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Effect of salinity on growth, yield and ion contents of rice (*Oryza sativa* L.) genotypes

Ghulam Sarwar Channa[1], Abdul Razak Mahar[1], Inayatullah Rajpar[2], Abdul HafeezMemon[3], Mumtaz Ali Saand[1], Ameer Ahmed Mirbahar[1], Abdul Majid[4], Sham Lal[5], Muzafar Hussain Sirohi[2*]

[1]*Department of Botany, Shah Abdul Latif University, Khairpur, Pakistan*
[2]*Department of Soil Science, Sindh Agriculture University, Tandojam, Pakistan*
[3]*Agriculture Research Institute, Tandojam, Pakistan*
[4]*Department of Biochemistry, Shah Abdul Latif University, Khairpur, Pakistan*
[5]*Institute of Microbiology, Shah Abdul Latif University, Khairpur, Paksitan*

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Abstract

Soil salinity is one of the most distressing ecological stresses which reduces the agrarian production. However, the impact of salinity varies among species and genotypes. The experiment tested the salt tolerance of ten rice genotypes including, four aromatic (DR-67, Latifee, Super Basmati and DR-66) and six non-aromatic genotypes (DR-92, DR-51, IR-6 Shahkar, NIA-19A and Shua-92 check). The study used two factorial completely randomized design (CRD) with four salinity levels (T1-2.3 (control), T2-6.0, T3-9.1 and T4-12.8 EC dS m^{-1}), at Green house, Department of Botany, Shah Abdul Latif University Khairpur. Initially, a nursery of all genotypes was developed in a normal soil. The seedlings (25 days old) were transplanted into pots filled with 10 kg air of dried soil. Each pot contained one plant $hill^{-1}$ and three hills pot^{-1}. The recommended rate of NPK (160:90:37 kg ha^{-1}) fertilizer was used. The results indicated that almost all agro-morphological traits like shoot height, root length, total tiller numbers and productive tiller numbers, total number of filled grains, 1000 grains weight, spikelet fertility percentage root and shoot dry weight, and harvest index percentage were reduced significantly with a rise in salt concentrations. Genotypes DR-92, DR-51 and IR-6 accumulated less sodium (Na^+), more potassium (K^+) and had higher K^+/Na^+ ratio in straw and grain samples hence were less affected against all salinity levels as compared to other rice genotypes. On contrary, genotypes Super Basmati and DR-66 showed meager performance regarding all tested traits against all salinity levels.

* **Corresponding Author:** Muzafar Hussain Sirohi ✉ muzafar.sirohi@salu.edu.pk

Introduction

Soil salinity is one of the numerous ecological stresses that is associated with huge crop losses worldwide (Samant and Jawali, 2015; Mondal and Borromeo, 2016). Soil salinity creates an osmotic stress in plant body, leading to stunt growth due to nutritional imbalance (Zhu, 2003). About one fifth of the agricultural land is affected by certain level of salinity globally (Shrivastava and Kumar 2014). The major causes of salinity may include climate change, excessive use of ground water for irrigation and poor drainage. The salinity problem is expected to be severe if the current trends in climate change and soil management practices continues (Munns and Tester, 2008; Ismail *et al.*, 2010).

Rice is a vital staple food providing a substantial amount of calories intake to the human population globally (Ghosh *et al.* 2016). It is one of the major agricultural commodity and a source of foreign exchange of Pakistan (Chandio *et al.*, 2016; PBS, 2018). Nevertheless, plants may be recognized as glycophytes and halophytes, based on their salt tolerance capability. The rice species (*Oryza sativa* L.) and its variants may tolerate a varied concentrations of salt, generally by two mechanisms; ion exclusion and osmotic tolerance (Munns and Tester, 2008; Roy *et al.*, 2014).Screening of salt tolerant plants under controlled environments has been discovered more effective than under field conditions; because of heterogeneity in edaphic factors and other soil related stresses such as temperature, relative humidity and sun oriented radiations (Glenn *et al.*, 1997). This study tests the salinity tolerance level of aromatic and non-aromatic rice genotypes cultivated in Pakistan at large scale and determine the impact of salinity levels on ion contents of the plants.

Methodology

Study site and rice genotypes

The experiment was conducted in July 2017 at Green house, Department of Botany Shah Abdul Latif University Khairpur. Ten rice genotypes including four aromatic (DR-66, DR-67, Latifee and SuperBasmati) and six non-aromatic (DR-92, DR-51, IR-6, Shahkar, NIA-19A and Shua-92 salt-tolerant check) were selected. Soil was collected from the rice growing field of Taluka Bakrani, District Larkana. The soil was analyzed for the physicochemical properties (Table 1). In order to increase the soil salinity level pure NaCl was mixed with soil having EC 2.3 dS m^{-1} (control) to create 6.0, 9.1 and 12.8 EC dS m^{-1} soil salinity level, respectively(Rowell, 1994).

Experimental design

The experiment used four treatments with three replicates laid out in a completely randomized design (CRD). Initially, a nursery of all genotypes were established in a non-saline soil. Twenty five days old seedlings were transplanted to pots for various saline treatments. NPK fertilizer was used with recommended rate to all plants. Growing weeds in the pots were hand-picked frequently. Water to each pot was maintained on regular basis and salt concentrations on weekly basis.

Determination of agro-morphological characters

Agro-morphological attributes, for example plant height (cm), root length (m), number of tillers $hill^{-1}$, number of productive tillers $hill^{-1}$, number of filled grains $panicle^{-1}$, spikelet fertility percentage (SFP), 1000 grains weight, dry shoot and root weight (g), and harvest index (HI) percentage were recorded at the time of harvest. The crop was harvested when more than 80% of the grains and straw turned into yellow colored.

Mensuration of salt stress

The flowing formulas were used to quantify salt stress on vegetative and yield components (Donald, 1962; Ali *et al.*, 2004; Ali *et al.*, 2007; Beakal *et al.*, 2017; Mari, 2018).

$$\%\ \text{reduction over control (PROC)} = \frac{\text{Volume in control} - \text{Value in saline environment}}{\text{Value in control}} \times 100$$

$$\text{Spikelet fertility \% (SFP)} = \frac{\text{Number of filled spikelets}}{\text{Total number of spikelets}} \times 100$$

$$\text{Harvest index (HI)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

$$\text{Salt tolerance index (STI)} = \frac{\text{Value of traits under stress condition}}{\text{Value of traits under control condition}} \times 100$$

Determination of nutrients

Plant residues were dried for 48 hour at 65 °C to record their root and shoot dry weights. The Na^+ and K^+ ion contents and K^+/Na^+ ratio in dry matter of plants (straw and grain) were calculated using Dry-Ash processing technique (Chapman and Pratt, 1961).The statistical software (Statistix 8.1, Inc., Tallahassee, FL., USA) was used to perform anova ($p<0.05$). Least Significant Difference (LSD) test was used to determine the mean difference among salinity treatments.

Results

Shoot height and Root length (cm)

The Shoot height and root length of aromatic and non-aromatic rice genotypes was significantly affected by different salinity levels. The rate of reduction in vegetative parts varied among genotypes. The growth rate of root and shoot significantly decreased with the increase in salinity level (Fig. 1 a&b). The minor effect of salinity was observed under EC 6.0 dS m^{-1} where an average minimum (6.9% PROC) in shoot height for all genotypes was recorded.

Table 1. Soil properties used in experiment.

Soil properties	Value
Texture	
Sand	17.2 %
Silt	51.3 %
Clay	21.5 %
Textural class	Silty clay loam
Electrical conductivity (1:5)	2.3 dSm^{-1}
pH (1:5)	7.4
Organic matter	0.75 %
$CaCO_3$	6.0 %

The severe effect of salinity was observed at EC 12.8 dS m^{-1} where reduction in growth surged up to maximum (26.9 PROC) for shoot height of all genotypes. The genotypes Shua-92, DR-92 and DR-51were less affected by salinity level by showing the least reduction in vegetative growth (Fig. 2). Whereas Super Basmati, DR-67, DR-66 and Shahkar showed a high reduction in shoot height (>40% at EC 12.8 dS m^{-1}) and root length (> 50% at EC 12.8 dS m^{-1}).

Number of tillers hill^{-1}

The salinity levels also affected the number of tillers hill^{-1} (Fig. 1c& d). The genotypes produced on average 11.40% and 48% less tillers on salinity treatments T2 and T4, respectively. None of genotypes produced productive tillers at salinity level EC 12.8 dS m^{-1}.The better performance was observed in genotypes DR-92, Shua-92 and NIA-19A, at all salinity levels with average minimum (17.44, 21.62 and 22.22 respectively) PROC in number of tillers. Most significantly affected genotypes at higher salinity level EC 12.8 dS m^{-1}were DR-66, Super Basmati and IR-6 with maximum (75.5, 67.3 and 53.3 respectively) PROC (Fig. 2). While less affected genotypes were DR-92, Shua-92 and DR-51 with minimum (25.64, 32.01 and 40.51 respectively) PROC. Moreover, thegenotypes DR-92, Shua-92 and Latifee produced more reproductive tillers (19.2, 24.9 and 25 PROC, respectively) at all salinity levels excluding T4 (EC 12.8 dS m^{-1}). Whereas average reproductive tillers reduced more than 40% in genotypes DR-66, Super Basmati and Shahkar (Fig. 2).

Spikelet fertility % and total number of filled grains panicle^{-1}

The salinity levels affected the number of filled gains panicle^{-1} (Fig. 3a). The genotypes showed ≤ 35 % reduction in filled grains panicle^{-1} at T2 (EC 6.0 dS m^{-1}) which surged to ≤ 54 % at T3 (EC 9.1 dS m^{-1}). Most significant effect of salinity was found at higher EC 12.8 dS m^{-1} where none of the genotypes produced either filled or unfilled grains.

The genotypes Shua-92, DR-92 and DR-51 had better results with an average less than 15% reduction in number filled gains panicle^{-1} (Fig. 2). Likewise, spikelet fertility decreased significantly when levels of salinity were gradually raised. Genotype exhibited an average 6.4 % reduction in spikelet fertility at T2 (EC 6.0 dS m^{-1}) in all genotypes (Fig. 3b). Genotypes DR-92, Shua-92 and DR-51 has the highest spikelet fertility (≤ 7 PROC) on average. In contrast, more than 20% reduction in spikelet fertility was observed in genotypes DR-92, Shua-92 (Fig. 2).

1000 grain weight (g)

Grain yield significantly reduced with increased salinity levels in all genotypes (Fig.3c).Genotypes Super Basmati, DR-66 and Shahkar were more affected even at lower salinity treatment (EC 6.0 dS m^{-1}) where maximum ≥ 24 PROC was recorded, whereas less affected genotypes were Shua-92, NIA-19A and DR-51 where minimum ≥ 10 PROC was noted (Fig. 2). Similarly at EC 9.1 dS m^{-1}, the maximum more than 40 PROC was recorded in genotypes Super Basmti, NIA-19A and DR-66, whereas minimum < 20PROC was observed in genotypes Shua-92, DR-92 and DR-51.

Table 2. Salt-tolerance traits index (STTI) of aromatic and non-aromatic rice genotypes grown at EC 6.0 (dS m^{-1}).SDW=Shoot dry weight, NTPH=Number of tillers per hill, NFGPP=Number of filled grains per panicle, TGW=Thousand grains weight, SFP=Spikelet fertility percentage, HIP=Harvest index percentage, K$^+$/Na$^+$=Potassium/Sodium ratio, STI=Salt-tolerant index.

Genotypes	SDW	NTPH	NFGPP	TGW	SFP	HIP	K$^+$/Na$^+$	STI	RANK
Shua-92	97.8	87.8	92.7	92.6	97.3	94.7	79.0	91.7	1
DR-92	90.3	90.0	87.6	90.4	98.7	94.6	85.5	91.0	2
DR-67	88.2	94.1	92.1	90.0	97.8	91.6	78.3	90.3	3
DR-51	93.5	80.2	91.2	90.5	97.2	91.3	82.5	89.5	4
IR-6	92.6	83.3	91.5	88.8	98.7	95.2	76.0	89.4	5
Latifee	91.6	90.6	90.7	89.9	95.0	84.9	71.0	87.7	6
NIA-19A	87.9	96.7	83.2	91.2	91.2	90.8	70.5	87.4	7
Shahkar	89.5	81.4	87.8	86.6	96.5	90.6	70.3	86.1	8
DR-66	88.3	89.9	70.7	83.5	80.7	81.7	55.3	78.6	9
Super Basmati	82.5	91.5	64.6	76.0	82.8	82.9	54.0	76.4	10

Shoot and root dry weight

The reduction in vegetative growth at salinity treatments also affected the shoot and root dry mass (Fig. 4 a&b). The study recorded an average 9.04 % reduction in shoot dry mass in all genotypes at T2 (EC 6.0 dS m^{-1}).

The PROC reached average more than 50% at T4 (EC 12.8 dS m^{-1}). Furthermore, at all salinity levels the average least (≤ 24) PROC was noted in genotypes Shua-92, DR-51 and DR-92.

The highest (≤ 35) PROC was noted in genotypes Super Basmati, DR-66 and Shahkar as compared to other genotypes. Likewise, At all salinity levels an average ≤ 23 PROC in root dry mass was recorded in genotypes Shua-92, DR-92 and DR-67, while the average maximum ≤56 PROC was recorded in genotypes Super Basmati, NIA-19A and DR-66 as compared to other genotypes (Fig. 2).

Harvest index %

Salinity affects the harvest index percentage (Fig. 4c).The HI reduced ≤18 % maximum at T3 (EC 9.1 dS m^{-1}). Whereas none of the genotypes withstand at higher salinity T4. Moreover, the poor performance with highest ≥ 29PROC was recorded in genotypes Super Basmati, DR-66 and Latifee at all salinity treatments excluding T4 (EC 12.8 dS m^{-1}).Whereas better performance with least ≤ 9PROC was recorded in genotypes Shua-92, DR-92 and IR-6 as compared to other genotypes (Fig. 2).

Sodium (Na$^+$) content in (straw and grain)

Sodium (Na$^+$) accumulation in straw and grains were higher at higher salinity treatments (Fig. 5 a&b). The accumulation of sodium in straw varied between 11-

27% with various treatment in genotypes whereas the same remained ≤ 13% in grains. The lowest average amount of sodium in straw (≤ 0.13%) and grains (≤ 0.09 %) accumulated in genotypes Shua-92, DR-92 and DR-51. On contrast, the genotypes DR-66 followed by Super Basmati, NIA-19A and Shahkar were the most affected with higher accumulation of average amount of sodium in straw (≤ 0.30%) and grains (≤ 0.19%).

Table 3. Salt-tolerance traits index (STTI) of aromatic and non-aromatic rice genotypes grown at EC 9.1 (dS m^{-1}). SDW=Shoot dry weight, NTPH=Number of tillers per hill, NFGPP=Number of filled grains per panicle, TGW=Thousand grains weight, SFP=Spikelet fertility percentage, HIP=Harvest index percentage, K$^+$/Na$^+$=Potassium/Sodium ratio, STI=Salt-tolerant index.

Genotype	SDW	NTPH	NFGPP	TGW	SFP	HIP	K$^+$/Na$^+$	STI	RANK
DR-92	77.6	83.3	77.9	87.8	92.9	87.8	73.0	82.9	1
Shua-92	92.1	79.3	78.0	89.1	91.3	89.1	61.4	82.9	2
DR-51	78.6	71.7	72.6	79.9	89.5	79.9	65.0	76.7	3
IR-6	82.0	70.0	65.9	78.7	87.8	78.7	52.9	73.7	4
Shahkar	76.7	72.3	61.1	68.5	80.0	68.5	45.5	67.5	5
Latifee	79.9	81.3	62.6	64.4	76.5	64.4	42.1	67.3	6
DR-67	68.8	73.5	58.4	66.9	74.2	66.9	42.9	64.5	7
NIA-19A	79.8	80.0	57.3	55.6	80.1	55.6	42.5	64.4	8
DR-66	69.8	46.0	50.0	59.4	71.6	59.4	36.7	56.1	9
Super Basmati	67.0	62.1	46.3	48.1	74.2	48.0	37.9	54.8	10

Potassium (K$^+$) content in (straw and grain)

In contrast to sodium, the higher salinity levels significantly reduced K$^+$ content in all genotypes (Fig. 5 c&d). The K contents on control treatment were 0.41% in straw which reduced to 0.25% at the highest salinity treatment (12.8 dS m^{-1}).

The same were 0.32% in grains at the highest. On average, Shua-92 followed by DR-92 and DR-51 exhibited high accumulation of K$^+$ in straw (39-41%) and grains (0.30-0.34%) at all salinity levels. Whereas the genotypes NIA-19A followed by DR-66 and Super Basmati were the most affected with the lowest accumulation of K$^+$ (Fig. 2).

K$^+$/Na$^+$ ratio (straw and grain)

Due to the lower accumulation of K$^+$ in plant, the K$^+$/Na$^+$ ratio significantly reduced in straw and grains with increase in salinity level (Fig. 6). The genotypes maintained 3.78 and 3.53 K$^+$/Na$^+$ average ratio at control treatment in straw and grain, respectively. The ratio reduced to 1.14% in straw at the highest salinity level. The highest K$^+$/Na$^+$ ratio (between 3.21 - 4.26 in straw and 3.34 – 4.73 in grain) retained in genotypes DR-92, Shua-92 and DR-51. DR-66 followed by NIA-19A and Super Basmati revealed the minim K$^+$/Na$^+$ ratio as compared to control (Fig. 2).

Salt-tolerance index (STI)

The data regarding aromatic and non-aromatic rice genotypes were evaluated for salt-tolerance index (Table 2). Results showed the highest (91.68, 91.02 and 90.32) STI determined in genotypes Shua-92 followed by DR-92 and DR-67 at salinity level 2 (EC 6.0 dS m^{-1}). Whereas the lowest STI (76.35, 78.58 and 86.09) was observed in genotypes Super Basmati followed by DR-66 and Shahkar. Similarly, the maximum (82.91, 82.89 and 76.73) STI was noted in genotypes DR-92 followed by Shua-92 and DR-51 at salinity level 3 (EC 9.1 dS m^{-1}).While the minimum (54.81, 56.14 and 64.41) were noted in genotypes Super Basmati followed by DR-66 and NIA-19A (Table 3). The remaining genotypes showed medium response against salt-tolerance index.

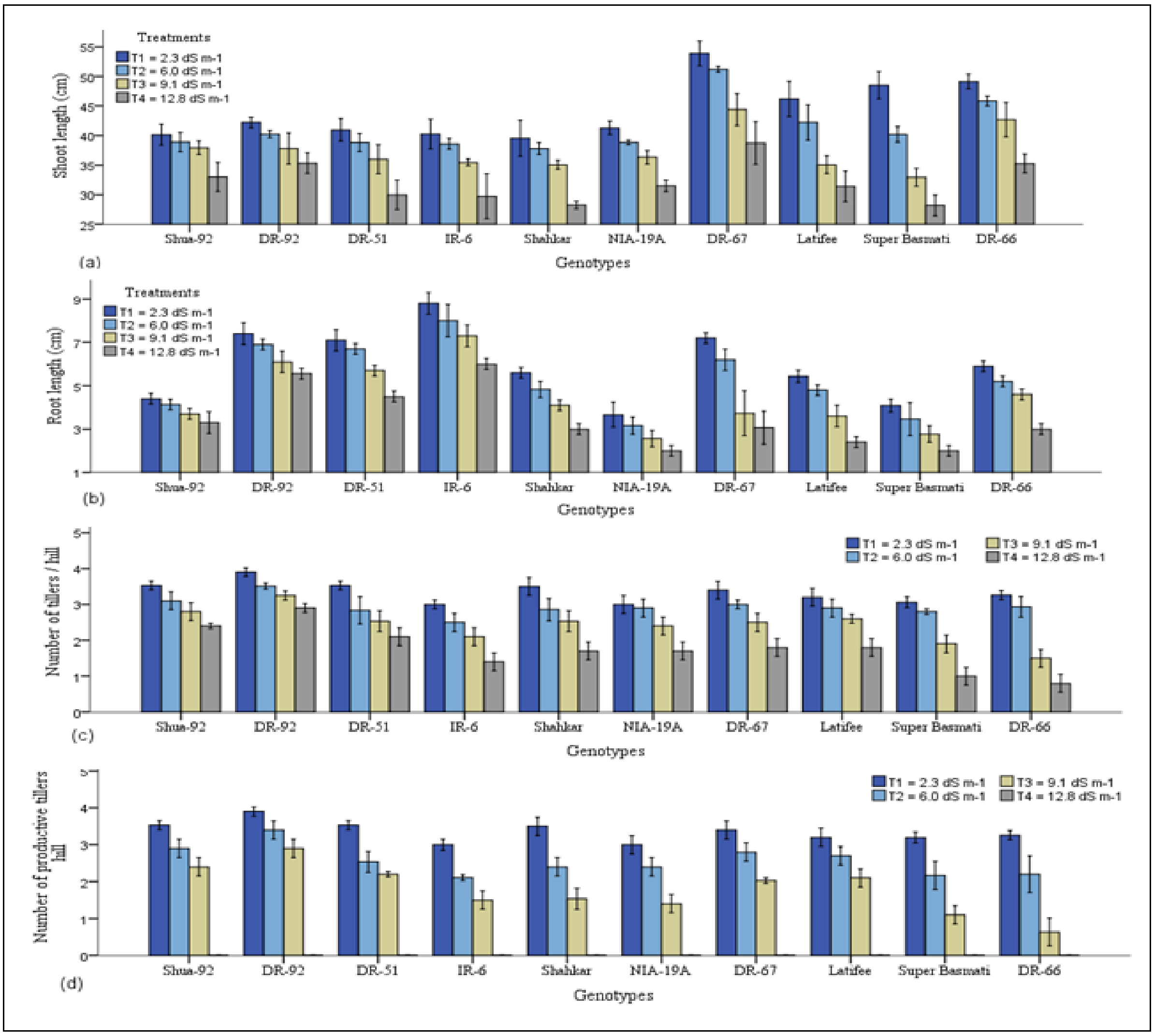


Fig. 1. Effect of salinity on agronomic characters of rice genotypes (a) Shoot height, SE_d = 0.33, 0.05% LSD=0.64, (b) Root length SE_d = 0.06, 0.05% LSD=0.14, (c) Number of tiller/hill^{-1} SE_d = 0.02, 0.05% LSD=0.05, (d) Number of productive tillers/hill^{-1} SE_d = 0.03, 0.05% LSD=0.05. The genotypes did not produce reproductive tillers at salinity T4 (12.8 dSm^{-1}) therefore the 4th bar for the treatment is not visible in the certain parts.

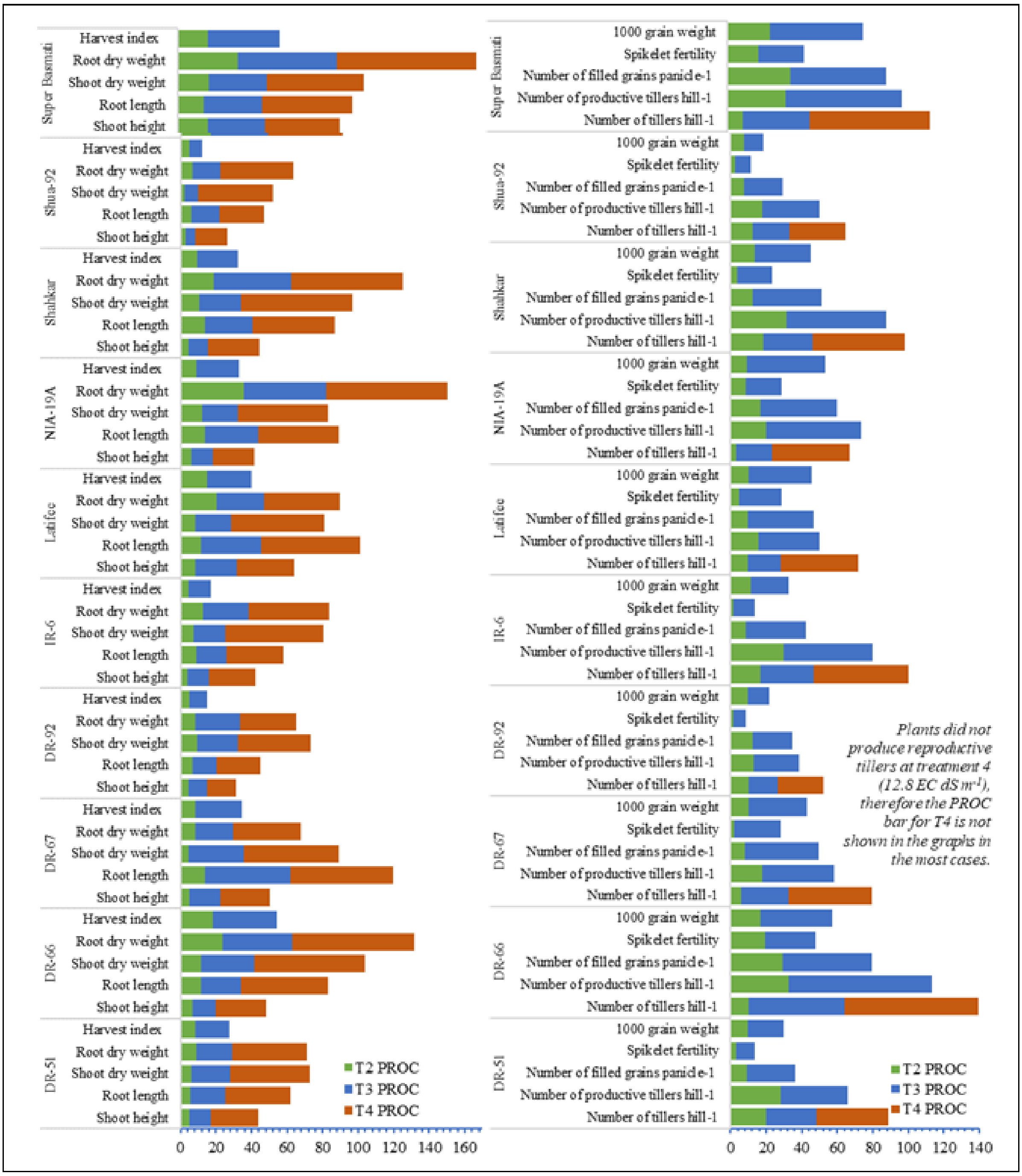
Discussion

Impact of salinity on agro-morphological attributes of rice

The rice plants exposed to salt treatments showed significant inhibitory effects on all the growth and yield attributes. Symptoms of leaf burn, tip burn, leaf sizzling, stunted plant growth, reduction in spikelet fertility and kernel size were evident. However, the extent of symptoms varied among the genotypes. These symptoms were less noticeable in salt tolerant genotypes. This study indicated that, amongst all genotypes, DR-92 and NIA-19A performed well and showed least reduction after check variety Shua-92, both genotypes remained dominant over other genotypes. Whereas salinity exhibited sever effect on genotype Super Basmati which showed highest (>30 %ROC) as compared to other genotypes.

In present study, a significant reduction in shoot and root parts was recorded at increased salinity levels, consequently reducing the dry mass of root and shoot. The roots are the point of contact with saline soil. Therefore it would be a good criterion for the screening of salt-tolerant plant (Khan *et al.*, 2007).

Various studies have reported severe effects of salinity on vegetative characters (Hakim *et al.*, 2010; Abbas *et al.*, 2013; Gupta and Huang, 2014).



Plants did not produce reproductive tillers at treatment 4 (12.8 EC dS m-1), therefore the PROC bar for T4 is not shown in the graphs in the most cases.

Fig. 2. Reduction in vegetative and reproductive characters of rice genotypes. The bars show the percentage reduction over control (PROC) at three salinity treatments. The genotypes did not produce reproductive tillers at salinity T4 (12.8 dSm^{-1}) therefore the 4th bar for the treatment is not visible in the certain parts.

In saline environment reduction in seedling height due the inhibitory effect of sodium is common phenomenon of various species including rice (Abbas *et al.*, 2013; Rajakumar, 2013). An imbalance of salts contents in plants affect the physiological processes in plant body. It alters the conductance of CO_2 through mesophyll and stomata, consequently inhabiting photosynthetic activity due to limitation of CO_2 availability (Flexas *et al.*, 2007).

Salinity expressively affected the yield characteristics of rice genotypes. Tillering in plant reveals a valuable evidence of stress on plants in response to detrimental abiotic conditions (Nobuhiro *et al.*, 2005).Total tiller numbers, productive tillers, number of filled grains and grain weight significantly affected with increased salinity levels in all genotypes including check variety Shua-92 (Fig. 2). A higher salinity level at EC 12.8 dS m^{-1} had severe impact on plants where none of genotypes produced productive tillers. Our findings are close confirmation with the findings of Rozema and Flowers (2008); Mahmood *et al.* (2009); Dawit (2010); Hakim *et al.* (2014).

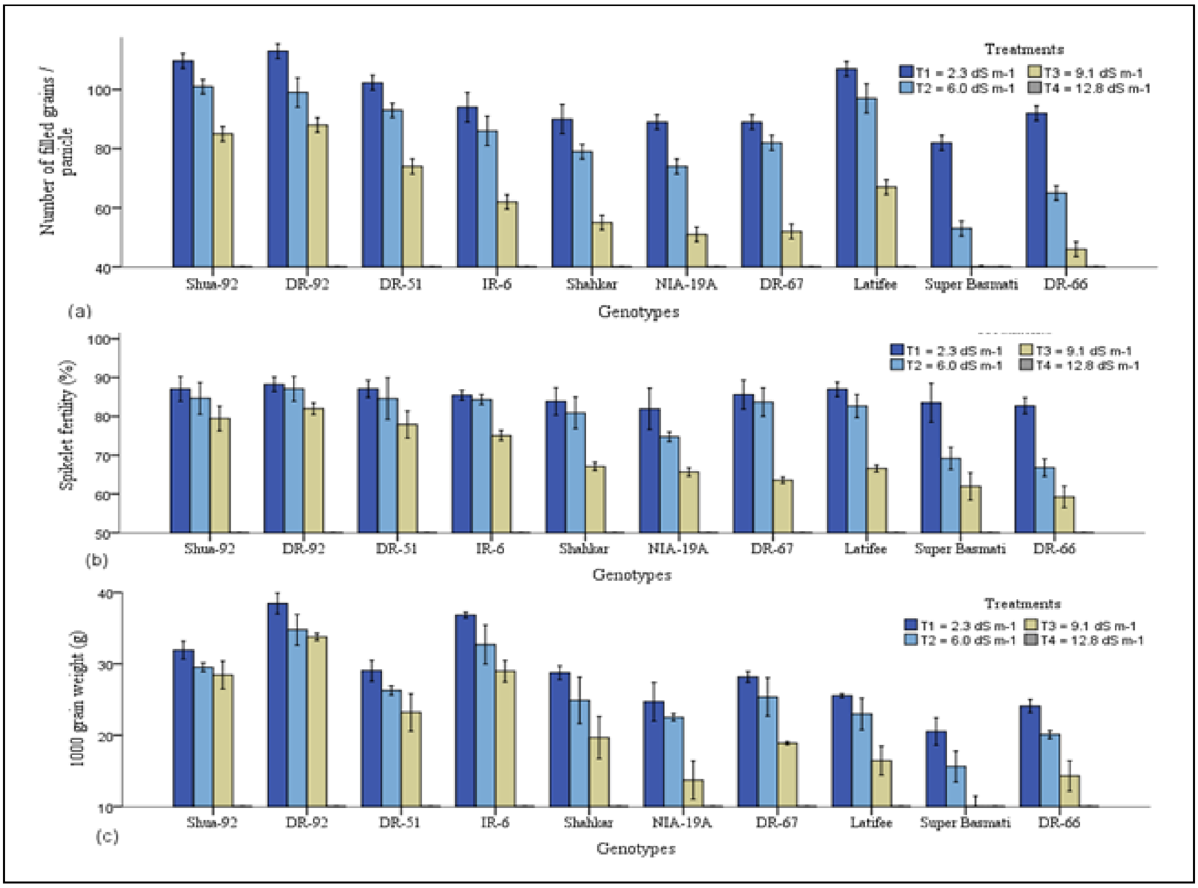


Fig. 3. Effect of salinity on agronomic characters of rice genotypes (a) Number of filled grains/panicle, SE$_d$ = 0.32, 0.05% LSD=0.63, (b) Spikelet fertility, SE$_d$ = 0.31, 0.05% LSD=0.62, (c) 1000 grain weight SE$_d$ = 0.19, 0.05% LSD=0.38. The genotypes did not produce reproductive tillers at salinity T4 (12.8 dSm^{-1}) therefore the 4th bar for the treatment is not visible in the certain parts.

They reported a significant affect at all salinity levels even at lower salinity level EC 4 dS m^{-1} on tillering of plants. Salt stress reduces yield of rice through decreasing number of filled grains panicle^{-1}. The salinity reduces pollen viability in plants. Moreover, it affects the receptivity of pollens on the surface of stigma consequently reducing the seed set in flowers (Abdullah *et al.*, 2001).

Effect of salinity for ion contents in rice

Nevertheless, nutrients are essential for plants to maintain vigor. Their accumulation in excess may become hazardous for plants. Present study demonstrated a higher amount of Na$^+$ accumulation and declined K$^+$ concentration in straw and root at higher salinity treatments. This significantly reduced the K$^+$/Na$^+$ ratio in plant body and grain. The accumulation of Na$^+$ contents in rice roots and shoots were progressively rise with the escalation in salinity stress but the rate of accumulation depends on salt concentration in the soil. A similar impact of salinity has also been reported in other genotypes of rice (Mahmood *et al.*, 2009; Ikram-ul-Haq *et al.*, 2010; Summart *et al.*, 2010). Salt stress creates a nutritional imbalance in plant body by accumulating additional Na$^+$ ions in root and shoot (Djanaguiraman *et al.*, 2006; Hakim *et al.*, 2014). K$^+$ compete with other elements present in soil for absorption in plant body

(Babourina *et al.*, 2000).

Ionic presence in the plants provides an imperious evidence about toxicities in plant body. Ionic disproportion generally affects the physiological processes in the plant body (Rahman *et al.*, 2008). The K^+/Na^+ ratio preserves metabolism and regulate the growth and development in plant body under saline environment (Pardo *et al.*, 2006).

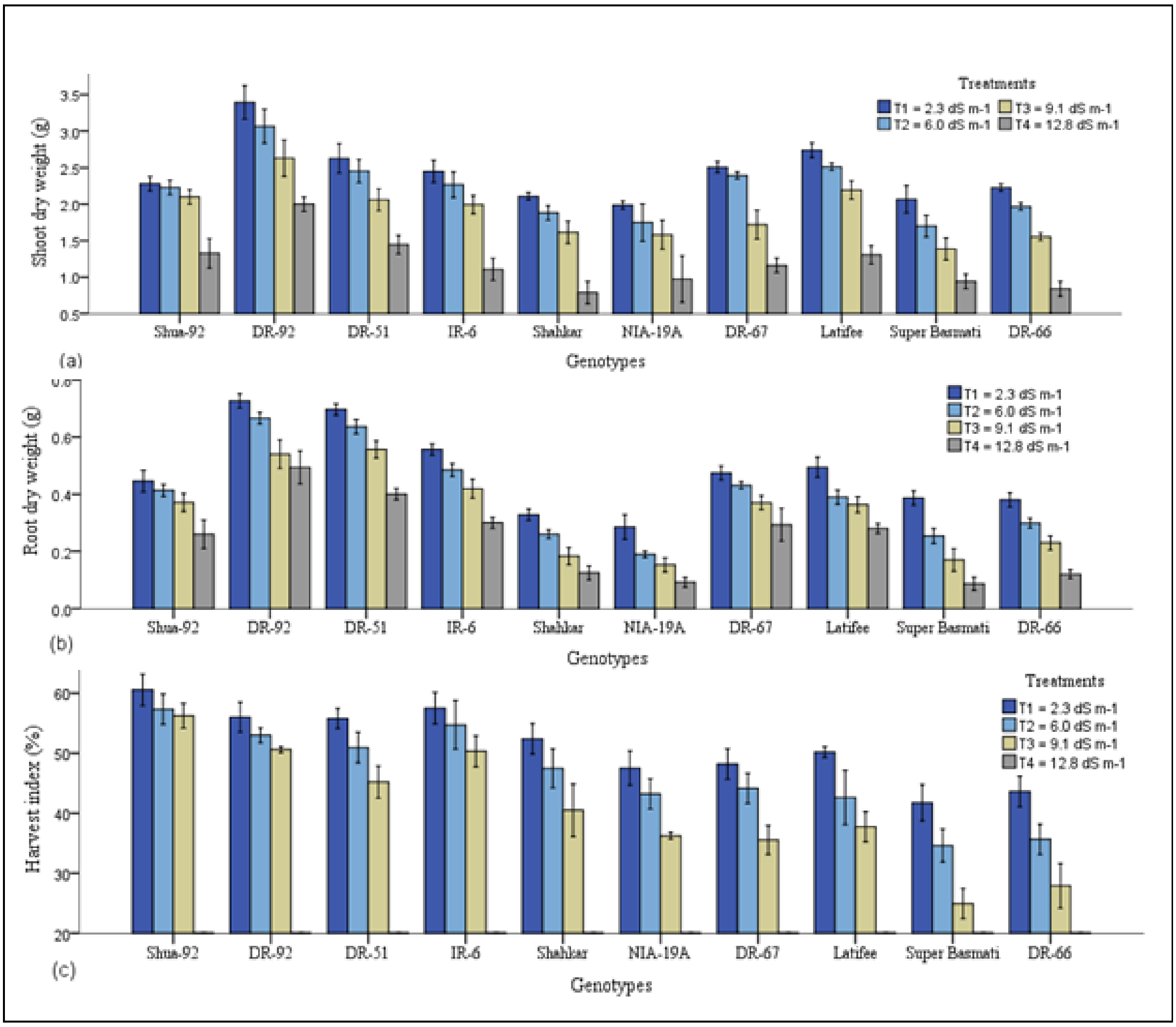


Fig. 4. Effect of salinity on agronomic characters of rice genotypes (a) Shoot dry weight, SE_d = 0.03, 0.05% LSD=0.05, (b) Root dry weight, SE_d = 4.84, 0.05% LSD=9.64, (c) Harvest index, SE_d = 0.28, 0.05% LSD=0.56. The genotypes did not produce reproductive tillers at salinity T4 (12.8 dSm^{-1}) therefore the 4th bar for the treatment is not visible in the certain parts.

Salt stress significantly decreased K^+/Na^+ ratio in current study. Kiberia *et al.* (2017) also recorded a similar trend in reduction of K^+/Na^+ ratio in vegetative parts of plant with increased salinity concentrations. Salt-tolerant plant species have adopted to maintain accreted K^+/Na^+ ratio. It is believed to be an appropriate attribute which maintains the ion equilibrium and high biomass under saline environment (Moradi and Ismail, 2007; Mardani *et al.*, 2014; Reddy *et al.*, 2014).

Salt-tolerance indices (STI)

Substantial difference among tested aromatic and non-aromatic rice genotypes was recorded for vegetative and yield attributes under saline conditions. STI is a useful tool to calculate the sensitivity of plants against salinity stress.

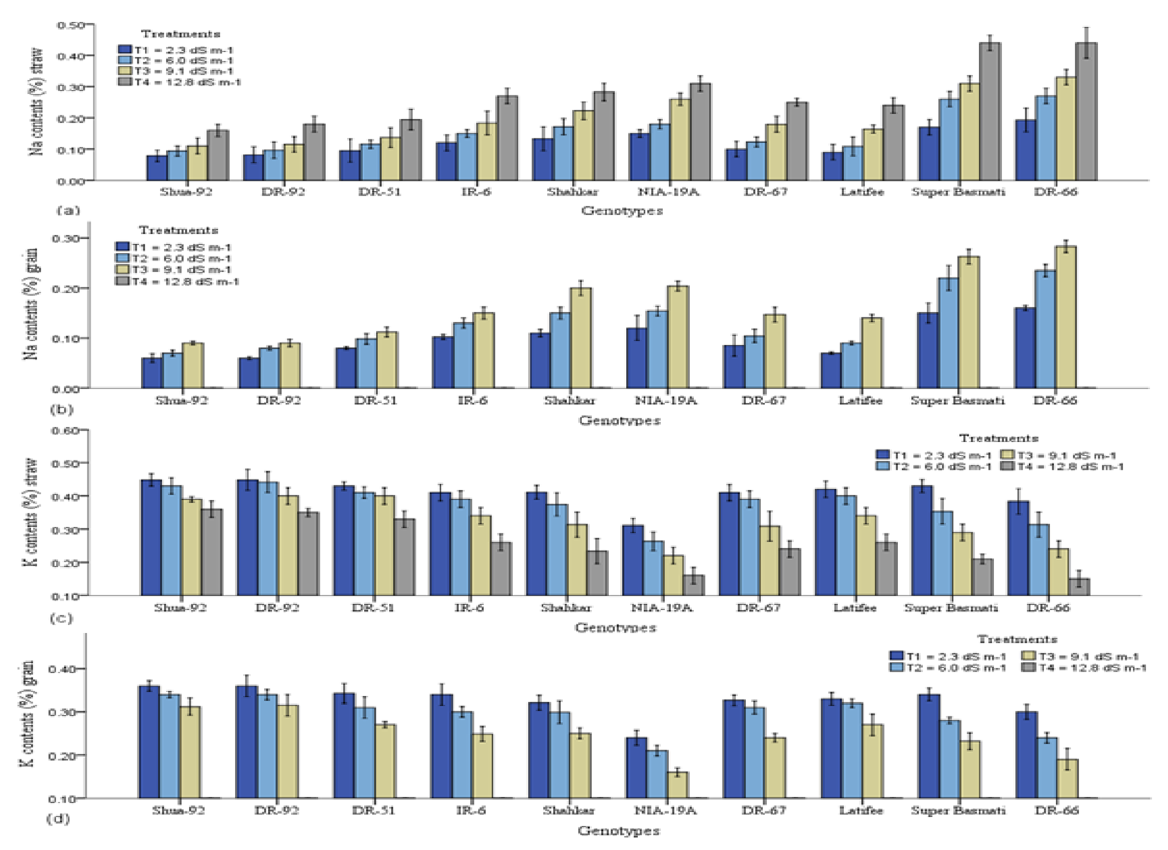


Fig. 5. Effect of salinity treatments on accumulation in plant body (a) Na^+ contents in straw, $SE_d = 2.72$, 0.05% LSD = 5.41, (b) Na^+ contents in grain, $SE_d = 1.27$, 0.05% LSD = 2.52, (c) K^+ contents in straw, $SE_d = 2.78$, 0.05% LSD = 5.54, (d) K^+ contents in grain, $SE_d = 1.81$, 0.05% LSD = 3.62. The genotypes did not produce reproductive tillers at salinity T4 (12.8 dSm^{-1}) therefore the 4th bar for the treatment is not visible in the certain.

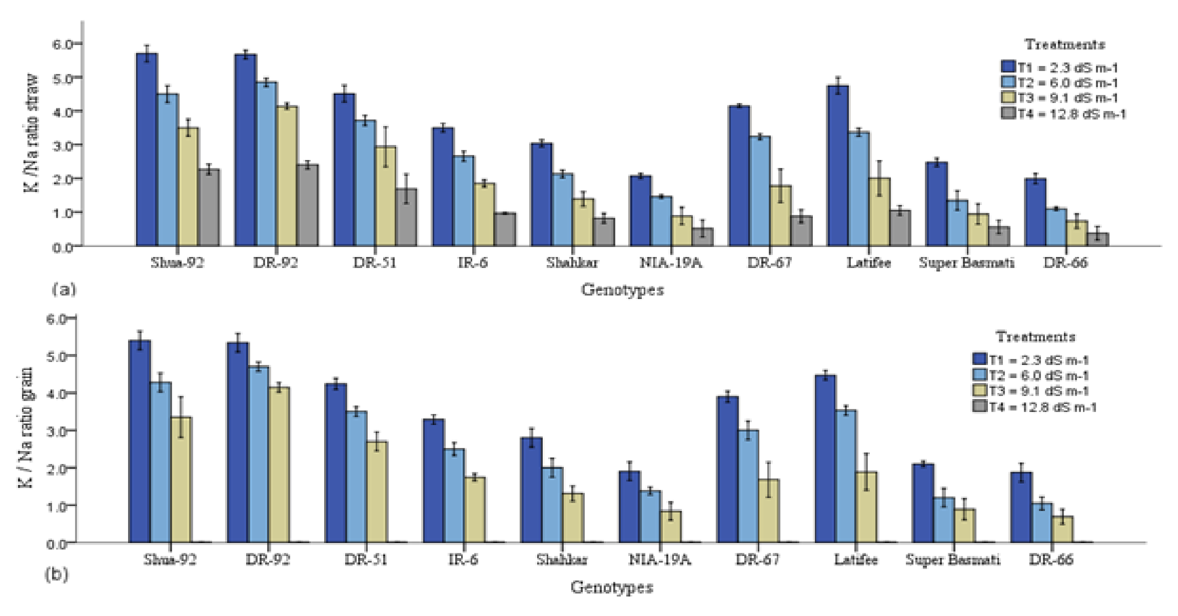


Fig. 6. Effect of salinity treatments on K^+/Na^+ ratio in genotypes (a) K^+/Na^+ ratio in straw, $SE_d = 0.02$, 0.05% LSD = 0.05, and (b) K^+/Na^+ ratio in grain, $SE_d = 0.03$, 0.05% LSD = 0.05. The genotypes did not produce reproductive tillers at salinity T4 (12.8 dSm^{-1}) therefore the 4th bar for the treatment is not visible in the certain parts.

The index was determined on the seven important morpho-physiological attributes (Table 2 & 3). The plant data indicated that three rice genotypes (Shua-92, DR-92 and DR-67) were revealed a higher tolerance at EC 6.0 dS m^{-1}. Their tolerance index was closely associated with accretion of K^+ and raised K^+/ Na^+ ratio in plant body. A similar trend was followed at treatment 3 (EC 9.1 dS m^{-1}), where high (>82) STI score was documented in genotypes Shua-92 followed by DR-92 and DR-51, respectively. The higher values of salt-tolerance index (STI) indicate superiority of genotypes having higher yield potential and salt-tolerance as well, thus making it a more desirable and helpful criterion for screening salt tolerant plants.

Conclusion

Salinity adversely affects growth, yield and ion contents. Encouraging reduction regarding all agro-morphological traits and ion contents was displayed at EC 6.0 and at EC 9.1 dS m^{-1}. The plant could not with stand EC 12.8 dSm$_{-}{}^{1}$ and did not produce any reproductive tillers. Results revealed that aromatic rice genotypes are more salt-tolerant as compared to non-aromatic genotypes against saline environment. Genotypes Shua-92 followed by DR-92 and DR-51 showed less PROC vegetative and yield traits hence categorized as salt-tolerant, whereas genotypes Super Basmati and DR-66 were more affected for same traits against salinity and classified as salt-sensitive rice genotypes.

The salt-tolerant genotypes sustained growth and development by reducing Na^+ and accruing K^+ ions in the body. The genotypes maintained a high K^+/Na^+ ratio as compared to sensitive genotypes in this study.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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