Pak.J.Bot., 29(2): 313-318, 1997.

THE POTENTIAL OF USING K/Na RATIO AS INDEX OF SALINITY TOLERANCE IN TOMATO

MARIO V. LOPEZ AND M.E. SATTI

Department of Agronomy,
College of Agriculture, 2989 Makiling Subdivision, Anos,
Los Banos, Laguna 4030, Philippines.

Abstract

The effects of adding K, P and Ca to saline nutrient solutions on K/Na ratio and salinity tolerance in tomato (*Lycopersicon esculentum* Mill) in five tomato cultivars viz., Tropic, Marikit, Montecarlo, Strain B and Pearson was studied. Addition of K, K+P and K+P+Ca to saline nutrient solutions significantly increased K/Na ratios in the leaf, stem and root as well as fruit yield by 25-35%, whereas addition of P alone significantly reduced K/Na ratio in the stem but not in the leaf and root with a increase in fruit yield by 9%. Two types of physiological mechanism conferring salinity tolerance to tomato cultivars based on their respective K/Na ratios were detected where Marikit exhibited a typical halophytic characteristic while Tropic, Montecarlo, Strain B and Pearson showed typical glycophytic response, reaction.

Introduction

Soil salinity is a major problem world-wide especially in arid and semi-arid regions causing reduction in crop yield and rendering large areas of land non-arable. Leaching salts alleviates the problem but it is extremely costly. Fertilizer application under saline conditions and the use of tolerant crop cultivars have generated considerable interest with the increasing use of saline water in agriculture.

Presence of salts and nutrient elements as a result of fertilizer application in the root zone can influence ion uptake whereby synergistic and antagonistic interaction effects may increase or decrease the intensity of salinity. Specific ion effect can be controlled depending on the cationic and anionic balance especially the K/Na ratio. Addition of K to saline nutrient solution is reported to increase dry weight and shoot K content in rice (Muhammed *et al.*, 1987) resulting in a favourable K/Na ratio (Bohra & Doerffling, 1993). Phosphorus also modifies the effects of salinity ranging from an induced enhancement of tolerance (Awad *et al.*, 1990; Gibson, 1988) to antagonism (Bernstein *et al.*, 1974; Cerda *et al.*, 1977).

Analysis of plant material for specific ions has been suggested as a method to measure salinity tolerance since wider K/Na ratio was found in tolerant varieties of higher plant species (Chauhan *et al.*, 1980; Giriraj *et al.*, 1976; Hedge & Joshi, 1974). Salt sensitivity have been reported in plants with lower Na to K content ratios (Rush & Epstein, 1981) whereas others reported high salinity tolerance in plants with high Na and Cl contents (Dehan & Tal, 1978; Figdore *et al.*, 1989).

The objectives of the study were To determine salinity tolerance of tomato cultivars and the possible mechanism involved and the effects of added K,P and Ca on K/Na ratio of tomato grown in saline nutrient solutions. In addition, the efficacy of using K/Na ratio as an index of salinity tolerance in tomato was also studied.

Materials and Methods

Sand Culture System: Sand culture system was practically designed for this study in a greenhouse at the Agricultural Experiment Station, Sultan Qaboos University, Sultanate of Oman. Nutrient solutions were pumped to PVC pots (with height of 28.5 cm and 15 cm diameter) filled with washed seaside sand. Excess nutrient solutions leaching through the sand was collected by a tube and drained back to the supply tank. The experiment consisted of five different treatments each one with a basal nutrient solution (half-strength Hoagland solution) and their respective amendments. Solutions in all treatments were pumped automatically for 20 minutes using an electrically-controlled timing system. The solutions were pumped two times a week for the first month and three times a week thereafter up to the last harvest. All tanks were emptied, cleaned and replaced with new solutions every week. The pH of solutions and EC (electrical conductivity) were monitored before watering 2-3 times weekly. The pH was adjusted using 1.0 M HNO_3 or 1.0 M NaOH to 5.8 $\pm$ 0.2 for all solutions.

Experimental Design: The study was conducted using a 5x5 Factorial design in a randomized complete block (RCB) with tomato viz., Tropic, Marikit, Montecarlo, Strain B and Pearson as the first factor and salinity treatments as the second factor. Details of the salinity treatments are given in Table 1.

Seeds of the tomato cultivars were germinated in seedling trays and the seedlings at five-leaf stage were transplanted to pots filled with washed seaside sand at an inter-row and intra-row distance of 20 cm. The main shoot was allowed to develop and lateral shoots were regularly removed. Maximum daily temperature in the greenhouse was 27 $\pm$ 2°C and minimum 18$\pm$2°C with daily mean R.H of 67%.

Table 1. Analyses of different salinity treatments used to grow different tomato cultivars.

Salinity Treatments	Electrical conductivity (mS/cm)	K (mM)	P (mM)	Ca^{++} (mM)
1/2 Hoagland solution	1.58	1.11	0.11	0.42
1/2 Hoagland solution 50 mM NaCl + 3.0 mM K_2SO_4	7.18	1.78	0.11	0.42
1/2 Hoagland solution + 50 mM NaCl +1.5 mM Orthophosphoric acid	6.75	1.11	0.58	0.42
1/2 Hoagland solution + 50 mM NaCl +3 was K_2O_4 + 1.5 mM ortho-phosphoric acid	7.29	1.78	0.58	0.42
1/2 Hoagland solution + 50 mM NaCl + 3mM K_2SO_4 + mM Ortho-phosphoric acid + 10 mM $CaSO_4$	8.41	1.78	0.58	3.36

Data collection and Analysis: Fruit yield in terms of number per plant was obtained by counting the number of fruits harvested per plant for ten weeks (first to last harvest). After the last harvest, leaf, stem and root samples were collected. Root samples were initially washed with tap water and then with distilled water to remove sand particles and air-dried. The plant samples were separately oven-dried at 70°C for 3 days, ground in a Wiley mill with 20-mesh screen size and ashed in a muffle furnace at 550°C for 3 hours. Extracts were obtained from the ashed samples after heating with 5.0 ml of 2.0 N HCl. A volume of 0.25 ml of the extract was mixed with 5.0 ml of 2.0 N HCl and made to final volume of 50 ml with deionized water. Potassium(K) and sodium(Na) concentrations of the samples were determined using a Corning 410 Flame Photometer.

Analysis of variance was done for each parameter and the least significant difference was calculated. Correlation analysis among parameters was also made.

Results

Effect of Saline-Solution Added K, P and Ca on K/Na Ratio and Fruit Yield: K/Na ratio in the leaf ranged from 0.49-1.0 (Table 2). The ratio significantly increased to 0.85-1.0 with the addition of K, K+P and K+P+Ca to saline nutrient solutions as compared to control (0.58). Addition of P alone reduced K/Na ratio to 0.49 which was even lower than the control although reduction was not significant. K/Na ratio in the stem ranged from 0.32-0.80. The ratio significantly increased to 0.63 - 0.80 with the addition of K, K+P and K+P+Ca to saline nutrient solutions as compared to the control (0.57). Addition of P alone, as found in the leaf significantly lowered the ratio to 0.32 as compared to the control. In the root, K/Na ratio ranged from 0.20 -0.42 and

Table 2. Leaf, stem and root K/Na ratio and fruit yield of tomato in response to saline nutrient solutions.

K/Na Ratio		Fruit Yield		Percent	
Salinity Treatments	Leaf	Stem	Root	(Number/Plant)	of Control
Control	0.58 c	0.57 c	0.26 bc	14.00 c	--
NaCl + K	0.85 b	0.63 bc	0.32 b	18.90 a	35.00
NaCl + P	0.49 c	0.32 d	0.20 c	15.35 bc	9.64
NaCl + K + P	0.81 b	0.74 ab	0.41 a	18.50 a	32.14
NaCl + K + P + Ca	1.00 a	0.80 a	0.42 a	17.55 ab	25.36
Cultivars					
Tropic	0.75 ab	0.57 bc	0.29 b	11.45 c	--
Marikit	0.58 c	0.48 c	0.34 ab	28.85 a	--
Montecario	0.73 b	0.63 ab	0.27 b	14.45 bc	--
Strain B	0.87 a	0.75 a	0.40 a	14.20 bc	--
Pearson	0.81 ab	0.62 ab	0.30 b	15.35 b	--

**Means within a column, having the same letter are not significantly different from each other at 5% level (LSD).

like in the leaf and stem, K/Na ratio in the root significantly increased to 0.32-0.42 with the addition of K, K+P and K+P+Ca to saline nutrient solutions as compared to control (0.26).

Fruit yield in terms of number per plant significantly increased with addition of K, K+P and K+P+Ca to saline nutrient solutions from 14.0 (in control) to 17.55 - 18.90. Addition of P alone did not significantly increase fruit number per plant (15.35). On the basis of percent of control,fruit number produced per plant increased by 35.0, 9.64, 32.14 and 25.36% with the addition of K, P, K+P and K+P+Ca, respectively to saline nutrient solutions.

Among the tomato cultivars tested, Strain B was significantly found to have the highest leaf K/Na ratio (0.87), followed by Pearson (0.81), Tropic (0.75), Montecarlo (0.73) and lastly by Marikit (0.58) (Table 2). In the stem, Strain B also significantly showed the highest ratio (0.75), followed by Montecarlo (0.63), Pearson (0.62), Tropic (0.57) and Marikit (0.48).

In root, Strain B still had the highest ratio (0.40), followed by Marikit (0.34), Pearson (0.30), Tropic (0.29) and Montecarlo (0.27). On fruit yield, Marikit was found to produce greater number of fruits per plant (28.85) followed by Pearson (15.35), Montecarlo (14.45), Strain B (14.20) and Tropic (11.45).

Correlation coeffecients between K/Na ratios of various plant parts and fruit yield exhibited significant relationships on all plant parts but non-significant values with fruit yield (Table 3).

Discussion

The adverse effects of salinity on the growth and development of tomato are mainly due to competition in uptake between nutritive and toxic ions. It has been reported that the main salt interference to nutrient uptake is by K - Na competition (Silverbush & Ben-Ashir, 1987). Addition of K alone or in combination with P and Ca to saline nutrient solutions significantly increased K/Na ratios in the leaf, stem and root. An increased K/Na ratio is an indication of increased K and reduced Na ion uptake (Bernstein, 1964; Joshi, 1984; Muhammed *et al.*, 1987; Saxena & Rewari,1993). This increased uptake of K could possibly be a result of direct competition between K and Na at sites of uptake in the plasmalemma (Epstein, 1966), an effect of K on Na transport

Table 3. Correlation coefficients of leaf, stem and root K/Na ratios as well as fruit yield.

	Stem K/Na Ratio	Root K/Na Ratio	Fruit Number Per plant
Leaf K/Na Ratio	0.901^{*}	0.911^{*}	0.773^{ns}
Stem K/Na Ratio	---	0.958	0.596^{ns}
Root K/Na Ratio	---	---	0.711^{ns}

*Significant and ^{ns}Not significant, respectively at 5% level.

into the xylem and/or a K-induced net Na extrusion from the root (Jeschke & Nassery, 1981).

Addition of P alone to saline nutrient solution reduced K/Na ratio in leaf, stem and root although reduction was not statistically significant in the leaf and root. Awad *et al.*, (1990) observed that increasing P concentration in saline solution decreased Na and increased K concentrations in immature leaves but increased Na and decreased K in mature leaves of tomato.

Addition of K,P and Ca alone or in combination with each other significantly increased yield in terms of fruit number per plant. However, it has been noticed that addition of P to saline nutrient solution had mininum effect in increasing the number of fruits produced per plant as compared to those with K alone or in combination with P and Ca. The improvement in yield could have been indirectly due to higher K/Na ratio (Devitt *et al.*, 1981). Although there are no significant correlations between leaf, stem and root K/Na ratios and fruit number/plant, the increase in fruit yield could presumably be due to osmotic adjustments effect. Higher K/Na ratio is known to improve leaf water potential (Devitt *et al.*, 1981) and consequently, photosynthetic capacity (Bohra & Doerffling, 1993).

Different plant parts were not equally affected by salinity. Salinity tolerance rating based on K/Na ratio are usually on the ions translocation of the shoot, more particularly the leaf as reported in sorghum (Yang *et al.*, 1990), wheat (Schachtman *et al.*, 1989) and rice (Muhammed *et al.*, 1987) since foliar Na content is a highly heritable trait (Sacher *et al.*, 1981). In tomato, Marikit was found to have the lowest K/Na ratio in the leaf and stem while Strain B had the highest K/Na ratio. Other cultivars such as Pearson, Montecarlo and Tropic were found to have K/Na ratios in between Marikit and Strain B.

Strain B, Tropic, Montecarlo and Pearson seemed to exhibit typical glycophytic reactions with preferential absorption of K over Na (Bestford, 1978), which in reality is an avoidance mechanism. On the other hand, Marikit, a cultivar developed in the University of the Philippines at Los Banos showed a typical halophytic reaction wherein Na concentration increased and K concentration decreased with salinity as observed in some wild relatives of tomato (Perez Alfocea *et al.*, 1993). This could be the reason for its observed high level of salt-tolerance (Del Rosario *et al.*, 1991).

Acknowledgement

The author gratefully acknowledge the suggestions and editing made by Mr. Vic C. Rodriguez.

References

Awad, A.S., D.G. Edwards and L.C. Campbell. 1990. Phosphorus enhancement of salt tolerance in tomato. *Crop Sci.*, 30:123-128.

Bernstein, L. 1964. Effects of salinity on mineral composition and growth of plants. *Plant Anal. Probl.*, 4:25-45.

Bernstein, L., L.E. Francois and R.A. Clark. 1974. Interactive effects of salinity and fertility on yields of grains and vegetables. *Agron. J.*, 66:412-421.

Bestford, R.T. 1978. Effect of replacing nutrient potassium by sodium on uptake and distribution of sodium in tomato plants. *Plant and Soil*, 50:399-409.

Bohra, J.S. and K. Doerffling. 1993. Potassium nutrition of rice (*Oryza sativa* L.) varieties under NaCl salinity. *Plant and Soil*, 152:299-303.

Cerda, A., F.T. Bingham and G.J. Hoffman. 1977. Interactive effect of salinity and phosphorus on sesame. *J. Soil Sci.*, 41:915-918.

Chauhan, R.P.S., C.P.S. Chauhan and D. Kumar. 1980. Free proline accumulation in cereals in relation to salt tolerance. *Plant and Soil*, 57:167-175.

Dehan, K. and M. Tal. 1978. Salt tolerance in the wild relatives of the cultivated tomato: Responses of *Lycopersicon esculentum, L. peruvianum and L. esculentum minor* to sodium chloride solution. *Irr. Sci.*, 1:71-76.

Devitt, D., W.M. Jarrell and K.L. Stevens. 1981. Sodium - potassium ratios in soil solution and plant responses under saline conditions. *Soil Sci. Soc. Am. J.*, 45:80-86.

Epstein, E. 1966. Dual pattern of ion absorption by plant cells and by plants. *Nature*, 212:1324-1327.

Figdore, S.S., W.H. Gabelman and G.C. Gerloff. 1989. Inheritance of potassium efficiency, sodium substitution capacity and sodium accumulation in tomatoes grown under low potassium stress. *J. Am. Soc. Hort. Sci.*, 114:322-327.

Gibson, T.S. 1988. Carbohydrate metabolism and phosphorus/ salinity interactions in wheat (*Triticum aestivum* L). *Plant and Soil*, 111:25-35.

Giriraj, K., A.S.P. Murthy and K.V. Janardhan. 1976. Comparative study of growth, yield and nutrition in rice as affected by saline water application. *Sabrao J.*, 8:47-52.

Hedge, B.A. and G.V. Joshi. 1974. Mineral absorption in saline rice variety Kala Rata. *Plant and Soil*, 41:421-424.

Jeschke, W.D. and H. Nassery. 1981. K^+- Na^+ selectivity in roots of *Triticum, Helianthus and Allium. Physiol. Plant.*, 52:217-224.

Joshi, S.S. 1984. Effect of salinity stress on organic and mineral constituents in the leaves of pigeon pea (*Cajanus cajan* L. Var. C-11). *Plant and Soil*, 82:69-76.

Rush, D.W. and E. Epstein. 1981. Comparative studies on the sodium, potassium and chloride relations of a wild halophytic and a domestic salt-sensitive tomato species. *Plant Physiol.*, 68:1308-1313.

Sacher, R.F., R.C. Staples and R.W. Robinson. 1981. Salt tolerance in hybrids of *Lycopersicon esculentum* x *Solanum pennellii* and selected breeding lines. IInd Int. Workshop on Biosaline Research.*La Paz, Mexico*. 1980.

Saxena, A.K. and R.B. Rewari. 1993. Effect of potassium on the growth and nodulation of chickpea (*Cicer arietinum* L.) under different levels of salinity.*Trop. Agric.*,70:372-374.

Schachtman, D.P., A.J. Bloom and J. Dvorak. 1989. Salt-tolerant *Triticum* x *Lophopyrum* derivatives limit the accumulation of sodium and chloride ions under salt-stress. *Plant Cell Environ.*,12:47-55.

Silverbush, M. and J. Ben-Asher. 1987. The effect of salinity on parameters of potassium and nitrate uptake of cotton. *Comm. Soil Sci. Plant Anal.*,18:65-81.

Yang, Y.W., R.J. Newton and F.R. Miller. 1990. Salinity tolerance in Sorghum. I. Whole plant response to sodium chloride in *S. bicolor* and *S. halepense*. *Crop Sci.*, 30:775-781.

(Received for publication 15 March, 1995)