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EFFECT OF SALINITY ON MINERAL CONTENT IN DIFFERENT PLANT PARTS OF RICE GENOTYPES

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ABSTRACT

The effect of salinity on mineral content in stem, leaf sheath, leaf blade and grain of rice genotypes differing in salt tolerant (The genotypes PVSB19, PVSB9, PNR519, PNR381, Iratom24 and Pokkali representing salt tolerant and NS15 representing salt-sensitive) were studied in an experiment conducted in two factors Completely Randomized Design. The susceptible genotype NS15 showed higher concentration of Na^+, Cl^-, Ca^{2+} and Mg^{2+} and lower amount of K^+ in stem, leaf sheath and leaf blade of rice compared to tolerant ones. The concentration of Na^+, Ca^{2+}, Mg^{2+} and Cl^- followed an increasing pattern in different plant parts of all the selected rice genotypes due to increasing salinity levels except Ca^{2+} and Mg^{2+} in grain, where these two ions decreased with increasing salinity levels. But the concentration of K^+ showed decreasing pattern in stem, leaf sheath, leaf blade and grain with increasing salinity levels. In different plant parts, the Na^+ and Cl^- content increased very sharply and K^+ decreased very rapidly in susceptible genotype as compared to other genotypes. The highest amount of Na^+ and K^+ were obtained in stem followed by leaf sheath, leaf blade and grain at different salinity levels. But the content of Ca^{2+}, Mg^{2+} and Cl^- were high in leaf blade followed by leaf sheath and stem at different levels of salinity.

Key words: Rice, salinity, mineral ions content

INTRODUCTION

The present population of Bangladesh is about 140 million and rice is the principal food item of her population. The alarming growth of population and loss of arable land due to urbanization are main causes of concern for finding ways and means for augmenting food production particularly rice. The possibility of increasing food production by increasing land area is quite out of question in Bangladesh. The only feasible alternative is to increase the cultivable land areas by bringing salt affected soils under cultivation with high yielding salt tolerant rice cultivars. The lack of an effective evaluation method for salt tolerance in the screening of genotypes is one of the reasons for the limited success in conventional salt tolerant breeding. Ashraf (1994) stated that the deleterious effects of salinity on plant growth are associated with (i) low osmotic potential of soil solution (water stress), (ii) nutritional imbalance, (iii) specific ion effect, or (iv) a combination of these factors. 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). Considerable improvements in salinity tolerance have been made in crop species in recent times through conventional selection and breeding techniques (Ashraf, 1994). Osmotic adjustment in plants subjected to salt stress can occur by the accumulation of high concentration of either inorganic ions or low molecular weight organic solutes. Although both of these play a crucial role in higher plants grown under saline conditions, their relative contribution varies among species, cultivars and even between different compartments within the same plant (Ashraf, 1994). 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

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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). So, this research work on mineral content in different plant parts of rice genotypes under various salinity levels may be helpful in breeding salt tolerant cultivars by identifying chemical potential of salinity tolerance.

MATERIALS AND METHODS

The experiment was conducted in plastic pots at the glasshouse of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh during the period from December, 2003 to June, 2004 and laid out in two factorials CRD (Completely Randomized Design) with four replications. Factor 1: Rice genotypes -7 and Factor 2: Salinity levels-6 (0, 3, 6, 9, 12 and 15 dSm^{-1}). Among the seven rice genotypes, five of them were of advanced lines/ mutants (PVSB19, PVSB9, PNR519, PNR381 and NS15) of which NS15 represented salt-sensitive and rest 4 were salt-tolerant genotypes. Pokkali was included as an internationally salt tolerant check and Iratom 24 was modern mutant variety developed by BINA. Soil for the experiment was collected from the field of BINA Farm, which was non-calcarious Dark Grey Floodplain having loamy texture and belonging to the Agro-Ecological Zone of Old Brahmaputtra Floodplain. Each pot was filled with 8 (eight) kg sun-dried soil and was fertilized with 100 kg N, 60 kg P_2O_5, 75 kg K_2O and 20 kg S ha^{-1} as sources of urea, triple supper phosphate (TSP), muriate of potash (MOP) and gypsum, respectively. The whole amount of TSP, MOP, gypsum and $1/3^{rd}$ of urea was applied at the final preparation of the pots. Thereafter, the soil in pots was moistened with water and commercial NaCl salt was added to develop salinity upto the level of 3 dSm^{-1}. Six-week old seedlings of selected rice genotypes were transplanted maintaining one seedling per hill with three hills per pot. Two weeks after transplanting, the remaining salt solutions were applied in each pot according to the treatments. 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 from each pot at 24-hour intervals and electrical conductivity (EC) was measured with a conductivity meter and necessary adjustments were made. The remaining $2/3^{rd}$ urea was top-dressed in two equal installments at 25 and 50 days after transplanting. Weeds grown in the pots and visible insects were removed time to time by hands in order to keep the pots neat and clean. Necessary watering was done in each pot to hold the constant soil water level and salt concentration.

Analysis of different chemical constituents in rice plant samples

Rice plants after harvest were separated into roots, stems, leaf sheaths, leaf blades and grains 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.

i) Grinding: Oven-dried samples were ground in a Wiley Hammer Mill, passed through 40 mesh screens, mixed well and stored in plastic vials.

ii) Digestion: Rice plant samples were analysed to determine the amount of Na, K, Ca, Mg and Cl contents therein. All elemental analyses were conducted on acid digested material through micro-Kjeldahl digestion system (Thomas *et al.*, 1967). The contents of Na, K, Ca and Mg were measured by Atomic Absorption Spectrophotometer (AAS) and Cl was determined by argentometric method of titration according to the methods outlined by Clesceri *et al.* (1988).

Statistical analysis: The collected data were analyzed statistically following completely randomized design (CRD) by MSTAT-C computer package programme developed by Russel (1986). The treatment means were compared by Duncan's Multiple Range Test (DMRT) where necessary.

RESULTS AND DISCUSSION

Based on the results the genotypes PVSB9, PVSB19, PNR519, PNR381 were found tolerant while Iratom24 was moderately tolerant and NS15 as susceptible and Pokkali was a standard check tolerant cultivars. Plant parts such as stem, leaf sheath, leaf blade and grain were taken into account for estimating concentration of Na^+, K^+, Ca^{2+}, Mg^{2+} and Cl^- there in up to 9 dSm^{-1} level of salinity, because plant of neither of the genotypes except Pokkali and PVSB9 survived at 12 dSm^{-1} and at more higher salinity levels after treating NaCl.

Concentration of Na^+, K^+, Ca^{2+}, Mg^{2+} and Cl^- in stem, leaf sheath, leaf blade and grain

Significant variations in Na^+, K^+, Ca^{2+}, Mg^{2+} & Cl^- content were observed in different plant parts viz. stem, leaf sheath, leaf blade and grain of seven rice genotypes due to different salinity levels (Table1).

Table 1. The effect of different salinity levels on Na^+, K^+, Ca^{2+}, Mg^{2+} and Cl^- concentration (%) in stem, leaf sheath and leaf blade of rice (each value is a mean of 7 genotypes)

Salinity level (dSm^{-1})	In stem				
	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-
0	0.995 d	3.395 a	0.082 d	0.183 c	0.389 d
3	1.877 c	3.006 b	0.090 c	0.214 b	1.004 c
6	2.452 b	2.170 c	0.100 b	0.232 ab	1.766 b
9	3.493 a	1.512 d	0.108 a	0.241 a	2.592 a
Significance level	**	**	**	**	**
CD $_{0.05}$	0.224	0.130	0.002	0.020	0.090
CV (%)	16.43	8.34	14.08	11.77	9.97
Salinity level (dSm^{-1})	**In leaf sheath**				
0	0.625 d	2.662 a	0.098 d	0.297 b	0.389 d
3	1.105 c	2.166 b	0.120 c	0.299 b	1.080 c
6	1.527 b	1.644 c	0.150 b	0.313 b	2.225 b
9	2.524 a	1.069 d	0.177 a	0.350 a	2.972 a
Significance level	**	**	**	**	**
CD $_{0.05}$	0.210	0.094	0.019	0.028	0.117
CV (%)	23.50	8.12	28.08	14.47	11.35
Salinity level (dSm^{-1})	**In leaf blade**				
0	0.279 d	1.818 a	0.312 b	0.333 d	0.515 d
3	0.511 c	1.507 b	0.310 b	0.379 c	1.569 c
6	1.058 b	1.285 c	0.311 b	0.429 b	3.215 b
9	2.386 a	1.235 c	0.345 a	0.456 a	4.170 a
Significance level	**	**	**	**	**
CD $_{0.05}$	0.231	0.105	0.019	0.019	0.102
CV (%)	35.40	11.69	10.48	6.75	6.95
Salinity level (dSm^{-1})	**In grain**				
0	0.013 d	0.628 a	0.054 a	0.131 a	0.291 d
3	0.056 c	0.598 a	0.049 b	0.122 b	0.741 c
6	0.061 b	0.555 b	0.044 c	0.115 c	1.188 b
9	0.076 a	0.435 c	0.035 d	0.096 d	1.375 a
Significance level	**	**	**	**	**
CD $_{0.05}$	0.0019	0.0391	0.0196	0.0019	0.0648
CV (%)	19.90	11.46	16.53	6.74	11.87

Values having same letter(s) in a column do not differ significantly at 5% level of probability

**CD→ Critical difference at 5% level of probability; ** Significant at 0.01 level of probability

The concentration of Na^+ and Cl^- in stem, leaf sheath, leaf blade and grain increased while concentration of K^+ decreased in all the plant parts with increasing the salinity levels. But Ca^{2+} and Mg^{2+} content increased in stem, leaf sheath and leaf blade with increasing the salinity levels while their contents decreased in grain. When the effect of all the salinity levels was considered together *i.e.* the mean effect of salinity levels, the content of Na^+, K^+, Ca^{2+}, Mg^{2+} and Cl^- in seven selected rice genotypes was found to differ significantly in different plant parts. The highest content of Na^+, Ca^{2+}, Mg^{2+}, Cl^- and the lowest content of K^+ were found in NS15 in all the plant parts except grain (Table 2).

Table 2. Genotypic effect on Na^+, K^+, Ca^{2+}, Mg^{2+} and Cl^- concentration (%) in stem, leaf sheath, leaf blade and grain of seven selected rice genotypes [each value is a mean of 4 salinity levels (0, 3, 6 & 9 dSm^{-1})]

Genotype	In stem				
	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-
Pokkali	2.069 b	2.175 d	0.075 e	0.182 d	1.500 b
PVSB19	1.667 c	2.450 c	0.090 cd	0.201 cd	1.440 b
PVSB9	2.221 b	3.050 a	0.088 cd	0.198 cd	1.518 b
PNR519	2.177 b	2.745 b	0.091 c	0.243 b	1.139 c
PNR381	2.161 b	2.448 c	0.088 d	0.186 d	1.223 c
NS15	3.091 a	1.758 e	0.135 a	0.290 a	1.755 a
Iratom24	2.046 b	3.021 a	0.096 b	0.224 bc	1.489 b
Significance level	**	**	**	**	**
$CD_{0.05}$	0.296	0.172	0.003	0.026	0.119
CV (%)	16.43	8.34	14.08	11.77	9.97
Genotype	**In leaf sheath**				
Pokkali	0.944 e	1.804 c	0.109 c	0.256 e	1.732 b
PVSB19	1.040 de	1.889 c	0.126 bc	0.320 bc	1.713 b
PVSB9	1.411 bc	2.083 b	0.148 b	0.301 cd	1.597 b
PNR519	1.435 bc	1.882 c	0.123 bc	0.323 bc	1.562 b
PNR381	1.251 cd	1.655 d	0.127 bc	0.267 de	1.564 b
NS15	2.454 a	1.653 d	0.183 a	0.378 a	1.899 a
Iratom24	1.581 b	2.232 a	0.138 b	0.357 ab	1.600 b
Significance level	**	**	**	**	**
$CD_{0.05}$	0.277	0.124	0.026	0.037	0.1552
CV (%)	23.50	8.12	28.08	14.47	11.35
Genotype	**In leaf blade**				
Pokkali	0.394 c	1.468 cd	0.325 b	0.349 d	2.488 b
PVSB19	0.887 b	1.588 bc	0.283 c	0.305 e	2.527 b
PVSB9	0.940 b	1.827 a	0.278 c	0.385 c	2.281 cd
PNR519	1.222 b	1.331 d	0.333 ab	0.398 c	2.032 e
PNR381	1.047 b	1.489 bc	0.326 b	0.428 b	2.170 d
NS15	1.954 a	0.903 e	0.355 a	0.485 a	2.755 a
Iratom24	0.963 b	1.621 b	0.348 ab	0.445 b	2.319 c
Significance level	**	**	**	**	**
$CD_{0.05}$	0.306	0.139	0.026	0.026	0.134
CV (%)	35.40	11.69	10.48	6.75	6.95
Genotype	**In grain**				
Pokkali	0.038 e	0.468 d	0.053 a	0.109 c	0.842 bc
PVSB19	0.045 d	0.632 ab	0.048 b	0.125 a	0.842 bc
PVSB9	0.052 c	0.556 c	0.049 b	0.123 a	0.966 a
PNR519	0.064 b	0.645 a	0.048 b	0.123 a	0.874 b
PNR381	0.069 a	0.581 bc	0.045 c	0.126 a	0.971 a
NS15	0.045 d	0.458 d	0.036 e	0.090 d	1.005 a
Iratom24	0.051 c	0.536 c	0.039 d	0.113 b	1.043 a
Significance level	**	**	**	**	**
$CD_{0.05}$	0.0026	0.0517	0.0026	0.0026	0.0858
CV (%)	19.90	11.46	16.53	6.74	11.87

Values having same letter(s) in a column do not differ significantly at 5% level of probability
**CD→ Critical difference at 5% level of probability; ** Significant at 0.01 level of probability

In case of grain, the elevated amount of Na^+, K^+, Ca^{2+}, Mg^{2+} and Cl^- was found in genotypes PNR381, PNR519, Pokkali, PNR381 and Iratom24, respectively and the lowest amount of Na^+ was in grains of Pokkali; K^+, Ca^{2+} and Mg^{2+} in NS15 and Cl^- in PVSB19 and Pokkali, respectively.

The content of Na^+ and Cl^- increased sharply in all genotypes due to increase in salinity levels (Fig.1) but there was an inverse effect on K^+ content in rice stem, leaf sheath, leaf blade and grain of all the genotypes under study due to different salinity levels (Fig.2). The results presented in Fig.3 showed that the percent content of Ca^{2+} and Mg^{2+} increased in stem, leaf sheath and leaf blade with increasing the salinity levels while their content decreased in grains of all the selected genotypes due to increase in salinity levels. The Na^+ and Cl^- content increased very sharply (Fig.1) and inversely K^+, Ca^{2+} and Mg^{2+} content decreased rapidly indifferent plant parts of susceptible genotype NS15 as compared to other genotypes (Fig. 2 and Fig. 3).

The susceptible genotype NS15 contained highest amount of Na^+, Ca^{2+}, Mg^{2+}, Cl^- and lowest amount of K^+ in different plant parts such as stem, leaf sheath and leaf blade among the rice genotypes due to the mean effect of different salinity (Table 2) and the higher amount of these ions (Na^+, Ca^{2+}, Mg^{2+}, Cl^-) was found at higher levels of salinity except Na^+ and Mg^{2+} in grain (Fig.1, 2 & 3). The highest amount of Na^+ and K^+ were obtained in stem followed by leaf sheath, leaf blade and grain at different salinity levels (Fig.1 & 2). But the content of Ca^{2+}, Mg^{2+} and Cl^- were high in leaf blade followed by leaf sheath and stem at different levels of salinity (Fig.1 & 3). These findings were in agreements with Boniface *et al.* (1994). Alam *et al.* (2001) observed that Na^+ and Cl^- in the leaves and stems increased and the K^+ and Ca^{2+} decreased due to salinity. They further stated that most of the Cl^- was localized in leaf blades and stems. Cho *et al.* (1996) reported that the Na^+ concentration in the leaf blade, leaf sheath and root increased with increasing salinity levels but the K^+ concentration decreased in root and leaf sheath and increased in the leaf blade with the increase in Na^+ concentration. They further stated that there was no relationship between the extent of accumulation of Na^+ and K^+ in the leaf blade and salt tolerance. Islam *et al.* (1995) observed that salinity stress increased Na^+ and decreased K^+ in roots, stems and leaves. On the contrary, El-Hendawy *et al.* (2005) observed that greater amount of K^+ in the leaves; and Ca^{2+} in the leaves and stems were closely associated with genotypic differences in salt tolerance among the genotypes.

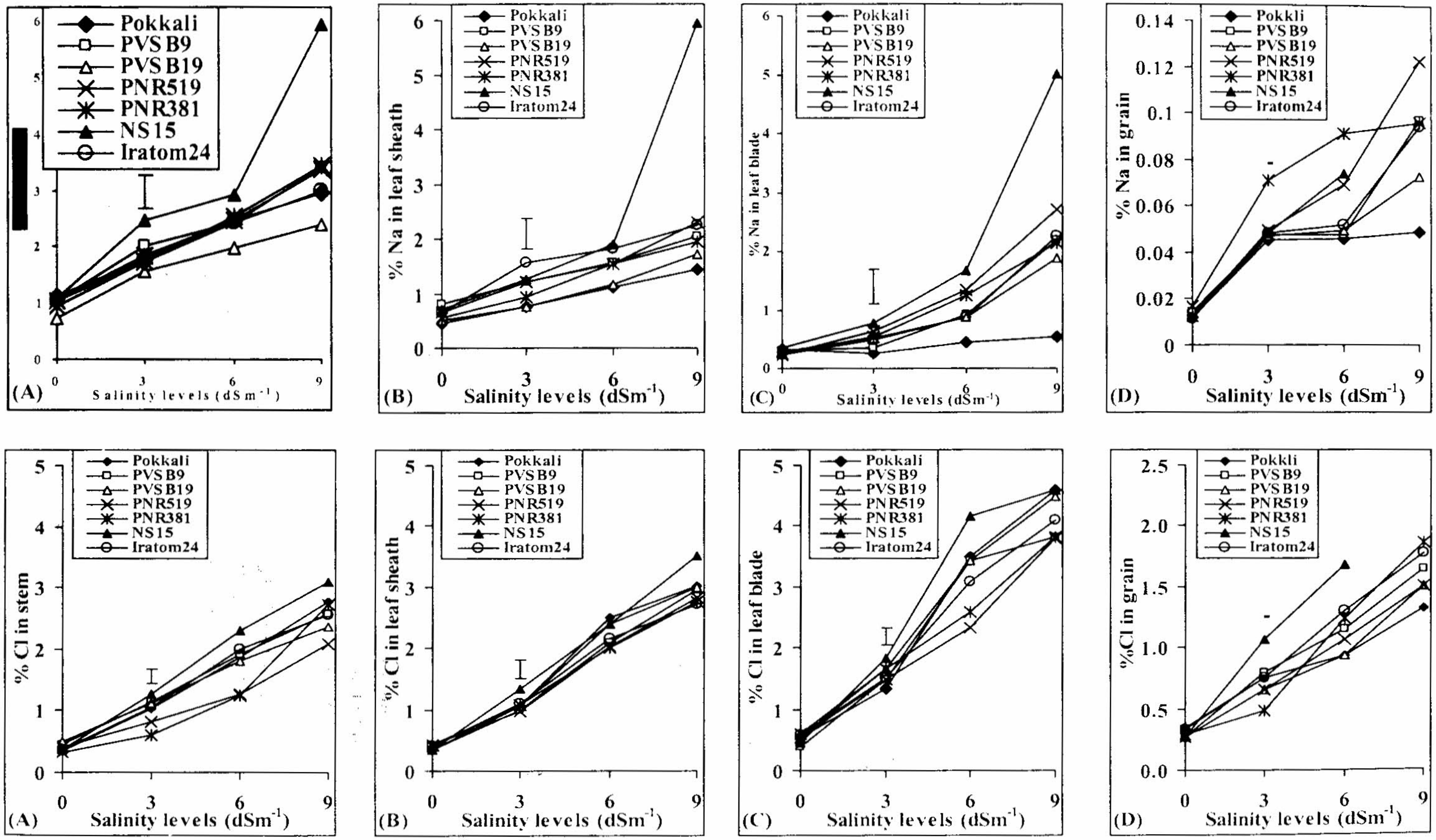

Figure 1. The effect of different salinity levels on Na and Cl content in (A) stem, (B) leaf sheath, (C) leaf blade and (D) grain of seven selected rice genotypes (vertical bars represent critical difference at 0.05 level of significance)

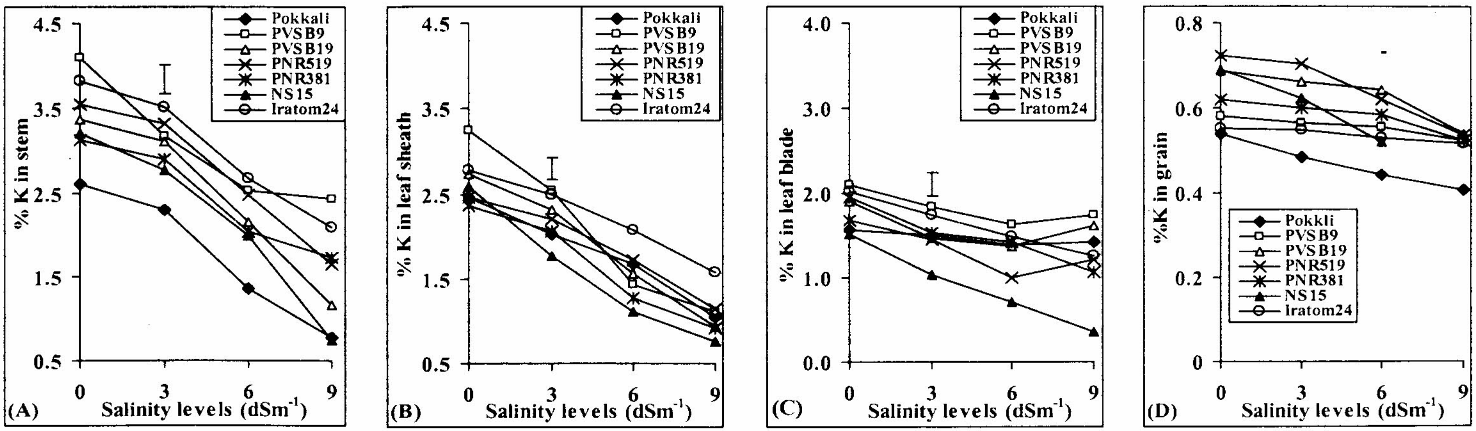

Figure 2. The effect of different salinity levels on K content in (A) stem, (B) leaf sheath, (C) leaf blade and (D) grain of seven selected rice genotypes (vertical bars represent critical difference at 0.05 level of significance)

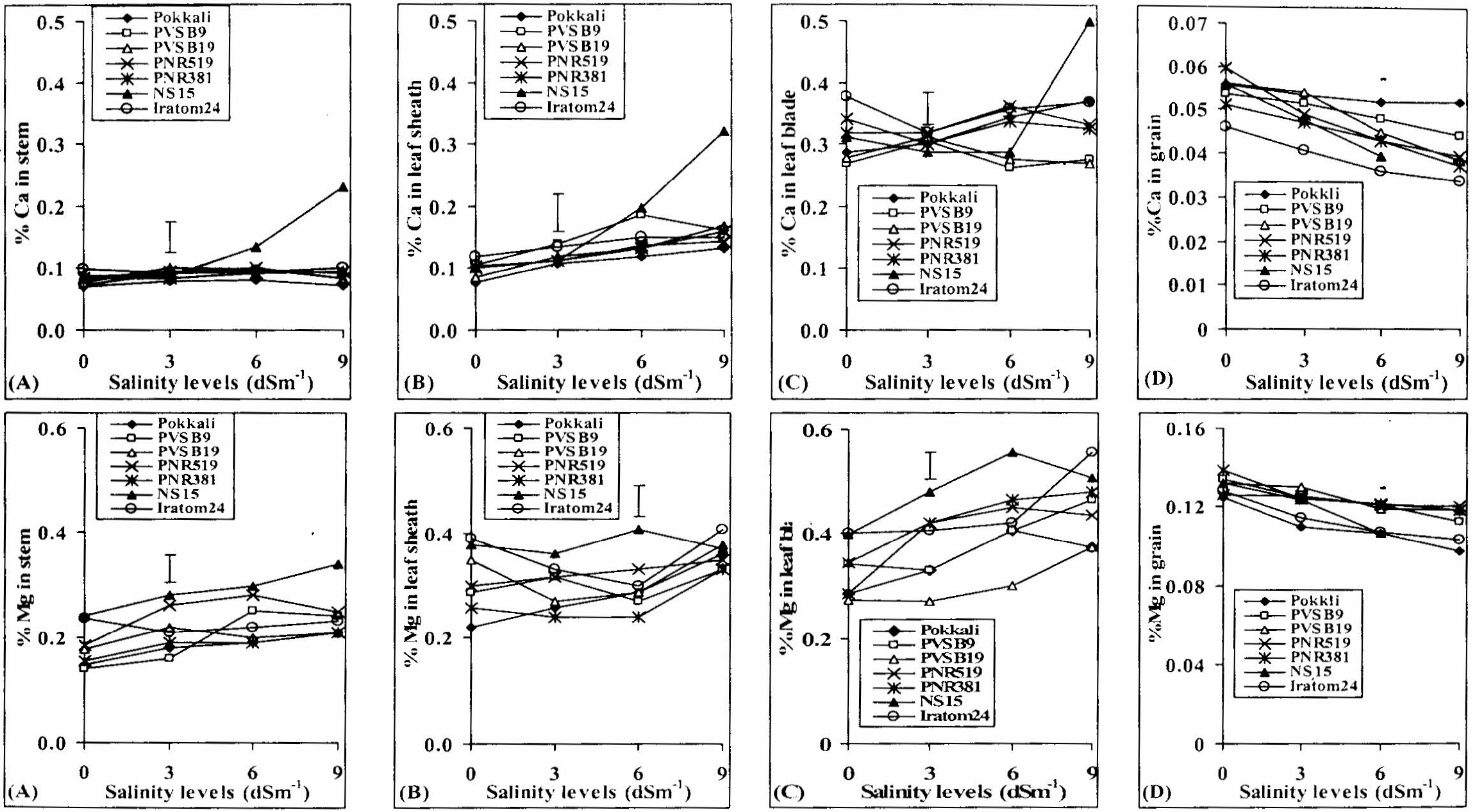

Figure 3. The effect of different salinity levels on Ca and Mg content in (A) stem, (B) leaf sheath, (C) leaf blade and (D) grain of seven selected rice genotypes (vertical bars represent critical difference at 0.05 level of significance)

Sodium was not distributed uniformly but accumulated in the older leaves before the younger ones and at least some leaves maintained a sub-lethal salt concentration in the salt resistant rice varieties (Yeo and Flowers, 1982). They also stated that there was a gradient along the leaf blades with leaf sheaths having the higher Na^+ concentration, particularly in the younger leaves. This established a static pattern, in which there was a steep gradient in salt concentration between the younger and older leaves. This pattern also holds for Cl^- contents.

Abdullah *et al.* (2002) stated that salinity significantly inhibited pollen viability, K^+ content in flag leaf and panicle and increased Na^+ content in different leaves and all the floral parts, which they apprehended to be one of the reasons of sterility of rice grain. Yeo and Flowers (1982) reported that the salt concentration in the older leaves increased rapidly while the younger leaves had lower concentrations, which might be evident in the resistant varieties and the sensitive variety was unable to maintain it. The concentration of Na^+, Ca^{2+}, Mg^{2+} and Cl^- in stem, leaf sheath, leaf blade and grain showed an increasing patterns in different plant parts of all the selected rice genotypes due to increasing salinity levels except Ca^{2+} and Mg^{2+} in grain, where these two ions decreased with increasing salinity levels (Fig.1&3). But the concentration of K^+ showed decreasing pattern in different plant parts with increasing salinity levels. In different plant parts, the Na^+ and Cl^- content increased very sharply and K^+ decreased very rapidly in susceptible genotype as compared to other genotypes, which might have diluted the Na^+ and Cl^- in plant system.

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