Salinity Stress Effect on Ion Uptake and Yield Attributes in Rice

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Abstract: The pot experiment was conducted under tropical condition (102^{0}12' N latitude and 101^{0}42' E longitudes) to evaluate salinity tolerance level of three rice cultivars viz., MR219, Binashail and IR20 during November 2012 to March 2013. Salinity levels were 0.34 (control), 4.2 and 8.8 dS/m. Salinity stress was evaluated in terms of ion uptake in plant straw (leaves & stems) and yield attributes. Sodium ion increased with increasing salinity levels whereas reverse trend was observed in potassium and calcium ions content in straw. However, among the cultivars, MR219 contained less sodium ions in straw. Sodium content was the highest in IR20. The number of effective tillers/hill, number of filled grains/panicle, 1000-grain weight and harvest index decreased with increasing salinity levels whereas reverse trend was observed in case of non-effective tillers/hill and unfilled grains/panicle. MR219 showed the best performance in terms of yield and yield attributes up to 8.8 dS/m soil followed by Binashail. The yield and yield attributes of IR20 drastically decreased with the increase of soil salinity. MR219 was found tolerant, Binashail was moderately tolerant and IR20 was susceptible to imposed moderate salinity.

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1. Introduction

Salinity affects nutritional status of rice plants. It may reduce crop yield due to its toxic effect to salt sensitive plant (Singh *et al*., 2007; Bandehagh and Moghbeli, 2011). Rice plant (*Oryza sativa* L.) can tolerate salinity stress by the following four mechanisms: i) Exclusion-restrict uptake of Na ions, ii) Dilution-directly attributable to the dilution effect of faster or rapid vegetative growth, iii) Compartmentalization-accumulation of high Na^+ to inactive part or older leaves and younger leaves remain green and iv) High K:Na ratio-remaining a higher K:Na ratio (Kyu-sen and Senadhira, 1996). Susceptible rice variety had higher sodium content coupled with low potassium content compared to moderately tolerant and tolerant genotypes (Bhatt *et al*., 2008; Sarker *et al*., 2012). On the other hand, salt tolerant genotypes have lower Na^+ and higher K^+ content (Singh and Singh, 2008). Pokkali was the most tolerant variety showed less accumulation of Na^+ and Cl^- and maintained its specificity for K+ (Mondal *et al*., 2013). In Malaysia, 4.3 million hectares are in the coastal area (MOA, 2010). This area is largely affected by varying degrees of soil salinity. Agricultural land uses in these areas are very poor. The effective reclamation of the saline soils is difficult and complex due to frequent inundation and tidal flooding. It would therefore be wise to grow salt tolerant cultivars of rice. Development of salt tolerant rice cultivars is highly demanding to enhance the national production of rice. Study on the response of rice to salinity stress may be helpful in breeding salt tolerant cultivars by identifying physiological characters responsible for salt tolerance such as active osmotic adjustment in cells sap, accumulation of toxic Na^+ and Cl^- ions in the older parts of plant, higher photosynthetic efficiency of the young leaves, escaping ability to uptake Na^+ and Cl^- etc. So, the work was undertaken to assess the effect of salinity stress on ion uptake and yield attributes in three rice cultivars and evaluate their salt tolerance levels.

2. Materials and Methods

The pot experiment was conducted at the glass house of Universiti Putra Malaysia during during November 2012 to March 2013. Geographically the experimental area is located at 102^{0}12' N latitude and 101^{0}42' E longitudes at the elevation of 31 m above the sea level. The pH value, cation exchange capacity (CEC) and electrical conductivity (EC) of the soil were 5.58, 16.30 meq/100 g soil and 0.34 dSm^{-1}, respectively. Inner wall of each plastic pot is covered by a polythene bag so that water cannot easily leach. Seven kg of soils were taken in each pot. The experiment was laid out completely randomized design with four replicates. Urea 397 mg, TSP 515 mg, MP 152 mg and gypsum 140 mg were incorporated to each pot soils which is equivalent to 170 kg urea, 135 kg TSP, 65 kg MP and 60 kg gypsum per hectare. All TSP, MP, gypsum and one third of urea were applied as basal dose. The remaining two third of urea were applied in two equal splits in each pot at 25 and 50 days after transplanting (DAT) of seedlings. The treatments of the experiment were: three rice genotypes viz., MR219, Binashail and IR20, and three levels of salinity viz., 0.34, 4.4 and 8.8 dS/m. At 30 DAT, adding 14.4 g and 28.8 g of NaCl in each pot made salinity levels of 4.4 and 8.8 dS/m, respectively and maintained unitil harvest. The salinity levels of pot water was monitored weekly by EC meter (Model: Z865, SCHOTT Instruments, Germany) and saline solution was added (when necessary) to maintained required salinity level in the pot. Weeding was done as and when necessary. Water was supplied to each pot as and when needed to maintain a specific water height to ensure sufficient moisture for the normal growth of the crops.

Sodium, potassium and calcium contents were determined from straw. Analysis of mineral ion contents was carried out after extracting of given amount of plant sample in nitric acid for at least 2h at 90 ^{0}C. Alkali cations were determined by atomic absorption spectrophotometry (AA-660, Shimadzu, Japan). At harvest, yield attributes and grain yield was recorded. Harvest index was calculated by dividing economic yield to biological yield of plant multiplied with 100 and expressed in percentage. The collected data were analyzed statistically following the analysis of variance (ANOVA) technique and the mean differences were adjudged by Duncan's Multiple Range Test (DMRT) using the statistical computer package program, MSTAT-C.

3. Results and Discussion

Mineral ion content in straw: The effect of salinity on Na^+, K^+ and Ca^{++} content in straw was significant (Table I). Results showed that Na^+ ion content in straw increased with increasing salinity levels while reverse trend was observed in case of K^+ and Ca^{++} uptake. This might be due to restricted uptake of K^+ and Ca^{++} by the rice plant under saline condition. The excess amount of Na^+ creates a toxic effect on plant metabolic processes and susceptible genotypes having high amount of Na^+ with less amount of K^+ and Ca^{++} (Bhatt *et al*., 2008). Among the cultivars, Na^+ content in straw was the highest in IR20 with less K^+ and Ca^{++} content (Table 1). In contrast, the lowest Na^+ content was recorded in MR232 with highest K^+ and Ca^{++} content followed by Binashail. These results indicate that IR20 was susceptible and MR232 was comparatively tolerant to moderate salinity. The results are conformity with Mondal *et al.* (2013) who reported that tolerant genotypes of rice accumulated less Na^+ and more K^+ than susceptible one.

The interaction effect of salinity levels and genotypes on Na^+ and K^+ content in straw was significant but had non-significant influence on Ca^{++} (Table II). Results showed that Na^+ uptake in straw increased with increasing Na concentration in growth media in all the varieties but the increment of Na^+ accumulation was not similar among the varieties. Less reduction in K^+ and Ca^{++} accumulation in plant tissue due to salinity were also observed in saline tolerant cultivar MR232 than the susceptible cultivar IR20. These results are consistent with the findings of many workers (Pandey and Sharma, 2002; Islam *et al*., 2007; Singh *et al*. 2007; Singh and Singh, 2008). Dionisio-Sese and Tobita (2000) opined that there was an inverse relationship between shoot Na^+ concentration and salt tolerance. The salt-sensitive cultivars IR20 exhibited significant increase in Na^+ content with increasing salinity levels in soil, whereas the salt-tolerant cultivar MR232 did not show pronounce accumulation of Na^+ (Table 2).

Yield attributes and grain yield: Results showed that number of effective tillers/hill, grains/panicle, 1000-grain weight, grain yield/hill and harvest index decreased with increased salinity levels (Table I). Contrarily, number of non-effective tillers/hill and sterile spikelets/panicle increased with increasing salinity levels. This result indicates that under saline condition, there may have unavailable assimilate supply to grain resulting more unfilled grains/panicle (Sultana *et al*., 1999). The highest effective tillers/hill, number of grains/panicle, 1000-grain weight, grain yield/hill and harvest index were recorded in control, which was significantly different from other salinity levels and the lowest was recorded in 8.8 dS/m. Reduced grains/panicle under saline condition might be due to lower chlorophyll content which in turn produced lower assimilates thereby fewer spikelets/panicle (Mondal *et al*., 2013). Similar result was also reported by Islam *et al*. (2007). They observed that grains/panicle decreased with increased salinity levels.

Interaction between salinity levels and genotypes had significant effect on yield attributes and yield (Table II). Among the variety, the yield loss due to salinity was less in MR232 (14.9-43.6% less over control), moderately yield loss was observed in Binashail (22.7-55.7% less over control) and the highest loss in yield due to salinity was observed in IR20 (26.8-76.0% less of the control). In saline susceptible variety, the increase production of sterile spikelets might be due to lower photosynthesis rate resulting less amount of assimilates production which may be not sufficient for all grain growth and development (Mondal *et al*., 2013).

All the studied rice varieties were variably affected in ion uptake and yield contributing characters by different levels of salinity; and among the varieties, MR232 was found comparatively more tolerant at 8.8 dS/m saline condition than the others.

Therefore, MR232 may be adopted in moderate saline condition.

Table I. Mean effect of different salinity levels and genotypes on ion concentration and yield attributes of three rice cultivars

Treatment	Mineral ion content (%)			Yield attributes and yield						
	Na^+	K^+	Ca^{++}	Effective tillers/ hill (no)	Non-effective tillers/ hill (no)	Filled grains/ panicle (no)	Unfilled grains/ panicle (no)	1000-grain weight (g)	Grain yield (g/hill)	Harvest index (%)
Salinity levels ($dS\ m^{-1}$)										
0.34	0.19 c	1.70 a	0.27 a	10.76 a	3.97 c	93.3 a	12.87 c	23.72 a	23.39 a	39.17 a
4.20	0.36 b	1.57ab	0.26 a	9.84 b	5.21 b	85.1 b	19.53 b	23.04 b	18.68 b	34.93 b
8.80	0.52 a	1.42 b	0.23 b	7.31 c	7.72 a	68.5 c	31.36 a	21.11 c	10.49 c	24.53 c
F-test	**	*	*	**	**	**	**	**	**	**
Cultivars										
MR232	0.29 c	1.68 a	0.28 a	11.49 a	5,01 b	91.2 b	16.23 b	24.26 b	25.75 a	36.81 a
Binashail	0.35 b	1.63 a	0.27 a	9.00 b	5.14 b	102.0 a	22.97 a	17.10 c	15.58 b	32.74 b
IR20	0.43 a	1.39 b	0.21 b	7.41 c	6.75 a	53.7 c	24.55 a	25.51 a	11.23 c	29.07 c
F-test	**	**	**	**	**	**	**	**	**	**
CV (%)	5.65	7.20	8.34	5.60	6.05	7.50	9.06	3.52	5.42	10.21

In a column, figures having the same letter (s) do not differ significantly as per DMRT;
*, ** = Significant at 5% and 1% level of probability, respectively

Table II. Interaction effect between salinity levels and genotypes on ion concentration and yield attributes of rice

Interaction		Mineral ion content (%)			Yield attributes and yield						
		Na	K	Ca	Effective tillers/ hill (no)	Non-effective tillers/ hill (no)	Filled grains/ panicle (no)	Unfilled grains/ panicle (no.)	1000-grain weight (g)	Grain yield (g/hill)	Harvest index (%)
Var.	Salinity (dS/m)										
V_1	0.34	0.19d	1.73a	0.29	12.99 a	3.50 e	98.4	12.64 de	25.03 b	31.99 a	41.49 a
	4.20	0.30c	1.72a	0.29	11.72b	4.55 d	93.3	14.92 d	24.90 c	27.23 b	38.50 a
	8.80	0.37b	1.58b	0.26	9.77 b	6.97 b	81.8	21.12 c	22.86 d	18.03 d	30.45 c
V_2	0.34	0.26c	1.80a	0.30	10.19 b	3.33 e	114.6	14.32 d	18.06 e	21.09 c	38.33 a
	4.20	0.37b	1.56b	0.27	9.42 b	4.40 d	105.4	20.65 c	17.43 e	16.31 e	34.40 b
	8.80	0.42b	1.52b	0.25	7.41 c	7.69 ab	86.1	33.95 b	15.81 f	9.34 g	25.50 d
V_3	0.34	0.13e	1.57b	0.22	9.09 b	5.07 c	66.9	11.64 e	28.08 a	17.08 d	37.69 a
	4.20	0.42b	1.43c	0.21	8.37 c	6.68 b	56.6	23.01 c	26.80 b	12.51 f	31.90 bc
	8.80	0.76a	1.16d	0.19	4.77 d	8.50 a	37.5	39.01 a	24.66 c	4.10 h	17.63 e
F-test		*	**	NS	**	**	*	*	*	**	*
CV (%)		5.65	7.20	8.34	5.60	6.05	7.50	9.06	3.52	5.42	10.21

V1 = MR232, V2 = Binashail, V_3 = IR20; In a column, figures having the same letter (s) do not differ significantly as per DMRT;
NS = Not significant; *, ** = Significant at 5% and 1% level of probability, respectively

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