JOURNAL OF PLANT NUTRITION, 19(5), 705–715 (1996)

FRUIT QUALITY AND PARTITIONING OF MINERAL ELEMENTS IN PROCESSING TOMATO IN RESPONSE TO SALINE NUTRIENTS

S. M. E. Satti, R. A. Al-Yhyai, and Fahad Al-Said

Department of Plant Sciences, P.O. Box 34, P.C. 123, Al-Khod, Sultan Qaboos University, Muscat, Sultanate of Oman

ABSTRACT: A sand culture experiment was conducted to study the effect of saline water on the growth and fruit quality of processing tomato (*Lycopersicon esculentum* Mill.) Seedlings of five tomato cultivars were transplanted in quartz-sand pots in a greenhouse at the Agricultural Experiment Station of Sultan Qaboos University. There were four saline nutrient solutions and a control consisting of half-strength Hoagland solution. Salinity treatments were: 50 mM NaCl + 3 mM K_2SO_4 (EC 6.75), 50 mM NaCl + 1.5 mM orthophosphoric acid (EC = 7.18), 50 mM NaCl + 1.5 mM orthophosphoric acid + 3 mM K_2SO_4 (EC 7.29), and 50 mM NaCL (EC = 5.6). Treatments were applied daily commencing two weeks after transplanting. Data were collected on growth, and fruit yield and quality. Partitioning of mineral elements was determined in the vegetative tissue. The results obtained clearly show that concentrations of total soluble solids were increased in fruits treated with saline nutrients. Dry matter content of fruits exposed to salinity were higher than those from the control plants. Fruit acidity was increased with salinity, possibly due to a lower water content and increased organic acid accumulation. In the saline treatments, sodium (Na) content was decreased when potassium (K) was applied with NaCl but Na was higher in stems followed by root and leaf tissues. The partitioning of K followed a trend opposite to that for Na but with higher content in leaves. A similar situation was observed for calcium (Ca) and magnesium (Mg). Accumulation of phosphorus (P) was the lowest among all the ions. These results indicated that survival under saline conditions was accompanied by high ion accumulation. The study confirmed that saline nutrients are important for improving fruit quality of processing tomatoes.

INTRODUCTION

Improvement of salt tolerance in crop plants is of paramount importance in the exploitation of the large areas of saline soils and the efficient use of saline water in coastal arid lands. Numerous management techniques have been proposed to enhance yield and improve fruit quality characteristics of tomatoes. Saline water has been used to improve fruit quality of tomato grown by nutrient film culture (Ehret and Ho, 1986) and under field conditions (Pasternak et al., 1986). Using a sand culture technique, Mitchell et al. (1991) found that fruit osmotic potential was significantly reduced by both water deficit and salinity which corresponded primarily to reductions in fruit water import rather than an increase in solute accumulation. Yield-salinity response models were applied not only to fruit yield but also to development characteristics, such as height (Anastasio et al., 1987) and vegetative yield (Shannon et al., 1987).

The flavor of salad tomatoes and processing qualities are closely related to the concentration of total soluble solids (TSS) in the fruit (Cornish, 1992). It has been suggested that irrigation with saline water has the potential to increase TSS in processing tomatoes (Pasternak et al., 1986; Mitchell et al., 1991). Field grown salad tomatoes in a coastal environment gave only small and inconsistent responses to irrigation water salinized with KCl (Cornish and Nguyen, 1989). In a sand culture experiment (Satti and Lopez, 1994) using salad tomatoes, total soluble solids were increased by 116% under saline treatments.

This study was conducted to investigate the potential of salinization regimes for improving tomato fruit quality and to determine its effect on fruit size and the partitioning of mineral elements in the tomato plant.

MATERIALS and METHODS

Sand Culture System

A sand culture facility was specifically designed for salinity studies in a greenhouse at the Agricultural Experiment Station of Sultan Qaboos University. Nutrient solutions were pumped from holding tanks with a submersible pump into tubes that feed plants in PVC pots filled with quartz sand. This consisted of five separate units. In each unit, the basal nutrient solution (Hoagland's solution) and saline treatments were fed by an emitter tube drip system from a 70-L polythylene reservoir. Solutions in all tanks were pumped intermittently (10 min on and 10 min off) for 30 minutes using electric submersible pumps. Treatments were applied daily. The system was controlled by a mechanical timing system. Drained solutions were filtered and returned to their respective holding tanks. All tanks were emptied and replaced with new solutions every week. Solution pH was adjusted with either NaOH or H_2SO_4 to maintain a pH of 5.8±0.2. The EC was adjusted by nutrient addition or water dilution, whenever necessary, to restore concentrations to their initial levels. Initial irrigation of all plants was done with a control solution consisting of a half-strength Hoagland solution in tap water. This regime was continued for two weeks after transplanting.

Seedlings were established in a standard potting mix in the greenhouse. Five tomato cultivars were used: Hybrid 898, Spectrum 579, Sierra Hybrid, UC 82L, and Napoli. At five weeks of age, seedlings were transferred to the sand culture for commencing the treatments. Plants were raised on main stems and were tied to stakes. Pests and diseases were controlled effectively with routine chemical sprays. The mean daily maximum temperature in the greenhouse was 28±2°C and the minimum 18±2°C. The mean daily hours of sunlight was 11.5 hours during the course of the experiment.

Experimental Design and Chemical Analysis

The experiment consisted of four salinity treatments and a control. The plots were arranged in a randomized block design with four replications. Each treatment received an half-strength modified Hoagland solution to provide the necessary nutrient elements for growth. The conductivity of the basal treatment was 1.58 mS/cm. Salinity treatments were: 50 mM NaCl + 3 mM K_2SO_4 (EC = 6.75), 50 mM NaCl + 1.5 mM orthophosphoric acid (EC 7.18), 50 mM NaCl + 1.5 mM orthophosphoric acid + 3 mM K_2SO_4 (EC = 7.29) and 50 mM NaCl (EC = 5.60).

Growth measurements of stem height and number of leaves developing on the main stem were recorded weekly and continued for 10 weeks after transplanting. All fruits were counted and weighed following harvest at incipient red. Soluble solids concentration (SSC) was determined with a hand-held refractometer (American Optical Corp., Keene, NH). Titratable acidity was determined by crushing 5 g fruit sample, and then boiling in 200 mL distilled water for 15 minutes. A 50 mL aliquot of the solution was titrated with NaOH and the acidity was computed as percent citric acid. Fruit electrical conductivity (EC) was determined using a portable digital electric conductivity meter (Model 4070). Fruit pH was determined in tomato juice using a pH meter model (Kent/EIL 7020). Plant shoots were separated from the roots and then divided into stems, leaves, and fruits remaining after last harvest. Fresh and dry weights were determined. Dried samples were ground in a stainless Wiley mill to a particle size ≤1-mm (20-mesh screen). Leaf and fruit samples were analysed after muffle furnace ashing for their Na, K, Ca, and Mg contents by atomic absorption spectrophotometry. Analysis of P in the leaf and fruit tissues was done by calorimetric methods. Absorbance of samples were measured using spectrophotometer (Bausch and Lomb, Belgium) at 650 nm. Growth data collected in this study were analyzed using ANOVA procedure and mean separation analysis using LSD.

RESULTS and DISCUSSION

Salinity did not decrease the number of tomato fruits harvested and none of the saline treatments significantly reducted fruit formation (Table 1). High EC increased the number of fruits smaller than 60 mm, but had no statistically significant effect on the total number of fruits produced (Cornish, 1992).

Fruit weight was found to be influenced by the type of salinity (Table 2). When NaCl was applied alone, fruit weight were decreased by 50% in relation to the control. The least reduction in fruit weight was found with the NaCl treatment with K alone. Ehert and Ho (1988) found that an EC of about 5 mS/cm actually increased yield and there was no reduction at about 7.0 mS/cm compared with that for the controls (EC 2 mS/cm). Why the reason for differences between experiments are not known with certainty, the probable variation could result from cultivar response, type of salinity, and stage of plant growth at which saline applications were made.

The concentration of total soluble solids was increased in fruits treated with the saline solutions (Table 3), being higher in the saline treatment with K and P than with NaCl alone. The highest value was 9.00% determined in cultivar Sierra hybrid. The increase in total soluble solids of the fruit was more than 50% in the saline treatments as compared with fruit from the control plants. Mizrahi et al. (1988) reported the concentration of reducing sugars and total soluble solids to increase in fruits from salinated plants. The increase in fruit soluble solids was possibly due to a decrease in fruit water content and an increased ion content. These results are in general agreement with (Mitchell et al. 1991) who found in sand

Table 1. Tomato fruit yield showing the number of fruits harvested per plant.

CULTIVAR	Nutrient Solutions With 0.5 Strength Hoagland Formulation				
	Control	NaCl + K	NaCl + P	NaCl + K + P	NaCl
HYBRID 898	16.75	19.00	11.00	16.25	12.75
SPECTRUM 579	14.50	21.00	18.75	17.25	17.00
SIERRA HYBRID	17.25	18.00	14.00	21.75	17.50
UC 82L	18.25	19.00	18.25	19.25	12.75
NAPOLI	27.00	29.25	31.50	26.75	25.50
MEAN	18.75 a	21.25 a	18.70 a	20.25 a	17.10 a

Means within row, having the same letter are not significantly different from each other at 5% level.

Table 2. Fruit yield(g/plant) showing reduction in fruit weight when saline regimes were applied.

CULTIVAR	Nutrient Solutions With 0.5 Strength Hoagland Formulation				
	Control	NaCl + K	NaCl + P	NaCl + K + P	NaCl
HYBRID 898	719.20	488.50	333.30	430.60	339.70
SPECTRUM 579	813.00	531.30	433.60	351.90	421.40
SIERRA HYBRID	730.90	468.10	367.70	455.00	462.40
UC 82L	647.70	335.80	350.70	342.00	254.60
NAPOLI	898.10	433.00	452.70	380.40	408.00
MEAN	761.80 a	451.30 b	387.60 b	392.00 b	377.20 b
% REDUCTION	—	40.76	49.12	48.54	50.49

Means within row, having the same letter are not significantly different from each other at 5% level.

Table 3. **Tomato soluble solids concentrations showing percent increase under five levels of salinity.**

CULTIVAR	Nutrient Solutions With 0.5 Strength Hoagland Formulation				
	Control	NaCl + K	NaCl + P	NaCl + K + P	NaCl
HYBRID 898	A 4.75 b	A 7.75 a	A 7.25 a	B 7.31 a	A 6.75 a
SPECTRUM 579	A 4.94 b	A 7.88 a	A 7.81 a	B 7.56 a	A 7.50 a
SIERRA HYBRID	A 4.69 c	AB 7.25 b	A 6.56 b	A 9.00 a	A 7.38 b
UC 82L	A 4.38 b	AB 6.44 a	A 7.63 a	B 6.63 a	A 6.38 a
NAPOLI	A 4.38 b	B 6.25 a	A 7.44 a	B 6.94 a	A 6.69 a
MEAN	4.63 b	7.11 a	7.34 a	7.49 a	6.94 a
% INCREASE	---	53.56	58.53	61.77	49.89

Means within row, having the same letter are not significantly different from each other at 5% level.

culture experiments, higher levels of salt stress when imposed at later stages of growth than occurred in our present study.

The dry matter content of fruits for plants exposed to the saline treatments was significantly higher than that for the control plant fruit (Table 4). Different salts appeared to be equally effective in increasing fruit dry matter, suggesting that osmotic effects on plant water relations under the the response, rather than specific ionic effects. It has been reported that fruit dry weight accumulation can be affected by decreased water import resulting in a fruit size reduction (Mitchell et al., 1991).

Fruit acid concentrations due to the saline treatments were significantly increased as compared to fruit from the control plants (Table 4). There were no significant interactions between tomato cultivar versus fruit quality and the salinity treatments. The addition of K to NaCl increased the titratable acidity of fruit by 20% as compared to fruit from the NaCl-treated plants, and by 133% when compared with fruit from the control plants. Higher fruit acid concentration for plants in the saline treatments was possibly due to a lower water content or increased organic

Table 4. **Changes in tomato fruit quality parameters in response to salinity.**

Treatments	% Fruit Dry Matter	% Citric Acid	E.C. (mS/cm)	pH
Control	6.36[x] b[y]	0.27 c	1.20 c	4.66 b
NaCl + K	10.22 a	0.63 a	1.92 ab	4.46 a
NaCl + P	10.31 a	0.45 b	1.67 b	4.48 a
NaCl + K + P	10.23 a	0.53 a	2.03 a	4.47 a
NaCl	9.87 a	0.52 a	1.79 ab	4.51 a

x: Values shown are means of four replications.

y: Means within columns, separated by LSD at P= 0.05.

acid accumulation. It has been shown that the tomato plant maintains turgor when under sub-lethal salt stress by accumulating organic solutes in its leaves in order to osmotically balance the increased concentration of inorganic ions in the growing medium (Rush and Epstein, 1976).

Fruit juice conductivity and pH were significantly affected with the salinity treatments (Table 4). The increase in EC was likely due to ion accumulation and import under saline conditions, whereas the decrease in pH was significant when compared with fruit from the control plants, probably the result of an increase in organic acid content. For fruit from salt-treated plants, reduced fruit water content and increased ion import probably both account for the higher ion concentrations found (Ehret and Ho, 1986).

Partitioning of ions in different leaves or stem and root tissues is often used to explain salt tolerance. Accumulation of Na was found to be higher in the stem tissue followed by the root and leaf tissues in almost all treatments used in this study (Fig. 1). However, there was no significant interactions in the accumulation of the mineral elements among the tomato cultivars used in this study or saline treatments. With the various saline treatments, the concentration of Na was lower when K when combined with NaCl. The concentration of K in the leaves, and stem and root tissues followed a trend opposite to that of Na, but the highest content was found in the leaves, irrespective of the treatment (Fig. 2). A similar response can be seen in the accumulation of Ca (Fig. 3) and for Mg in various tomato tissues (Fig. 4). The concentration of P was the lowest of all the ions determined in this study, with

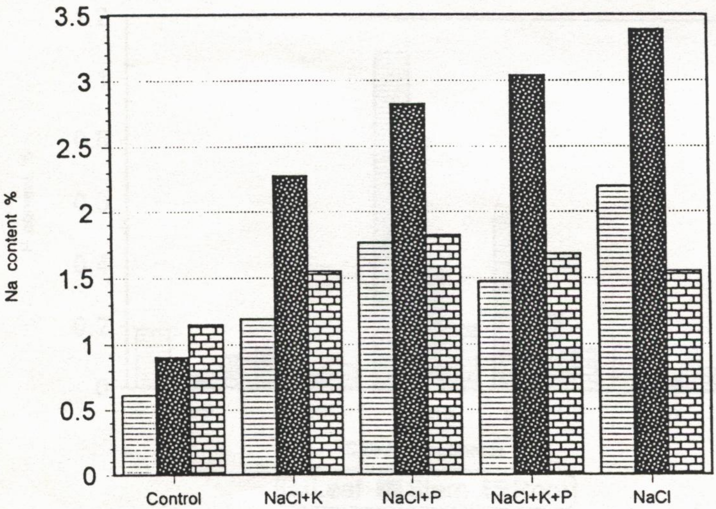

FIGURE 1. Sodium content (%) in dry tomato leaf, stem, and root in response to salinity.

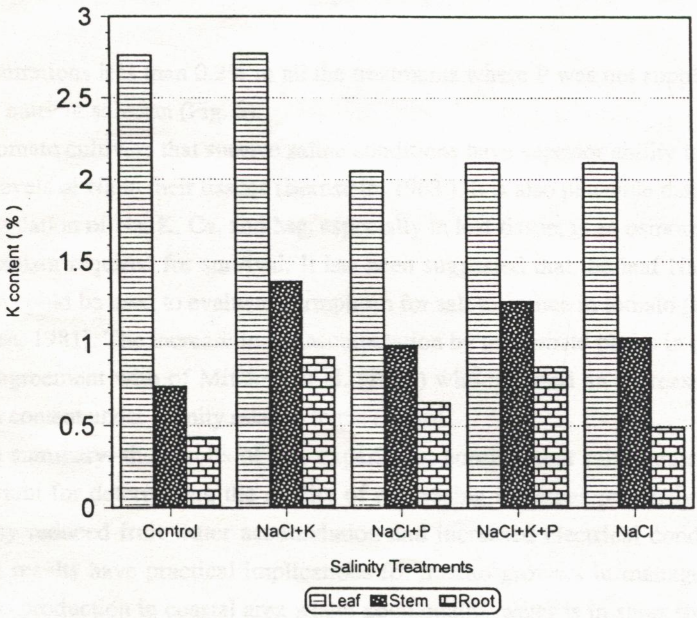

FIGURE 2. Potassium content (%) in dry tomato leaf, stem, and root in response to salinity.

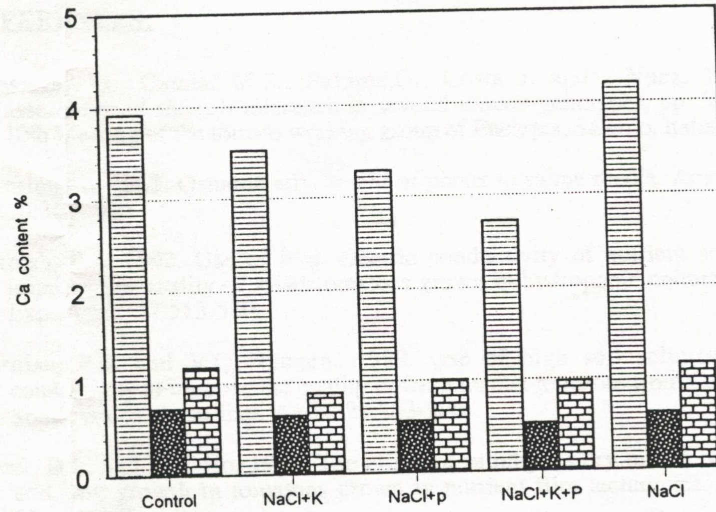

FIGURE 3. Calcium content (%) in dry tomato leaf, stem, and root in response to salinity.

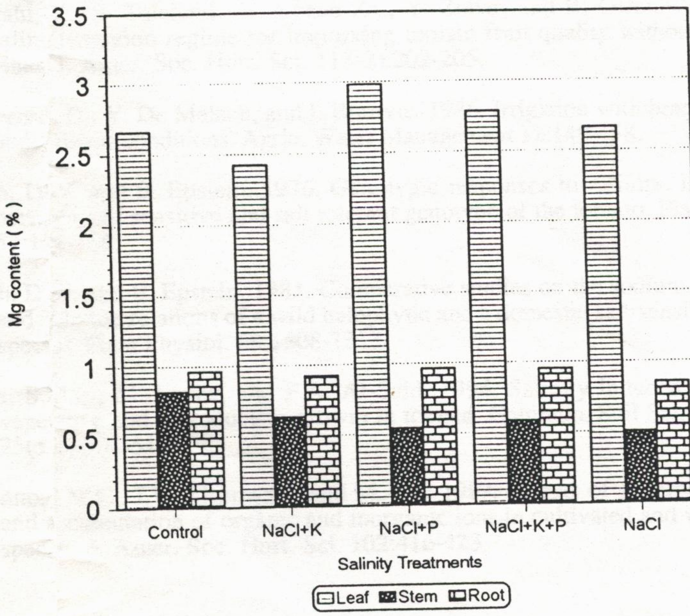

FIGURE 4. Magnesium content (%) in dry tomato leaf, stem, and root in response to salinity.

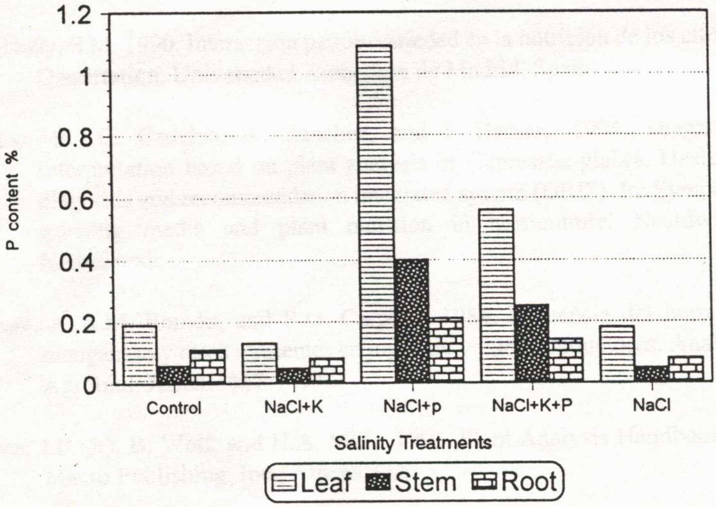

FIGURE 5. Phosphorus content (%) in dry tomato leaf, stem, and root in response to salinity.

concentrations less than 0.2% in all the treatments where P was not supplemented in the nutrient solution (Fig. 5).

Tomato cultivars that survive saline conditions have superior ability to tolerate high levels of Na in their tissues (Bernstein, 1963). It is also plausible that high ion accumulation of Na, K, Ca, and Mg, especially in leaf tissue, is an osmoregularoty mechanism required for survival. It has been suggested that the leaf Na concentration could be used to evaluate germplasm for salt tolerance in tomato (Rush and Epstien, 1981). The increase in ion accumulation by the tomato plants in our study is in agreement with of Mitchell et al. (1991) who reported an increase in total cation content under salinity relative to the control.

In summary, the results of this experiment confirm that saline nutrients are important for determining the quality of processing tomatoes primarily because salinity reduced fruit water accumulation and increased electrical conductivity. These results have practical implications for tomato growers in management of tomato production in coastal area where good quality water is in short supply and soil salinization is increasing. However, long-term studies are required to justify the environmental hazards of using saline water.

REFERENCES:

Anastasio, G., Catala, M.S., Paloma,G., Costa J. and F.Nuez. 1987. An assessment of the salt tolerance in several tomato genotypes, pp. 57-61. IN: 10th Meeting of the tomato working group of Eucarpia, Salerno, Italia.

Bernstein, L. 1963. Osmotic adjustment of plants to saline media. Amer. J. Bot. 50:360- 370.

Cornish, P.S. 1992. Use of high electric conductivity of nutrient solution to improve the quality of salad tomatoes grown in hydroponic culture. Aust. J. Exp. Agric. 32:513-520.

Cornish, P.S. and V.Q Nguyen. 1989. Use of high soil solution electric conductivity to improve the quality of fresh market tomatoes from Coastal New South Wales. Aust. Exp. Agric. 29:893-900.

Ehret, D.L. and L.C. Ho. 1986. The effect of salinity on dry matter partitioning and fruit growth in tomatoes grown in nutrient film techniques. Hort. Sci. 61:361-367.

Mitchell, J.P., C.Shennan, S.R.Grattan, and P.M. May 1991. Tomato fruit yields and quality under water deficit and salinity. J. Amer. Soc. Hort. Sc. 116(2): 215-221.

Mizrahi, Y., E. Taleisnik, V. Kagan-Zur, Y. Zohar, and R. Offenbak. 1988. A saline irrigation regime for improving tomato fruit quality without reducing yield, J. Amer. Soc. Hort. Sci. 113(2):202-205.

Pasternak, D., Y. De Malach, and I. Borovic. 1986. Irrigation with brackish water under desert conditions. Agric. Water Management 12:149-158.

Rush, D.W. and E. Epstein. 1976. Genotypic responses to salinity. Differences between salt sensitive and salt tolerant genotype of the tomato. Plant Physiol. 57:162-166.

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.

Satti, S.M.E., M. Lopez, and F.A. Al-Said. 1994. Salinity induced changes in vegetative and reproductive growth in tomato. Commun. Soil Sci. Plant Anal. 25(5-6):501-510.

Shannon, M.C., J.W. Grouwald, and M. Tal. 1987. Effects of salinity on growth and accumulation of organic and inorganic ions in cultivated and wild tomato species. J. Amer. Soc. Hort. Sci. 102:416-423.