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THE EFFECT OF SALINITY ON GROWTH, ION ACCUMULATION AND YIELD OF RICE VARIETIES

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ABSTRACT

The experiment was conducted to assess the responses of salinity on the growth, nutrient accumulation and yield of rice genotypes. Five Malaysian genotypes (MR33, MR52, MR211, MR232 and MR219), two salt sensitive (BRRI dhan 29 and IR20) and one salt tolerant genotypes (Pokkali) were evaluated in four levels of salinity. Two factors complete randomized design (CRD) was used with four replications. Dry weight of root, shoot and yield significantly decreased with the increase of salinity levels, while MR232 and MR211 were less affected. Na^+ ions accumulations increased in the root and shoot with the increase of salinity, while the lowest accumulation was in MR211. Na^+/ K^+ratio sharply increased in the root with increasing the salinity. Whereas, Ca^{++}/Na^+ and Mg^{++}/Ca^{++} ratio showed decreasing trend with increasing salinity level. The maximum amount of nitrogen and phosphorous accumulation was observed in the shoot of MR211, while Na^+ in BRRI dhan29, K^+ in Pokkali. The highest accumulation of Na^+ and K^+ observed in the root of MR219. The maximum Ca^{++} and Mg^{++} were found in MR33 and MR211, respectively. Considering all, genotypes MR211 andMR232 were found to be relatively tolerant to salt than the other genotypes.

Keywords: Salinity, Rice, yield, mineral nutrients, Malaysia.

INTRODUCTION

Rice is the grain that has shaped the cultures, diets and economies of billions of Asians. It is a staple food to feed more than 3 billion people and to provide 50- 80% daily calorie intake (Khush, 2005). People get 66% calorie from rice in Malaysia. The Malaysian rice production is lower than its consumption and thus resulting in rice importation which gave the rice self-sufficiency of about 70% for many years (Bergama, 2008). Khan and Abdullah (2003) reported that rice crop identified as salt-susceptible both in seedling and reproductive stages. Salinity is a major abiotic stress for all stages of ricedue to anthropogenic contributionsto global warming, the rate of sea-level rise is expected to increase and possess dramatic effect on rice production especially in coastal areas (Hakim *et al.*, 2013). Increasing global warming increases the average temperatures which might cause the ‘melting’ of polar ice caps, resulting from the rise-up of the sea-water level gains (2.8 – 3.1 mm/year), and thus causing salty water intrusion into the coastal areas. Selamat and Ismail (2008) reported that fifty per cent yield is being lost of the salt-sensitive rice genotypes due to salinity. In arid and semi-arid regions, limited water and hot dry climates frequently increase salinity levels that limit or prevent crop production (Michael *et al.*, 2004). The major inhibitory effect of salinity on plant growth has been attributed to: 1) osmotic effect 2) ion toxicity 3) nutritional imbalance leading to reduction in photosynthetic activities and other physiological disorders (Ali *et al.*, 2004). Na^+ and Cl^- derived from NaCl are well known as the toxic ions to damage the plant cells in both ionic and osmotic levels. Plant growth and development are directly inhibited, leading to low yield prior to plant death (Mansour and Salama, 2004; Chinnusamy *et al.*, 2005).

In normal conditions, the Na^+ concentration in the cytoplasm of plant cells was low in comparison to the K^+ content, frequently 10^{-2} versus 10^{-1} and even in conditions of toxicity, most of the cellular Na^+ content was confined into the vacuole (Apse *et al.*, 1999). Salt tolerance in plants is generally associated with low uptake and accumulation of Na^+, which is mediated through the control of influx and/ or by active efflux from the cytoplasm to the vacuoles and also back to the growth medium (Jacoby, 1999). Energy-dependent transport of Na^+ and Cl^- into the apoplast and vacuole can occur along the H^+ electrochemical potential gradients generated across the plasma membrane and tonoplast (Hasegawa *et al.*, 2000). Increasing of Na and Cl ion and decreasing of potassium (K), phosphorus (P), nitrogen (N), calcium (Ca), and magnesium (Mg) in different tissues of crop plant with increasing NaCl concentration in growing medium (El-Sayed Emtithal *et al*., 1996). Therefore, researchers and policy makers must invent ways for the efficient utilization of the salinity prone areas. The selection of salt tolerant rice variety might be the best approach to bring the salinity susceptible areas under rice cultivation (Shereen *et al*., 2005; Ali *et al*., 2004). Although much research have been done for understanding the influences of saline habitats on seed germination, growth, reproduction and population dynamics of crop plants (Khan *et al*., 2002) but report on total dry matter accumulation, mineral nutrients and yield of coarse rice under saline environments is still scanty. Therefore, the study was undertaken todetermine dry matter accumulation, nutrient concentration and yield of rice under varied salinity stress.

MATERIALS AND METHODS

This study was conducted in pot (33 diameter and 23 cm depth) at the glasshouse, Universiti Putra Malaysia during October 2009 to December 2010. The experiment was laid out in a Complete Randomized Design (CRD) with four replications. Among the selected eight rice varieties chosen, five were Malaysian (e.g. MR33, MR52, MR211, MR232 and MR219) and three were exotic (BRRI dhan29, IR20 and Pokkali) origins. BRRI dhan 29 and IR20 were salt sensitive and were used as negative control. On the other hand, Pokkali was a well-known salt resistant cultivar and was used as a positive control.

Soil for this experiment was collected from a rice field in Tanjung Karang, Selangor, Malaysia. The experimental soil was loamy clay in texture (18.3% sand, 43.7% silt, 38% clay) and acidic in reaction (pH 6.1) with 1.02% organic carbon, EC-1.56 dSm^{-1}, soil nutrient status was 0.19% total N, 11.12 ppm available P, 122 ppm available K, 620 ppm Ca, 290 ppm, 7.63 ppm S and 0.96 ppm Zn.Ten kg of clean soil was put in each pot. The pots were kept in the glass house and the average temperature and humidity of the glass house were 33 degree Celsius and 72%, respectively. The pot soil was fertilized with urea, triple supper phosphate (TSP), murate of potash (MOP) and gypsum as the sources of N, P, K and S at the rates of 170 kg N, 80 kg P_2O_5, 150 kg K_2O and 20 kg S ha^{-1}, respectively. The whole amount of TSP, MOP and gypsum were applied in the pot before final preparation. Thereafter, the soil in the pots was saturated with water. Five week-old rice seedlings were transplanted at the rate of three seedlings per pot. Two weeks after the transplanting, the salt solutions were applied in each pot as per treatment. To avoid osmotic shock, salt solutions were added in three equal installments on alternate days until the expected conductivity was reached. Salt solutions were collected every 24 hours from each pot and their electric conductivities were measured with a conductivity meter. Conductivity of the soil was compared with the conductivity meter (model: EC Testr, Spectrum Technologies, Inc.) and the necessary adjustments were made. One-third of urea was applied at 15 days after transplanting (DAT) and the remaining 2/3rd was top dressed in two equal installments at 45 and 75 DAT, respectively. Weeds grown in the pots were manually removed from time to time. Watering was done in each pot when needed to maintain the required soil moisture and salt concentrations. The root and shoot weights were recorded at harvest after oven dried at 65^0 C for 72 hours. The grain yield was harvested and adjusted to 12% moisture content and grain yield hill^{-1} was also recorded.

Analysis of different mineral constituents: After maturity, the harvested rice plants were separated into roots and shoots and rinsed repeatedly with tap water and finally with distilled water and then dried in an oven at 70^o C to obtain constant weight. Oven-dried samples were ground in a Wiley Hammer Mill, passed through 40 mesh screens, mixed well and stored in plastic vials. Rice plant samples were analyzed to determine the amount of N, P, Na, K, Ca, Mg, Mn and Zn content both in shoot and root. All elemental analyses were conducted on acid digested material through micro-Kjeldahl digestion system (Thomas *et al*., 1967) and were measured by Atomic Absorption Spectrophotometer (AAS). The Na/K ratio was calculated from concentrations of Na and K, Ca/Na ratio from the concentration of Ca and Na and Mg/Ca ratio from Mg and Ca concentration in the plant tissues.

Data analyses: Statistical analysis of data in this experiment was performed using Analysis of Variance (ANOVA) and the significance of variation between means was tested by Least Significant Difference (LSD) using the computerized Statistical Analysis System Software (SAS version 9.0).

RESULTS

Effect of salinity on shoot and root dry weight: The result of salt effect on shoot and root dry weight is presented in Table 5. Shoot dry weights (SDW) were varied significantly due to different salt concentrations. At 4 dS m^{-1}, Pokkali produced highest shoot dry weight (21.2 g hill^{-1}) which was significantly higher than other varieties followed by MR232 (19.4 g hill^{-1}) and MR219 (18.1 g hill^{-1}). The lowest SDW was found in BRRI dhan 29 (14.6 g hill^{-1}). Pokkali also produced highest SDW (15.5 g hill) followed by MR232 (14.6 g hill^{-1}) and the minimum was in IR20 (8.10 g hill^{-1}) at 8 dS m^{-1}. Among salinity levels, the highest SDW (21.2 g hill^{-1}) was recorded in 4 dS m^{-1} followed by 8 dS m^{-1} (15.5 g hill^{-1}). The lowest SDW (3.9 g hill^{-1}) was obtained in 12 dS m^{-1}.

It was observed that SDW gradually decreased with increase in salinity level. In case of root dry weight (RDW), the highest value (2.63 g hill^{-1}) was found in MR232 at 4 dS m^{-1} followed by MR33 (2.28 g hill^{-1}) and the lowest (1.56 g hill^{-1}) was in IR20. At 8 dS m^{-1}, genotype MR232 also showed highest (1.19 g hill-1) and the lowest (0.86 h hill^{-1}) was in BRRI dhan29. Among the different salinity levels, the highest (2.63 g hill^{-1}), RDW was observed in 4dS m^{-1} and the lowest (0.86) was in 12dS m^{-1}. It was also found that RDW decreased with the increase of salinity level.

Effect of salinity on ions concentrations in shoot and root: Ion concentrations in shoot and root were significantly influenced by different salinity levels.

N ion concentrations: In shoot, nitrogen ion concentration ranged from 1.93 to 2.20%, having the highest (2.20) in the control followed by 12dS m^{-1} (2.11) and the minimum (1.93) was in 8dS m^{-1}(Table 1). In the case of root, N ion was also significantly varied. The highest N ion (1.24) was found in the control which was significantly highest and followed by 4 dS m^{-1} (1.11). The lowest N ion (0.93) was in 12 dS m^{-1}. It was observed that N ion deceased in the root with the increase in salinity levels.

Phosphorous concentration: In shoot, the highest phosphorous concentration (0.47) was found in the control (non saline condition) followed by 4 dS m^{-1} (0.37) and the lowest (0.22) was in 12 dS m^{-1}. In higher salinity level (12 dS m^{-1}) showed maximum phosphorous accumulation (0.27) in the root which was significantly higher than the other salinity levels and the minimum accumulation (0.10) was in the control (Table 1). It was observed that phosphorous ion accumulation decreased in the shoot with the increase in salinity but reverse was true in case of root.

Na^+ ion accumulation: Highest sodium accumulation in root and shoot was found at 12dS m^{-1} followed by 8 dS m^{-1}(3.65 % in root and 2.48% in shoot). The lowest (0.54 and 0.76% for shoot and root, respectively) absorption was in the control. It was found that Na accumulation in the shoot and root increased with the increase in salinity in the growth media (Table1).

Potassium and Calcium ions accumulation: Potassium and calcium ions accumulation were significantly influenced by the root and shoot of rice. In shoot, the highest potassium and calcium ion accumulations were found (2.76 %K and 0.78%Ca) in the control followed by 4dS m^{-1} (2.33% K and 0.67% Ca) and the lowest was noted in 12 dS m^{-1} (1.28% K and 0.31% Ca) (Table 1). Similar trended was also followed by the root in the case of K and Ca accumulation. It was observed that K^+ and Ca^{++} ions accumulation decreased with the increase of salinity levels. It was also found the K^+ and Ca^{++} ions accumulation were higher is the shoots than the roots.

Magnesium ion accumulation: Magnesium ion accumulation was also followed by the same trend like potassium and calcium. The control showed the highest accumulation (0.63 and 0.43% for shoot and root, respectively) and the minimum (0.34 and 0.15 for shoot and root, respectively) was in 12 dS m^{-1}(Table 1).

Yield: Rice yield was significantly varied due to different salinity levels. It ranged from 0.57 to 14.45 g hill^{-1} having the highest (14.45 g hill^{-1}) in the control which was significantly higher than the different salinity levels. The second highest yield (9.57 g hill^{-1}) was found in 4dS m^{-1}. The minimum rice yield (0.57 g hill^{-1}) was recorded in 12 dS m^{-1}. It was observed that rice yield drastically decreased with the increasing the salinity levels.

Effects of rice genotypes on ions accumulation by the root and shoot

Nitrogen and phosphorous ions accumulation: Phosphorous and potassium ions accumulation were significantly varied among the genotypes. In shoot, MR211 showed highest accumulation (2.86% N and 0.41 %P). IR20 showed second highest N accumulation (2.30%) and the minimum was in MR52 (1.80%). The minimum P ion accumulation (0.29%) was noted in MR 33. In the case of root, IR20 showed highest N ion accumulation (1.22%) followed by MR33 (1.19%) and the lowest (0.91%) was in Pokkali. The highest P ion accumulation (0.24%) was found in MR 33 and the minimum (0.11%) was in MR 211 and MR 232.

Sodium and Potassium ions accumulation: In shoot, BRRI dan29 showed highest Na^+ion accumulation followed by MR219 and IR20. The minimum Na^+ ion accumulation (1.60%) was in Pokkali whereas; Pokkali showed highest K^+ ion (2.83%) accumulation by the shoot and the lowest (1.63%) was in IR20 and BRRI dhan29. In the case of root, the highest Na^+ and K^+ ion accumulation (3.46% and 0.64%) were found in MR 219 followed by MR33 (2.97 and 0.57 % for Na^+ and K^+, respectively). The minimum K^+ and Na^+ ions were noted in MR232 and Pokkali, respectively.

Calcium and Magnesium ions concentration: MR232 showed highest Ca^{++} ions (0.69) and the minimum (0.55%) was in MR33 while MR211 showed highest Mg^{++} ions accumulation (0.51%). The minimum Mg^{++} ion accumulation (0.45%) was in BRRI dan 29. In root, the highest Ca^{++} ion accumulation (0.56%) was observed in MR 211 which was identical to MR 52 and MR 232. The lowest Ca^{++} ion was noted in IR 20. BRRI dan29 showed the highest Mg^{++} ion accumulation (0.33) which was significantly higher than the other genotypes and the minimum (0.24) was in IR 20.

Yield: Rice yield varied significantly among the genotypes. The genotype MR211 produced highest yield (8.80 g hill^{-1}) followed by MR 232 (8.61) and MR 52 (8.18). The lowest rice yield (4.68) was obtained in IR20 which is susceptible to salinity.

Interaction effect of genotypes and salinity levels on ions accumulation in rice

Nitrogen accumulation: Nitrogen ion accumulation in rice root and shoot significantly influenced due to interaction of genotypes and salinity. It shoot, MR211 genotype showed highest concentration (3.38%) in the control followed by MR211 at 4 dS m^{-1}(2.99%). MR211 showed highest accumulation at different salinity levels in comparison to other genotypes. However, Genotypes IR20, MR33, MR219 and BRRI dhan29 showed maximum nitrogen accumulation at highest salinity level whereas, MR232 showed minimum nitrogen accumulation at all salinity levels.

In root, the genotypes, BRRI dhan29, MR232, MR219, MR33 and IR20 producedhigher nitrogen accumulation then the other genotypes. In control, IR20 showed highest accumulation (1.55%) followed by MR33 (1.41%). Nitrogen accumulation in the root decreased with the increase in salinity level. It was observed that N ion accumulation in the shoot was higher than the root.

Phosphorous accumulation: Phosphorous ion absorption by the root and shoot significantly varied due to interaction effect of genotypes and salinity levels. In control, MR211 showed maximum accumulation (0.59%) followed by BRRI dhan29 (0.56%). The lowest P ion accumulation was found in IR20 at 12dS m$^{-1.}$ It was noted that P accumulation decreased with the increasing the salinity level. In root, the highest phosphorous (0.47%) accumulation was found in BRRI dhan29 at 12dS m^{-1}. MR211 showed lowest accumulation in the control (0.07%). It was also observed that P accumulation in the root increased with the increasing the salinity level.

Na$^+$ ion accommodation: Na$^+$ ion accumulation was also significantly varied among different genotypes and salinity levels. IR20 showed highest Na$^+$ ion accumulation at 12dS m^{-1}in the shoot (4.33%) followed by BRRI dhan29 (4.19%) and MR219 (4.14%) at 12 dS m^{-1}. It was found that Na$^+$ ion accumulation increased with the increasingthe salinity level. Among the genotypes BRRI dhan29 showed highest accumulation in different salinity levels. (Table3).

In root, BRRI dhan29 also showed maximum Na$^+$ ion accumulation at 12 dS m^{-1}(5.39%) which was followed by MR33. The minimum accumulation was found in Pokkali at the control condition (0.64%). It was also observed that Na$^+$ ion accumulation increased in root with the increasing the salinity levels. BRRI dhan29 also produced highest accumulation at different salinity levels.

Potassium ion accumulation: Potassium ion accumulation in the root and shoot was also influenced by the rice genotypes and salinity (Table 3). In shoot, it ranged from 0.58 to 3.74%, having the highest (3.74%) in Pokkali at the control followed by MR 211(3.41%). The lowest accumulation was receded in IR20 at the control. It was observed that K$^+$ ion accumulation decreased with the increasing salinity level. Genotypes Pokkali and MR211 produced highest K$^+$ ion accumulation than the other genotypes in different salinity levels. In root, the highest K$^+$accumulation were found in BRRI dhan29 at the control followed by MR23. It was found that the K$^+$ ion accumulation was lowest in the root than the shoot. Moreover, K$^+$ accumulation in the root decreased with the increased in salinity levels.

Calcium ion accumulation: Calcium ion accumulation was also varied significantly among different treatments. In shoot, Ca^{++} ion accumulation decreased with the increasingthe salinity but revise is true in case of root. In shoot and root, all genotypes showed similar Ca^{++} ion accumulation in the respective salinity levels. BRRI dhan29 showed highest Ca^{++} ion accumulation in the root at 1212 dS m^{-1} (followed by IR20 (Table 4).

Magnesium ion accumulation: Magnesium ion concentration was also varied in the root and shoot due to genotypes and salinity. It was found that Mg^{++} ion concentration decreased in the shoot and root with the increasing the salinity levels. MR211 showed highest Mg^{++} ion accumulation in the shoot at the control followed by BRRI dhan29 (Table 4).

Yield: Yield of rice was significantly influenced by the genotypes and salinity. The highest yield (16.97 g hill^{-1}) was recorded in MR52 at the control condition. Rice yield drastically reduced with the increasing the salinity levels. Genotypes IR20, MR33, MR52 and MR219 failed to produce rice grain at 12 dS m^{-1}. Moreover genotypes IR20 and BRRI dhan29 also did not able to initiate rice panicle at 8 dS m^{-1}and this might be due to these two genotypes are very much susceptible to high level of salinity.

Salts salinity relationships: The Relationship between different levels of salinity and measured traits of rice plant were showed in figure 1 and 2. In the figure, the sodium accumulation were showed gradually higher with increasing the salinity level but the increasing rate was more higher in root than shoot and their changed polynomially (R^2=0.998, 0.999) under salinity stress. However, the potassium was showed decreased in both root and shoot with increasing the salinity levels and the potassium decreased polynomially with R^2 =0.990 and 0.999 respectively (Fig. 1).

Sodium-potassium ratio was influenced by the different levels of salinity in both shoot and root and the ratios increased polynomially with their relationship

99%. But the increasing rate was higher in root than shoot (Fig. 2). However, the calcium-sodium ratio in shoot were decreased polynomially with R^2=0.9831 while in root at lower salinity levels (up to 8 dS m^{-1}) were slightly decreased but at higher salinity level (12 dS m^{-1}) increased polynomially with R^2=0.9752. The magnesium-calcium ratio was showed also changed due to the effect of different salinity levels. The magnesium-calcium ratio in shoot were slightly decreased upto the salinity levels of 8 dS m^{-1} but at 12 dS m^{-1} increased greater than control while in root gradually decreased polynomially with R^2= 0.966 and 0.999, respectively (Fig. 2).

Correlation matrix: Correlation matrix showed that the eleven mineral characters of rice with in both shoot and root at different salinity levels are presented in table 6. The correlation coefficient between nitrogen and all parameters showed not significant in both the shoot and root except sodium in root. The correlation coefficient in between phosphorus and potassium were showed statistically positively significant at 5% level of significance in shoot and also 1% level in root. Similar trend followed phosphorus with calcium, Na: K, Mg: Ca. Potassium was found to have highly significant and positive correlation with Ca (0.99^{**}), Mg (0.99^{**}), Mn (0.99^{**}) and Mg:Ca ratio in the root. In shoot, K also showed strong correlation with P, Na, Ca, Mg and Mn while it was significantly (≤0.05) correlated with Zn and Na:K.

The correlation of sodium with maximum parameters showed negatively correlation at 5% and 1% level of significance but with phosphorus and potassium appeared positively correlated. Zinc and phosphorus showed positively significant (<0.05). Similar trend followed with potassium, calcium, magnesium, manganese but Na: K, Ca: Na and Mg: Ca was showed statistically non significance in shoot, but the correlation in root was showed statistically not significant in all parameters except sodium. Na: K with potassium, sodium, magnesium, manganese, Ca: Na and Mg: Ca resulted positively correlated at 5% level of significance in shoot while in root nitrogen, potassium, sodium, calcium and magnesium showed not significant but with phosphorus manganese Mg: Ca showed highly significant at 1% level of significance and with Ca: Na appeared 5% level significant. Correlation between Ca: Na and maximum parameters were showed statistically not significant in shoot except Na: K and Mg: Ca. But in root similar trend except Manganese. Correlation of magnesium and calcium ratio with maximum tested mineral elements exposed statistically not significant in shoot but highly significant at 1% level of significance in root (Table 6).

Table 1. The main effect of salinity on mineral nutrients and yields of eight rice varieties.

Treatments	Nitrogen		Phosphorus		Sodium		Potassium		Calcium		Magnesium		Yield (g $hill^{-1}$)
Salinity levels (dSm^{-1})	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	
0	2.20^{a}	1.24^{a}	0.47^{a}	0.10^{d}	0.54^{d}	0.76^{d}	2.76^{a}	0.77^{a}	0.78^{a}	0.61^{a}	0.63^{a}	0.43^{a}	14.45^{a}
4	2.02^{c}	1.11^{b}	0.37^{b}	0.13^{c}	1.45^{c}	2.27^{c}	2.33^{b}	0.54^{b}	0.67^{b}	0.55^{b}	0.52^{b}	0.32^{b}	9.57^{b}
8	1.93^{d}	1.05^{c}	0.28^{c}	0.18^{b}	2.48^{b}	3.65^{b}	1.89^{c}	0.36^{c}	0.57^{c}	0.45^{c}	0.44^{c}	0.22^{c}	3.51^{c}
12	2.11^{b}	0.93^{d}	0.22^{d}	0.27^{a}	3.67^{a}	4.37^{a}	1.28^{d}	0.31^{d}	041^{d}	0.32^{d}	0.34^{d}	0.15^{d}	0.57^{d}
F-test	**	**	**	**	**	**	**	**	**	**	**	**	**
Variety													
IR20	2.30^{b}	1.22^{a}	0.28^{d}	0.19^{c}	2.25^{ab}	2.43^{de}	1.63^{d}	0.42^{d}	0.58^{bcd}	0.39^{d}	0.48^{ab}	0.24^{c}	4.68^{e}
Pokkali	2.08^{c}	0.91^{d}	0.32^{bc}	0.13^{e}	1.60^{e}	2.67^{cd}	2.83^{a}	0.34^{e}	0.61^{bc}	0.48^{c}	0.48^{ab}	0.29^{b}	7.39 ^{c}
MR33	1.82^{d}	1.19^{ab}	0.29^{cd}	0.24^{b}	2.10^{bc}	2.97^{b}	2.11	0.57^{b}	0.55^{d}	0.43^{cd}	047^{ab}	0.29^{b}	6.61^{cd}
MR52	1.80^{d}	1.10^{c}	0.34^{b}	0.16^{d}	2.02^{c}	2.36^{e}	1.91^{c}	0.43^{d}	0.63^{b}	0.55^{a}	0.50^{a}	0.28^{b}	8.18^{b}
MR211	2.86^{a}	0.93^{d}	0.41^{a}	0.11^{f}	1.80^{de}	2.84^{bc}	2.73^{a}	0.51^{c}	0.58^{bcd}	0.56^{a}	0.51^{a}	0.28^{b}	8.80^{a}
MR219	2.13^{c}	1.10^{c}	0.30^{cd}	0.17^{d}	2.27^{ab}	3.46^{a}	1.68^{d}	0.64^{a}	0.56^{cd}	0.49^{bc}	0.48^{ab}	0.28^{b}	6.49^{cd}
MR232	1.63^{e}	1.07^{c}	0.35^{b}	0.11^{f}	1.90^{cd}	2.41^{e}	2.02^{bc}	0.56^{b}	0.69^{a}	0.54^{ab}	0.8^{ab}	0.27^{b}	8.61^{ab}
BRRI dhan29	1.88^{d}	1.13^{bc}	0.35^{b}	0.28^{a}	2.34^{a}	2.93^{b}	1.63^{d}	0.54^{bc}	0.62^{b}	0.44^{cd}	0.45	0.33^{a}	5.46^{d}
CV (%)	5.93	6.23	9.68	10.75	11.25	14.38	7.71	8.72	7.08	14.03	11.85	6.50	16.37

Means with the same letter in the columns do not differ significantly (P ≤0.05).

Table 2. Interaction effect of variety and salinity levels on nitrogen and phosphorus of rice varieties.

Treatments		%Nitrogen		%Phosphorus	
Rice variety	Salinity levels (dSm^{-1})	Shoot	Root	shoot	Root
IR20	0	2.25 c	1.55 a	0.43 c	0.16 a
	4	2.15 c (95)	1.42 a (92)	0.30 d (70)	0.18 a (112)
	8	1.98 c (88)	0.78 e (50)	0.24 b (55)	0.20 b (125)
	12	2.82 a (125)	1.10 bc (71)	0.18 b (42)	0.35 c (219)
Pokkali	0	2.61 b	0.96 f	0.44 c	0.10 b
	4	2.37 b (91)	0.91 d (95)	0.36 bcd (82)	0.11 cd (110)
	8	1.95 c (75)	0.85 de (88)	0.27 ab (61)	0.16 cd (160)
	12	1.40 f (54)	0.95 cd (99)	0.24 ab (56)	0.17 ef (170)
MR33	0	1.85 e	1.41 ab	0.39 c	0.10 b
	4	1.74 e (94)	0.98 cd (69)	0.33 d (85)	0.15 b (151)
	8	1.61 e (87)	1.13 a (80)	0.25 b (64)	0.28 a (280)
	12	2.10 d (113)	1.21 a (86)	0.22 ab (50)	0.42 b (420)
MR52	0	1.84 e	1.53 a	0.47 bc	0.10 b
	4	1.80 de (98)	1.17 b (76)	0.42 abc (89)	0.14 bc (140)
	8	1.82 d (99)	0.94bcd (61)	0.30 ab (64)	0.18 bc (180)
	12	1.81 e (98)	0.78 e (51	0.19 b (40)	0.23 d (230)
MR211	0	3.38 a	1.02 e	0.59 a	0.07 c
	4	2.99 a (88)	0.92 d (90)	0.46 a (78)	0.10 cd (142)
	8	2.67 a (76)	0.81 de (79)	0.33 a (56)	0.12 e (171)
	12	2.42 b (71)	0.97 d (95)	0.29 a (49)	0.18 ef (257)
MR219	0	2.17 cd	1.26 cd	0.45 c	0.09 bc
	4	1.93 d (71)	1.07 c (85)	0.29 d (64)	0.11 cd (122)
	8	2.29 b (105)	0.92 cde (73)	0.25 b (55)	0.14 de (155)
	12	2.19 cd (101)	1.18 ab (94)	0.20 b (42)	0.34 c (377)
MR232	0	1.67 e	1.35 bc	0.44 c	0.08 bc
	4	1.55 f(93)	1.25 b (93)	0.43 ab (98)	0.09 d (112)
	8	1.45 f (87)	1.06 ab (78)	0.33 a (75)	0.13 e (162)
	12	1.85 e (111)	0.91 d (67)	0.24 ab (54)	0.15 f (186)
BRRI dhan29	0	1.91 de	1.22 d	0.56 ab	0.15 a
	4	1.65 ef (86)	1.01abc (83)	0.35 cd(66)	0.23 a (153)
	8	1.66 e (85)	1.01abc (83)	0.27 ab (48)	0.29 a (193)
	12	2.31 bc (121)	1.20 a (98)	0.21 b (37)	0.47 a (313)

Means with the same letter in the columns do not differ significantly ($P \leq 0.05$).
Values within parenthesis indicate percent relative to control.

Table 3. Interaction effect of variety and salinity levels on sodium and potassium of rice varieties.

Treatments		%Sodium		%Potassium	
Rice variety	Salinity levels (dSm^{-1})	shoot	Root	shoot	Root
IR20	0	0.49 b	0.67 a	2.24 c	1.79 cd
	4	0.97 ab (199)	1.34 e (200)	1.89 e (84)	0.98 de (55)
	8	2.21 ab (451)	3.37 c (503)	1.01 c (45)	0.44 f (25)
	12	4.33 a (884)	4.51 bc (663)	0.58 d (26)	0.18 d (10)
Pokkali	0	0.51 b	0.64 a	3.74 a	1.39 f
	4	0.75 ab (147)	1.90 cd (336)	3.34 a (89)	0.90 e (65)
	8	1.38 c (270)	3.11 c (485)	2.48 a (66)	0.51 de (37)
	12	2.87 d (563)	3.41 e (533)	1.10 bc (37)	0.24 c (17)
MR33	0	0.75 a	0.75 a	2.95 b	1.96 ab
	4	1.06 ab (141)	2.32 bc (309)	2.21 c (75)	1.18 b (60)
	8	1.92 bc (256)	3.59 b (479)	1.36 (46)	0.56 cd (29)
	12	3.80 abc (507)	5.05 ab (673)	1.12 ab (40)	0.33 b (17)
MR52	0	0.55 ab	0.76 a	2.44 c	1.49 e
	4	1.03 ab (187)	2.28 bc (300)	2.14 cd (88)	1.06 cd (71)
	8	1.81 bc (329)	3.32 c (437)	1.45 b (56)	0.59 bc (40)

	12	3.80 abc (690)	3.99 cd (525)	0.81 cd (33)	0.31 b (20)
MR211	0	0.58 ab	0.86 a	3.47 a	1.73 d
	4	0.70 b (121)	2.77 b (326)	3.06 b (88)	1.08 c (62)
	8	1.37 c (236)	3.10 c (360)	2.26 a (65)	0.63 b (36)
	12	3.35 cd (577)	4.47 bc (526)	1.33 a (38)	0.44 ab (25)
MR219	0	0.51 b	0.78 a	2.31 c	1.92 ab
	4	1.16 a (227)	3.58 a (458)	1.96 de (85)	1.21 ab (63)
	8	2.37 ab (464)	4.68 a (600)	1.07 c (46)	0.5 ab (39)
	12	4.14 ab (812)	4.90 ab (628)	0.57 d (25)	0.34 b (18)
MR232	0	0.45 b	0.70 a	2.55 c	1.88 bc
	4	0.79 ab (175)	1.71 de (244)	2.24 c (88)	1.30 a (69)
	8	1.80 bc (400)	3.13 c (447)	1.45 b (57)	0.80 a (43)
	12	3.68 bc (818)	4.05 cd (578)	1.05 abc (41)	0.49 a (26)
BRRI dhan29	0	0.50 b	0.85 a	2.42 c	1.99 a
	4	1.17 a (234)	2.27 bc (252)	1.85 e (76)	1.09 c (55)
	8	2.62 a (504)	4.45 a (524)	0.86 c (36)	0.50 e (25)
	12	4.19 ab (806	5.39 a (634)	0.61 d (25)	0.19 d (9)

Means with the same letter in the columns do not differ significantly (P ≤0.05).
Values within parenthesis indicate percent relative to control.

Table 4. Interaction effect of variety and salinity levels on calcium and magnesium of rice varieties.

Treatments		%Calcium		%Magnesium	
Rice variety	**Salinity levels (dSm^{-1})**	**shoot**	**Root**	**Shoot**	**root**
IR20	0	0.81 ab	0.22 c	0.63 a	0.40 b
	4	0.68 ab (84)	0.37abcd (142.4)	0.54 ab (86)	0.27 c (67)
	8	0.55 ab (68)	0.56 abc (255)	0.41 ab (65)	0.19 d (47)
	12	0.30 c (37)	0.90 ab (346)	0.34 ab (54)	0.11 e (27)
Pokkali	0	0.74 ab	0.25 b	0.58 a	0.41 b
	4	0.67 ab (89)	0.32 cd (128)	0.52 ab (90)	0.30 bc (73)
	8	0.60 ab (81)	0.36 d (144)	0.46 ab(79)	0.27 ab (66)
	12	0.45 b (60)	0.61 e (244)	0.37 ab (64)	0.18 ab (44)
MR33	0	0.69 b	0.35 a	0.62 a	0.50 a
	4	0.60 c (87)	0.42 abc(131)	0.49 b (79)	0.32 abc (64)
	8	0.50 b (72.5)	0.52 abcd (148)	0.43 ab(69.4)	0.20 cd (40)
	12	0.37 bc (54)	0.73 cde (228)	0.34 ab (55)	0.17 abc (34)
MR52	0	0.82 a	0.26 abc	0.62 a	0.44 ab
	4	0.71 a (87)	0.38 abcd (146)	0.52 ab(84)	0.33 abc (75)
	8	0.57 ab (69)	0.50 bcd (192)	0.49 a (79)	0.22 cd (50)
	12	0.32 c (39)	0.78 bcd (300	0.39 ab (63)	0.17 abc (39)
MR211	0	0.70 b	0.29 ab	0.64 a	0.39 b
	4	0.62 bc (88)	0.46 a (159)	0.52 ab(81)	0.32 abc (82)
	8	0.57 ab (81)	0.60 ab (207)	0.47 ab(73)	0.21 cd (54)
	12	0.47 b (67)	0.74 cde (255)	0.40 a (62)	0.19 a (49)
MR219	0	0.77 ab	0.23 bc	0.67 a	0.39 b
	4	0.64 bc (83)	0.43 ab (187)	0.56 a (85)	0.35 ab (90)
	8	0.53 ab (69)	0.64 a (278)	0.40 ab(60)	0.23 bc (59)
	12	0.30 c (39)	0.85 abc (370)	0.30 ab(45)	0.14 cde (36)
MR232	0	0.80 ab	0.27 abc	0.59 a	0.38 b
	4	0.71 a (89)	0.28 d (117)	0.51 ab(86)	0.33 abc (87)
	8	0.66 a (83)	0.40 cd (148)	0.47 ab (80)	0.21 cd (55)
	12	0.55 a (69)	0.62 e (229)	0.39 a (66)	0.16 bcd (42)
BRRI dhan29	0	0.81 ab	0.22 c	0.66 a	0.50 a
	4	0.71 a (88)	0.34 bcd (155)	0.49 b (74)	0.38 a (76)
	8	0.60 ab (74)	0.64 a(291)	0.38 b (57)	0.31 a (62
	12	0.37 bc (46)	0.93 a (423)	0.28 b (42)	0.13 de (26)

Means with the same letter in the columns do not differ significantly (P ≤0.05).
Values within parenthesis indicate percent relative to control.

Table 5. Interaction effect of variety and salinity levels on shoot dry weight, root dry weight and yield of rice varieties.

Rice variety	Salinity levels (dS m^{-1})	Shoot dry weight (g hill^{-1})	Root dry weight (g hill^{-1})	Yield (g hill^{-1})
IR20	0	21.6 cd	2.77 c	13.24 b
	4	16.4 e (76)	1.56 f (56)	5.48 d (41)
	8	8.1 d (37)	1.19 cd(43)	0.00 d
	12	4.1 e (19)	0.57 d (20)	0.00 c
Pokkali	0	24.2 a	2.09 e	12.62 b
	4	21.2 a (87.6)	1.60 f (76)	10.76 ab (85)
	8	15.5 a (64)	1.06 e (51)	4.90 b (39)
	12	7.9 b (32.6)	0.85 b (41)	1.28 b (10)
MR33	0	22.8 b	3.28 a	14.45 ab
	4	15.9 e (70)	2.28 b (69)	8.42 c (58)
	8	11.8 c (52)	1.40 b (43)	3.58 c (25)
	12	6.2 c (27)	0.87 b (26)	0.00 c
MR52	0	21.0 d	2.51 d	16.97 a
	4	16.9de (80)	1.90 d (76)	12.44 a (73)
	8	14.4 b (68)	1.41 b (56)	3.31 c (19)
	12	6.1 c (29)	0.74 c (29)	0.00 c
MR211	0	19.9 e	2.19 e	14.37 ab
	4	17.5cd (88)	1.77 e (81)	12.35 a (86)
	8	14.3 b (72)	1.12de (51)	7.00 a (49)
	12	8.1 b (41)	0.88 b (40)	1.50 b (10)
MR219	0	22.5 bc	3.19 ab	14.90 ab
	4	18.1 c (80)	2.17 c (68)	8.69 bc (58)
	8	11.6 c (51)	1.25c (39)	2.37 c (16)
	12	4.9 d (22)	0.66 c (21)	0.00 c
MR232	0	21.7 cd	3.16 b	13.99 b
	4	19.4 b (89)	2.63 a (83)	11.74 a (84)
	8	14.6 b (67)	1.91 a (60)	6.95 a (50)
	12	8.8 a (41)	1.06 a (34)	1.76 a (13)
BRRI dhan29	0	22.9 b	2.87 c	15.12 ab
	4	14.6 f (64)	1.77 e (62)	6.73 cd (44)
	8	8.3 d (36)	0.86 f (30)	0.00 d
	12	3.9 e (17)	0.52 d (18)	0.00 c

Means with the same letter in the columns do not differ significantly ($P \leq 0.05$).
Values within parenthesis indicate percent relative to control.

Table 6. Pearson Correlation Coefficients between the characteristics of independent variable in rice shoot and root.

	N	P	K	Na	Ca	Zn	Na : K	Ca : Na	Mg : Ca
N	-	0.87^{ns}	0.80^{ns}	0.95*	0.86^{ns}	0.90^{ns}	0.82^{ns}	0.68^{ns}	0.82^{ns}
P	0.51^{ns}	-	0.99**	0.95*	0.99**	0.89^{ns}	0.99**	0.91^{ns}	0.99**
K	0.34^{ns}	0.98*	-	0.92^{ns}	0.99**	0.87^{ns}	0.92^{ns}	0.92^{ns}	0.99**
Na	-0.35^{ns}	0.98*	0.99**	-	0.95*	0.98*	0.75^{ns}	0.75^{ns}	0.92^{ns}
Ca	0.32^{ns}	0.98*	0.99**	-0.99*	-	0.90^{ns}	0.91^{ns}	0.91^{ns}	0.99**
Mg	0.42^{ns}	0.99**	0.99**	-0.99**	0.99**	0.92^{ns}	0.89^{ns}	0.89^{ns}	0.99*
Na : K	0.63^{ns}	0.98*	0.94*	-0.94*	0.93^{ns}	0.90^{ns}	-	0.94*	0.99**
Ca : Na	0.72^{ns}	0.93^{ns}	0.86^{ns}	-0.86^{ns}	0.85^{ns}	0.79^{ns}	0.97*	-	0.94*
Mg : Ca	0.70^{ns}	0.95*	0.88^{ns}	-0.88^{ns}	0.88^{ns}	0.82^{ns}	0.98*	0.99**	-

Note: Above diagonal root and below diagonal shoot. *, ** indicate significant at 5 and 1% levels respectively, ns = non-significant

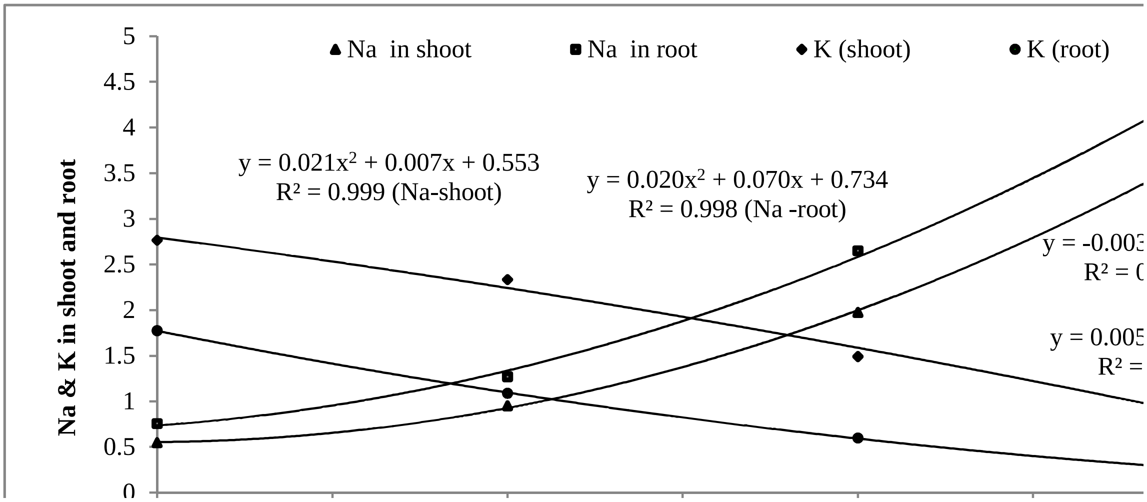

Fig 1.Relationship between sodium and potassium in shoot and root of rice varieties.

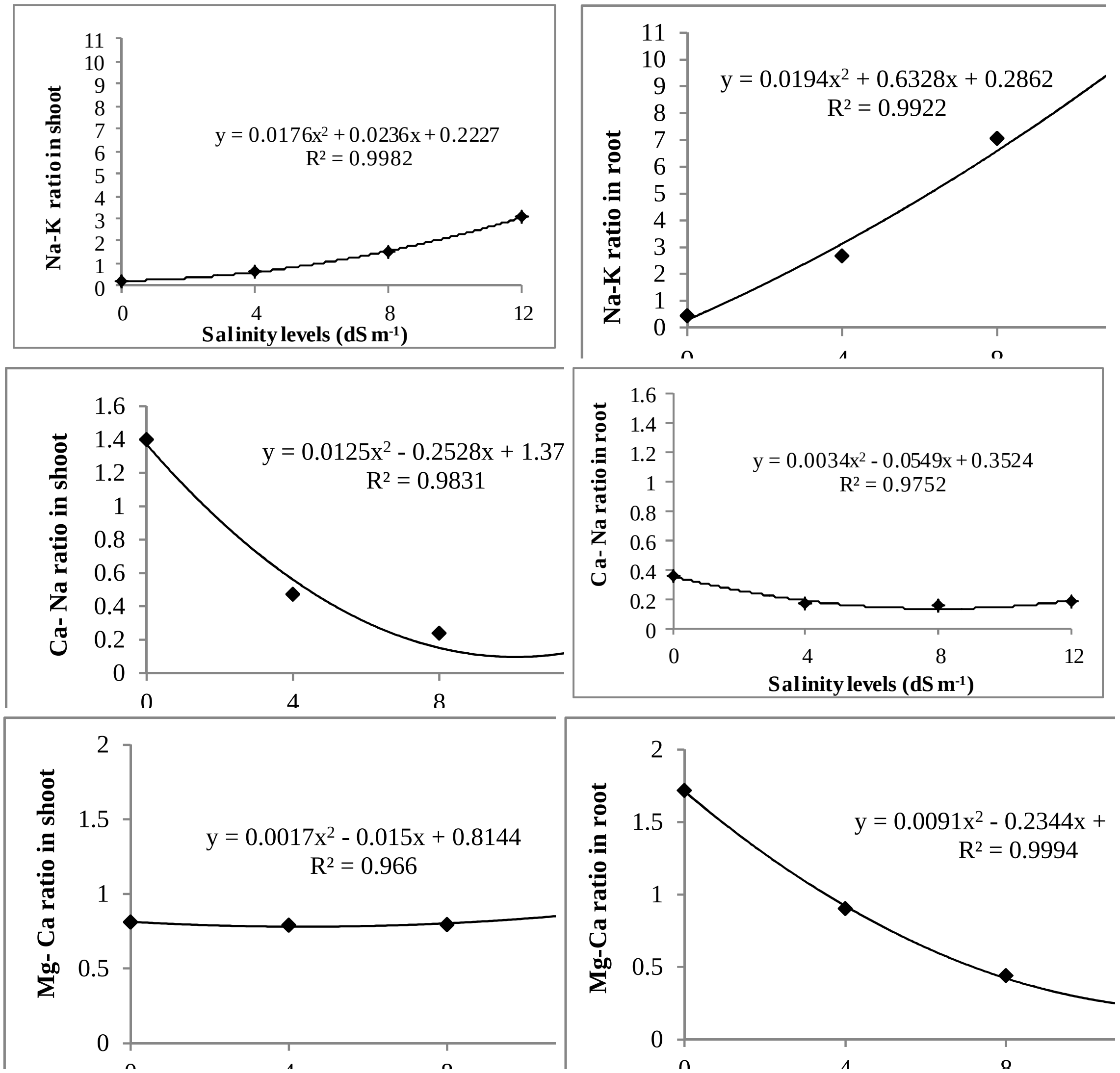

Fig 2.Relationship between salinity and cation levels measured in rice (pooled across the verities).

DISCUSSION

Rice including other cereal crops (viz. wheat, corn) is generally sensitive to salt. Roots always remain in direct contact with the surrounding salt solution. After transplanting, the previous roots of seedling die and new roots grow that support the plant (Alam *et al*., 2004). Absorption of minerals, plant growth and yield of rice under different saline condition were observed in this study. Shoot and root dry weights of rice significantly deceased with the increase in the salinity levels. The decrease of shoot and root dry weight might be due to some reasons such as (i) salt stress reduced photosynthesis per unit leaf area which turned intolimited supply of carbohydrate needed for shoot growth, (ii) reduced turgor resulting in lower water potential and (iii) disturbance in mineral supply might have directly affected growth. In addition, salinity affected final cell size as well as rate of cell production and thereby resulting in reduced shoot and root dry weight. The results are in agreement with the findings of Alam *et al*., 2004; Mahmood *et al*., 2009.

Nitrogen accumulation in shoot and root decreased due to different levels of salinity. P concentrations also influenced by the different salinity levels. P accumulation reduced at 4 to 12 dS m^{-1} salinity levels. Similar results were reported by Wilson *et al.* (2000) where phosphorus of young leaves was reduced 23% in a salt-sensitive *Glycine* species at 80 mM NaCl after 4 days salt stress initiation. It was also observed that P accumulation in the roots increased with the increase in salinity. The results are in accordance with the findings of Talei *et al.* (2012) where phosphorus increased in maize plants under salt condition.

Sodium concentrations both in shoot and root were increased with the increase in salinity levels but the reverse wastrue in case of K^+ accumulations. This result indicated that after saltstress initiation, it created nutritional imbalance with increasing salinity levels and formed ion antagonism and caused excess accumulation of sodium ions in both shoot and roots. Na^+ increased proportionally to different levels of salinity in both root and shoot but in root, rate of increasewas higher than the shoot. The higher amounts of Na^+ ions in both the rice shoot and root indicated a signal of nutritional imbalance. The sodium ions in rice shoots and roots were gradually accumulated and increased in salt-stressed condition but the increasing rate depends on salt concentrations (Djanaguiraman *et al*., 2006). In the present study, K^+ concentrations decreased with the increase in salinity levels in all rice genotypes. The results indicated that K^+ ion decreased more in the root than the shoot and the reduction was about 38, 65 and 78% at 4, 8 and 12 dS $m^{-1,}$ respectively (Table 3). K^+ ions strongly compete with other elements for absorption by the root (Babourina *et al*., 2000). This might be due to (i) high external Na negatively effects on K acquisition because of similar physiochemical properties of Na and K; (ii) KUP (potassium uptake permease) /HAK (High Affinity K) transporters are extremely selective for Kand they are blocked by Na under salt stress (Grabov, 2007). Genotypes MR232 and MR211 showed relatively salt tolerance which accumulated less salt and restricted the entry of Na^+ ions in both shoot and root. Momayezi *et al.* (2009) reported that concentration of sodium ion in the rice shoot and root increased at high salt levels. Similar result was also found by Mahmood *et al.* (2009) where the sodium ion increased and K ion in the shoot and root of rice genotypes was significantly decreased with the increase of salinity levels. Ahmad *et al.* (2006) reported that the Na^+ increased and K^+ ion decreased significantly in the shoot and root of two barley cultivars with the increase of salinity in the growth medium. Similar results were also observed by Ikram-ul-Haq *et al.* (2010) where Na^+ ions increased and K^+ ions decreased in the shoot and root of rice genotypes with the increase of NaCl levels. Amirjani (2010) found that the K^+ ion in seedling of Soybean significantly decreased with the increase in salinity levels. Summart *et al*. (2010) also reported that sodium and potassium ion in rice significantly influenced by the effect of different levels of salinity.

Calcium is essential for the maintenance of cell membrane integrity. Calcium plays an important role in the synthesis of new walls in cell, particularly the middle lamellae that separate newly divided cells (Taiz and Zeiger, 2006). The rice membrane was damaged and enhanced permeability due to displacement of Ca^{2+} and increasing Na^+ from the binding sites of phospholipids of membranes. In the present study, calcium ion decreased with the increase in salinity levels. Calcium influx increased in the shoot and decreased in the root with the increase in salinity levels (Table 4). Nutritional distribution might have a role in both shoot and root but these results showed that the salt accumulation in Pokaali and other proposed line viz MR211 and MR232 increased in shoot and decreased in root but their changing rate showed less compared to others. Magnesium and calcium are important essential plant nutrients and both are typically accumulated in the roots and shoots. In the present study, Mg^{2+} decreased in the shoot and root. These results indicate that root was severe affected might be due to salt stress and abnormal situation with nutritional imbalance. The results are in accordance with the findings of Razzaque *et al.* (2009) ; Momayezi *et al.* (2009); Amirjani (2010) ; Summart *et al*. (2010).

Ionic ratios are very important to determine the relative toxicities that could provide relative biological processes rates under specific ionic antagonisms (Wilson *et al*., 2000; Rahman *et al*., 2008). Relative proportions are also important in plant nutrition. The ratio of Na^+/K^+, Ca^{2+}/Na^+ and Ca^{2+}/Mg^2 both in shoot and root of rice plant showed an indication of the nutritional status under salt environment. Pardo *et al.* (2006) observed thatthe Na^+/K^+ plays a role for growth of plants, since metabolism is adversely affected by low Na^+/K^+ ratios under salt condition. Na^+/K^+ ratio impressively increased in the root under salt stress (Fig.4). K^+ and Ca^{2+} uptake significantly influenced in wheat and increased Na^+/K^+ and Na^+/Ca^{2+} ratios as well as reduced the growth and yield (Perveen, 2012, Din *et al.*, 2008). Salt-sensitive genotypes expressed more nutritional imbalance while the salt tolerant varieties were able to maintain balance among the nutrients in the tissues whereas, the sensitive varieties showed lacking such type of mechanisms and thus suffered nutritional imbalance.In present study, the leaf K:Na ratio, showed differences in the wheat cultivars used and those having higher leaf

Rice yield drastically reduced with the increase in salinity levels. The maximum yield reduction (64 and 41% for IR20 and BRRI dhan29, respectively) was found in 4 dS m^{-1}.It indicated that these two genotypes are more sensitive to salinity than the others. All genotypes are failed to produce any grain except MR211, MR232 and Pokkali at 12 dS $m^{-}1$. The result indicated that MR211, MR232 relatively tolerant compared to salt tolerant check variety Pokkali. The grain yield reduction might be due to salts modify the metabolic activities of the cell wall which limit the cell wall elasticity, and thus cell walls become rigid and consequently the turgor pressure efficiency in cell enlargement is decreased. In addition, salt disturbed in photosynthesis, the shrinkage of cell contents, reduced development and differentiation of tissues, unbalanced nutrition and damage of membranes. So affected the growth and also yield contributing characters resulted grain yield. The present results are supported by many research findings (Ali *et al.*, 2004; Mahmood *et al*., 2009; Nejad *et al.*, 2010).

Conclusion: In conclusion, the results showed that the dry weight of root, shoot and yield significantly decreased with the increase of salinity levels, while MR232 and MR211 were less affected. The uptake of Na^+, increased and the uptake of K^+ decreased in the shoots of rice with increasing salinity irrespective ofrice genotypes, where the resistant genotypes contained significantly lower amountsof Na^+, higher amounts of K^+compared to susceptible genotype BRRI dhan29 and IR20 while the lowest accumulation was in MR211. Na^+/K^+ ratio was sharply increased in the root with increasing salinity. Ca^{++}/Na^+ and Mg^{++}/Ca^{++} ratio showed decreasing trend with increasing salinity. Highest nitrogen and phosphorous accumulation was observed in the shoot of MR211, while Na^+ in BRRI dhan29, K^+ in Pokkali. MR219 showed highest Na^+ and K^+ accumulation in the root. Maximum Ca^{++} and Mg^{++} were found in MR33 and MR211, respectively. Considering all, genotypes MR211 andMR232 were found to be relatively tolerant to salt than the other genotypes.

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