VARIATION IN GROWTH AND ION UPTAKE IN RICE CULTIVARS UNDER NaCl STRESS IN HYDROPONICS

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The study was planned to screen rice genotypes against different levels of salinity. Nursery was sown in sand. At two leaf stage, nursery was shifted to iron tubs floating over Yoshida nutrient solution in wire house-based hydroponics unit at three salinity levels (60 mol m^{-3}, 100 mol m^{-3} and 150 mol m^{-3}) using CRD factorial arrangement. Phenotypic performance based on survival of tolerant and susceptible genotypes was evaluated after 28 days of salt (NaCl) stress. Results of trial showed that the increase in salinity level decreased the growth of the seedlings of rice genotypes. However, decrease was more pronounced at 150 mol m^{-3} NaCl concentrations in the growth medium. Genotype KS-282 performed best at all levels of salinity on basis of shoot, root fresh and dry weight basis, respectively. Chemical analysis of shoots using flame photometer showed an increase in Na^+ contents and reduction in K^+ contents with each increment in salinity, irrespective of rice genotypes. A rapid increase in the K^+:Na^+ ratio in shoots was mainly the result of a high accumulation of Na^+. The genotype KS-282 exhibited a low accumulation of Na^+ contents and high accumulation of K^+ contents followed by IR-6 when compared to the other genotypes in saline environment. The physio-chemical analysis indicated that KS-282 was the most tolerant and KS-412 was the most sensitive genotypes. However, the selectivity of K^+ over Na^+, as exhibited by KS-282 and IR-6, appeared to be an important salt tolerant determinant.
Key words: NaCl stress, rice genotypes, growth variation, Ions uptake, salinity tolerance

INTRODUCTION

Soil salinity is a major abiotic stress in agriculture, strongly influencing crop productivity worldwide (Borsani *et al*. 2003). The available information suggests that salinity is highly damaging to economic prosperity and morale in agricultural communities, especially in developing countries. According to FAO and UNESCO estimates as much as half of all existing irrigation systems of the world are more or less under the influence of secondary salination, sodication and waterlogging (Szabolics, 1987). Plants are generally more sensitive to salinity during germination and early seedling stage.

Pakistan is situated in arid and semi-arid regions of the world. Economic use of salt-affected land has a special relevance to Pakistan where heavy pressure is on its natural resources because of increasing population. In Pakistan about 6.8 million hectares (Khan, 1998) of land is salt-affected, of which only 3.16 million hectares are within canal command, (Aslam, 2002).

Rice is the second most important crop of the world after wheat with more than 90% currently grown in Asia (Anonymous, 1992). Rice is highly valuable cash crop that earns substantial foreign exchange for the country. It accounts for 6.1% of total value added in agriculture and 1.3% of GDP. Rice is cultivated on an area of 2620 thousand hectares (Economic Survey, 2005-06).

In Pakistan estimated rice production is 5 million tons per annum, which accounts for 17 percent of the total production of food grain ("Dawn" Economic Review, 2003). It is now well known that some plant species can tolerate high salinity (Schachtman and Munns, 1992). Reduction in rice yield because of salinity is 40-60% (Aslam *et al.*, 1993b). The paddy yield is much low in Pakistan as compared to other rice producing countries. The soil in the famous rice grown area, called 'kallar tract' is characterized by the presence of slight to moderate salinity and sodicity. Rice is usually recommended as first choice during reclamation of salt-affected soils because of its special ability to grow in standing water as it helps in rapid leaching of salt-affected soils. There is enough scope for increasing yield from the salt affected soils by ensuring successful cultivation of rice cultivars capable of good yields is a pre-requisite. However, a significant difference for paddy yield under saline conditions has been reported among rice cultivars (Yeo and Flowers, 1984; Muhammad and Aslam, 1998).

In order to improve paddy yield from salt-affected lands, development of salt tolerant rice genotypes is basic requirement. Keeping in view the above facts, the aim of present study was the investigation of physiological differences under salt stressed conditions to find out which grow better and produce more yields under salt stress environment.

MATERIALS AND METHODS

The research work (solution culture experiment) was carried out under natural conditions in the wire house at Saline Agriculture Research Center, Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad. The wire house has a glass roof with no control over temperature, humidity and sunlight.

Raising of nursery

The seeds of 16 rice cultivars (KS-413, KS301, 99704, KS-282, 00518, Bas-385, Super Basmati, Bas-2000, IR-6, KS-133, PK-3712-12, 33608, KS-407, KS-410, KS-412) obtained from Rice Research Institute, Kala Shah Kaku, Lahore were sown in trays having 2 inch layer of gravel. After emergence, the seedlings were sprayed with half strength Yoshida nutrient solution (Yoshida *et al.*, 1972). At two leaf stage, the seedlings were transplanted to 100 L iron tubs lined with polythene sheet containing Yoshida nutrients solution. Two plants of each cultivar/genotype were transplanted randomly into foam plugged holes in polystyrene sheets floating over Yoshida nutrient solution in CRD factorial arrangement.

Development of salinity

Three salinity levels 60 mol m^{-3}, 100 mol m^{-3} and 150 mol m^{-3} NaCl were developed by dissolving calculated amounts of NaCl along with control (non-saline). After 6 days of transplanting, salinity was imposed gradually by adding NaCl salt. The pH (5.0) was maintained with addition of acid (HCl) or base (NaOH). Solutions were changed after every week during the entire experimental period. The EC of solution was checked daily and loss of water was made up. After 4 weeks, data regarding root/shoot fresh weight and root/shoot dry weight were recorded.

Extraction of leaves sap

After 28 days of transplanting, plants were harvested and prior to harvesting fully expanded third leaf samples were collected, rinsed in distilled water, blotted with tissue paper and stored in separate 1.5 cm^{-3} eppendrof tubes at -10 ºC. Frozen leaves samples in eppendrof tubes were thawed and crushed using a stainless steel rod (diameter: 0.65 cm) with tapered end. Tissue sap was collected in the other eppendrof tubes by a Gilson pipette and centrifuged at 6500 revolutions per minute (rpm) for 10 min (Clandon T-53 centrifuge machine; internal chamber: 0.35m × 0.18m; radius of rotation: 0.15 m). The supernatant sap was taken in the new eppendrof tubes and was stored at freezing temperature. Sodium and Potassium was determined by using flame photometer (Methods 10a and 11a of USDA Handbook 60 (Richards, 1954). Data of the experiment was subjected to statistical analysis.

RESULTS AND DISCUSSION

Result of hydroponic study showed that the increase in salinity level decreased the growth of the seedlings of rice genotypes. However decrease was more pronounced at 150 mol m^{-3} NaCl concentrations in the growth medium for all rice genotypes.

Shoot fresh weight

Data (Table 1) regarding shoot fresh weight (SFW) showed the comparison of rice genotypes at different salinity levels. In control, maximum SFW was recorded in KS–282 followed by Bas-385, 00518 and KS-133, respectively. The comparison of rice genotypes at low level of salinity (60 mol m^{-3}) showed the maximum SFW (6.26g/plant) in genotype KS-282 followed by KS-133 (4.24g) while the lowest SFW was recorded in genotype KS-410 (2.02g). However, at the highest salinity level (150 mol m^{-3}) the genotype

KS-282 performed better as compared to other genotypes, whereas KS-410 yielded the lowest SFW (0.75g). Almost similar trend was also observed at 100 mol m^{-3} salinity level.
The obtained results are in confirmation with Costa and Zoysa (1995), Qadir and Shams (1997) and Akhtar and Azhar (2001). The possible causes of this trend in SFW were attributed to shrinkage of cell contents, reduced development, differentiation of tissues and disturbed avoidance mechanism as described by Kent and Lauchli (1985).

Shoot dry weight

Data in Table 2 showed the shoot dry weight (SDW) of rice genotypes at different salinity levels. The maximum SDW, respectively at 60 mol m^{-3}, 100 mol m^{-3}, and 150 mol m^{-3} was observed by KS-282 and minimum SDW, respectively at 60, 100 and 150 mol m^{-3} was noted in KS-301.
The decrease in SDW of rice genotypes with the increase in salinity was also reported earlier by Iram *et al.* (1996) and Shannon *et al.* (1998). The decrease in SDW of rice genotypes with increase in salinity might be due to increased uptake (Brugnoli and Lauteri, 1991) and toxicity of Na^+ into the shoot (Shannon *et al.* 1998). Salinity affects the metabolic processes of plants, which results in growth reduction and ultimately decreases SDW (Cheesman, 1988). Proton exposure to salt brings large amount of toxic ions like Na^+ and Cl^- which interfere growth processes and reduce growth and biomass production or results in plant death, (Munus and Termat, 1986; Sharma, 1989).

Table 1. Effect of NaCl salinity on shoot fresh weight (g/plant) of different rice genotypes

Genotypes	Control	60 mol m^{-3} NaCl	100 mol m^{-3} NaCl	150 mol m^{-3} NaCl
KS-413	*3.4 ± 0.24	3.08 ± 0.02	1.79 ± 0.02	1.34 ± 0.03
KS-301	2.98± 0.03	2.11 ± 0.17	1.44 ± 0.02	1.29 ± 0.01
99704	4.59 ± 0.03	3.57 ± 0.02	2.22 ± 0.02	1.69 ± 0.02
KS-282	7.44 ± 0.04	6.26 ± 0.03	4.15 ± 0.03	2.49 ± 0.03
00518	5.44± 0.03	4.02 ± 0.02	2.56 ± 0.02	1.12 ± 0.02
Bas-385	5.71 ± 0.03	4.18 ± 0.03	2.15 ± 0.02	1.41 ± 0.02
Super Bas	3.69 ± 0.04	3.07 ± 0.02	1.59 ± 0.04	0.89 ± 0.01
Bas 2000	3.65 ± 0.05	3.36 ± 0.02	2.15 ± 0.02	1.08 ± 0.01
IR-6	3.77 ± 0.02	3.36 ± 0.02	2.05 ± 0.03	1.23 ± 0.02
KS-133	5.23 ± 0.03	4.24 ± 0.02	2.1 ± 0.13	1.25 ± 0.01
Pk-3712-12	4.5 ± 0.16	3.39 ± 0.02	2.68 ± 0.03	1.34 ± 0.03
33608	4.27 ± 0.02	3.63 ± 0.04	2.16 ± 0.02	1.32 ± 0.02
KS-406	4.56 ± 0.03	3.27 ± 0.04	2.4 ± 0.24	1.32 ± 0.01
KS-407	3.24 ± 0.04	2.23 ± 0.03	1.52 ± 0.03	0.68 ± 0.00
KS-410	2.61 ± 0.4	2.02 ± 0.02	1.25 ± 0.03	0.75 ± 0.03
KS-412	3.09 ± 0.04	2.94 ± 0.03	1.77 ± 0.03	1.52 ± 0.02
Mean	4.26 A	3.42 B	2.12 C	1.30 D

*Average ± Standard error of three replications.

Table 2. Effect of NaCl salinity on shoot dry weight (g/plant) of different rice genotypes

Genotypes	Control	60 mol m^{-3} NaCl	100 mol m^{-3} NaCl	150 mol m^{-3} NaCl
KS-413	*0.99 ± 0.02	0.81 ± 0.03	0.55 ± 0.02	0.42 ± 0.01
KS-301	0.44 ± 0.02	0.31 ± 0.02	0.22 ± 0.02	0.17 ± 0.01
99704	0.91 ± 0.03	0.68 ± 0.02	0.57 ± 0.02	0.45 ± 0.02
KS-282	3.92 ± 0.02	2.78 ± 0.02	1.6 ± 0.24	0.81 ± 0.02
00518	2.39 ± 0.02	1.88 ± 0.03	0.95 ± 0.02	0.57 ± 0.02
Bas-385	2.03 ± 0.02	1.61 ± 0.02	0.64 ± 0.03	0.38 ± 0.02
Super Bas	1.21 ± 0.02	0.88 ± 0.02	0.55 ± 0.02	0.28 ± 0.03
Bas 2000	1.11 ± 0.02	0.87 ± 0.04	0.64 ± 0.04	0.38 ± 0.02
IR-6	2.21 ± 0.02	1.24 ± 0.02	0.65 ± 0.02	0.33 ± 0.02
KS-133	2.13 ± 0.02	1.62 ± 0.03	0.64 ± 0.02	0.45 ± 0.02
Pk-3712-12	1.52 ± 0.02	0.78 ± 0.02	0.65 ± 0.03	0.46 ± 0.00
33608	1.02 ± 0.02	0.94 ± 0.02	0.57 ± 0.01	0.35 ± 0.01
KS-406	1.1 ± 0.06	0.95 ± 0.03	0.59 ± 0.02	0.38 ± 0.02
KS-407	0.69 ± 0.04	0.46 ± 0.01	0.47 ± 0.02	0.22 ± 0.02
KS-410	0.85 ± 0.02	0.57 ± 0.02	0.44 ± 0.02	0.27 ± 0.01
KS-412	0.65 ± 0.02	0.42 ± 0.03	0.34 ± 0.04	0.23 ± 0.03
Mean	1.45 A	1.05 B	0.63 C	0.39 D

*Average ± Standard error of three replications.

Root fresh weight

Table 3 summarized the result of root fresh weight (RFW) at different salinity levels. The maximum root fresh weight (3.01, 2.41, 1.92g, respectively) was produced by KS-282 at 60, 100, and 150 mol m^{-3} salinity levels. Whereas at salinity level 60 mol m^{-3} minimum root fresh weight (1.55g) was produced by genotype Bas-385. At salinity 100 mol m^{-3} and 150 mol m^{-3} minimum root fresh weight of (1.36g, 0.51g) was produced by genotypes Super Bas and PK-3712-12 respectively.

Decrease in RFW with increasing salinity was also reported in rice by (Muhammad and Aslam, 1998) and in wheat by Qureshi *et al.,* 1991; Akhtar *et al.* 2000. Reduction in RFW was due to decreased water uptake, and decreased osmotic potential (Terry and Waldron, 1984). This could also be due to ion toxicity and nutrition imbalance (Levitt, 1980).

Root dry weight

Data in Table 4 describe the root dry weight (RDW) of rice genotypes at different salinity levels. The comparison of rice genotypes showed that maximum RDW of (0.49, 0.31, 0.27g,) was produced by genotype KS-282 at salinity levels of 60, 100 and 150 mol m^{-3}, respectively. However minimum RDW of (0.14, 0.08, 0.05g) was produced by three genotypes KS-410, Super Bas, and KS-407 at salinity levels 60, 100, 150 mol m^{-3}, respectively.

Similar results were observed by Qadir and Shams (1997) and Costa and Zoysa (1995). The overall reduction in RDW could be attributed due to toxic effect of salt and reduced nutrients availability to growing roots (Qadir and Shams, 1997).

Nutrient concentration in leaf sap

Na^{+} concentration

Table 3. Effect of NaCl salinity on root fresh weight (g/plant) of different rice genotypes

Genotypes	Control	60 mol m^{-3} NaCl	100 mol m^{-3} NaCl	150 mol m^{-3} NaCl
KS-413	*2.48 ± 0.04	2.4 ± 0.16	1.39 ± 0.03	1.09 ± 0.02
KS-301	2.85 ± 0.02	2.58 ± 0.03	2.17 ± 0.02	1.31 ± 0.01
99704	3.01 ± 0.02	2.44 ± 0.03	1.93 ± 0.03	1.44 ± 0.01
KS-282	4.45 ± 0.02	3.01 ± 0.02	2.41 ± 0.02	1.92 ± 0.01
00518	3.21 ± 0.03	2.53 ± 0.02	2.03 ± 0.02	1.37 ± 0.01
Bas-385	3.69± 0.02	1.55 ± 0.02	1.45 ± 0.02	0.98 ± 0.01
Super Bas	2.75 ± 0.02	2.3 ± 0.24	1.36 ± 0.03	0.84 ± 0.02
Bas 2000	2.72 ± 0.02	1.99 ± 0.03	1.42 ± 0.02	1.01 ± 0.01
IR-6	2.14 ± 0.02	1.92 ± 0.02	1.39 ± 0.01	0.87 ± 0.02
KS-133	3.49 ± 0.03	2.92 ± 0.03	1.81 ± 0.02	1.17 ± 0.01
Pk-3712-12	2.95 ± 0.03	2.12 ± 0.02	1.36 ± 0.03	0.51 ± 0.01
33608	3.07 ± 0.43	2.04 ± 0.02	1.54 ± 0.03	0.84 ± 0.01
KS-406	2.95 ± 0.04	2.18 ± 0.02	1.92 ± 0.03	0.75 ± 0.02
KS-407	3.64 ± 0.04	1.93 ± 0.03	1.6 ± 0.24	0.71 ± 0.01
KS-410	2.51 ± 0.03	1.63 ± 0.02	1.37 ± 0.02	0.82 ± 0.02
KS-412	3.5 ± 0.16	1.82 ± 0.02	1.74 ± 0.02	1.17 ± 0.01
Mean	3.09 A	2.21 B	1.69 C	1.05 D

*Average ± Standard error of three replications.

Data (Table 5) showed the Na^+ concentration in various rice genotypes at different salinity levels. The highest Na^+ concentration was found at 150 mol m^{-3} salinity level. The comparison of rice genotypes at different levels showed that minimum Na^+ concentration of 31, 51 and 61 mol m^{-3} were found in genotype KS-282 at 60, 100 and 150 mol m^{-3} salinity levels, respectively. Whereas maximum Na^+ concentration of 65 mol m^{-3} was found in KS- 407 at 60 mol m^{-3} salinity level. At salinity level 100 mol m^{-3} and 150 mol m^{-3}, maximum Na^+ concentrations of 95 and 141 mol m^{-3}, respectively was found in genotype KS-410.

Increasing Na^+ concentration with increasing salinity was in accordance with findings of Aslam *et al.* (1993) in rice, Qureshi *et al.* (1991), Akhtar *et al.* (2000), Nawaz *et al.* (1998) in wheat and Claudia *et al.* (1995) in rape seed.

Table 4. Effect of NaCl salinity on root dry weight (g/plant) of different rice genotypes

Genotypes	Control	60 mol m^{-3} NaCl	100 mol m^{-3} NaCl	150 mol m^{-3} NaCl
KS-413	*0.27 ± 0.02	0.21 ± 0.02	0.11 ± 0.02	0.08 ± 0.01
KS-301	0.27 ± 0.01	0.2 ± 0.02	0.14 ± 0.02	0.12± 0.01
99704	0.31 ± 0.02	0.29 ± 0.02	0.13 ± 0.01	0.10 ± 0.02
KS-282	0.61 ±0.02	0.49 ± 0.02	0.31 ± 0.02	0.27 ± 0.01
00518	0.45 ± 0.02	0.31 ± 0.02	0.17 ± 0.02	0.11 ± 0.01
Bas-385	0.44 ±0.02	0.26 ± 0.02	0.16 ± 0.02	0.1 ± 0.01
Super Bas	0.23 ±0.02	0.19 ± 0.01	0.08 ± 0.02	0.06 ± 0.01
Bas 2000	0.35 ±0.02	0.21 ± 0.02	0.1 ± 0.01	0.09 ± 0.01
IR-6	0.37 ±0.02	0.25 ± 0.03	0.14 ± 0.02	0.09 ± 0.01
KS-133	0.43 ±0.02	0.33 ± 0.03	0.14 ± 0.02	0.11 ± 0.01
Pk-3712-12	0.36 ± 0.01	0.26 ± 0.01	0.15 ± 0.02	0.11 ± 0.01
33608	0.34 ± 0.02	0.33 ± 0.02	0.11 ± 0.02	0.08 ± 0.01
KS-406	0.38 ± 0.02	0.26 ± 0.02	0.14 ± 0.02	0.13 ± 0.01
KS-407	0.33 ± 0.03	0.18 ± 0.01	0.1 ± 0.02	0.05 ± 0.01
KS-410	0.27 ± 0.01	0.14 ± 0.02	0.12 ± 0.01	0.07 ± 0.00
KS-412	0.28 ± 0.01	0.17 ± 0.02	0.13 ± 0.01	0.11 ± 0.01
Mean	0.36 A	0.26 B	0.14 C	0.11 D

*Average ± Standard error of three replications.

Table 5. Effect of NaCl salinity on Na^+ concentration (mol m^{-3}) in leaf sap

Genotypes	Control	60 mol m^{-3} NaCl	100 mol m^{-3} NaCl	150 mol m^{-3} NaCl
KS-413	*20 ± 0.5	42 ± 1.6	76 ± 1.1	96 ± 0.8
KS-301	25 ± 0.9	46 ± 1.2	82 ± 1.6	104 ± 1.3
99704	16 ± 0.3	38 ± 0.9	84 ± 0.7	110 ± 1.6
KS-282	12 ± 0.3	31 ± 0.9	51 ± 0.1	61 ± 0.3
00518	15 ± 0.2	33 ± 0.6	61 ± 0.8	88 ± 0.5
Bas-385	17 ± 0.3	42 ±1.7	63 ± 1.2	96 ± 1.2
Super Bas	14 ± 0.7	37 ± 1.2	79 ± 0.6	115 ± 1.2
Bas 2000	15 ± 0.5	55 ± 1.1	87 ± 0.8	127 ± 0.7
IR-6	19 ± 0.4	39 ± 0.2	58 ± 0.7	92 ± 1.3
KS-133	14 ± 0.2	45 ± 0.8	83 ± 0.8	108 ± 1.5
Pk-3712-12	13 ± 0.2	44 ± 0.6	69 ± 0.8	103 ± 0.5
33608	16 ± 0.3	50 ± 1.0	76 ± 0.4	107 ± 0.9
KS-406	19 ± 0.4	56 ± 0.1	86 ± 0.7	130 ± 0.2
KS-407	22 ± 0.5	65 ± 0.6	90 ± 0.3	134 ± 0.4
KS-410	17 ± 0.2	61 ± 0.8	95 ± 1.3	141 ± 1.1
KS-412	18 ± 0.6	63 ± 0.4	92 ± 0.6	126 ± 0.4
Mean	17.61 D	47.20 C	77.56 B	109.29 A

*Average ± Standard error of three replications.

K^+ concentration

Table 6 describes K^+ concentration in the rice genotypes at different salinity levels. On an overall average basis the increase in salinity decreased K^+ concentration significantly at all levels of salinity, however, decrease was more pronounced at 150 mol m^{-3} NaCl concentration in growth medium. The comparison of rice genotypes at 60, 100, and 150 mol m^{-3} level of salinity showed the maximum K^+ concentration of

Table 6. Effect of NaCl salinity on K^+ concentration (mol m^{-3}) in leaf sap

Genotypes	Control	60 mol m^{-3} NaCl	100 mol m^{-3} NaCl	150 mol m^{-3} NaCl
KS-413	*290 ± 0.8	269 ± 0.8	244 ± 1.2	209 ± 0.2
KS-301	220 ± 0.8	200 ± 0.7	170 ± 0.8	155 ± 1.7
99704	204 ± 0.6	198 ± 0.6	171 ± 1.3	145 ± 0.4
KS-282	361 ± 1.3	305 ± 0.8	303 ± 2.1	291 ± 1.4
00518	301 ± 0.8	285 ± 0.9	263 ± 0.6	250 ± 0.9
Bas-385	311 ± 0.9	274 ± 0.7	254 ± 1.0	238 ± 0.7
Super Bas	194 ± 0.7	171 ± 0.6	159 ± 0.8	141 ± 0.3
Bas 2000	198 ± 0.7	176 ± 0.9	163 ± 0.4	135 ± 0.9
IR-6	305 ± 1.2	291 ± 0.3	271 ± 0.9	260 ± 0.5
KS-133	173 ± 1.1	150 ± 0.5	153 ± 1.0	130 ± 1.0
Pk-3712-12	191 ± 0.7	182 ± 1.7	164 ± 0.7	144 ± 0.4
33608	298 ± 0.5	272 ± 0.1	260 ± 0.9	230 ± 1.0
KS-406	244 ± 0.8	252 ± 1.2	232 ± 1.4	202 ± 1.3
KS-407	249 ± 0.8	223 ± 2.3	205 ± 1.6	184 ± 0.6
KS-410	191 ± 0.8	169 ± 1.2	151 ± 0.8	139 ± 0.6
KS-412	159 ± 0.7	143 ± 1.5	132 ± 1.6	124 ± 0.7
Mean	243.60 A	223.04 B	206.39 C	186.49 D

*Average ± Standard error of three replications.

Table 7. Effect of NaCl salinity on K^+/Na^+ ratio

Genotypes	Control	60 mol m^{-3} NaCl	100 mol m^{-3} NaCl	150 mol m^{-3} NaCl
KS-413	*14± 0.4	6± 0.3	3± 0.05	2.2± 0.02
KS-301	8± 0.3	4± 0.1	2± 0.04	1.5± 0.03
99704	12.1± 0.2	5.1± 0.3	2± 0.03	1.3± 0.02
KS-282	28.6± 0.7	9.7± 0.1	5.9± 0.1	4.7± 0.05
00518	19.1± 0.3	8.5± 0.1	4.2± 0.06	2.8± 0.03
Bas-385	18.2± 0.4	6.4± 0.3	3.9± 0.9	2.4± 0.04
Super Bas	13.7± 0.8	4.5± 0.1	2± 0.03	1.2± 0.01
Bas 2000	13.1± 0.4	3.1± 0.05	1.8± 0.02	1.1± 0.01
IR-6	15.6± 0.4	7.4± 0.03	4.6± 0.07	2.8± 0.03
KS-133	11.7± 0.2	3.3± 0.07	1.8± 0.01	1.2± 0.03
Pk-3712-12	13.8± 0.2	4.1± 0.07	2.3± 0.03	1.4± 0.01
33608	17.7± 0.4	5.3± 0.1	3.4± 0.03	2.1± 0.03
KS-406	12.3± 0.3	4.4± 0.03	2.6± 0.02	1.5± 0.01
KS-407	10.9± 0.3	3.4± 0.06	2.2± 0.02	1.3± 0.01
KS-410	10.7± 0.1	2.7± 0.05	1.5± 0.03	1.0± 0.01
KS-412	8.6± 0.3	2.3± 0.03	1.4± 0.03	1.0± 0.0
Mean	14.33 A	5.09 B	2.85 C	1.86 D

*Average ± Standard error of three replications.

305, 303 and 291 mol m^{-3}, respectively in genotype KS-282 as compared to other genotypes. Similarly, the minimum K^+ concentration of 143, 132 and 124 mol m^{-3} was observed in genotypes KS-412 at salinity levels of 60, 100, 150 mol m^{-3}, respectively. Decreased in K^+ concentration with increasing salinity was also recorded in rice Aslam *et al.* (1993), in wheat (Qureshi *et al.*, 1991; Akhtar *et al.*, 2001; Nawaz *et al.*, 1998). High external Na^+ concentration interferes with K^+ absorption resulting in low leaf K^+ concentration (Cramer *et al.* 1985) increased K^+ selectivity for absorption (Flowers *et al.* 1977). This increased maintenance of K^+ at high external NaCl could be due to salt tolerance behaviour (Benes *et al.* 1996).

K^+/Na^+ ratio

Data in Table 7 summarized the results of K^+/Na^+ ratio in the rice genotypes at different salinity levels. The comparison of genotypes on an over all average basis showed significantly higher K^+/Na^+ concentration in genotypes KS-282. The comparison of genotypes at 60, 100 and 150 mol m^{-3} showed that maximum K^+/Na^+ value of 9.7, 5.9 and 4.7, respectively was found in genotype KS-282. Where as minimum K^+/Na^+ value of 2.3, 1.4 and 1.0 was observed in genotype KS-412 at salinity levels 60, 100 and 150 mol m^{-3}, respectively. Decrease in K^+/Na^+ ratio with increased salinity was found in rice by (Aslam, 1993) in wheat by (Qureshi *et al.,* 1991) and (Akhtar *et al.,* 2000).

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