-67 genotypes were less affected by salinity at all treatments. While, the Mahek, Khusboo and DR-83 genotypes are ranked as salt-sensitive in nature, further studies in laboratory and field conditions at other growth and development stages are proposed to establish and classify the salt-tolerant and salt-sensitive genotypes of rice.

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