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Effects of salinity on taste quality and biochemical traits of four tomato varieties (*Solanum lycopersicum*) grown under hydroponic conditions

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ABSTRACT

Nowadays, contamination of agricultural soils by different ways of salinity is increasing as a result of human and environmental factors that would reduce yield and quality of agricultural crops. However, there are some plants that can tolerate some degrees of salinity. Tomato is one of the horticultural crops, moderately sensitive to salinity even that salinity can improve its quality. So, a study was conducted using four varieties of tomato under normal and salt stress (3, 6 and 9 dS m^{-1}) hydroponic conditions to evaluate tomato quality. The results showed that increasing in salinity improves the quality and taste of tomato with a reduction in pericarp thickness, fresh weight and total protein. However, when the degree of salinity exceeds 6 dS m^{-1}, a significant difference was observed in fruit yield which was variety dependent. Also, there was a significant difference between salt tolerance, performance, and taste of different varieties. Furthermore, it is found that the activity of guaiacol peroxidase and catalase enzymes increased as well as an increase in the level of salinity. Tomato cv. Super Chief with the highest number of fruits per plant, high level of proline and catalase activity, had the best performance against salinity levels and was more resistant to salinity than other varieties. Also, tomato 'Super Chief' had the highest taste index with a slightly decline in the yield. Salt stress tomatoes had more carotenoid than control but the level of 9 dS m^{-1} salinity was not tolerable by all varieties.

INTRODUCTION

In arid and semi-arid lands, the plants are exposed to different undesirable conditions throughout their life cycle; some of these plants can tolerate these stresses in different ways depending upon plant species and type of stress. Salinity as the most severe abiotic factors is one of the major environmental factors limiting plant growth and productivity. It is estimated that about one-third of world's cultivated land is affected by salinity (Kaya et al., 2002). Also in some regions near to Urmia Lake which going to be dried completely, change to be a crisis. Excessive salinity reduces the productivity of many agricultural crops including most of the vegetables. So, knowledge of salt tolerance in vegetable plants is necessary to increase productivity and profitability of crops imposed to salt stress. According to USDA report, out of all vegetables, the tomato is moderately sensitive to salinity (La Peña & Hughes, 2007). In this case, several studies in the literature related the effects of the salinity on tomato crop. Some of the projects rely on the sensitivity of most commercial varieties of tomato to moderate levels of salinity up to 2.5 dS m^{-1}, without significant yield reduction (Singh et al., 2012). The effects of the salinity on tomato may be either harmful, reducing the yield and increasing the incidence of blossom-end rot, or beneficial (antioxidant), increasing fruits concentration of soluble solids (Mizrahi & Pasternak, 1985; Pascale et al., 2001) and acidity (Pascale et al., 2001), resulting in larger profit at processing. However, soluble solids, sugars, acidity and pH are important quality parameters for both fresh market produce and processing tomatoes.

Although much work has been done on the effect of salinity on various aspects of plant growth and development, very little attention has been paid to the effect of salinity on fruits quality and taste (Walker et al., 1979; Mizrahi, 1982). Increasing salinity can improve various aspects of fruit quality, such as (I) proportion of 'Extra' fruits (high visual quality), (II) soluble solids content, and (III) titratable acidity content. Also, salinity decreased fruit size, which is a major determinant of price. Mizrahi (1982) demonstrated that percentage of dry weight, total soluble solids, and titratable acidity; content of reducing sugars, Cl^{-}, Na^{+}, and various pericarp pigments; and electrical conductivity of the juice was higher in fruits of saline-treated plants compared to control plants, while the pH was lower. In the other study, the fruit pH slightly decreased in accordance with the increase in total acidity and moderate salinity, reduced tomato yield (Cuartero & Muñoz, 1999). Increasing in acidity has been reported before, about salt-stressed vegetable crops such as tomato (Feigin et al., 1987; Martinez & Cerdá, 1989), cucumber (Martinez & Cerdá, 1989), eggplant (Savvas & Lenz, 1996), and melon (Feigin et al., 1987), and it has been associated with an increase in the level of organic acids. On the other hand, pulp thickness was significantly decreased by application of 30 mM NaCl in pepper (Navarro et al., 2010). It has been shown that pepper salt tolerance is cultivar-dependent (Chartzoulakis & Klapaki, 2000). But today's there are some of the literature which imply on the improving effect of salinity stress on quality of tomato by increasing the level of total soluble solids, including sugars, organic acids, and amino acids in fruits (Krauss et al., 2006; Saito et al., 2008). An increase in soluble solids enhances not only the market value of fresh fruit but also its processing efficiency is enhances because it increases flavor and decreases water content (Stark et al., 1996). Sugar content is most important in terms of fruit taste. However, in tomato, most investigations into salinity stress have been agronomic and have tended to explain the phenomenon as a 'concentration effect' due to a reduction in the size of the fruit and these fruits alled 'fruity tomato' (Saito & Matsukura, 2015). Salinity stress limits the productivity of agricultural crops, with adverse effects on germination, plant vigor and crop yield (Munns & Tester, 2008), and by a decrease in fruit size and fruit number per plant in tomato (Magan et al., 2008). However according to the difference between cultivars (species and genotypes) in salinity tolerance (Maggio et al., 2004; Tester & Davenport, 2003), studies with new cultivars should be continued to evaluate their degree of tolerance to saline stress. So, the objective of the present work was to investigate the response of four tomato varieties which are cultivated widespread in regions near to Urmia Lake affected by the salt.

MATERIALS AND METHODS

Plant materials

In this study, the effects of four levels of salinity (S0=0, S1=3, S2=6, and S3=9 dS m^{-1}) were evaluated on yield and fruit quality (physiological and biochemical) of four cultivated tomato varieties in East Azarbaijan, Iran. The mentioned varieties including; Falat, Super Chief, Stone and Lesto and it is also notable that all of them possess appropriate yield, storability, tasty and suitable for processing. Tomato seedlings were transplanted in 10-Liter black polyethylene containers with dimensions of 30 cm top diameter, 24.2 cm base diameter and 23.8 cm depth, including sand under greenhouse conditions until fruit ripening. Irrigation was done with one-half Hoagland solution supplemented with 0, 25, 50 and 75 mM of NaCl solution with ECe values of 0.18 (control), 3, 6 and 9 dS m^{-1}, respectively.

Measurements

Estimation of fruit quality and yield

Fruits were picked up when fully ripe and yield, fresh and dry weight of fruit, fruit diameter and the qualitative characteristics of the fruits including total soluble solids (TSS), titratable acidity (TA) and taste index (TSS/TA) were evaluated in three replications. At harvest time, fruit number per plant was recorded. Fresh and dry (dried at 70 °C for 48 h) weight of fruits were determined. Total soluble solids of tomato juice samples were measured with a digital refractometer expressed as °Brix (Seyoum et al., 2009). Titratable acidity was determined by titration of juice with 0.1 M NaOH (Magán, 2008). Fruit diameter was measured on three points of the equatorial area of each fruit by Digital Caliper and recorded as mm. Fruit carotenoids were extracted from the fruit pericarp by acetone (85%) and determined spectrophotometrically according to Lichtenthaler and Weliburn (1983) method. Total carbohydrates were measured following the method of Irigoyen et al. (1992), with appropriate adaptations being made for our plant material. A sample of 0.5 g fresh matter was homogenized twice with 95% ethanol (v/v) and washed with 70% ethanol (v/v), followed by centrifugation at 1500 rpm at 2 °C for 15 min. Glucose, fructose, and sucrose were determined in the resulting supernatant using spectrophotometer at 650 nm, using the colorimetric assay with anthrone (Van Handel, 1968).

Antioxidant enzymes activity measurements

One gram of either fresh leaf or root material was weighted individually and immediately homogenized in 5 ml of 50 mM K–phosphate buffer (pH 7.0), brought to 5 mM Na–ascorbate and 0.2 mM EDTA by the addition of concentrated stocks. The homogenate was centrifuged at 10 000 rpm for 15 min at 4 °C. The resulting supernatant was used for enzyme assays. The extraction was carried out at 4 °C. Proteins were quantified according to Bradford (1976) method using albumin bovine serum as a standard. The activity of Catalase (CAT) was determined by monitoring the disappearance of H_2O_2 at 240 nm (extinction coefficient of 0.036 mM^{-1} cm^{-1}) (Aebi, 1984). One unit of activity was defined as the amount of enzyme required to decompose 1 µmol H_2O_2 per min at 25 °C. The activity of Guaiacol Peroxidase

(GPOX) was measured by monitoring the increase in absorbance at 470 nm ($\varepsilon = 26.6$ mM^{-1} cm^{-1}) during polymerization of guaiacol (Fielding & Hall, 1978). One unit of activity was defined as the amount of enzyme producing 1 µmol of tetraguaiacol per min at 25 °C.

Proline

Proline concentration was estimated by homogenizing 0.2 g fresh weight of fruit in 2 ml of 3% aqueous sulfo salicylic acid, centrifugation at 10000 rpm for 30 min. The supernatant was decanted and the pellet was washed twice with 3% aqueous sulfo salicylic acid. The supernatants were pooled and proline content was measured using ninhydrin reagent and toluene extraction (Bates et al., 1973) and the method was calibrated for each determination with standard proline solutions within the detection range of the method (0-39 µg ml^{-1}).

Malondialdehyde (MDA) concentration was determined as 2-thiobarbituric acid (TBA) reactive metabolites (Zhang et al., 2007). About 1.5 ml extract was homogenized in 2.5 ml of 5% TBA made in 5% trichloroacetic acid (TCA). The mixture was heated at 95 °C for 15 min, and then quickly cooled on ice. After centrifugation at 5000 rpm for 10 min, the absorbance of the supernatant was measured at 532 nm. Correction of non-specific turbidity was made by subtracting the absorbance value measured at 600 nm. The concentration of MDA was calculated in terms of nmol gFW^{-1}.

Statistical analysis

A randomized block design as a factorial experiment with three replicates was adopted. The data were statistically analyzed using one-way analysis of variance, and the means were separated by Duncan's multiple range test by the least significant difference ($P \leqslant 0.05$) method using SPSS and MSTATC software.

RESULTS AND DISCUSSION

In this study, the effects of salt stress on physiological responses of tomato fruits grown hydroponically in the greenhouse were investigated. Results showed that different levels of salinity affect significantly on dry and fresh weight, pericarp diameter and yield ($P \leqslant 0.01$) (Table 1). Fruit fresh weight, pericarp thickness and yield decreased significantly in treated fruit as compared to control fruit but dry weight was increased.

Yield

The total yield of tomato is significantly reduced at 9 dS m^{-1} salinity level, and it was about 10-fold reduction compare to control as there was just one to two fruit per plant in 9 dS m^{-1} level of salinity in 'Lesto'. The highest yield was obtained in 'Super Chief' although the decrease in yield showed in all varieties (Table 1). Our results indicated that tomato yield increased as EC of the nutrient solution increased from 0 to 3 dS m^{-1} due to greater available amounts of nutrients, while decreased as EC of the nutrient solution increased from 3 to 9 dS m^{-1} likely due to an increase of salinity stress. This was in agreement with findings of Rosadi et al. (2014). It can be because of variation in photosynthetic products translocation toward root, decrease of plant top especially leaves, partial or total enclosed of stomata, direct effect of salt on photosynthesis system and ion balance (increasing activity if Na^+ and Cl^- ions in the root zone) (Greanway & Munns, 1980), however, it would be different between varieties. It has been demonstrated that the reduction of tomato fruit (cv. Daniela) yield by salinity can be due to a reduction in both size and number of fruits (Del Amour et al., 2001).

According to obtained results there is an inverse relationship between fresh and dry weight with salinity as increasing in salinity levels resulting in a decrease in fresh weight (Fig. 1) while an increase in dry weight (Fig. 3) occurred. Among all verities fresh weight in 'Falat' decreased from 120 g plant^{-1} to 80, 78 and 63 in 'Stone', 'Lesto' and 'Super Chief' respectively (Fig. 2). In addition, production of biomass increased with salinity and it was cultivar dependent as 'Falat' had the highest dry weight compare to other cultivars (Fig. 4). Such variability between tomato cultivars for biomass reduction after the salt stress has been stated previously by Alian et al. (2000), although Dasgan et al. (2002) study did not get similar results.

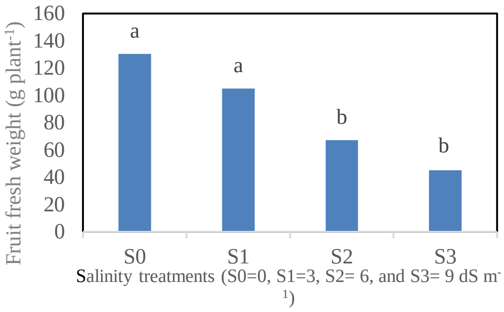

Fig. 1. The effect of different salinity levels on tomato fruit fresh weight

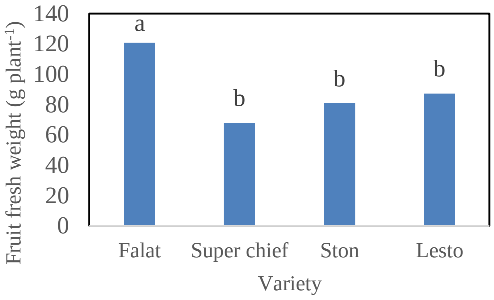

Fig. 2. The effect of different tomato varieties on fruit fresh weight

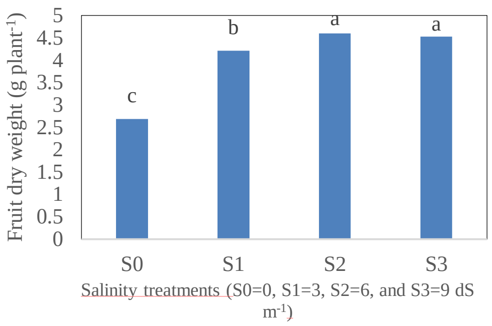

Fig. 3. The effect of different salinity levels on tomato fruit dry weight

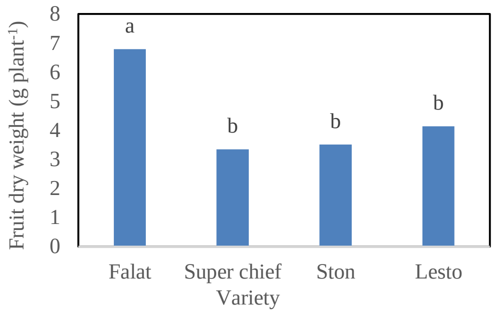

Fig. 4. The effect of different tomato varieties on fruit dry weight

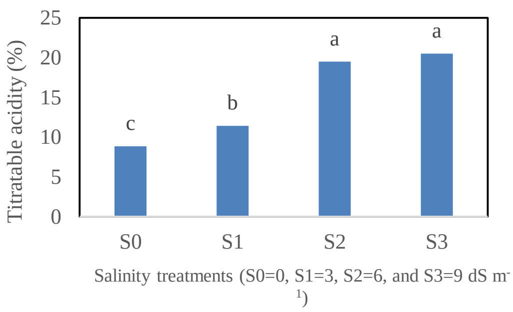

Fig. 5. The effect of different salinity levels on tomato fruit titratable acidity

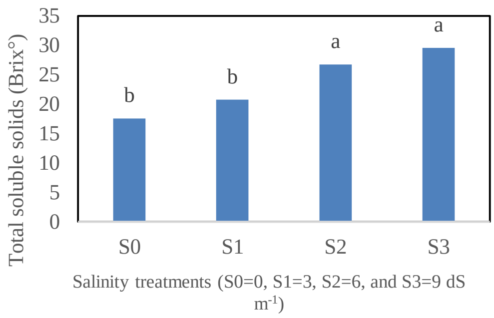

Fig. 6. The effect of different salinity levels on tomato fruit total soluble solids

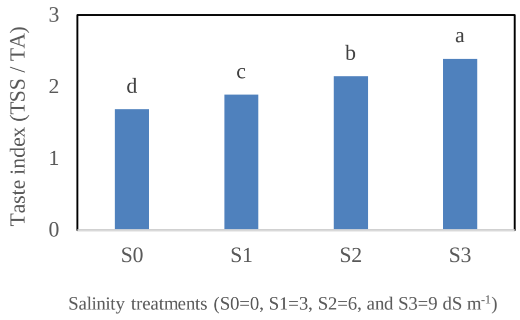

Fig. 7. The effect of different salinity levels on tomato fruit taste index

Fig. 8. The effect of different tomato varieties on fruit taste index

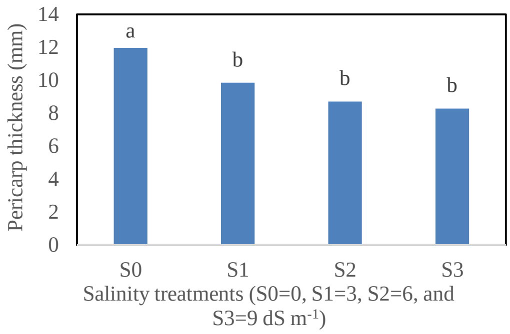

Fig. 9. The effect of different salinity levels on tomato fruit pericarp thickness

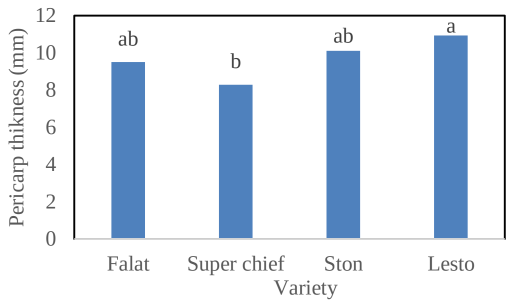

Fig. 10. The effect of different tomato varieties on fruit pericarp thickness

Total soluble solids and titratable acidity

Our results showed that salt enrichment in nutrient solution cause to increase in titratable acidity (Fig. 5) and total soluble solids (Fig. 6) by 2.3% and 1.6 ºBrix, respectively per 9 dS m^{-1} salinity level. However, many researchers believe that tomato plants grown under salinity conditions have increased fructose, glucose, total soluble solids, amino acids and organic acids (Sato et al., 2006). The increase of soluble solids with the increasing water salinity might have been caused by the reduction of the import of water by the fruit in saline conditions (Sakamoto et al., 1999), and an active accumulation of solutes, mainly ions and organic molecules typically produced in salt-stressed plants (Munns, 2002), with consequent concentration of the soluble solids in the pulp. The increase in total soluble solids can be an advantage but the increase in titratable acidity in higher levels of salinity is disadvantages because the mentioned tomatoes require extra time and higher temperature for processing (Giordano et al., 2000), and consequently the final product is costly. There was no significant difference among varieties in both traits as all of them behave the same in regard to TSS and TA. It seems that increasing in TSS and TA under salinity is not dependent to variety. Similar results reported in previous works on tomato (Qaryouti et al., 2007; Zhang et al., 2016). Also, the amount of taste index (TSS/TA) increased by 1.4 as salinity increased to 9 dS m^{-1} (Fig. 7). However, there was a significant difference among cultivars as 'Lasto' had the lowest taste index compare to others as illustrated (Fig. 8). Some researchers have defined sugars, acids (Kader et al., 1978) and sugars/acids ratio as good indicators of tomato flavor (Stevens, 1972), as an important parameter in differentiating tomato flavor among varieties. In addition, increasing salt stress negatively affected growth and development of tomato. Although fruits of salt-treated plants were smaller but had better taste than fruits of control plants.

Pericarp thickness

Results showed that salinity lead to a reduction in pericarp thickness but there were differences between varieties in this regard. 'Lesto' had thicker pericarp than 'Super Chief', although it did not affected by salinity (Fig. 9). This difference is highly likely due to variety traits (Fig. 10). The carotenoid content of tomato in control was less than other levels of salinity till 6 dS m^{-1} as the pattern of the trend was dramatically increased (about 3.5-fold). However, the amount of carotenoid was decreased at 9 dS m^{-1} level of salinity in all varieties. Salinity stress in 'Super Chief' led to a 3.1-fold increment in carotenoid content at 6 dS m^{-1} in compare to control treatment. Although, the amount of carotenoid of tomato diminished at 9 dS m^{-1} in all varieties but 'Super Chief' had more color which was visually distinguishable from those of other genotypes (Table 1).

The effect of salinity on fruit biochemical traits

Results showed that the interaction between variety and different levels of salinity had a significant effect on fruit biochemical traits such as total protein, proline and carotenoid. In addition, there was a significant effect of salinity on total carbohydrate, and also the interaction between salinity and variety was significant in catalase and malondialdehyde traits. In all the varieties, total protein value was more in control level and decreased at 3 dS m^{-1} level of salinity but there was no significant difference between other levels of salinity regarding the amount of total protein (Table 1). Protein content measurement revealed genotype dependent variations as the lowest total protein value was found in 'Falat' in the control and salinity treatments, while the others were similar. It seems that reduction of total protein can be because of a decrease in protein synthesis or increase in protein hydrolysis. Nevertheless, some of the findings showed that salinity causes a decrease in nitrate and ammonium adsorption, and subsequently the amount of N and protein diminished in the plant (Parviz & Satyawati, 2008). The results showed that the amount of proline in fruit significantly increased as plants treated with greater salinity levels by 6 dS m^{-1} (Table 1).

Table 1. Mean comparisons of different salinity levels and tomato varieties in studied traits

Variety	Salinity levels (dS m^{-1})	Total protein (mg gFW-^{1})	Proline (nM gFW-1)	Carotenoid (mM g^{-1})	Yield
Falat	0	$0.68^{bcd\dagger}$	8.97^{e}	0.78^{jh}	20.333^{b}
	3	0.48^{d}	17.17^{d}	0.84^{j}	21.667^{b}
	6	0.26^{d}	33.04^{bc}	2.07^{de}	8.333^{ef}
	9	0.22^{d}	30.37^{c}	1.16^{f}	7^{f}
Super Chief	0	2.99^{a}	14.62^{d}	1.21^{f}	26.667^{a}
	3	1.01^{bcd}	36.69^{bc}	1.31^{f}	27^{a}
	6	0.49^{d}	64.77^{a}	3.85^{a}	10.333^{de}
	9	0.57^{cd}	61.45^{a}	2.82^{c}	7.333^{f}
Stone	0	2.45^{a}	7.97^{e}	0.54^{h}	12.667^{c}
	3	1.36^{bc}	15.2^{d}	0.81^{j}	11.667^{cd}
	6	0.65^{bcd}	39.81^{b}	2.77^{c}	6.333^{f}
	9	0.67^{cd}	28.48^{c}	1.77^{e}	3^{g}
Lesto	0	2.59^{a}	9.83^{d}	0.87^{j}	10.333^{de}
	3	1.5^{b}	15.83^{d}	1.85^{e}	10^{de}
	6	0.92^{bcd}	31.78^{bc}	3.27^{b}	2^{gh}
	9	0.67^{bcd}	28.48^{c}	2.24^{d}	0.667^{i}

†Numbers followed by the same letter are not significantly differents ($P<0.05$) based on Duncan's multiple range test.

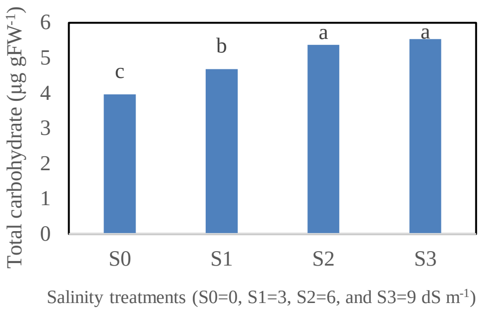

Fig. 11. The effect of different salinity levels on tomato fruit total carbohydrate

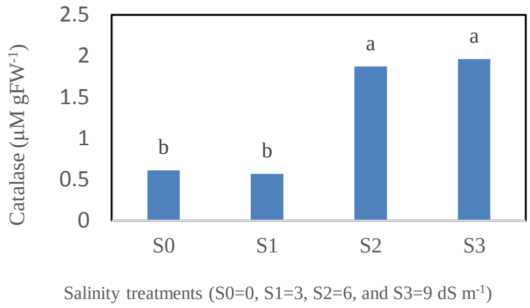

Fig. 12. The effect of different salinity levels on the activity of catalase enzyme

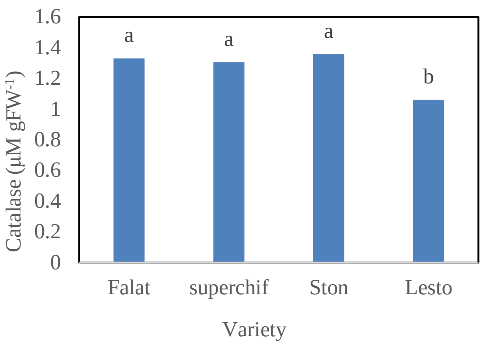

Fig. 13. The effect of different tomato varieties on the activity of catalase enzyme

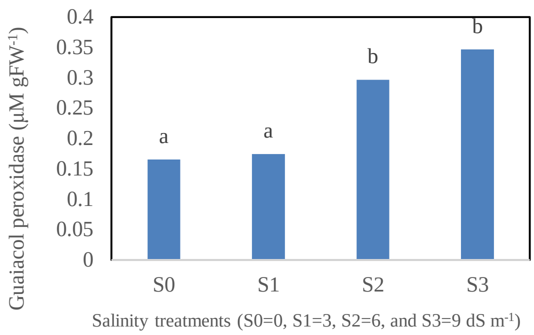

Fig. 14. The effect of different salinity levels on the activity of guaiacol peroxidase enzyme

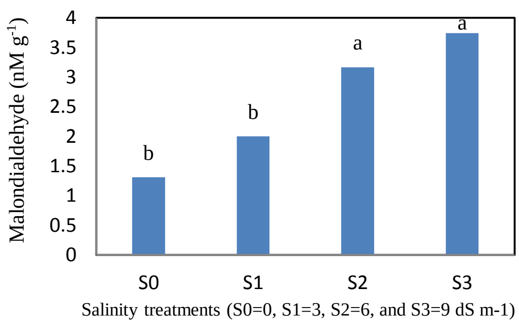

Fig. 15. The effect of different salinity levels on the amount of malondialdehyde

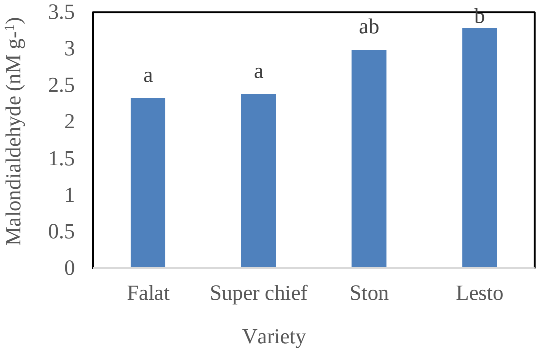

Fig. 16. The effect of different tomato varieties on the amount of malondialdehyde

However, the values of proline in all varieties were lower in control. A significant difference also showed among varieties in relation with proline accumulation as ‘Super Chief’ had more proline at 6 dS m^{-1}. It is clear that proline is one of the compatible osmolites that is produced in salt stress to adjust osmotic situation of cells (Gharsallah et al., 2016) but this capability is dependent to variety (Lutts et al., 1996) as shown in this report. Salinity stress enhanced carbohydrate accumulation in fruits by 1.3 at 6 and 9 dS m^{-1} concentrations of NaCl and it was not related to variety (Fig. 11) as illustrated by fruit Brix (%) (Fig. 6). The influences of salinity on carbohydrate content increment on tomato demonstrated by Yin et al. (2009). Increasing in total carbohydrate could be because of starch accumulation and increasing or changing in glucose, sucrose and fructose content (Yin et al., 2009).

The effect of salinity on antioxidant enzymes activity

The activity of Catalase (EC 1.11.1.6) enzyme increased at 6 and 9 dS m^{-1} levels of salinity compare to 3 dS m^{-1} and control (Fig. 12). Also, the most activity of CAT enzyme belonged to 'Falat', 'Super Chief' and 'Stone' (Fig. 13). The response pattern of guaiacol peroxidase (EC 1.11.1.7) activity was also the same as catalase in different levels of salinity (Fig. 14). In contrast, the activity of guaiacol peroxidase (EC 1.11.1.7) was variety independent. Similar results has been reported in maize (Gondim et al., 2012). The results revealed that increasing in salt concentration resulted in higher levels of malondialdehyde content in fruit (Fig. 15). Among different varieties, 'Lesto' with 3.3 had the highest amount of malondialdehyde compare to 'Falat' and 'Super Chief' (Fig. 16). MDA, a lipid peroxidation product, has been used as an appropriate biomarker to evaluate the free radicals levels in the living cells (Molassiotis et al., 2006). The results suggesting that 'Lesto' could be more sensitive to salinity as the most decay occurs in their cell membrane lipids in compare with 'Super Chief' and 'Falat' varieties.

CONCLUSION

In hydroponic system adding salt to the nutrient solution is an easy way that improved tomato fruit quality by increasing dry matter, total soluble solids and titratable acidity, but plant growth and fruit production are negatively affected. The total yield of tomato significantly reduced at salinity of 9 dS m^{-1}. Fruit quality was the only parameter which is positively affected by salinity increment in nutrient solution. Although the tomato is moderately sensitive to salinity but it was more variety dependent. The results show that the threshold level of salinity for tomato, which has no significant effect on fruit yield, is 3.0 dS m^{-1}. However, the higher levels of salinity (6 or 9 dS m^{-1}) cause a yield reduction of about 3.5% in Falat and Super Chief, 5% in Stone, and 10% in Lesto varieties. It is suggested that moderate salinity, with a low concentration of sodium, can be used in the production of the industrial tomato, without significant yield losses. Furthermore, the results indicated that salinity stress can lead to an increase in tomato carotenoids, although it was more variety dependent. The changes were accompanied by visually discernible color differences in tomato products. Our findings also show the considerable potential of salt stress in tolerable levels to obtain tomatoes with higher levels of secondary metabolites like carotenoids and anthocyanin, and consequently increasing its nutritional quality.

REFERENCES

Aebi, H. (1984). Catalase in vitro. *Methods in Enzymology*, *105*, 121-126.

Alian, A., Altman, A., & Heuer, B. (2000). Genotypic difference in salinity and water stress tolerance of fresh market tomato cultivars. *Plant Science*, *152*(1), 59-65.

Bates, L. S., Waldren, R. P., & Teare, I. D. (1973). Rapid determination of free proline for water-stress studies. *Plant and Soil*, *39*(1), 205-207.

Bradford, M. M. (1976). A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. *Analytical Biochemistry*, *72*(1-2), 248-254.

Chartzoulakis, K., & Klapaki, G. (2000). Response of two greenhouse pepper hybrids to NaCl salinity during different growth stages. *Scientia Horticulturae*, *86*(3), 247-260.

Cuartero, J., & Fernández-Muñoz, R. (1998). Tomato and salinity. *Scientia Horticulturae*, *78*(1), 83-125.

Dasgan, H. Y., Aktas, H., Abak, K., & Cakmak, I. (2002). Determination of screening techniques to salinity tolerance in tomatoes and investigation of genotype responses. *Plant Science*, *163*(4), 695-703.

Del Amor, F. M., Martinez, V., & Cerda, A. (2001). Salt tolerance of tomato plants as affected by stage of plant development. *HortScience*, *36*(7), 1260-1263.

Feigin, A., Rylski, I., Meiri, A., & Shalhevet, J. (1987). Nitrogen: Response of melon and tomato plants to chloride- nitrate ratio in saline nutrient solutions. *Journal of Plant Nutrition*, *10*(9-16), 1787-1794.

Fielding, J. L., & Hall, J. L. (1978). A biolchemical and cytochemical study of peroxidase activity in roots of Pisum sativum: I. a comparison of DAB-peroxidase and guaiacol-peroxidase with particular emphasis on the properties of cell wall activity. *Journal of Experimental Botany*, *29*(4), 969-981.

Gharsallah, C., Fakhfakh, H., Grubb, D., & Gorsane, F. (2016). Effect of salt stress on ion concentration, proline content, antioxidant enzyme activities and gene expression in tomato cultivars. *AoB Plants*, 8. doi:10.1093/aobpla/plw055

Giordano, L. D. B., de Ávila, A. C., Charchar, J. M., Boiteux, L. S., & Ferraz, E. (2000). Viradoro': A Tospovirus-resistant processing tomato cultivar adapted to tropical environments. *HortScience*, *35*(7), 1368-1370.

Gondim, F. A., Gomes-Filho, E., Costa, J. H., Alencar, N. L. M., & Prisco, J. T. (2012). Catalase plays a key role in salt stress acclimation induced by hydrogen peroxide pretreatment in maize. *Plant Physiology and Biochemistry*, *56*, 62-71.

Greanway, H., & Munns, R. (1980). Mechanisms of salt tolerance in nonhalophytes. *Annual Review of Plant Physiology*, *31*(1), 149-190.

Irigoyen, J. J., Einerich, D. W., & Sánchez- Díaz, M. (1992). Water stress induced changes in concentrations of proline and total soluble sugars in nodulated alfalfa (*Medicago sativa*) plants. *Physiologia plantarum*, *84*(1), 55-60.

Kader, A. A., Morris, L. L., Stevens, M. A., & Holton, M. A. (1978). Composition and Flavour Quality of Fresh Market Tomatoes as Influenced by Some Postharvest Handling Procedures. *Journal of American Horticultural Science*, *103*(1), 6-13.

Kaya, C., Kirnak, H., Higgs, D., & Saltali, K. (2002). Supplementary calcium enhances plant growth and fruit yield in strawberry cultivars grown at high (NaCl) salinity. *Scientia Horticulturae*, *93*(1), 65-74.

Kopeliovitch, E., Mizrahi, Y., Rabinowitch, H. D., & Kedar, N. (1980). Physiology of the tomato mutant alcobaca. *Physiologia Plantarum*, *48*(2), 307-311.

Krauss, S., Schnitzler, W. H., Grassmann, J., & Woitke, M. (2006). The influence of different electrical conductivity values in a simplified recirculating soilless system on inner and outer fruit quality characteristics of tomato. *Journal of Agricultural and Food Chemistry*, *54*(2), 441-448.

La Pena, R. D., & Hughes, J. (2007). Improving vegetable productivity in a variable and changing climate. *International Crops Research Institute for the Semi-Arid Tropics*, *4*, 1-22.

Lichtenthaler, H. K., & Wellburn, A. R. (1983). Determinations of total carotenoids and chlorophylls a and b of leaf extracts in different solvents. *Biochemical Society Transactions*, *11*(5), 591-592.

Lutts, S., Kinet, J. M., & Bouharmont, J. (1996). Effects of salt stress on growth, mineral nutrition and proline accumulation in relation to osmotic adjustment in rice (*Oryza sativa* L.) cultivars differing in salinity resistance. *Plant Growth Regulation*, *19*(3), 207-218.

Magán, J. J., Gallardo, M., Thompson, R. B., & Lorenzo, P. (2008). Effects of salinity on fruit yield and quality of tomato grown in soil-less culture in greenhouses in Mediterranean climatic conditions. *Agricultural water management*, *95*(9), 1041-1055.

Maggio, A., De Pascale, S., Angelino, G., Ruggiero, C., & Barbieri, G. (2004). Physiological response of tomato to saline irrigation in long-term salinized soils. *European Journal of Agronomy*, *21*(2), 149-159.

Martinez, V., & Cerda, A. (1989). Influence of N source on rate of Cl, N, Na and K uptake by cucumber seedlings grown in saline condition. *Journal of Plant Nutrition*, *12*(8), 971-983.

Mizrahi, Y. (1982). Effect of salinity on tomato fruit ripening. *Plant Physiology*, *69*(4), 966-970.

Mizrahi, Y., & Pasternak, D. (1985). Effect of salinity on quality of various agricultural crops. *Plant and Soil*, *89*(1), 301-307.

Molassiotis, A., Sotiropoulos, T., Tanou, G., Diamantidis, G., & Therios, I. (2006). Boron-induced oxidative damage and antioxidant and nucleolytic responses in shoot tips culture of the apple rootstock EM 9 ((*Malus domestica*). *Environmental and Experimental Botany*, *56*(1), 54-62.

Munns, R. (2002). Comparative physiology of salt and water stress. *Plant, Cell & Environment*, *25*(2), 239-250.

Munns, R., & Tester, M. (2008). Mechanisms of salinity tolerance. *Annual Review of Plant Biology*, *59*, 651-681.

Navarro, J. M., Garrido, C., Flores, P., & Martínez, V. (2010). The effect of salinity on yield and fruit quality of pepper grown in perlite. *Spanish Journal of Agricultural Research*, *8*(1), 142-150.

Parvaiz, A., & Satyawati, S. (2008). Salt stress and phyto-biochemical responses of plants-a review. *Plant Soil and Environment*, *54*(3), 89.

Pascale, S. D., Maggio, A., Fogliano, V., Ambrosino, P., & Ritieni, A. (2001). Irrigation with saline water improves carotenoids content and antioxidant activity of tomato. *The Journal of Horticultural Science and Biotechnology*, *76*(4), 447-453.

Qaryouti, M. M., Qawasmi, W., Hamdan, H., & Edwan, M. (2006, February). Influence of NaCl salinity stress on yield, plant water uptake and drainage water of tomato grown in soilless culture. In *VIII International Symposium on Protected Cultivation in Mild Winter Climates: Advances in Soil and Soilless Cultivation under 747* (pp. 539-545).

Rosadi, R. B., Senge, M., Suhandy, D., & Tusi, A. (2014). The effect of EC levels of nutrient solution on the growth, yield, and quality of tomatoes (*Solanum lycopersicum*) under the hydroponic system. *Journal of Agricultural Engineering and Biotechnology*, *2*(1), 7-12.

Saito, T., & Matsukura, C. (2015). Effect of Salt Stress on the Growth and Fruit Quality of Tomato Plants. In *Abiotic Stress Biology in Horticultural Plants* (pp. 3-16). Springer Japan.

Saito, T., Fukuda, N., Matsukura, C., & Nishimura, S. (2009). Effects of salinity on distribution of photosynthates and carbohydrate metabolism in tomato grown using nutrient film technique. *Journal of the Japanese Society for Horticultural Science*, *78*(1), 90-96.

Sakamoto, Y., Watanabe, S., Nakashima, T., & Okano, K. (1999). Effects of salinity at two ripening stages on the fruit quality of single-truss tomato grown in hydroponics. *The Journal of Horticultural Science and Biotechnology*, *74*(6), 690-693.

Sato, S., Sakaguchi, S., Furukawa, H., & Ikeda, H. (2006). Effects of NaCl application to hydroponic nutrient solution on fruit characteristics of tomato (*Lycopersicon esculentum* Mill.). *Scientia horticulturae*, *109*(3), 248-253.

Savvas, D., & Lenz, F. (1996). Influence of NaCl concentration in the nutrient solution on mineral composition of eggplants grown in sand culture. *Angewandte Botanik (*Germany), *70*, 124-127.

Seyoum, T., Osthoff, G., Steyn, M. S., Engelbrecht, G. M., & Pretorius, J. C. (2011). The effect of preharvest treatment, disinfection and storage environment on quality of carrots. *Journal of Food Processing and Preservation*, *35*(3), 331-341.

Singh, J., Sastry, E. D., & Singh, V. (2012). Effect of salinity on tomato (*Lycopersicon esculentum* Mill.) during seed germination stage. *Physiology and Molecular Biology of Plants*, *18*(1), 45-50.

Stark, D. M., Barry, G. F., & Kishore, G. M. (1996). Improvement of food quality traits through enhancement of starch biosynthesis. *Annals of the New York Academy of Sciences*, *792*(1), 26-36.

Stevens, M. A. (1972). Relationships between components contributing to quality variation among tomato lines. *American Society for Horticultural Science*, *97*, 70–73.

Tester, M., & Davenport, R. (2003). Na+ tolerance and Na+ transport in higher plants. *Annals of Botany*, *91*(5), 503-527.

Van Handel, E. (1968). Direct microdetermination of sucrose. *Analytical Biochemistry*, *22*(2), 280-283.
Walker, R. R., Kriedemann, P. E., & Maggs, D. H. (1979). Growth, leaf physiology and fruit development in salt-stressed guavas. *Australian Journal of Agricultural Research*, *30*(3), 477-488.
Yin, Y. G., Kobayashi, Y., Sanuki, A., Kondo, S., Fukuda, N., Ezura, H. & Matsukura, C. (2009). Salinity induces carbohydrate accumulation and sugar-regulated starch biosynthetic genes in tomato (*Solanum lycopersicum* L. cv. 'Micro-Tom') fruits in an ABA-and osmotic stress-independent manner. *Journal of Experimental Botany*, *61*(2), 563-574.
Zhang, P., Senge, M., & Dai, Y. (2016). Effects of salinity stress on growth, yield, fruit quality and water use efficiency of tomato under hydroponics system. *Reviews in Agricultural Science*, *4*, 46-55.
Zhang, Y., Zhang, Y., Zhou, Y., & Yu, J. (2007). Adaptation of cucurbit species to changes in substrate temperature: root growth, antioxidants, and peroxidation. *Journal of Plant Biology*, *50*(5), 527-532.

تاثیر شوری بر کیفیت طعم و خصوصیات بیوشیمیایی چهار رقم گوجه فرنگی (*Solanum lycopersicum*) پرورش یافته در شرایط هایدروپونیک

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چکیده:
امروزه آلودگی خاک‌های کشاورزی به شوری به‌واسطه فاکتورهای محیطی و فعالیت بشر در حال افزایش می‌باشد، که منجر به کاهش عملکرد و کیفیت محصولات کشاورزی می‌شود. با این حال برخی گیاهان قادر به تحمل در برابر درجات متفاوتی از شوری می‌باشند. گوجه فرنگی یکی از محصولات باغبانی و نیمه حساس به شوری بوده به‌طوری که شوری، باعث بهبود کیفیت آن می‌شود. لذا پژوهشی با استفاده از ٤ رقم گوجه فرنگی در ٤ سطح شوری (۰، ۳، ٦ و ۹ دسی زیمنس بر متر) در شرایط هیدروپونیک به منظور ارزیابی کیفیت گوجه فرنگی انجام شد. نتایج نشان دهنده بهبود کیفیت و طعم گوجه فرنگی همراه با کاهش در ضخامت گوشت، وزن‌تر و پروتئین کل بود. اما با افزایش شوری به بیش از ٦ دسی زیمنس بر متر، تفاوت معنی‌داری در عملکرد میوه دیده شد که بسته به رقم متفاوت بود. همچنین تفاوت معنی‌داری در تحمل به شوری، مقاومت و طعم ارقام مختلف وجود داشت. به علاوه فعالیت آنزیم های گایاکول پراکسیداز و کاتالاز با افزایش شوری، افزایش یافت. رقم سوپرچیف با بیشترین تعداد میوه در بوته، پرولین و فعالیت کاتالاز بیشتر، دارای بهترین مقاومت در برابر شوری در مقایسه با سایر ارقام بود. همچنین رقم سوپرچیف دارای بالاترین شاخص طعم با کاهش جزیی در عملکرد بود. گوجه فرنگی‌های تحت تنش شوری کاروتنوئید بیشتری نسبت به شاهد داشتند اما هیچ یک قادر به تحمل سطح شوری ۹ دسی زیمنس بر متر نبودند.

کلمات کلیدی: آنزیم‌های آنتی اکسیدان، تنش شوری، عملکرد، کیفیت خوراکی