Effects of salinity stress on growth, yield, fruit quality and water use efficiency of tomato under hydroponics system

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REVIEWS

EFFECTS OF SALINITY STRESS ON GROWTH, YIELD, FRUIT QUALITY AND WATER USE EFFICIENCY OF TOMATO UNDER HYDROPONICS SYSTEM

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ABSTRACT

Salt added to nutrient solution is an easy method that can improve tomato fruit quality, but plant growth and fruit production are negatively affected. Salinity reduces tomato root elongation rate and lateral root growth due to restriction of root cell growth and increased root lesion. Tomato leaf, shoot height and stem diameter reduced under salinity stress caused by photosynthesis reduction, tissues expansion reduction and cell divided inhibition. Salinity also reduces leaf chlorophyll content, stomatal resistance and photosynthetic activities. Total yield of tomato is significantly reduced at salinity equal and above 5 dS m^{-1}, and a 7.2% yield reduction per unit increase in salinity. Salinity can decrease root water uptake through its osmotic effect, and subsequently induce water stress. Fruit quality is the only parameter which is positively affected with increased salinity.

Keywords: Fruit quality; Salinity stress; Soilless cultivation; Tomato growth; Water use efficiency; Yield

Introduction

Tomato (*Solanum lycopersicum*) is one of the most important vegetable plants in the world. Global production is estimated at 163.96 million metric tons, with China and India as the leading producers in 2013 (Faostat, 2015). Tomato is consumed fresh, cooked or after processing; canning process also transforms tomato into juice, pulp, paste, or a variety of sauces (Cuartero and Fernandez, 1999).

Soilless cultivation is a method of growing plants using mineral nutrient solutions, in water, without soil, is supported by using inter medium such as perlite, rockwool, clay pellets, peat moss, or vermiculite instead of the root system (Fan *et al*., 2012). Meric *et al*. (2011) reported that soilless cultivation is widely used in order to improve the control of the growing environment and avoid uncertainties in the water and nutrient status of the soil. It also overcomes the cumulation of salinity, pests and diseases (Fan *et al*., 2012) and minimizes environmental contamination stemming from fertigation runoff (Savvas, 2002; Rouphael *et al*., 2006). This technique (Fig.1) also aids in saving irrigation water and fertilizers, thereby appreciably increasing the water use efficiency by the crop (Schwarz *et al*., 1996; Zekki *et al*., 1996).

Salinity stress limits the productivity of agricultural crops, with adverse effects on germination, plant vigor and crop yield (Munns and Tester, 2008). Many studies report that tomato plants exposed to high concentrations of salt in their root zone cause the reduction of growth, fruit size and fruit yield (Mohammad *et al*., 1998; Scholberg and Locascio, 1999; Magan *et al*., 2008). According to Gama *et al*. (2007), plants grown under salinity conditions are basically stressed in three ways. These are, (1) reduction of water potential in the root zone and causing water deficit, (2) phytotoxicity of ions such as Na^+ and Cl^-, and (3) nutrient imbalance by depression in uptake and/or shoot transport. 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; Wu and Kubota, 2008).

Growing tomato with added salt in nutrient solution is an easy method to improve fruit quality; however, this may reduce plant growth and fruit yield under hydroponics system. Although many studies have reported the relation between solution salinity and tomato plant. Different cultivation conditions and tomato cultivars showed varied effects to salinity stress. Thus, we present a review

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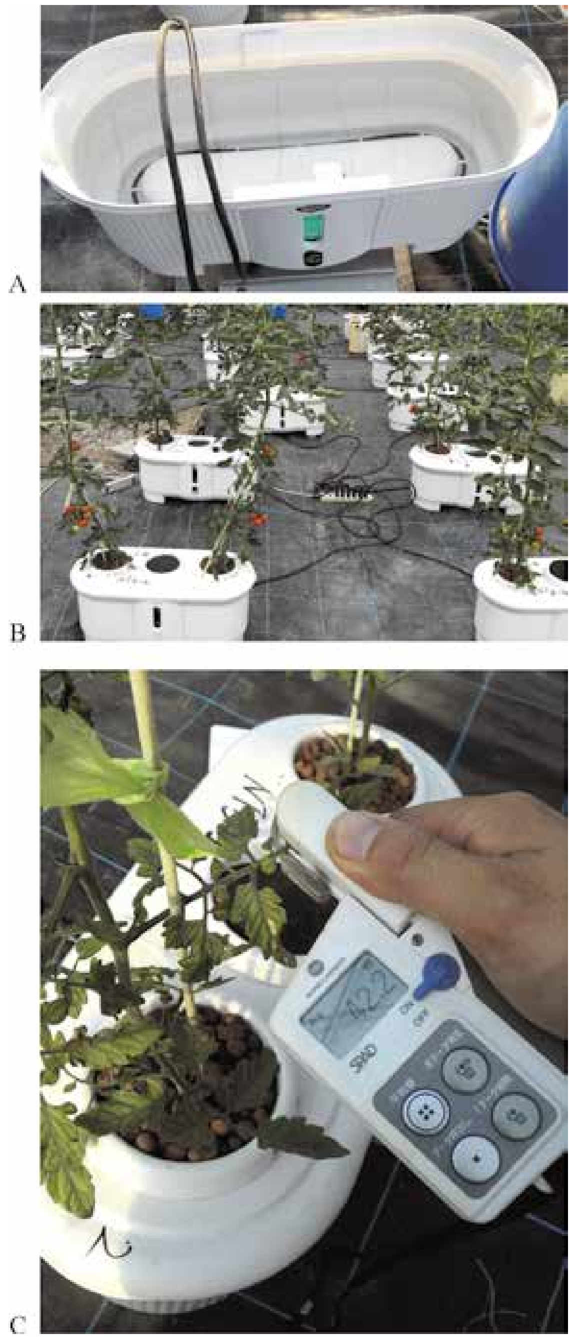

Fig.1. A simple equipment for hydroponic cultivation of tomato. (1A: Hydroponic kit – L61 x W26 x H29 cm, with an approximate volume of 14 L, 1B: Hydroponic cultivation of tomato plant in greenhouse, 1C: Monitoring of growth parameters of tomato plant. Photos by Pengfei Zhang).

on the influence mechanisms that influence salinity on the growth of tomato plant. This may contribute to the future development of growing tomato with salt addition, which improves fruit quality, without does not cause growth and yield reduction.

Effects of salinity stress on tomato growth

Effects on tomato root development

Root plays an important role in plant growth due to direct contact with salt solution under soilless cultivation. Root growth as well as, physiology and morphology of the plant are affected by salinity stress (Fig.2).

Salinity negatively affects tomato root growth under soilless cultivation. Leo (1964) reported that high salinity decreased elongation rates of roots and found that compared with the control nutrient solution, tomato root subjected to 1% NaCl solution reduced at 26% of the elongation rate. According to the studies of Snapp *et al.* (1991), salinity reduces tomato (*Lycopersicon esculentum* Mill., cv. UC82B) root length density in the late growing season (after 67 days after transplant). Albacete *et al.* (2008) had presented data that tomato (*Solanum lycopersicum L.*) root fresh weight reduced (30%) after three weeks under saline conditions (100 mM NaCl). Root dry matter also showed reduction under salinity (10 dS m^{-1}) together with an increase in root-shoot ratio (Lovelli *et al*., 2011). Evlagon *et al*. (1992) found that the root length reduced by 54% after 4 days exposure to Hoagland's solution salinized with 100 mM NaCl, while surface area reduced by 20% when 100 mM Ca was added to the salinized solution. Schwarz and Grosch (2003) also reported that fresh and dry mass of tomato (*Lycopersicon esculentum* [Mill] L. cv. Counter) root, total root length, number of adventitious root, tap root, and lateral root decreased with increasing EC of nutrient solution (EC range: 1.5-10 dS m^{-1}). Table 1 presents a compilation of studies reported on salinity tolerance in various tomato cultivars.

The reduction of root growth under salinity stress is caused by root cell growth restriction, root-zone water stress and root disease increase (Fig.2). Tomato grown under salinity condition causes root cell growth restriction, because of low water potential of external medium, interference of the ions or the toxicity of accumulated ions (Cuartero and Fernandez, 1999). Satti and Lopez (1994) reported that the reduction in root dry matter could be a result of salinity induced water stress, which inhibited photosynthesis and subsequent failure in the translocation of assimilates or photosynthates. Snapp *et al*. (1991) had also reported that salinity reduced net root growth in field-grown tomato, from the finding that is correlated with severe Phytophthora root rot in susceptible genotypes.

Effects on tomato shoot development

Salinity negatively affects tomato shoot growth under soilless cultivation. Studies by Bolarin *et al*. (1991, 1993) suggest that twenty-one genotypes belonging to four *Lycopersicon* wild tomato species (*L. pimpinellifolium*: PE-2, PE-8, PE-13, PE-14, PE-15; *L. peruvianum*: PE-16, PE-18, PE-20, PE-51, PE-52,

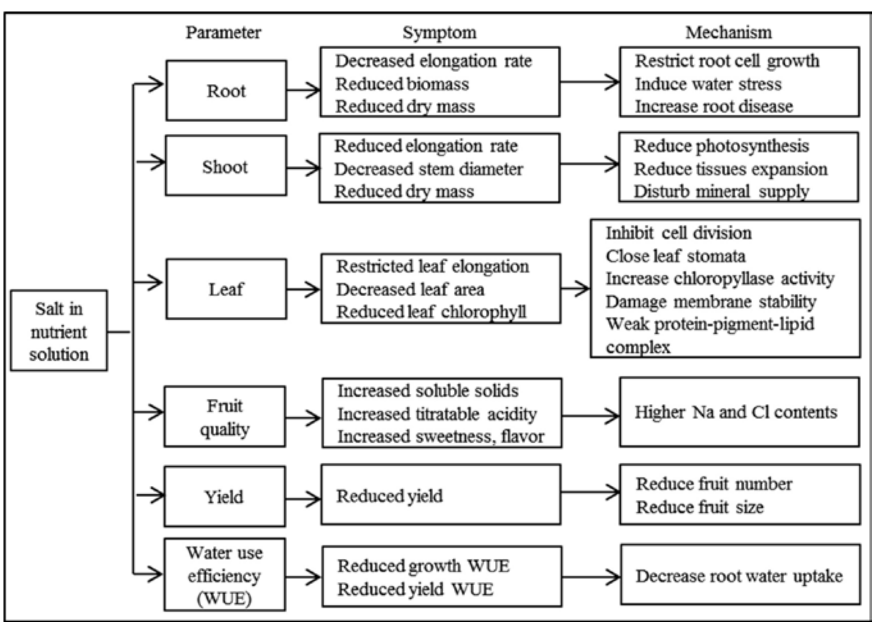

Fig.2. Effects of salinity stress on growth, yield and water use efficiency of tomato under Hydroponics system.

PE-40, PE-48; *L. pennellii*: PE-45, PE-47 and *L. hirsutum*: PE-34, PE-35, PE-36, PE-37, PE-39, PE-41, PE-43) show significant reductions in fresh and dry weight of shoots in response to salinity stress (EC range: 0-2.15 S m^{-1}). Kamrani *et al*. (2013) had shown that salinity should reach 20 mM to show effect on tomato shoot development; they also pointed that increased salinity decreases shoot height significantly. Oztekin and Tuzel (2011) reported that average tomato (21 commercially available cultivars) plant height showed 29.03% reduction under 200 mM NaCl treatment when compared with no salinity treatment. Tomato plant height reduced significantly from 8 weeks and 10 weeks after transplant under 4dS m^{-1} and 3dS m^{-1}, respectively (Bustomi *et al*. 2014). Cruz *et al*. (1990) reported that reducing the tomato stem length was one of the most reliable indicators for a wide range of tomato genotypes under saline stress. Saberi *et al*. (2011) also reported that stem diameter was one of the growth parameters which decreased with increasing salinity, similar in forage sorghums (*Sorghum bicolor L.*) stem diameter decreased with increasing salinity (Table 1).

Shoot reduction under salinity stress is caused by reduction in photosynthesis, that leads to reduction in expansion of tissues and disturbance in the mineral supply (Fig.2). Zhu (2002) had inferred that reduction in shoot growth under saline conditions is possible due to three reasons: (1) salinity reduced photosynthesis, which in turn limits the supply of carbohydrate needed for growth; (2) salinity reduced shoot and roots growth by reducing turgor in expanding tissues resulting from lowered water potential in root growth medium; and (3) salinity disturbs mineral supply, either an excess or deficiency; induced changes in concentrations of specific ions in the growth medium, may have a direct influence on growth.

Effects on tomato leaf development

Salinity also inhibits tomato leaf expansion under hydroponics system. Adams *et al*. (1990) reported a significant decrease in tomato plant leaves with increasing salinity levels. Subsequently, Azarmi *et al*. (2010) also showed that total leaf area of tomato (*Lycopersicon esculentum* Mill.) decreased with increasing salinity (EC range: 2.5-6 dS m^{-1}). Kamrani *et al*. (2013) also reported that leaf area at salinities of 40 and 60 mM was decreased in tomato plants. Data presented by Romero-Aranda *et al*. (2001) also shows that the leaf expansion of two tomato cultivars (*Lycopersicon esculentum*. Daniela F1 and Moneymaker) is reduced by salinity (Table 1).

The reasons for inhibition of tomato leaf expansion by salinity stress are due to inhibition of cell division, disturbance of water balance and closure of leaf stomata. Wignarajah *et al*. (1975) had shown that high NaCl levels inhibits leaf cell division in *Phaseolus vulgaris*. Reports by Erdei and Taleisnik (1993) in maize and sorghum, as well as Huang and Redmann (1995) in wild barley indicate that leaf expansion inhibition is related to salt-induced disturbance of water balance and to loss of leaf turgor under extreme conditions. Parida and Das (2005) reports in their review that salt accumulation in leaves may first inhibit photosynthesis by increasing stomatal and mesophyll conductance to carbon dioxide (CO_2) diffusion and is known to impair Ribulose biphosphate (RuBp) carboxylase.

Salinity also reduces leaf chlorophyll content (Fig.2). Azarmi *et al*. (2010) had presented data to show that leaf chlorophyll content is reduced with salinity. According to Taffouo *et al*. (2010), total chlorophyll concentration of tomato leaves is significantly reduced under salt stress in all cultivars except for *Lindo* at 50 and 100 mM NaCl and *Ninja* at 50 mM NaCl. Recently, Shimul *et al*. (2014) also reported that total tomato (*var. BARI* Tomato 14) leaf chlorophyll content, stomatal resistance and photosynthetic activities are significantly reduced with increasing salinity (Table 1).

Reduction in leaf chlorophyll content has been related to salt-induced increasing chloropyllase activity, adverse effects on membrane stability and weakening of protein-pigment-lipid complex (Taffouo *et al*., 2010). Hanafy *et al*. (2002) reported that salinity could increase chlorophyllase activities, which might be due to the salinity adverse effects on some ions absorption, such as Mg and Fe, which were involved in the chloroplast formation. Based on experiments in rice, Ashraf and Bhatti (2000) had proposed that decrease in chlorophyll content under salinity condition may be due to its adverse effects on membrane stability.

In addition, salinity also causes adverse effects of leaf photoassimilate production and ions absorption. The amount of photoassimilate production is limited by leaves stomatal closure or no stomatal formation and chlorophyll reduction caused by Na^+ and Cl^- accumulation in leaves (Romero-Aranda and Syvertsen, 1996). Salinity raised Na^+ concentration in the leaves of tomato plants, while Ca^{2+} and K^+ concentrations are greatly reduced (Cuartero and Fernandez, 1999).

Effects of salinity stress on tomato yield

That tomato yield is reduced under salinity above threshold values condition is an unquestioned fact. Qaryouti *et al*. (2007) had reported that the total yield of tomato (*Lycopersicon esculentum M*. cv. Durinta F1) is significantly reduced at salinity equal and above 5 dS m^{-1}, and a 7.2% yield reduction per unit increase in salinity. In addition, Magan *et al*. (2008) also reported that tomato (*Lycopersicon esculentum* Mill) total and marketable fresh fruit yield decreased significantly with increasing salinity. Dalton *et al*. (1997) observed that yield is reduced uniformly with decreasing osmotic potential of the nutrient solution. Hajiboland *et al*. (2010) had proposed that tomato (*Solanum lycopersicum L.*) growth and yield reduction affected by salinity could be the reasons for

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Table 1: Characteristics related to salinity tolerance in tomato

Table 1

Characteristic	Cultivar	Conclusion	Reference
Inhibit root growth	*Lycopersicon esculentum* Mill., cv. UC82B	Salinity stress (8-16 dS m^{-1}) led to net root growth greatly reduced (by 40-50%).	Snapp *et al*., 1991
	Solanum lycopersicum L.	Root fresh weight reduced (30%) after 3 weeks under saline conditions (100 mM NaCl).	Albacete *et al*., 2008
	-------	Root length reduced by 54% after 4 days exposure to Hoagland's solution salinized with 100 mM NaCl	Evlagon *et al*., 1992
	Lycopersicon esculentum Mill L. cv. Counter	Fresh root, dry mass root, total root length, number of adventitious root, tap root, and lateral root decreased with increasing EC of nutrient solution (EC range: 1.5-10 dS m^{-1}).	Schwarz and Grosch, 2003
Inhibit shoot development	*L. pimpinellifolium*; *L. peruvianum*; *L. pennellii* and *L. hirsutum*	Fresh and dry weight of shoots was significant reduction with salinity increasing (EC range: 0-2.15 S m^{-1}).	Bolarin *et al*., 1991 Bolarin *et al.*, 1993
	Lycopersicum esculentum permata	Plant height reduced significantly from 8 weeks and 10 weeks after transplant under 4 dS m^{-1} and 3 dS m^{-1}, respectively.	Bustomi *et al*., 2014
Inhibit leaf development	*Lycopersicon esculentum* Mill.	Total leaf area were decreased with increasing salinity (EC range: 2.5-6 dS m^{-1}).	Azarmi *et al*., 2010
	Lycopersicon esculentum. Daniela F1 and Moneymaker	Leaf expansion was reduced by salinity.	Romero-Aranda *et al*., 2001
Reduce leaf chlorophyll content	*Lycopersicon esculentum* lindo and ninja	The total chlorophyll concentration of tomato leaves was significantly reduced under salt stress.	Taffouo *et al*., 2010
	var. BARI Tomato 14	Leaf chlorophyll content, stomatal resistance and photosynthetic activities were significantly reduced in increasing salinity.	Shimul *et al*., 2014
Reduce yield	*Lycopersicon esculentum* M. cv. Durinta F1	Total yield significantly reduced at salinity equal and above 5 dS m^{-1}, and a 7.2% yield reduction per unit increase in salinity.	Qaryouti *et al*., 2007
	Lycopersicon esculentum Mill	Total and marketable fresh fruit yield decreased significantly with increasing salinity.	Magan *et al*., 2008
	Solanum lycopersicum	Yield decreased as EC of nutrient solution increased from 3 to 5 dS m^{-1}.	Bustomi *et al*., 2014
	Tainan ASVEG Hualien ASVEG Taiwan Seed ASVEG	Number of marketable fruits and fruit set under 150 mM NaCl stress were less than those in the 0 mM NaCl condition.	Liu *et al.*, 2014
	Lycopersicon esculentum Mill	A reduction in fruit number of 2.0% with an increase of 1 dS m^{-1} beyond the threshold value of 4.4 dS m^{-1}.	Magan *et al*., 2008
Improve fruit quality	Tainan ASVEG Hualien ASVEG Taiwan Seed ASVEG	Total soluble solids and titratable acid under 150 mM NaCl stress condition were higher than those in the 0 mM NaCl condition.	Liu *et al*., 2014
	-------	Total soluble solid and titratable acidity were significantly increased at EC above 3 dS m^{-1}.	Azarmi *et al*., 2010
	Lycopersicon esculentum *M*. cv. 'Durinta F1	Tomato fruit quality parameters increased by increasing salinity up to 5 dS m^{-1} as compared to the control.	Qaryouti *et al*., 2007
	Lycopersicon esculentum. pepe	Increased nutrient solution salinity from 0.78 dS m^{-1} to 1.58 dS m^{-1} led to the increase of sugar and acid content were increased up to 14.3% and 28%, respectively.	Zhang *et al*., 2016

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. Observations of Bustomi *et al*. (2014) indicate that tomato (*Solanum lycopersicum*) yield increased as EC of nutrient solution increased from 0 to 3 dS m^{-1} due to increase of nutrients, while decreased as EC of nutrient solution increased from 3 to 5 dS m^{-1} due to increase of salinity stress. Findings of Del Amour *et al*. (2001) show that the reduction of tomato (*Lycopersicon esculentum Mill*. cv. Daniela) fruit yield by salinity was due to a reduction in both size and number of fruit (Table 1).

Some researchers have inferred that tomato yield reduction is due to reduction in number of fruits produced. The number of tomato fruits/plant depends on the number of trusses/plant, the number of flowers/truss and the fruit set index (number of fruits/ number of flowers) at each truss (Cuartero and Fernandez, 1999). The tomato cultivars of *Tainan ASVEG* No. 19, *Hualien ASVEG* No. 21 and *Taiwan Seed ASVEG* No. 22 under 150 mM NaCl stress condition showed 73%, 83.3% and 79.3% in number of marketable fruits per plant and 59%, 66.4% and 61.4% in fruit set, respectively, less than those in the 0 mM NaCl condition (Liu *et al*., 2014). Magan *et al*. (2008) found a threshold value of 4.4 dS m^{-1} and a reduction in tomato (*Lycopersicon esculentum* Mill) fruit number of 2.0% with an increase of 1 dS m^{-1} beyond the threshold. However, other researchers have opined that fruit size is significantly decreased with increasing salinity (Cuartero and Fernandez, 1999; Chretien *et al*., 2000; Fernandez *et al*., 2004). Li *et al*. (2001) and Eltez *et al*. (2002) also reported that the number of fruits are unaffected by moderate salinity, and yield reduction was entirely due to smaller fruits. Nevertheless, salinity stress in the root zone is accompanied by yield loss through a reduction in fruit weight, but not in the number of fruits (Willumsen *et al*., 1996; Li *et al*., 2001). Inference of Sakamoto *et al*. (1999) that tomato (*Lycopersicon esculentum* L. cv. Momotaro) fruit size reduction under salinity stress is caused by inhibition of water uptake by the root resulting in reduction of water transport to the fruit, and increased concentration of soluble solids is of some relevance. Adams (1991) as well as Cuartero and Fernandez (1999) also reported that yield reduction in tomato under salinity stress is caused by decrease in mean fruit weight (Table 1).

Effects of salinity stress on tomato fruit quality

Tomato root zone salinity positively affects tomato fruit quality under hydroponics system (Fig.2). Soluble solids, sugars, acidity and pH are important quality parameters for both fresh market produce and processing tomatoes; other characteristics such as taste and shelf life are more important only for the fresh market produce (Cuartero and Fernandez, 1999).

Petersen *et al*. (1998) had reported that hydroponically produced tomato with NaCl enriched nutrient solution had higher consumer preference because of increasing sweetness and flavor, but also made the fruit harder. Salt enrichment in nutrient solution is known to increase ascorbic acid as well, which adds acidic taste to the fruit (Zushi and Matsuzoe, 1998). Magan *et al*. (2008) reported that total soluble solids (Brix index) and titratable acidity increased by 5.4 and 9.2% per dS m^{-1}, respectively in tomato grown in soil-less greenhouses in Mediterranean climate. According to the data presented by Liu *et al*. (2014), tomato cultivars of *Tainan ASVEG* No. 19, *Hualien ASVEG* No. 21 and *Taiwan Seed ASVEG* No. 22 under 150 mM NaCl stress condition showed 16.3%, 78.4% and 50% in total soluble solids and 50%, 263.6% and 45.3% in titratable acid, respectively, higher than those in the 0 mM NaCl condition. Azarmi *et al*. (2010) reported that total soluble solid and titratable acidity were significantly increased at EC of above 3 dS m^{-1}, and EC increased from 2.5 to 6 dS m^{-1}, total soluble solid and titratable acidity were increased to 13.4% and 28.9%, respectively. Qaryouti *et al*. (2007) also reported that tomato (*Lycopersicon esculentum M*. cv. ʻDurinta F1) fruit quality parameters (Fruit dry matter %, total soluble solids, and titratable acidity) increased by increasing salinity up to 5 dS m^{-1} as compared to the control, while fruit firmness decreased with increasing salinity. Mizrahi *et al*. (1988) had suggested that adding salts to the root media for better tomato fruit quality. Zhang *et al*. (2016) also confirmed that tomato (*Lycopersicon esculentum*. Pepe) total fruit sugar and total acid content increased with increased salinity; in addition, increased nutrient solution salinity from 0.78 dS m^{-1} to 1.58 dS m^{-1} led to an increase of sugar and acid content to 14.3% and 28%, respectively (Fig. 3).

Fruit juice acidity increased with increasing salinity, which could be due to the higher Na^+ and/or Cl^- contents in the fruit juice since these were the only ions that increased with salinity (Del Amour *et al.,* 2001). Petersen *et al*. (1998) reported that NaCl treatment improved the sweetness of tomato more than other elements because of higher Na^+ and Cl^- contents in the fruit.

Effects of salinity stress on tomato water use efficiency

Water use efficiency (WUE) does not have a single precise definition. Its definition depends upon the particular context in which it is being discussed. WUE is generally used to define the relationship between plant growth, yield and water use in terms of agronomy (Chaves *et al*., 2004). Soilless cultivation researchers usually determined plant water consumption by irrigation nutrient solution volume minus draining method (Meric *et al*., 2011).

Salinity can decrease root water uptake through its osmotic effect, and then induce water stress. Plant water uptake is reduced

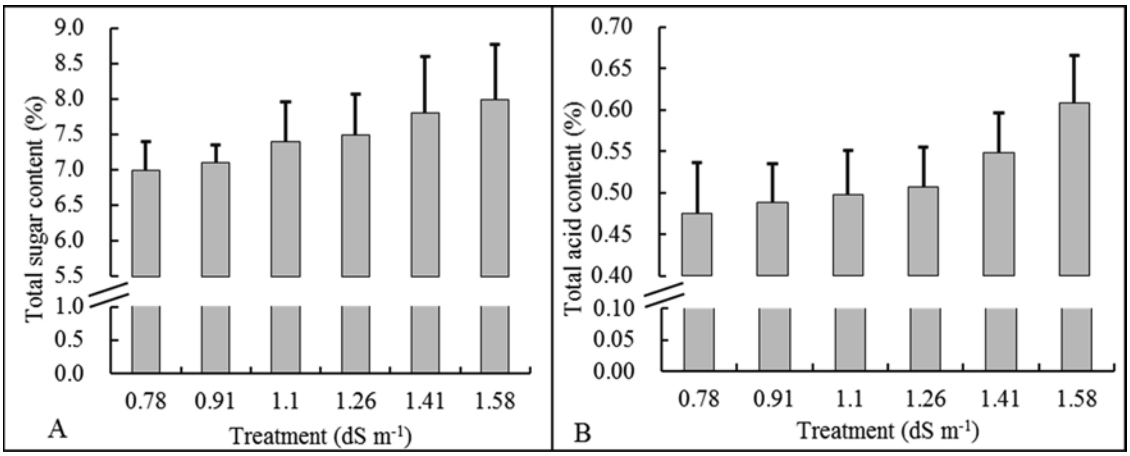

Fig.3. Total fruit sugar and total acid contents under salinity stress condition. Total fruit sugar content (%) is measured by hand refractometer (N-1E, ATAGO, Japan). Total fruit acid content (%) is measured by pocket acid meter (PAL-AC1, ATAGO, Japan).

with increased salinity (Romero-Aranda *et al*., 2001). Al-Harbi *et al*. (2009) and Al-Omran *et al*. (2012) concluded that the adverse effect of irrigation with saline water on total dry biomass and total fresh tomato fruit yield is due to the reduction in WUE of plant growth and total yield under soil cultivation. Al-Karaki (2000) found a decrease in tomato dry matter produced per litre of water with increased salinity. However, WUE is constant in the range of salinity inclusive between 4.7 and 9.1 dS m^{-1} (Van Os, 2001; Reina *et al*., 2005). This difference, apart from the type of tomato used, can be attributed to other factors, including climatic conditions.

How to ameliorate effects of salinity on tomato plants under hydroponic cultivation?

As mentioned above, root zone salinity negatively affects tomato root, shoot, leaf and yield, while positively affects tomato fruit quality under soilless cultivation. Improving tomato fruit quality without growth and yield reduction has always been a difficult task under salinity condition. Here, we review some strategies, such as increased potassium concentration, increased calcium concentration and use of daily high salt pulses.

Rengel (1992) pointed out increasing in external calcium concentration could have positive effect on tomato plants under NaCl stress. Increasing Ca^{2+} and K^+ in nutrient solution can ameliorate effects of salinity on most of tomato cultivars; for example, addition of 20 mM Ca $(NO_3)_2$ and 2 mM KNO_3 to salinity nutrient solution (NaCl: 50 mM) increased root volume by 25.3% and 66.7% for *Strain B*, 131.3% and 12.5% for *Pakmore* (Lopez and Satti, 1996). Through cross mixed three phosphorus levels (0.5, 1 and 2 mM P) and four levels of NaCl salt (0, 50, 100 and 200 mM NaCl), Mohammad *et al*. (1998) showed that increasing the phosphorus levels tended to enhance tomato (cv Riogrande) root growth through increasing both root growth and root surface area. Kaya and Higgs (2003) reported that the yield, dry matter, plant height and total chlorophyll of bell pepper (*Capsicum annum cv. 11B 14*) showed 63.0%, 23.7%, 28.1% and 27.5%, increase respectively, under salinity soil (EC: 7.2 dS m^{-1}) with KNO_3 (1g/kg) supplementary, higher than those under salinity soil only. Rubio *et al*. (2009) also pointed out that an increase of potassium concentration (0.2, 2, 7 and 14 mM) in the root medium under saline conditions (NaCl: 30 mM) increased the number of fruits per plant in bell pepper (*C. annuum* L. cv. Somontano), but total fruit yield was not affected. Tabatabaei (2006) reported that increasing potassium concentration could increase growth in olives. This is probably related to role of K^+ in enzymes stability and alleviation of Na^+ toxicity effects. Use of daily high salt pulses is another method suggested to increase fruit quality without decreasing yield.

Conclusion

As a high consumption vegetable, yield and fruit quality of tomato are of some importance in its cultivation. In most environmental conditions and tomato cultivars, the tomato begins to suffer inhibited growth and lose yield when nutrient solution EC is above 2.5-4 dS m^{-1}. Higher salinity negatively affects tomato root, shoot, leaf, yield and water use efficiency, while improves fruit quality (Fig 2). Under salinity condition, tomato root is the first organ exposed to salinity stress, and salinity induced root-zone water stress. This may led to less water intake by the root and decreased transportation to the shoot. Consequently, less water is available for normal growth and development.

Supplementing K^+, Ca^{2+} and P concentrations to the saline nutrient solution can have positive effect on most tomato cultivars under NaCl stress, which promote mutual competition between two ions (Na^+ and K^+/Ca^{2+}) for a transport site.

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