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COMPARATIVE STUDY OF GRAIN YIELD AND BIOCHEMICAL TRAITS OF DIFFERENT RICE VARIETIES GROWN UNDER SALINE AND NORMAL CONDITIONS.

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ABSTRACT

Salinity is a major abiotic stress limiting rice production worldwide. Grain yield and different biochemical traits are important in crop adaptation and tolerance to salinity stress. In the present study, 24 rice varieties were evaluated by conducting field trials under natural saline condition (salinity block) and normal field condition during 2010 and 2011. Twenty four rice varieties were categorized into four groups- salt tolerant, moderately salt tolerant, moderately salt susceptible and salt susceptible based on salinity tolerance and grain yield data of two years. Pokkali, Basmati-198 and Sathra-278 were categorized as salt tolerant varieties. All categories of rice varieties showed distinct differences in studied biochemical traits under saline conditions compared to control. Higher amount of total cations were ruinous for rice plant, whereas, higher amount of K^+ and Ca^{++} were beneficial under saline condition signifying that uptake of selective cations were imperative for rice plant. Under saline condition, K^+ uptake ratio and total cations uptake ratio showed significant positive and very highly significant negative correlation with grain yield, respectively in 2010, whereas those traits showed non-significant correlation in 2011. Again, Na^+ uptake ratio showed non-significant negative and significant negative correlation with grain yield in 2010 and 2011, respectively. Both years data revealed that among salt tolerant varieties minimum amount of Na^+ and total cations uptake, maximum amount of K^+ and Ca^{++} and lower ratio of Na^+/K^+ uptake were observed under salinity stress. Na^+ uptake, Na^+/K^+ uptake, Na^+ uptake ratio and uptake ratio of Na^+/K^+ had negative correlation, whereas, K^+ uptake, Ca^{++} uptake, K^+ uptake ratio, Ca^{++} uptake ratio showed positive correlation with grain yield under saline condition indicating that lower uptake of Na^+, higher uptake of K^+ and Ca^{++} were responsible for higher grain yield under saline condition and salt tolerant category varieties had the same uptake trend of Na^+, K^+ and Ca^{++}.

Key words: rice, salinity, yield, biochemical.

INTRODUCTION

Rice is one of the most important cereals and is a major source of food for large number of the people worldwide. It is grown on about one-tenth of the earth's arable land. It is the single largest source of food energy to more than half of the world population (Ammar *et al.*, 2007). It is the leading staple food of Asia, accounting for more than 70% of caloric intake. Most of the rice in the world is cultivated and consumed in Asia (Khush and Brar, 2002). Half of the world's population survives on rice by receiving the highest (26.2%) calories intake from it (FAO, 2009).

Many biotic and abiotic stresses affect rice production all over the world, among which abiotic stress alone contributes to about 50% of the total yield losses. Soil/water salinity is one of the major and common stresses among the abiotic stresses and limiting rice production in the world (Ren *et al.* 2010). About 15% of the total land area of the world has been affected due to soil erosion and physical and chemical degradation, including soil salinization (Wild, 2003). Approximately 30% of the total irrigated land worldwide is salt-affected (Rengasamy, 2006) and that limits the total rice production in the planet. Salinity damages in different ways throughout the world like crop yield reduction, degradation of socioeconomic and environmental condition (FAO, 2005). As world population is increasing gradually and to feed the increasing population it is becoming crucial to utilize these saline soils either by reclamation of salinity or by growing salt tolerant plants (Ali *et al.*, 2012, Saeed *et al.*, 2012). Reclamation of salinity is difficult and expensive, and not the permanent solution of the problem. Introduction of salt-tolerant variety is the realistic approach to obtain better yield under saline conditions (Ashraf *et al.*, 2008, Saeed *et al.*, 2012).

Soil salinity decreases the plant growth rate and can harshly limit the crop production. Salinity tolerance differs extensively between species of plants and within species (Plett and Mollar, 2010). It is very crucial to select rice varieties that have a greater tolerance to salts for growing in an area where salinity is a problem. The rice varieties having salt tolerance characteristic may be selected for cultivation in saline areas. A number of plant traits including biochemical traits have been found associated with sustained yield under stress conditions such as, Na^+ uptake, K^+ uptake, Ca^{++} uptake, total cations uptake, Na^+/K^+ uptake etc. Few components, such as Na^+ uptake, ion balance and ion compartmentation, had great influence on plant growth and crop production. The reduction in shoot growth occurred in two phases: a rapid response to the increase in external osmotic pressure, and a slower response due to the accumulation of Na^+ in leaves (Munns and Tester, 2008).

Moreover, information about salt tolerance in respect of biochemical traits of different rice varieties would be useful for rice breeding programme. Limited research work was conducted on screening of different Pakistani rice varieties based on salinity tolerance and biochemical characterization of salt tolerant varieties.

The present study aims to screen out the salt tolerant rice varieties by evaluating grain yield performance of different rice varieties grown under saline and normal condition, biochemical characterization of salt tolerant varieties, and to study genotypic differences with respect to salinity tolerance in rice.

MATERIALS AND METHODS

Plant material: Seeds of 24 rice varieties/lines were collected from Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan. List of rice varieties/lines are shown in Table 1.

Salinity Blocks: Two salinity blocks were constructed to avoid the experimental error and to obtain accurate results. Salinity blocks (each of 40 feet × 20 feet × 5 feet) with glass roofs were constructed so that glass roofs would not create any hindrance in light reception and dilution of salt by rainfall could be avoided. Soil was collected from saline areas of District Sheikhupura, Punjab, Pakistan having electrical conductivity of 6-9 ds/m and used in the salinity blocks. Leaching, percolation and surface runoff of soil water were strictly controlled so that electrical conductivity remained constant.

Raising of seedlings: Twenty four large size glass Petri plates (14.6 cm diameter) were taken and washed thoroughly with distilled water. Petri plates were marked with variety/line names mentioned in table 1. Equal amount of sterilized distilled water was poured in to the Petri plates (with 2 layers of Whatman filter paper) such a way that bottom parts of the Petri plates were just dipped. Rice seeds of all varieties/lines were washed thoroughly one by one. One hundred seeds of each variety/line were placed in the specific marked Petri plate. Water of all Petri plates was changed with equal amount of sterilized distilled water daily. After five days seeds were nicely sprouted (both radicle and plumule) in all Petri plates.

Twenty four plastic pots of 40 cm diameter were washed thoroughly with clean water. Plastic pots were marked with variety/line names mentioned in table 1. The pots were filled-up with normal sieved crop land soil. Soils of pots were irrigated properly and the pots were kept undisturbed for about two hours. After that soil of each pot was mixed well with water and mud was prepared. Sprouted seeds of each variety/line were then transferred from Petri plates to marked plastic pot one by one. The plastic pots were kept in glass-house. Rice seedlings of each plastic pot were taken care and given irrigation properly and timely. Forty eight large plastic pots (two for each variety/line) of 40 cm diameter were washed thoroughly with clean water. Marking, irrigation and making mud were done as earlier. A common fertilizer dose for rice seedling i.e., diammonium phosphate (DAP) @ 1g/pot; urea @ 1.5 g/pot; potassium sulphate @ 0.5 g/pot and zinc sulphate @ 0.1 g/pot were applied in each large plastic pot. Fertilizer dose was calculated as follows:

Area of the plastic pot = $\pi r^2 = 3.14 \times (0.20)^2$

[r = radius of the pot=20cm=0.20m]

= 0.1256 square meter

Dose of potassium sulphate = 40 kg/ha = 40000/10000 g/square meter [1 ha = 10,000 square meter]

Potassium sulphate required for one pot (0.1256 square meter) = 40000/10000 X 0.1256 = 0.5 g

Similarly, all other fertilizers were calculated.

Ten days old rice seedlings of each variety/line grown in plastic pot were transplanted in respective two plastic pots. The plastic pots were kept in glass-house. Rice seedlings of each plastic pot were taken care and given irrigation properly and timely.

Transplantation of seedlings: Transplantation of seedlings in salinity block and normal field were designed as split plot design with three replications. Salinity block and normal field were taken as main plots, while genotypes were assigned to subplots. A total of seventy two (variety 24 × replication 3) experimental units were prepared in both salinity block and normal field. Each experimental unit size was 0.63 squares meter and contained 9 seedlings with spacing of 22.8 cm × 30.5 cm. Thirty days old seedlings of each variety/line grown in two large plastic pots were uprooted carefully and transplanted in both salinity block and normal field on June 25, 2010 and July 1, 2011 at a hill spacing of 22.8 cm × 30.5 cm with one seedling per hill. Twenty seven seedlings (seedling 9 × replication 3) of all 24 varieties/lines were transplanted in both salinity block and normal field.

A common fertilizer dose was applied in both saline and normal field at the rate of nitrogen (N_2) 148 kg/ha; phosphorus (P) 74 kg/ha; potassium (K) 62 kg/ha and zinc (Z) 5 kg/ha. Full doses of phosphorus (P), potassium (K), zinc (Zn) and one-third of nitrogen (N_2) were applied as basal dose during final land preparation. One-third of nitrogen (N_2) was applied at 28 days after transplanting (DAT) and remaining one-third of nitrogen

(N_2) was applied at 45 days after transplanting (DAT) as top dressing. Weeds, diseases and insect pests were controlled throughout the whole rice growth period. Irrigation was done according to the requirement of the soil.

It is noted that rice seedlings were grown in plastic pots those were kept in glass house for the protection of seedlings from rainfall, storm or any other adverse weather and there was no problem of light reception. Thirty days old seedlings were transplanted in salinity block that had glass roofs so that glass roofs would not create any barrier in light reception and rice plants were protected from rainfall. Rice plants were grown in appropriate season in both years so there were similar weather conditions in both years but weather parameters like temperature, relative humidity etc were not recorded.

The soil properties of the salinity block and the normal field for 2010 and 2011 are shown in Table 2.

Biochemical traits and grain yield measurement and data analysis: At flag leaf stage flag leaves were collected from rice plants grown under both salinity block and normal field conditions, and sodium, potassium and calcium contents were quantified by using Atomic Absorption Spectrophotometer. The cations uptake analysis was performed using dried plant material following the method described by Gillingham *et al.* (1987) with slight modification.

The following biochemical traits were measured:

i. Sodium content in flag leaf (Sodium uptake).
ii. Potassium content in flag leaf (Potassium uptake).
iii. Calcium content in flag leaf (Calcium uptake).
iv. Total cation content in flag leaf (Total cation uptake).
v. Sodium and potassium ratio in flag leaf (Ratio of Sodium and Potassium uptake).
vi. Uptake ratio of sodium content (compared to soil).
vii. Uptake ratio of potassium content (compared to soil).
viii. Uptake ratio of calcium content (compared to soil).
ix. Uptake ratio of sodium and potassium content (compared to soil).
x. Uptake ratio of total cation content (compared to soil).

Sodium uptake ratio by rice plant was calculated by using the following formula:

$$\text{Sodium uptake ratio by plant} = \frac{\text{Sodium content in flag leaf}}{\text{Total sodium content in soil}}$$

Total sodium content in soil= sodium content in soil during harvesting time + sodium content in flag leaf at maturity stage.

Similarly, potassium, calcium and total cation uptakes by plant were calculated.

Total cation was calculated by adding sodium, potassium and calcium (It is noted that other minor cations were not considered).

Grain yield data was collected at maturity stage of each rice variety grown under saline and normal field conditions. Number of effective tillers per plant (panicle bearing tillers) and number of grains per panicle were counted, and 1000 grain weight (weight of 1000 number of grains) were recorded.

Grain yield was calculated by using the following formula:

$$\text{Grain yield (g/plant)} = \frac{\text{Number of effective tillers/plant}}{} \times \text{Number of grain/panicle} \times \text{Thousand grain weight (g)} / 1000$$

Data collected from nine plants of each rice variety for each replication was averaged and thus data were collected for each rice variety for 3 replications. Data was analyzed using the statistical software COSTAT v6.303.

RESULTS

All 24 rice varieties were assessed and categorized based on salinity tolerance performing comparative study of grain yield traits under normal and saline conditions using t-test: two sample assuming equal variances. Based on the grain yield data of two years (2010 and 2011) all 24 rice varieties were classified into four categories- salt tolerant, moderately salt tolerant, moderately salt susceptible and salt susceptible (Table 3 and Table 4). Pokkali, Basmati 198 and Sathra 278 were categorized as salt tolerant varieties; Super Basmati, Basmati 385, SRI-8, SRI-12, SHP were categorized as moderately salt tolerant varieties; Pak Basmati, Super Kernal, PB-95, B-515, KS-282, IRP-1, SN 4365 were categorized as moderately salt susceptible varieties, and IR36, Shaheen Basmati, Basmati 2000, Basmati 370, Basmati 6129, IR-6, KSK-133, TN-1, IRP-2 were categorized as salt susceptible varieties. Salt tolerant varieties showed non-significant difference and salt susceptible varieties showed very highly significant difference for grain yield trait under salinity stress condition compared to normal condition (control) in both 2010 and 2011.

In case of field trials of 2010 and 2011, analysis of variance showed that considerable differences occurred for salt, genotypes and salt-genotype interactions for all 4 categories of rice varieties in respect of grain yield, Na^+ uptake, K^+ uptake, Ca^{++} uptake and total cations uptake. For Na^+/K^+ uptake, there was non-significant difference for salt treatment and salt-genotype interaction in both 2010 and 2011 i.e., salt treatment and salt-genotype interaction affected this parameter a little. There were non-significant differences for salt-genotype interactions for the traits Na^+ uptake ratio, K^+ uptake ratio, Ca^{++} uptake ratio, total cations uptake ratio and uptake ratio of Na^+/K^+ in both years trial i.e., salt-genotype interaction did not affect these parameters too much (Table 5).

K^+ uptake showed very highly significant ($P \leq 0.001$) differences for salt-genotype interactions in 2010, whereas in 2011 it showed non-significant ($P > 0.05$) differences.

Mean value indicated that all 4 categories of rice varieties showed marked differences in studied biochemical traits under saline conditions compared to the control treatments in both years field trials (Table 3 and Table 4). All four categories of rice varieties were significantly different from each other for almost all the biochemical traits and varied under saline condition to normal. All 4 categories of rice varieties showed higher response to Na^+, K^+ and Ca^{++} uptake in salinity stress compared to normal condition. It revealed that Na^+, K^+ and Ca^{++} uptake were higher in saline condition compared to normal condition and it was true for all 4 categories of rice varieties. This finding supports the study of Garca- a Morales*et al.* (2012) who reported that Na^+ concentration was significantly ($p \leq 0.05$) higher in NaCI-treated rice plants.

In both years field trial, all the biochemical traits were significantly lower under saline condition for salt tolerant varieties except K^+ uptake, Ca^{++} uptake, K^+ uptake ratio, Ca^{++} uptake ratio, total cations uptake ratio. It revealed that under salinity stress salt tolerant varieties uptook minimum amount of Na^+ and total cations, uptook maximum amount of K^+ and Ca^{++} and made the lower ratio of Na^+/K^+ uptake. Balance uptake of Na^+ and K^+, and lower ratio of Na^+/K^+ uptake were observed in salt tolerant varieties under saline condition. Whereas, inverse trend i.e significantly higher uptake of Na^+ and total cations, significantly lower uptake of K^+ and Ca^{++}, imbalance uptake of Na^+ and K^+, and higher ratio of Na^+/K^+ uptake were observed in other categories of rice varieties specially in salt susceptible varieties.

In 2010 field trial, all the biochemical traits except Na^+ uptake, K^+ uptake, Na^+ uptake ratio and K^+ uptake ratio showed positive correlation with grain yield under normal condition and among those Ca^{++} uptake ($r = 0.245$; $P \leq 0.01$) and Ca^{++} uptake ratio ($r = 0.298$; $P \leq 0.01$) showed highly significant positive correlation (Table 6). Whereas, all the biochemical traits except Na^+ uptake, Na^+/K^+ uptake, total cation uptake, Na^+ uptake ratio, total cation uptake ratio and uptake ratio Na^+/K^+ showed positive correlation with grain yield under saline condition and among those Ca^{++} uptake ($r = 0.433$; $P \leq 0.001$), K^+ uptake ratio ($r = 0.227$; $P \leq 0.05$) and Ca^{++} uptake ratio ($r = 0.492$; $P \leq 0.001$) had significant positive correlation.

In 2011 field trial, all the biochemical traits except Na^+ uptake, Na^+/K^+ uptake and uptake ratio of Na^+/K^+ showed negative correlation with grain yield under normal condition and among those K^+ uptake, total cations uptake, K^+ uptake ratio, total cations uptake ratio showed very highly significant negative correlation (Table 7). Whereas, all the biochemical traits except K^+ uptake, Ca^{++} uptake, K^+ uptake ratio, Ca^{++} uptake ratio showed negative correlation with grain yield under saline condition and among those Na^+ uptake ($r = -0.7082$; $P \leq 0.01$), Na^+/K^+ uptake ($r = -0.6133$; $P \leq 0.05$), Na^+ uptake ratio ($r = -0.6286$; $P \leq 0.05$) and uptake ratio of Na^+/K^+ ($r = -0.6225$; $P \leq 0.05$) had highly significant or significant negative correlation. K^+ uptake, Ca^{++} uptake ($r = 0.7484$; $P \leq 0.01$), K^+ uptake ratio, Ca^{++} uptake ratio showed positive correlation with grain yield under saline condition.

Under normal condition, Ca^{++} uptake ($r = 0.245$; $P \leq 0.001$) and Ca^{++} uptake ratio ($r = 0.298$; $P \leq 0.001$) showed very highly significant positive correlation with grain yield in 2010, whereas in 2011 those traits showed non-significant negative correlation. Again, total cations uptake ($r = -0.851$; $P \leq 0.001$), K^+ uptake ratio ($r = -0.8779$; $P \leq 0.001$) and total cations uptake ratio ($r = -0.8496$; $P \leq 0.001$) showed very highly significant negative correlation with grain yield in 2011, while those traits showed non-significant positive, non-significant negative and non-significant positive correlation, respectively in 2010 (Table 6 and Table 7).

Under saline condition, K^+ uptake ratio showed significant positive correlation ($r = 0.227$; $P \leq 0.05$) with grain yield in 2010, whereas in 2011 that trait showed non-significant positive correlation. Again, total cations uptake ($r = -0.223$; $P \leq 0.001$) and Na^+ uptake ratio showed very highly significant negative and non-significant negative correlation with grain yield in 2010, whereas those traits showed non-significant negative and significant negative correlation, respectively in 2011 (Table 6 and 7).

Both year correlation data revealed that lower uptake of Na^+, higher uptake of K^+, higher uptake of Ca^{++} and lower uptake of Na^+/K^+ were responsible for higher grain yield under salinity stress condition and salt tolerant category varieties had the same uptake trend of Na^+, K^+ and Ca^{++}. This finding partially supports the study of Garca- a Morales *et al.* (2012) who observed that K^+ concentration in stem and older leaves also decreased and the lowest K^+/Na^+ ratio (or highest Na^+/K^+ ratio) in stem was recorded in salt susceptible rice variety under saline condition. Similar result was also obtained in *Brassica* Sp. by Shirazi *et al.* (2011) and in rice by Zhang *et al.* (2011) and Nemati *et al.* (2011). Total cation uptake and total cation uptake ratio (compared to soil) showed negative correlation with grain yield under saline condition in both years field trial. It revealed that higher amount of total cations were harmful for rice plant and might cause of grain yield reduction under saline condition. So uptake of selective cation (not all the cations) was important for rice plant in respect of grain yield.

Table 1 List of rice varieties/lines used in this study

Sl. No.	Variety	Origin
1	IR 36	International Rice Research Institute, Philippines
2	Pokkali	Kerala Agricultural University, India
3	Shaheen Basmati	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
4	Basmati 2000	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
5	Basmati 198	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
6	Super Basmati	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
7	Pak Basmati	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
8	Basmati 370	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
9	Basmati 385	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
10	Super Kernal	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
11	PB-95	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
12	B-515	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
13	Basmati 6129	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
14	IR-6	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
15	KS-282	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
16	KSK-133	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
17	Sathra 278	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
18	TN-1	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
19	SRI-8	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
20	SRI-12	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
21	SHP	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
22	IRP-1	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
23	IRP-2	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
24	SN 4365	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan

Table 2 Soil analysis report of salinity block and the normal field in 2010 and 2011

Parameter	2010		2011	
	Soil sample collected from salinity block	Soil sample collected from normal field	Soil sample collected from salinity block	Soil sample collected from normal field
EC (dS/m)	7.6	2.1	7.5	2.3
Available Sodium (mg/kg or ppm)	4200	460	4120	450
Available Potassiumm (mg/kg or ppm)	120	100	123	101
Available Calcium (mg/kg or ppm)	120	65	115	62
Available Phosphorus (mg/kg or ppm)	12.0	8.0	12.5	8.8
pH	8.2	7.8	8.2	8.0
Organic matter (%)	0.40	0.70	0.40	0.70
Saturation (%)	41	41	41	41
Texture	Loam	Loam	Loam	Loam

Table 3 Mean values for grain yield and biochemical traits of rice varieties grown in 2010 under normal and saline condition

Name of the variety	Grain yield			Na^+ uptake		K^+ uptake		Ca^{++} uptake		Status of salt tolerance
	Normal	Saline	Mean difference	Normal	Saline	Normal	Saline	Normal	Saline	
IR 36	38.48	19.85	18.63***	30.142	60.340	7.454	13.357	15.632	55.129	Salt susceptible
Pokkali	29.77	28.68	1.08^{NS}	30.236	34.714	16.477	18.552	15.088	52.697	Salt tolerant
Shaheen Basmati	37.99	18.15	19.84***	22.240	34.699	6.107	10.447	6.608	16.872	Salt susceptible
Basmati 2000	47.71	13.43	34.28***	22.653	40.310	6.476	11.138	9.848	20.581	Salt susceptible
Basmati 198	33.60	31.35	2.24^{NS}	22.154	35.495	9.850	15.275	16.774	31.694	Salt tolerant
Super Basmati	42.41	34.16	8.24*	23.688	43.199	8.079	13.321	20.332	50.081	Moderately salt tolerant
Pak Basmati	30.11	19.99	10.12**	37.225	57.067	10.962	15.890	9.347	28.392	Moderately salt susceptible
Basmati 370	21.91	8.45	13.45***	23.697	47.014	4.802	8.906	11.341	17.895	Salt susceptible
Basmati 385	43.10	33.19	9.91*	26.199	41.164	8.602	12.544	14.241	17.016	Moderately salt tolerant
Super Kernal	25.11	12.46	12.65**	25.936	54.700	8.023	15.399	9.477	18.714	Moderately salt susceptible
PB-95	29.19	11.74	17.45**	25.681	55.429	8.045	15.801	8.229	25.549	Moderately salt susceptible
B-515	59.56	47.60	11.97**	22.209	55.473	7.145	14.951	18.564	33.924	Moderately salt susceptible
Basmati 6129	38.19	18.49	19.70***	24.781	56.174	5.861	15.501	7.351	19.338	Salt susceptible
IR-6	56.77	17.58	39.19***	16.720	52.376	3.788	13.135	10.130	20.793	Salt susceptible
KS-282	59.60	21.12	38.49**	22.828	62.597	6.410	16.555	10.815	18.719	Moderately salt susceptible
KSK-133	64.00	20.97	43.02***	24.851	61.535	7.676	13.425	16.355	27.669	Salt susceptible
Sathra 278	14.29	12.43	1.87^{NS}	21.669	38.717	11.746	20.105	11.003	20.871	Salt tolerant
TN-1	13.91	4.34	9.56***	24.100	64.575	6.068	14.398	16.291	30.631	Salt susceptible
SRI-8	28.22	21.74	6.48*	25.072	43.654	9.549	13.828	16.668	31.658	Moderately salt tolerant
SRI-12	28.78	20.94	7.84*	13.330	43.153	4.224	13.170	10.081	18.066	Moderately salt tolerant
SHP	37.95	29.17	8.78*	11.019	49.905	4.395	15.821	11.554	41.380	Moderately salt tolerant
IRP-1	22.96	17.62	5.34**	14.193	58.482	4.438	16.401	14.200	51.987	Moderately salt susceptible
IRP-2	35.33	9.46	25.87***	14.144	68.064	4.467	16.377	6.987	12.352	Salt susceptible
SN 4365	6.83	3.74	3.09**	22.668	36.692	6.441	10.102	4.504	11.254	Moderately salt susceptible

NS = non-significant; * = significant ($P \leq 0.05$); ** = highly significant ($P \leq 0.01$); *** = very highly significant ($P \leq 0.001$)

Table 3 Mean values for grain yield and biochemical traits of rice varieties grown in 2010 under normal and saline condition (continued)

Name of the variety	Total cations uptake		Na^+/K^+ uptake		Uptake ratio of Na^+		Uptake ratio of K^+		Uptake ratio of Ca^{++}		Uptake ratio of total cations		Uptake ratio of Na^+/K^+	
	Normal	Saline	Normal	Saline	Normal	Saline	Normal	Saline	Normal	Saline	Normal	Saline	Normal	Saline
IR 36	53.228	128.826	4.081	4.527	0.985	0.935	0.987	0.991	0.996	0.998	0.988	0.967	0.998	0.943
Pokkali	61.802	105.963	1.837	1.872	0.985	0.892	0.994	0.994	0.996	0.998	0.990	0.960	0.991	0.898
Shaheen Basmati	34.955	62.017	3.691	3.332	0.980	0.892	0.984	0.989	0.990	0.993	0.982	0.933	0.996	0.902
Basmati 2000	38.977	72.029	3.540	3.633	0.980	0.906	0.985	0.989	0.993	0.994	0.984	0.942	0.995	0.915
Basmati 198	48.778	82.463	2.258	2.328	0.980	0.894	0.990	0.992	0.996	0.996	0.987	0.949	0.990	0.901
Super Basmati	52.099	106.601	2.952	3.252	0.981	0.911	0.988	0.991	0.997	0.998	0.988	0.960	0.993	0.920
Pak Basmati	57.534	101.349	3.410	3.597	0.988	0.931	0.991	0.992	0.993	0.996	0.989	0.958	0.997	0.938
Basmati 370	39.839	73.815	5.053	5.314	0.981	0.918	0.979	0.987	0.994	0.993	0.984	0.943	1.002	0.930

Basmati 385	49.041	70.724	3.064	3.289	0.983	0.907	0.988	0.990	0.995	0.993	0.987	0.941	0.994	0.916
Super Kernal	43.436	88.812	3.257	3.556	0.983	0.929	0.988	0.992	0.993	0.994	0.986	0.952	0.995	0.936
PB-95	41.955	96.779	3.219	3.511	0.982	0.930	0.988	0.992	0.992	0.995	0.985	0.956	0.995	0.937
B-515	47.918	104.348	3.142	3.716	0.980	0.930	0.986	0.992	0.997	0.996	0.987	0.959	0.994	0.937
Basmati 6129	37.993	91.014	4.278	3.628	0.982	0.930	0.983	0.992	0.991	0.994	0.984	0.953	0.999	0.938
IR-6	30.638	86.304	4.573	3.995	0.973	0.926	0.973	0.991	0.994	0.994	0.980	0.951	1.000	0.934
KS-282	40.053	97.871	3.604	3.788	0.980	0.937	0.984	0.993	0.994	0.994	0.985	0.957	0.996	0.944
KSK-133	48.882	102.629	3.263	4.597	0.982	0.936	0.987	0.991	0.996	0.996	0.987	0.959	0.995	0.944
Sathra 278	44.418	79.693	1.849	1.927	0.979	0.902	0.992	0.994	0.994	0.994	0.986	0.947	0.988	0.907
TN-1	46.460	109.604	4.025	4.496	0.981	0.939	0.984	0.992	0.996	0.996	0.987	0.961	0.998	0.947
SRI-8	51.289	89.140	2.638	3.164	0.982	0.912	0.990	0.991	0.996	0.996	0.988	0.953	0.992	0.920
SRI-12	27.635	74.389	3.248	3.286	0.967	0.911	0.976	0.991	0.994	0.993	0.978	0.944	0.990	0.920
SHP	26.969	107.107	2.570	3.160	0.960	0.922	0.977	0.992	0.994	0.997	0.977	0.960	0.982	0.929
IRP-1	32.831	126.870	3.273	3.572	0.968	0.933	0.977	0.993	0.995	0.998	0.981	0.966	0.991	0.940
IRP-2	25.597	96.793	3.251	4.164	0.968	0.942	0.977	0.993	0.991	0.990	0.976	0.956	0.991	0.949
SN 4365	33.613	58.048	3.560	3.649	0.980	0.897	0.984	0.988	0.985	0.989	0.982	0.929	0.996	0.908

Table 4 Mean values for grain yield and biochemical traits of rice varieties grown in 2011 under normal and saline condition

Name of the variety	Grain yield			Na^+ uptake		K^+ uptake		Ca^{++} uptake		Status of salt tolerance
	Normal	Saline	Mean difference	Normal	Saline	Normal	Saline	Normal	Saline	
IR 36	39.68	20.55	19.13^{***}	31.292	62.140	7.854	14.407	16.782	56.929	Salt susceptible
Pokkali	30.97	29.38	1.58^{NS}	31.386	36.514	16.877	19.602	16.238	54.497	Salt tolerant
Shaheen Basmati	39.19	18.85	20.34^{***}	23.390	36.499	6.507	11.497	7.758	18.672	Salt susceptible
Basmati 2000	48.91	14.13	34.78^{***}	23.803	42.110	6.876	12.188	10.998	22.381	Salt susceptible
Basmati 198	34.80	32.05	2.74^{NS}	23.304	37.295	10.250	16.325	17.924	33.494	Salt tolerant
Super Basmati	43.61	34.86	8.74^{*}	24.838	44.999	8.479	14.371	21.482	51.881	Moderately salt tolerant
Pak Basmati	31.31	20.69	10.62^{**}	38.375	58.867	11.362	16.940	10.497	30.192	Moderately salt susceptible
Basmati 370	23.11	9.15	13.95^{***}	24.847	48.814	5.202	9.956	12.491	19.695	Salt susceptible
Basmati 385	44.40	33.99	10.41^{*}	27.449	43.064	9.102	13.694	15.491	18.916	Moderately salt tolerant
Super Kernal	26.41	13.26	13.15^{**}	27.186	56.600	8.523	16.549	10.727	20.614	Moderately salt susceptible
PB-95	30.49	12.54	17.95^{**}	26.931	57.329	8.545	16.951	9.479	27.449	Moderately salt susceptible
B-515	60.86	48.40	12.47^{**}	23.459	57.373	7.645	16.101	19.814	35.824	Moderately salt susceptible
Basmati 6129	39.49	19.29	20.20^{***}	26.031	58.074	6.361	16.651	8.601	21.238	Salt susceptible
IR-6	58.07	18.38	39.69^{***}	17.970	54.276	4.288	14.285	11.380	22.693	Salt susceptible
KS-282	60.90	21.92	38.99^{**}	24.078	64.497	6.910	17.705	12.065	20.619	Moderately salt susceptible
KSK-133	65.30	21.77	43.52^{***}	26.101	63.435	8.176	14.575	17.605	29.569	Salt susceptible
Sathra 278	15.54	13.18	2.37^{NS}	22.869	40.567	12.196	21.205	12.203	22.721	Salt tolerant
TN-1	15.16	5.09	10.06^{***}	25.300	66.425	6.518	15.498	17.491	32.481	Salt susceptible
SRI-8	29.47	22.49	6.98^{*}	26.272	45.504	9.999	14.928	17.868	33.508	Moderately salt tolerant
SRI-12	30.03	21.69	8.34^{*}	14.530	45.003	4.674	14.270	11.281	19.916	Moderately salt tolerant
SHP	39.20	29.92	9.28^{*}	12.219	51.755	4.845	16.921	12.754	43.230	Moderately salt tolerant
IRP-1	24.21	18.37	5.84^{**}	15.393	60.332	4.888	17.501	15.400	53.837	Moderately salt susceptible
IRP-2	36.58	10.21	26.37^{***}	15.344	69.914	4.917	17.477	8.187	14.202	Salt susceptible
SN 4365	8.08	4.49	3.59^{**}	23.868	38.542	6.891	11.202	5.704	13.104	Moderately salt susceptible

NS = non-significant; * = significant ($P \leq 0.05$); ** = highly significant ($P \leq 0.01$); *** = very highly significant ($P \leq 0.001$)

Table 4 Mean values for grain yield and biochemical traits of rice varieties grown in 2011 under normal and saline condition (continued)

Name of the variety	Total cations uptake		Na^+/K^+ uptake		Uptake ratio of Na^+		Uptake ratio of K^+		Uptake ratio of Ca^{++}		Uptake ratio of total cations		Uptake ratio of Na^+/K^+	
	Normal	**Saline**	**Normal**	**Saline**	**Normal**	**Saline**	**Normal**	**Saline**	**Normal**	**Saline**	**Normal**	**Saline**	**Normal**	**Saline**
IR 36	55.928	133.476	4.017	4.321	0.986	0.938	0.987	0.992	0.996	0.998	0.989	0.968	0.999	0.946
Pokkali	64.502	110.613	1.862	1.863	0.986	0.899	0.994	0.994	0.996	0.998	0.991	0.962	0.992	0.904
Shaheen Basmati	37.655	66.667	3.637	3.183	0.981	0.898	0.984	0.989	0.992	0.994	0.984	0.939	0.997	0.908
Basmati 2000	41.677	76.679	3.498	3.466	0.981	0.911	0.985	0.990	0.994	0.995	0.985	0.946	0.996	0.920
Basmati 198	51.478	87.113	2.282	2.288	0.981	0.900	0.990	0.993	0.997	0.997	0.988	0.952	0.991	0.907
Super Basmati	54.799	111.251	2.948	3.138	0.982	0.916	0.988	0.991	0.997	0.998	0.989	0.962	0.994	0.924
Pak Basmati	60.234	105.999	3.391	3.480	0.988	0.935	0.991	0.993	0.994	0.996	0.990	0.960	0.997	0.941
Basmati 370	42.539	78.465	4.873	4.929	0.982	0.922	0.980	0.988	0.995	0.994	0.986	0.947	1.002	0.934
Basmati 385	52.041	75.674	3.032	3.150	0.984	0.913	0.989	0.991	0.996	0.994	0.988	0.945	0.995	0.921
Super Kernal	46.436	93.762	3.211	3.423	0.984	0.932	0.988	0.993	0.994	0.994	0.987	0.956	0.995	0.939
PB-95	44.955	101.729	3.175	3.385	0.984	0.933	0.988	0.993	0.993	0.996	0.987	0.959	0.995	0.940
B-515	50.918	109.298	3.098	3.567	0.981	0.933	0.987	0.992	0.997	0.997	0.988	0.962	0.994	0.940
Basmati 6129	40.993	95.964	4.133	3.491	0.983	0.934	0.984	0.993	0.993	0.995	0.985	0.957	0.999	0.941
IR-6	33.638	91.254	4.306	3.805	0.976	0.929	0.976	0.991	0.995	0.995	0.982	0.954	0.999	0.937
KS-282	43.053	102.821	3.520	3.648	0.982	0.940	0.985	0.993	0.995	0.994	0.986	0.959	0.996	0.946
KSK-133	51.882	107.579	3.214	4.363	0.983	0.939	0.988	0.992	0.996	0.996	0.988	0.961	0.995	0.947
Sathra 278	47.268	84.493	1.879	1.914	0.981	0.908	0.992	0.994	0.995	0.995	0.987	0.951	0.989	0.913
TN-1	49.310	114.404	3.926	4.295	0.983	0.942	0.985	0.992	0.996	0.996	0.988	0.963	0.998	0.949
SRI-8	54.139	93.940	2.639	3.054	0.983	0.917	0.990	0.992	0.997	0.997	0.989	0.956	0.993	0.925
SRI-12	30.485	79.189	3.181	3.161	0.970	0.916	0.978	0.991	0.995	0.994	0.980	0.948	0.992	0.924
SHP	29.819	111.907	2.574	3.063	0.964	0.926	0.979	0.993	0.995	0.997	0.980	0.962	0.985	0.933
IRP-1	35.681	131.670	3.209	3.453	0.971	0.936	0.979	0.993	0.996	0.998	0.983	0.968	0.992	0.943
IRP-2	28.447	101.593	3.189	4.007	0.971	0.944	0.979	0.993	0.992	0.992	0.979	0.959	0.992	0.951
SN 4365	36.463	62.848	3.498	3.453	0.981	0.903	0.985	0.989	0.989	0.991	0.983	0.935	0.996	0.913

Table 5 Analysis of variance estimates for yield and biochemical traits of 24 rice varieties grown in 2010 and 2011 under normal versus saline conditions

Source of variation/Trait	2010			2011		
	Genotype	Salt	Genotype × Salt	Genotype	Salt	Genotype × Salt
Grain yield (g/plant)	750.413***	8514.436***	231.005***	56.1320**	974.4986***	144.3858***
Na^+ uptake (mg/g)	206.078***	26251.448***	219.274***	118.2422***	3737.937***	120.9154***
K^+ uptake (mg/g)	33.453***	1749.673***	12.077***	40.4420***	324.6923***	1.5483^{NS}
Ca^{++} uptake (mg/g)	403.479***	9112.766***	175.639***	64.2387***	1841.577***	13.9368***
Total Cation uptake (mg/g)	810.561***	89588.200***	494.770***	40.1397***	14901.4489***	77.2269***
Na^+/K^+ uptake	3.379***	2.042^{NS}	0.266^{NS}	3.9096***	0.1170^{NS}	0.0141^{NS}
Na^+ uptake ratio	0.0004^{NS}	0.1272^{NS}	0.0005^{NS}	0.0002^{NS}	0.0221^{NS}	0.0003^{NS}
K^+ uptake ratio	0.0001^{NS}	0.0017^{NS}	0.00004^{NS}	0.000035^{NS}	0.000183^{NS}	0.000012^{NS}
Ca^{++} uptake ratio	0.00003^{NS}	0.00003^{NS}	0.000004^{NS}	0.0000037^{NS}	0.0000022^{NS}	0.00000293^{NS}
Total cations uptake ratio	0.0002^{NS}	0.0375^{NS}	0.0001^{NS}	0.000006^{NS}	0.005715^{NS}	0.0000052^{NS}
Uptake ratio of Na^+/K^+	0.0005^{NS}	0.1606^{NS}	0.0003^{NS}	0.000417^{NS}	0.026708^{NS}	0.000182^{NS}

NS = non-significant; * = significant ($P < 0.05$); ** = highly significant ($P < 0.01$); *** = very highly significant ($P < 0.001$)

Table 6 Correlation coefficients for yield and biochemical traits of rice varieties grown in 2010 under normal versus saline conditions

Normal	Grain yield (g/plant)	Na^+ uptake (mg/g)	K^+ uptake (mg/g)	Ca^{++}uptake (mg/g)	Total Cation uptake (mg/g)	Na^+ / K^+ uptake	Na^+ uptake ratio	K^+ uptake ratio	Ca^{++} uptake ratio	Total cations uptake ratio	Uptake ratio of Na^+/K^+
Grain yield	1	-0.052^{NS}	-0.170*	0.245**	0.022^{NS}	0.146^{NS}	-0.019^{NS}	-0.124^{NS}	0.298**	0.021^{NS}	0.139^{NS}
(g/plant)		**-0.191***	**0.147**^{NS}	**0.433*****	**-0.223***	**-0.340*****	**-0.160**^{NS}	**0.227***	**0.492*****	**-0.259****	**-0.188***
Na^+ uptake		1	0.676***	0.168^{NS}	0.852***	-0.037^{NS}	0.937***	0.746***	0.131^{NS}	0.851***	0.393***
(mg/g)			**0.257****	**0.057**^{NS}	**0.640*****	**0.600*****	**0.987*****	**0.335*****	**0.092**^{NS}	**0.660*****	**0.979*****
K^+ uptake			1	0.336***	0.830***	-0.680***	0.618***	0.876***	0.302***	0.759***	-0.256**
(mg/g)				**0.314*****	**0.515*****	**-0.579*****	**0.228***	**0.965*****	**0.366*****	**0.590*****	**0.131**^{NS}
Ca^{++} uptake				1	0.617***	-0.339***	0.190*	0.358***	0.887***	0.583***	-0.198*
(mg/g)					**0.792*****	**-0.195***	**0.064**^{NS}	**0.350*****	**0.896*****	**0.723*****	**0.029**^{NS}
Total Cation					1	-0.366***	0.807***	0.844***	0.538***	0.964***	0.069^{NS}
uptake (mg/g)						**0.112**^{NS}	**0.634*****	**0.580*****	**0.745*****	**0.973*****	**0.589*****
Na^+/K^+						1	0.010^{NS}	-0.625***	-0.307***	-0.297**	0.858***
uptake							**0.616*****	**-0.539*****	**-0.209***	**0.073**^{NS}	**0.691*****
Na^+ uptake							1	0.758***	0.108^{NS}	0.872***	0.474***
ratio								**0.313*****	**0.125**^{NS}	**0.663*****	**0.995*****
K^+ uptake								1	0.279**	0.865***	-0.215*
ratio									**0.423*****	**0.661*****	**0.214***
Ca^{++} uptake									1	0.513***	-0.214*
ratio										**0.748*****	**0.084**^{NS}
Total cations										1	0.137^{NS}
uptake ratio											**0.611*****
Uptake ratio											1
of Na^+/K^+											

NS = non-significant; * = significant ($P < 0.05$); ** = highly significant ($P < 0.01$); *** = very highly significant ($P < 0.001$) Normal-sized font values = normal field; bold-sized font values = salinity block

Table 7 Correlation coefficients for yield and biochemical traits of rice varieties grown in 2011 under normal versus saline conditions

Normal	Grain yield (g/plant)	Na^+ uptake (mg/g)	K^+ uptake (mg/g)	Ca^{++}uptake (mg/g)	Total Cation uptake (mg/g)	Na^+ / K^+ uptake	Na^+ uptake ratio	K^+ uptake ratio	Ca^{++} uptake ratio	Total cations uptake ratio	Uptake ratio of Na^+/K^+
Grain yield (g/plant)	1										
Na^+ uptake (mg/g)	0.5699* **-0.7082****	1									
K^+ uptake (mg/g)	-0.8762*** **0.2603**^{NS}	0.5997* **-0.6129***	1								
Ca^{++} uptake (mg/g)	-0.4469^{NS} **0.7484****	-0.1648^{NS} **-0.9142*****	0.5934* **0.7672****	1							
Total Cation uptake (mg/g)	-0.8510*** **-0.4389**^{NS}	0.6532* **0.6412***	0.9815*** **0.1554**^{NS}	0.6121* **-0.3031**^{NS}	1						
Na^+/K^+ uptake	0.8275*** **-0.6133***	-0.3228^{NS} **0.9049*****	-0.9150*** **-0.8777*****	-0.7982** **-0.9612*****	-0.9015*** **0.2680**^{NS}	1					
Na^+ uptake ratio	-0.5216^{NS} **-0.6286***	0.9772*** **0.9911*****	0.5727* **-0.6525***	-0.2152^{NS} **-0.8877*****	0.6115* **0.6312***	-0.2601^{NS} **0.9118*****	1				
K^+ uptake ratio	-0.8779*** **0.3308**^{NS}	-0.8779*** **-0.6049***	0.9617*** **0.9877*****	0.5588^{NS} **0.7926****	0.9757*** **0.1913**^{NS}	-0.9131*** **-0.8847*****	0.6248* **-0.6334***	1			
Ca^{++} uptake ratio	-0.4626^{NS} **0.7214****	-0.1451^{NS} **-0.9000*****	0.6129* **0.7680****	0.9823*** **0.9951*****	0.6238* **-0.2806**^{NS}	-0.8030** **-0.9545*****	-0.1784^{NS} **-0.8772*****	0.5754* **0.7963****	1		
Total cations uptake ratio	-0.8496*** **-0.2802**^{NS}	0.7622** **0.4036**^{NS}	0.9540*** **0.3961**^{NS}	0.4809^{NS} **-0.0289**^{NS}	0.9809*** **0.9581*****	-0.8447*** **-0.0007**^{NS}	0.7279** **0.3961**^{NS}	0.9851*** **0.4370**^{NS}	0.4990^{NS} **-0.0020**^{NS}	1	
Uptake ratio of Na^+/K^+	0.6981* **-0.6225***	-0.0568^{NS} **0.9876*****	-0.7628** **-0.6959**^{NS}	-0.8909*** **-0.9040*****	-0.7494** **0.5841***	0.9567*** **0.9340*****	0.0168^{NS} **0.9982*****	-0.7701** **-0.6788***	-0.8818*** **-0.8944*****	-0.6667* **0.3420**^{NS}	1

NS = non-significant; * = significant ($P < 0.05$); ** = highly significant ($P < 0.01$); *** = very highly significant ($P < 0.001$)
Normal-sized font values = normal field; bold-sized font values = salinity block

DISCUSSION

Salinity is detrimental to crop production worldwide. Among the cereal crops, rice (*Oryza sativa*) is the most sensitive, bread wheat (*Triticum aestivum*) is moderately tolerant, and barley (*Hordium vulgare*) is the most tolerant (Munns and Tester 2008). The bad effect of salinity falls on grain yield and different biochemical traits like sodium uptake, potassium uptake, calcium uptake, total cation uptake, ratio of sodium and potassium uptake etc. Agronomic and biochemical traits were affected according to the severity of the salinity and susceptibility/tolerance of the crop variety (Dionisio-Sese and Tobita, 1998). Grain yield and shoots, 100 seeds weight, tiller number, root dry weight and K^+ uptake in seeds and shoot significantly decreased with increasing salinity (Mohiti *et al.*, 2011).

Different varieties of rice (*Oryza sativa* L.) had different sensitivity to NaCl. The rice seedlings of 3-week-old salt sensitive and tolerant varieties were given 0, 6 and 12 dS/m salinity levels for a week. Then antioxidant capacities and possible correlation, growth rate and Na^+ uptake of the leaves were analyzed. A decrease in growth rate was observed at high salinity level in all the varieties tested except Pokkali. The salt-sensitive varieties, Hitomebore and IR28, showed a decrease in superoxide dismutase activity and an increase in peroxidase activity under high salinity condition. These varieties also showed increase in lipid peroxidation and electrolyte leakage as well as higher Na^+ accumulation in the leaves under salt stress (Dionisio-Sese and Tobita, 998). Sodium (Na) toxicity is one of the most alarming challenges for crop production throughout the world. The pathways of Na^+ entry into the roots of plants under high salinity stress are still not clear (Kronzucker and Britto, 2011)

Potassium was the most important macronutrients taken up by plants. A potassium channel, OsAKT1, homologous to the Arabidopsis root inward rectifier AKT1 was isolated. OsAKT1 transcripts were predominantly found in the coleoptile and in the roots of young rice seedlings. K^+ channel mRNA decreased with the increase of salinity stress, and it was observed both in the shoot and in the root of 4-day-old rice seedlings. OsAKT1 was revealed as the dominant salt sensitive K^+ uptake channel in rice roots (Fuchs *et al.*, 2010).

Salt tolerance ability of Thai jasmine (KDML105) salt sensitive and Homjan (HJ) salt tolerant cultivars were investigated to grow under iso-osmotic stresses. Growth, ion contents, relative electrolyte leakage (REL), photosynthetic pigments and net photosynthetic rate (Pn) in iso-osmotic stressed seedlings were collected. Growth traits together with shoot height, fresh weight, dry weight and leaf area of salinity stressed rice seedlings were inhibited, depending on NaCl concentrations and rice genotypes. Sodium ion (Na^+) in salt-stressed tissues was rapidly accumulated, especially in KDML105, while potassium ion (K^+) was quickly decreased. Na:K ratio and proline content in salt-stressed leaves were increased, relating to salt concentrations (Cha-um *et al.* 2009). Salt sensitivity is associated with the accumulation of sodium (Na^+) in photosynthetic tissues of many plant species. Na^+ uptake to leaves involves a series of transport steps and for which only few candidate genes have been so far characterized (Benderradji, 2011)

Soil salinity has negative impact on agricultural yields. Excess Na^+ is toxic to plants so that sensitivity to salinity is common for crop plants due to the abundance of Na^+ in the soil. Reduction of Na^+ uptake is to be the most efficient approach for controlling Na^+ accumulation in crop plants and thereby to improve their salt resistance (Zhang *et al.*, 2010). K^+, Ca^{++}, Mg^{++} content and K^+/Na^+ ratio in the shoot tissue decreased, and Na^+ content in the shoot tissue increased with the increase of salinity. K^+, Ca^{++} and Mg^{++} ions uptake and their distribution to shoot tissues under salinity stress may be relevant issues for salt (Na^+) exclusion studies and for plant nutrition as well (Uddin *et al.*, 2011).

The accumulation of extra salts has destructive effects on crops which can result to nutritional disorders (Asch *et al.*, 2000), ions toxicity and also osmotic stress (Zhu, 2001). Salinity tolerance of plant is a function of Na^+ exclusion, tissue tolerance to Na^+ and osmotic tolerance (Munns and Tester, 2008) and it is dependent on varying extent on each of these three components, even within a single species (Rajendran *et al.*, 2009). The accumulation of extra salts has destructive effects on crops which can result to nutritional disorders (Asch *et al.*, 2000), ions toxicity and also osmotic stress (Zhu, 2001).

Ion toxicity is a common term for various impairments in different cellular processes due to promoted ion concentrations. Cellular Na^+ toxicity is the major ion toxicity in salinity stress, consequence in the inhibition of different processes such as K^+ absorption, vital enzyme reactions, protein synthesis and photosynthesis (Tsugane *et al.*, 1999). Photosynthesis is the most crucial cellular process for the protection of plant from Na^+ toxicity as the interruption of the process is directly associated with reduction of the carbon fixation and biomass production in plants (Flowers 1999). Under salinity stress, Na^+ is expelled from shoots and K^+ is accumulated in shoots and thereby stabilizing the high cytosolic K^+/Na^+ ratio particularly in leaves (Serrano & Rodríguez-Navarro, 2001; Shi *et al.*, 2002; Ren *et al.*, 2005; Sunarpi *et al.*, 2005).

Haro (2010) reported that there was high-affinity for Na^+ uptake in most land plants. It was probably mediated by HKT transporters in rice and species in the Triticeae and Aveneae tribes of the Poaceae family. Other than HKT one or several transporters were responsible to mediate high-affinity Na^+ uptake in other plants and their responses correlated with the existance of K^+ or Ca^{++}. Lan (2010) reported that one of the rice high-affinity K^+ transport (HKT) protein also plays role as a Ca^{++}-permeable cation channel that conducts current carried by a wide range of monovalent and divalent cations.

Potassium (K) is the most profuse inorganic cation in plants. It is necessary for the activation of many enzymes, as a cellular osmoticum for rapidly expanding cells, and as a counter cation for anion accumulation and electrogenic transport processes (White and Karley, 2010). Potassium is a necessary element for the growth and development of plant and is a tremendously dynamic ion in plant and soil system. Potassium is extremely mobile in the plant system but only moderately mobile in the soil system as an ion. There is a pre-determined ratio of nutrients that is essential by the plant system based on its life cycle, environment and its genotypic characteristics. This ratio of elements is more important than the actual concentration of the individual elements. Micronutrients balancing are imperative balancing macronutrients. Synergistic and Antagonistic relationships between nutrients are responsible for efficient/inefficient uptake and utilization of potassium (Malvi, 2011).

Calcium is another indispensable nutrient for plant growth and development. It is a crucial component of various structures in cell wall and membranes. In addition to some basic roles under normal condition, calcium acts as a major secondary-messenger molecule in plants under different developmental cues and various stress conditions including salinity stress (Kader and Lindberg, 2010). At low salinity level (25 mmol/L NaCl), Ca++ significantly decreased Na^+ accumulation in roots, increased K^+ accumulation in shoots, and maintained higher K^+/Na^+ ratios in both roots and shoots of rice plants. At high salinity level (125 mmol/L NaCl), however, Ca^{++} did not have any effects on Na^+, K^+ accumulation and K^+/Na^+ ratios in plants. It was also suggested that by enhancing the selectivity for K^+ over Na^+, reducing the Na^+ influx and efflux, and lowering the futile cycling of Na^+, Ca^{++} could regulate K^+/Na^+ homeostasis in rice at low salinity (Wu and Wang, 2012).

Din *et al.* (2008) reported that salt sensitive wheat variety showed higher uptake of Na^+ under saline condition. Low fluxes of Na^+, high of K^+, low of Na^+/K^+ were found to be useful parameters associated with salinity tolerance of wheat.

Higher amount of total cations were injurious for rice plant, whereas, higher amount of K^+ and Ca^{++} were beneficial under saline condition suggesting that selective uptake of cations were imperative for rice plant. Proper uptake of Na^+, K^+, Ca^{++} and Na^+/K^+ were crucial in grain yield under salinity stress condition. Excess Na^+ was toxic for plants and might be a cause of lower yield. On the other hand, higher uptake of K^+ and Ca^{++}, higher uptake of K^+ and Ca^{++} (compared to soil) and lower ratio of Na^+/K^+ uptake might reduce the bad effect of toxic Na^+ as well as minimize the grain yield reduction under salinity stress condition.

Pokkali, Basmati 198 and Sathra 278 were found as salt tolerant varieties and may be used to cultivate in saline areas. Lower uptake of Na^+, higher uptake of K^+, higher uptake of Ca^{++}, lower uptake ratio of Na^+/K^+, lower Na^+ uptake ratio (compared to soil), higher uptake ratio of K^+ (compared to soil), higher uptake ratio of Ca^{++} (compared to soil) and lower uptake ratio of total cations (compared to soil) were observed in salt tolerant varieties and those trend of ions uptake would be the characteristics of salt tolerant varieties. These biochemical traits can be employed in the development of elite salt tolerant rice cultivars. In future, efforts should be concentrated to explore the molecular mechanism underlying those biochemical traits in rice.

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