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Selectivity of Ions Absorption as Mechanism of Salt Tolerance in Rice (Variety Shaheen Basmati)

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Abstract: The water culture studies were conducted to investigate a physiological mechanism. Performance of this rice variety, ion concentration and uptake were studied under stress of three salinity levels (30, 60 and 90 mM1-1) created by NaCI. The results indicated that shoot dry matter was not affected significantly with all the three levels of salinity. However the root dry matter was affected appreciably by the levels of 60 and 90 mM NaCI. Sodium concentration and uptake was enhanced significantly by root and shoot with the first level of salinity (30 mM) but thereafter the differences were non-significant indicating the preferential absorption of this cation. The K concentration was decreased significantly in shoots with all the levels. The impact was less pronounced in roots as far as K absorption was concerned. There was no effect on Ca and Mg. The values of K: Na, Ca: Na and Ca+Mg: Na ratios in shoot and root were comparatively narrow under stress conditions which indicated that Shaheen Basmati variety used ion selectivity mechanism in showing its tolerance when grown in saline medium.

Key words: Shaheen Basmati Variety, fine rice, salt tolerance, ion selectivity, mechanism

Introduction

The accumulation of soluble salts in agricultural soils is a problem that has been faced by man since cultivation was started. The responses of plant to soil salinity emerge as complex phenomena not necessarily due to, or dominated by any single factor. As a consequence, the best response lays with the optimization of several, probably independent physiological characteristics. Salinity can damage the plant through its osmotic effect, specific ion toxicity effects and by disturbing the uptake of essential nutrients. Although appreciable progress has been made in the general understanding of the physiology of plant-salt-relationship, yet there is still lack of a comprehensive understanding of the principal physiologic mechanisms of salt damage and tolerance. Considerable research has been directed towards defining the effects of salts upon crop growth (Kurth *et al.*, 1986; Hurkman and Tanaka, 1987; Neuman *et al.*, 1988). A better understanding of the mechanisms involved in the inhibition of plant growth by salinity may accelerate the introduction of environmental and genetic manipulations aimed at increasing crop salinity resistance. Extending the knowledge on physiological mechanisms of salt tolerance is of utmost importance in developing plants better adapted to saline and sodic soils. A number of studies have been made to see the responses of different crops to saline substrates (Greenway, 1965; Ackerson and Youngner, 1975; Thomas, 1980; Flowers and Yeo, 1981; Shannon *et al.*, 1981; Rawson and Munns, 1984).

A major characteristic of the solute transport by plant in saline conditions is the degree of selectivity between potassium and sodium (Pitman, 1984). Plant vary in selectivity between potassium and sodium ranging from virtual exclusion of $Na1^+$ to preferential accumulation of this cation. One of the most important physiological mechanisms of salt tolerance of plant is the selective absorption of $K1^+$ by plant from the saline media. Rice is the plant extensively grown in salt-affect soils of Pakistan due to its salt tolerance potential. Shaheen Basmati is the fine rice variety which was specifically evolved for by Soil Salinity Research Institute, Pindi Bhattian, Pakistan and possess a fair salt tolerance the salinity level for 50% reduction of paddy yield was reported to be 7 dS m^{-1} (Shabbir *et al.*, 2001a). The variety was also claimed to possess the traits of better production, extra long grain, short duration and good cooking quality with strong aroma (Shabbir *et al.*, 2001b). However, the mechanism of salt tolerance of this variety was not studied. The present study was, therefore, conducted to investigate the physiological mechanism responsible for better performance of this variety under salinity stress. The ions selectivity phenomenon of this cultivar was studied in detail to elaborate the physiological functions during the early growth period.

Materials and Methods

This experiment was conducted in solution culture. Rice (*Oryza sativa* L. Variety Shaheen Basmati) seed was germinated in a seed germination assembly and seven day old seedlings were foam plugged in plastic pots (two seedling pre hill) with plastic lids having holes in them, filled with 2.5 l of half strength Hoagland's nutrient solution (Epstein, 1972). The solution was aerated with compressed air continuously throughout growing period. The nutrient solution was changed after a week interval. The pots were kept in a growth chamber under controlled conditions having light intensity of 450 μmol $m^{-2}S^{-1}$. The photoperiod was adjusted to 14 h light and 10 h dark period. The temperature was controlled at 30±2°C. The solution pH was adjusted to 5.9 with NaOH or HCI. There were four salinity levels (0, 30, 60 and 90 mM l^{-1} NaCI). The salinity was produced a week after transplanting by adding an increment of 30 mM l^{-1} NaCI on alternate days. The experiment was organized in a randomized complete block design (RCBD) with four replications. The experiment was harvested 60 days after transplanting. The plants were immediately separated into root and shoot and rinsed repeatedly in deionized water. The plant samples were oven dried at 60°C for 48 h and weighed (dry weight). The dried plant samples were ground to pass a 40 mesh screen in a Wiley mill for chemical analysis. Root and shoot samples were digested in HNO_3-$HClO_4$ mixture (2:1) and Na, K, Ca and Mg were determined by atomic absorption spectrophotometer. The data were statistically analyzed (Gomez and Gomez, 1976) using analysis of variance as factorial arrangement and treatment means were compared by Duncan's multiple rang (DMR) test.

Results and Discussion

The shoot dry matter yield (DMY) significantly decreased with increasing salinity. Non-significant differences in shoot DMY were recorded when plants were grown in 60 and 90 mML^{-1} NaCI. The highest shoot DMY (0.94 g/pot) was obtained in control (0 mM NaCI) followed by the yield (0.75 g/pot) at 30 mM NaCI. The root dry matter yield, however, decreased significantly with increasing salinity (Fig. 1). The differences in root DMY were non-significant for the two consecutive levels whereas the alternate salinity levels in the increasing order proved as significantly depressing root weight. This indicated that roots are more sensitive to salinity as compared with the shoots and their growth was sharply retarded. The roots were directly growing in the salty water and faced severe stress.

The decrease in shoot DMY with salinity might be due to limited supply of metabolites to young growing tissues (Mass and Nieman, 1978) or interference of NaCI with the production of proteins or damage to enzymic proteins exposed to low water potential (Weimberg *et al.*, 1982).

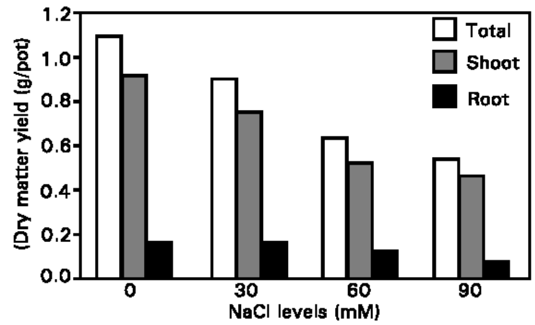

Fig. 1: Effect of salinty on dry matter yield of rice variety Shahbeen Basmati

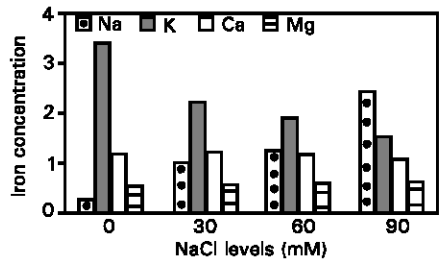

Fig. 2: Effect of salinty on concentration of ions (%) in shoots

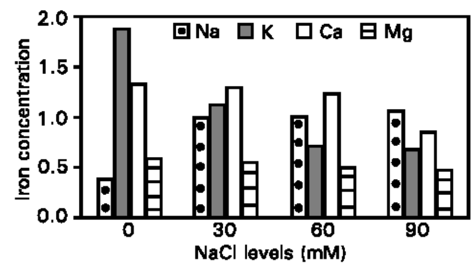

Fig. 3: Effect of salinityon concentration of ions (%) in roots

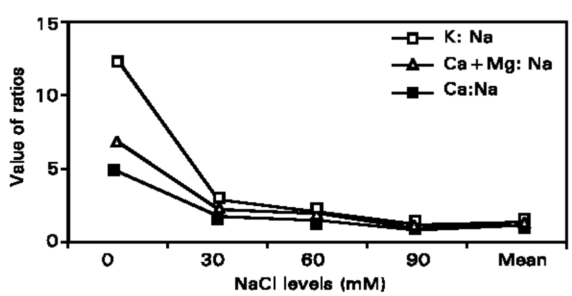

Fig. 4: Effect of salinity on ion ratios of shoot

Sodium concentration in shoot and root tissues was significantly affected in different salinity levels. It was increased with increasing salinity levels (Fig. 1 and 2). This increase might be due to increasing concentration of

Table 1: Effect of salinity of sodium, potassium, and calcium and magnesium uptake by Shaheen Basmati rice (g 100 g^{-1})

NaCl ($mM\ l^{-1}$)	Na uptake		K uptake		Ca uptake		Mg uptake	
	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
0	2.72c	0.68c	31.86a	3.44a	11.37a	2.44a	5.36 a	1.06a
30	7.57b	1.57a	16.62b	1.74b	8.82b	1.96b	4.22 b	0.87b
60	6.43b	1.22b	9.99c	0.82c	5.99c	1.47c	3.20 c	0.58c
90	11.74a	0.85c	7.26d	0.56c	5.02c	0.70d	2.92 c	0.38d
LSD	172	0.39	2.84	0.77	2.34	0.51	0.77	0.23

Means sharing same letters are statistically non-significant at 5%

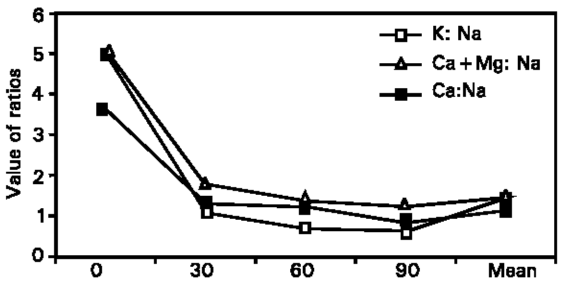

Fig. 5: Effect of salinity on ion ratios of root

sodium in the root medium which ultimately resulted in the increased uptake of sodium by plant (Aslam and Muhammad, 1972). Potassium concentration in root and shoot of Shaheen Basmati rice also significantly affected due to salinity. There was a non-significant difference in potassium concentration of root at 60 and 90 mM NaCI. The maximum potassium concentration in shoot (3.43%) and root (1.88%) was recorded at 0 mM NaCI while the respective minimum values were 1.54 and 0.69% at 90 mM NaCI (Table 1). The decease in potassium concentration due to salinity might be related to the competition and resultant selective uptake between potassium and sodium which caused increase in the uptake of sodium at the cost of potassium (Aslam and Muhammad, 1972; Kuiper, 1984). Effect of salinity on calcium concentration of rice shoot was statistically non-significant but it significantly affected the calcium concentration in root tissues (Fig. 2, 3). The highest calcium concentration in root (1.34%) was recorded with 30 mM NaCI while the lowest (0.88%) was recorded with 60 mM NaCI. Magnesium concentration in rice shoot was non-significantly affected by salinity (Fig. 2, 3). The first level of salinity (30 mM l^{-1}) did not cause any negative effect while the effect of highest two levels was significant, both remaining similar among themselves. The K: Na ratio in shoot and root significantly decreased due to salinity (Fig. 4, 5). The highest K: Na ratio in shoot (11.82) and root (5.08) was obtained with 0 mM NaCI while the lowest in shoot (0.63) and root (0.65) was observed with 90 mM NaCI. There was very rapid decrease at the initial level of data regarding the total uptake of sodium, potassium, calcium and magnesium are presented in Table 2. The data showed that total uptake increased significantly with increasing salinity both in shoot and root. In case of shoot, the difference between sodium uptake at 30 and 60 mM NaCI was non-signification but significant between 60 and 90 mM L^{-1}. Sodium uptake by roots increased significantly at 30 and 60 mMl^{-1}.

Sodium chloride salinity significantly decreased potassium uptake both in root and shoot tissue (Table 1). The difference between potassium uptake at 60 and 90 mM NaCI was non-significant both in shoot and root. The highest potassium uptake in shoot (31.86 mg g^{-1}) and root (3.44 mg g^{-1}) was recorded at 0 mM NaCI while the lowest potassium uptake in shoot (7.26 mg g^{-1}) and root (0.56 mg g^{-1}) was recorded at 90 mM NaCI. Salinity also affected the calcium uptake by plants significantly (Table 1). This parameter was decreased significantly except at the highest level (90 mM L^{-1}) in shoots. The results were significant at all the level in case of shoots. The highest calcium uptake by shoot (11.37 mg g^{-1}) was recorded at 0 mM NaCI while in root (2.44 mg g^{-1}) it was obtained at 30 mM NaCI. As far as the uptake of magnesium was concerned, it also decreased significantly both in shoot and root (Table 1). In case of shoot, this decease was non-significant at 90 mM NaCI while in roots it was significant at all the levels. The highest magnesium uptake in shoot (5.36 mg/kg) and root (1.06 mg/kg) was recorded at 0 mM NaCI.

A careful consideration of cations concentration in shoots indicated that there eas a gradual increase in Na and decrease in K while Ca and Mg remained almost constant with the highest salinity levels of 60 and 90 mM l^{-1} over 30 mM l^{-1}. The Na: K ratio was narrow for these salinity levels. The Ca: Na and Ca+Mg: Na ratios were also found to be narrow, especially in roots (Fig. 2). Hence, the tolerance mechanism of this variety may be regarded due to its selective control on cation absorption. It controlled the absorption of $Na1^+$ even when grown in more concentrated Na solution. The relative absorption of $K1^+$ was not affected pronouncly while the Ca and Mg percentages were not influenced at all.

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