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Effects of salinity stress induced by hot spring water on tomato growth, yield and fruit quality under hydroponic cultivation in Japan

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Summary: The objective of this research was to test hot spring water as a source of salt to improve tomato quality under the hydroponic system. This research was conducted at Yamagata University, in Japan from February to July 2017. Salt stress was induced using salts of hot spring wastewater collected from Yupoka Onsen (Tsuruoka, Japan). The treatments were EC 2, 4, 8 12, and 16 mS/cm which were arranged in a Randomized Complete Block Design (RCBD) with five replications. Tomato plants were grown at EC 2 until flowering and then subjected to different EC concentrations until harvesting. The data were collected on plant growth parameters and fruit quality. Fruits were harvested at the red stage until the 5th truss. The results showed that fruits' Soluble Solids Content, organic acid, Nitrate contents and Sugar: Acid ratio increased significantly at EC 16 mS/cm and in the upper trusses compared to EC 2 and in the lower trusses. In contrast, fruit weight significantly decreased at EC 16 mS/cm and in upper trusses. Leaf thickness, size and SPAD, and specific leaf weight significantly declined at EC 16 mS/cm and upper leaves compared to EC 2 and in lower leaves. Plant height started to decline significantly after three weeks of treatment at EC 16 compared to EC 2.

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Key words: electrical conductivity, hot spring water, organic acid, solids soluble concentration

Introduction

Tomato (*Solanum lycopersicum*) is economically among the most important vegetables grown worldwide (Agius et al., 2022). Tomato fruits are key ingredients in the preparation of meals in several countries. Tomato is also a vital source of vitamins, minerals and antioxidants essential for human health. Recently, more attention has been concentrated on the bioactive ingredients and health aspects of tomato fruits. The production of tomatoes in terms of quantity and quality aspects remains the priority for the satisfaction of consumers (Lu et al., 2019). The most significant quality aspects of any vegetable product are taste and aroma. Tomatoes are produced conventionally in soils or using soilless media. One of the soilless culture methods used to produce tomatoes is the hydroponic system. The hydroponic system uses a nutrient mineral solution for plant development. It improves the growth environment while limiting moisture and nutrient uncertainty. It contributes greatly to saving water and fertilizer thereby improving the water and nutrient use efficiency by crops (Zhang et al., 2016). Connections between the hydroponic environment and the salinity of the tomato plant are extremely complicated. Salt stress's destructive effects on tomatoes include slow plant growth (Kamrani et al., 2013) and the reduction of fruit yield and size (Rosadi et al., 2014).

Nevertheless, the high EC enhance quality aspects such as nutritional value and flavour. This results in an increased value in terms of market prices thereby balancing the yield losses (Ghoname et al., 2019).

There is no generalised level of salinity that could be recommended in tomato production, rather it varies according to quality traits and interaction between cultivars, climate factors, nutrient solution concentration as well as crop management (Safi et al., 2018; Zhang et al., 2016). Although tomato is moderately sensitive to salinity, yield reduction at higher salinity levels (> 2.5 dS m^{-1} EC) has been observed (Singh et al., 2012). This reduction of yield in tomatoes due to salinity is mainly a result of reduced biomass of roots, leaves and fruits. Nevertheless, salinity increases the content of tomato fruits in total soluble solids like sugars, amino acids and organic acids which are essential to human health (Ghoname et al., 2019; Parvin et al., 2015). To take advantage of this, many tomato growers use seawater for improving tomato fruit quality. However, it is difficult to use seawater for tomato production at high altitudes. Some “hot spring” water found at high altitudes has high salt concentrations. The present study aimed to investigate the response of tomato ‘Reika’ to salts collected from spring water under hydroponic cultivation.

Materials and methods

Reika tomato seeds were sown on 7 February 2017 on moist papers into Petri dishes in a culture room at 24 °C with a

14/10 h light/dark photoperiod and relative humidity of 45-50%. After three days, seeds were transferred into a cell tray (100 mL) filled with growing media (Baido 300, Pro-Bokash-KantoNosan, Tochigi, Japan) containing 0.22 g L^{-1} of nitrogen and grown for two weeks in the same culture room. Thereafter, seedlings were transplanted into plastic pots (500 mL) filled with growing media in a heated glasshouse (over 10 °C) for six weeks.

The hot spring water was naturally evaporated in the sheeting dam into the plastic greenhouse during the summer season, and the collected salts were used to increase solution EC. At the flowering initiation, 25 seedlings were transplanted into hydroponic established in the greenhouse. Styrofoam boxes (28 L) which were wrapped with aluminium foil to avoid excessively high temperatures were used for the cultivation. The boxes were filled with nutrient solutions of Otsuka 1 (macronutrient), Otsuka 2 (micronutrient), and Otsuka 5 (Oligo-elements) made by Otsuka Chemical in Osaka, Japan. The 75 g of Otsuka 1, 50 g of Otsuka 2, and 3 g of Otsuka 3 were diluted in 1 L of hot water without mixing the solutions, Then, both solutions were diluted with 97 L of tap water to make 100 L of the total solution, these solutions had EC 1.34 mS/cm and a pH of 6.5. Six weeks after planting, EC was enhanced up to EC 2 mS/cm by adding nutrient solution. The enhancement of ECs was continued every two days by adding 0.6 g of hot spring salts for 1L of water to get EC 4, EC8, EC 12 and EC 16 mS/cm treatments. Thus, five different salt stress treatments (EC 2 ± 0.2 mS/cm, 4 ± 0.2 mS/cm, 8 ± 0.2 mS/cm, 12 ± 0.2 mS/cm, and 16 ± 0.2 mS/cm) were provided, and the nutrient solution was renewed every week. These EC treatments to nutrient solutions were arranged in a Randomized Complete Block Design (RCBD) and replicated five times. Nitenpirum insecticide (Sumitomo Chemicals Co. Insecticide Best. Guard Grain) and fungicides (Tebuconazole, Agro China Pty Ltd, 188 Xinjunhuan Rd. Shanghai, P.R. China) were applied for controlling insect pests and powdery mildew.

The average temperature and relative humidity (RH) inside the greenhouse were 20.3 ºC and 68.9% respectively and the average temperature of the nutrient solution was 18.2 ºC during the growing season. The trellising was done with ropes and plants were kept as a single stem with seven trusses. The daily average temperature, RH and the average temperature of the medium solution in the greenhouse were 22.6 ºC, 70.9% and 20.1 ºC respectively during this experiment.

Data collection

Data for plant height were collected weekly during plant growth starting from salt stress induction until the 7th truss developed. Leaf size, thickness and SPAD data were measured on the first leaf under the truss until the fifth truss. Leaf size and thickness were measured at fruit green maturity of each truss until the 5th truss while SPAD was measured every week during the breaker stage. SPAD index was taken four times on each leave. Harvesting was done on all fruits on five trusses at full ripening. For the laboratory analyses of SCC, organic acids and NO_3^- ion, harvested fruits of the same colour were used. They were selected using the colour Reader (CR-10, Konica Minolta, Tokyo). These fruits were then cut into half longitudinally and samples were taken using the cork borer. Obtained samples were blended in a mortar and filtrated using a tissue filter. The extract was centrifuged at 6000 rpm for one minute. The SSC was measured using a Digital refractometer (PR-101, Atago, Tokyo), organic acid content was determined using the organic acid meter (PAL-BXIACID F5, Atago, Tokyo) and NO_3^- was measured using a nitrate ion meter (LAQUAtwin NO_3^- B-341, Horiba, Tokyo ATAGO). The use of materials consisted of opening and calibrating the glass electrode with distilled water/or standard solution and rinsing it with distilled water or cleaning it with tissue paper. Then after rinsing or cleaning, fill the juice sample slowly on the glass electrode without bubbling and measure the sample.

The juice for measuring organic acid was diluted with desalted water on a ratio of 1:50 (0.1 ml of juice into 4.9 ml of desalted water). The SSC was expressed in % Brix, organic acid in %, and NO_3^- in ppm. The sugar: acid ratio was calculated by dividing fruit SSC with an organic acid.

Data analysis

Data were analysed by GenStat 20th Edition. The analysis of variance (ANOVA) was used to test the difference among treatments and the Least Significant Differences (LSD) test at 5% was used to separate treatment means.

Results

Fruit SSC, NO_3^- and Sugar Acid ratio significantly increased by high EC and by truss level while organic acid increased by higher EC but decreased by the level of the truss. Fruit weight and size significantly decreased by high EC and by the level of the truss. Fruit SSC, NO_3^-, Organic acid and Sugar Acid ratio were significantly increased by the interaction of salt stress and level of the truss while the results showed no significant difference in fruit weight and size (***Table 1***).

The highest average on fruit weight, size, SSC, NO_3^-, Organic Acid and Sugar Acid ratio was 240.3 g at EC 4 on truss 5, 70.8 mm at EC 4 on truss 2, 8.7 brix % EC 16 on truss 3, 1779 ppm at EC 12 on truss 4, 2.85% at EC 16 on truss 5, and 4.032 at EC 16 on truss 4 respectively. About 75 of the fruits obtained in low EC were larger fruit sizes (67-82 mm) while 80 of the fruits obtained in high EC were smaller than 57 mm (***Table 1***).

The plant height curve showed a difference significant (p<.001) among salt stress treatments after three weeks of salt stress. The highest was EC 8 with 173.8 Cm while the lowest was EC 16 with 145.4 Cm (***Figure 1***).

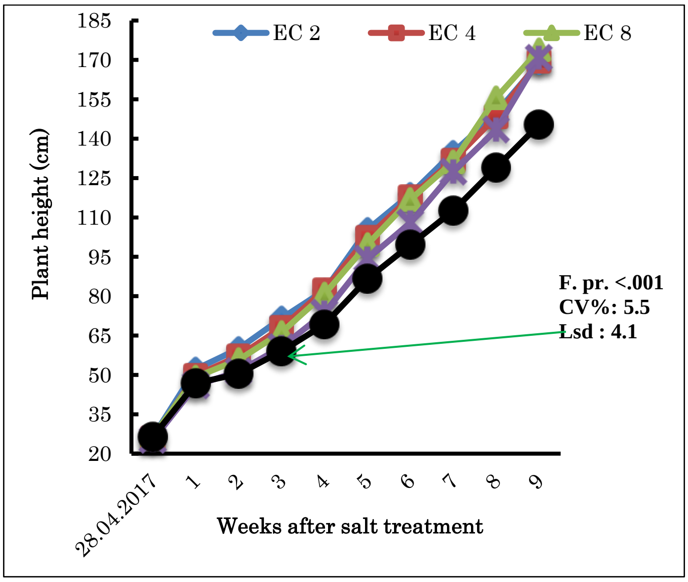

Figure 1: Effect of high salt treatment on plant height.

Significant differences among salt stress and level of leaf were recorded on leaf size, thickness, SPAD and Leaf Specific Weight. Leaf size was increased in leaves at the higher level but decreased by higher EC. Leaf thickness, leaf specific weight (LSW) and SPAD were increased by high EC while declining by the higher level of leaves (***Table 2***). There was no significant interaction between salt treatment and leaf level on the leaf size, LSW and SPAD while a significant difference was observed in leaf thickness (***Table 2***). The highest leaf thickness was recorded at EC 12 on the leaf under the 2nd truss (0.858 mm) while the lowest was at EC 2 on the leaf under the 5th truss (0.548 mm).

Discussion

In the present study, salinity effects were assessed concerning tomato fruits SSC, OA, Sugar Acid ratio, NO_3^-, weight and size. On plant growth, the assessment was done plant height, leaf size, thickness, SPAD and LSW. The reasonable response may be an alternative to tomato growers along distances from the Seashore. The results showed that fruit SSC, $NO3^-$ and Sugar Acid ratio increased by high increased EC and level of the truss while fruit weight and size decreased by high EC and level of truss (***Table 1-2***) ***(Figure 2)***. Similar results were reported by (Al Hassan et al. (2015) who showed that the total amount of soluble sugars slightly decreased in salt-stressed plants, but significant differences were registered only starting with 300 mM NaCl in both samplings. Under water stress conditions the decrease was also significant and more accentuated after a longer drought treatment.

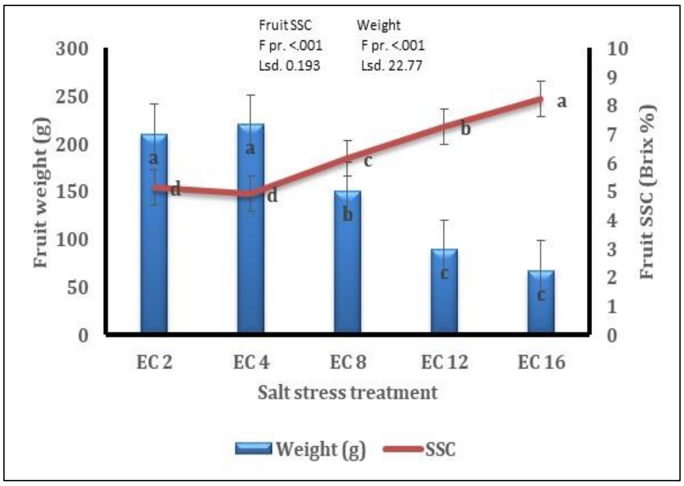

Figure 2. Relationship of tomato fruit SSC and weight.

This indicates that fruit water reduction in high EC affected weight loss and size reduction. It can be produced by inhibition of water uptake by the root resulting in the reduction of water transport to the fruit and increased concentration of soluble solids (Oztekin & Tuzel, 2011; Shabala et al., 2012).

For instance, the fruit weight of tomato was reported to show a significant variation at p<.001 among different germplasms of tomato, and in general, there was a significant decrease in fruit yield compared to controls in plants treated with high concentrations of salt (Siddiky et al., 2015, 2012). However, fruit organic acid was increased by higher EC but decreased by the level of the truss. Thus, the increase in acidity of the fruit juice could be due to the higher Na content in the fruit juice since this is the only ion that has a higher concentration in hot spring water used as a source of salinity. The decrease of fruit acidity at the high level of truss can be explained by high evapotranspiration due to high temperature and RH in the greenhouse during tomato cultivation. The higher fruit acidity of fruit tomatoes was also reported by Agius et al. (2022) who stated that the concentration of citric acid and malic acid remained unaffected, the pH dropped by approximately 0.1 unit and the titratable acidity increased slightly at higher salinity levels tested (17 and 34 mM).

Most plant growth parameters were negatively affected by salt stress, although leaf thickness, leaf specific weight (LSW) and SPAD were increased (***Table 2***). The reduction of the vessels' diameter is a common phenomenon among plants that decreases the incidence of cavitation. The increased thickening of the xylem vessels improves stability by enhancing the mechanical properties of the secondary cell walls (Eckert et al., 2019). Hoffmann et al. (2021) reported that the bottom leaflets showed stronger stress signs and response, while the top leaflets were less impacted by the abiotic stressor and had an increased expression of cell wall-related genes involved in the expansion. According to Oztekin and Tuzel (2011), plant height showed a 29.03% reduction in 200 mM NaCl treatment compared to 50 mM. According to Azarmi et al. (2010), the total leaf area decreased with increasing salinity (EC2.5-6 mS/cm). This overall decrease in plant growth may be associated with the reduction of plant water uptake in salinity conditions.

Conclusions

Results from this study showed that high EC induced by salinity obtained from hot spring water improves tomato fruit quality but yield and plant biomass are reduced. The hot spring water could be an alternative to salt stress at 8 mS/cm under hydroponic cultivation. It should create a balance between yield loss and fruit quality.

Acknowledgements

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Table 1. Chemical composition of hot spring water.

Hot spring water	ppm							
	Mg	B	K	Ca	P	Na	Fe	Mn
Concentration	0.0521	0.1075	1.7289	15.2106	0.0756	248.0394	0.0183	0.10541

Table 2. Chemical composition of nutrients applied.

Otsuka	%										
	N	**P_2O_5**	**K2O**	**MgO**	**MnO**	**B_2O_3**	**CaO**	**Fe**	**Cu**	**Zn**	**Mo**
No1	10	8	27	4	0.1	0.1		0.18	0.002	0.006	0.002
No2	11						23				
No5	6		9		2	2		5.7	0.04	0.08	0.043

Table 3. Effect of interaction of salt stress and long exposure on fruit SSC, NO_3^-, organic acid, sugar: acid ratio, weight and size.

Treatment	Fruit weight (g)	Fruit size (mm)	Fruit NO_3^- (ppm)	Fruit SSC (Brix%)	Fruit organic acid	Fruit sugar acid ratio
Factor 1: Salt treatment (S)						
EC 2	210.2±45.13^{a}	68.22±5.859^{a}	903±157.2^{d}	5.137±0.516^{d}	1.751±0.277^{c}	2.997±0.497^{b}
EC 4	220.3±40.42^{a}	68.83±4.524^{a}	1039±115.6^{c}	4.932±0.422^{d}	1.675±0.157^{c}	2.978±0.415^{b}
EC 8	150.3±62.87^{b}	60.44±7.938^{b}	1191±262^{b}	6.16±0.711^{c}	1.954±0.197^{b}	3.2±0.592^{ab}
EC 12	89.6±25.23^{c}	51.58±4.673^{c}	1397±376.6^{a}	7.261±0.514^{b}	2.298±0.329^{a}	3.257±0.639^{ab}
EC 16	67.6±25.23^{c}	48.21±3.79^{c}	1513±290.5^{a}	8.239±0.36^{a}	2.428±0.38^{a}	3.506±0.708^{a}
p-value	<.001	<.001	<.001	<.001	<.001	<.001
Factor 2: Truss level (T)						
Truss 1	155.9±67.89^{ab}	61.35±8.699^{a}	916±185.7^{c}	5.94±1.289^{b}	2.154±0.298^{a}	2.767±0.517^{d}
Truss 2	162.3±73.01^{a}	62.38±10.03^{ab}	1169±201.1^{b}	6.056±1.343^{b}	2.049±0.398^{ab}	2.985±0.513^{cd}
Truss 3	148.7±72.59^{ab}	60.28±10.22^{ab}	1174±306^{b}	6.447±1.45^{a}	2.012±0.395^{ab}	3.219±0.457^{bc}
Truss 4	143±78.04^{ab}	58.24±9.972^{bc}	1368±352.9^{a}	6.71±1.264^{a}	1.903±0.384^{b}	3.603±0.712^{a}
Truss 5	128.2±79.43^{b}	55.02±10.36^{c}	1418±370.2^{a}	6.576±1.401^{a}	1.989±0.515^{ab}	3.364±0.433^{ab}
p-value	0.041	<.001	<.001	<.001	0.014	<.001
Interaction (S x T)						
EC 2 X 1	222.8	69.7	5.2±0.82^{hijk}	666±84.25^{h}	2.04±0.305^{bcdef}	2.648±0.789^{cd}
EC 2 X 2	236.9	72.9	4.9±0.50^{ijk}	948±110.5^{fgh}	1.85±0.216^{cdef}	2.707±0.175^{bcd}
EC 2 X 3	206.2	68.9	5.0±0.39^{ijk}	907±79.64^{gh}	1.59±0.0911^{f}	3.159±0.375^{abcd}
EC 2 X 4	206.1	67.4	5.2±0.46^{ijk}	982±59.20^{efgh}	1.61±0.144^{f}	3.25±0.382^{abcd}
EC 2 X 5	179.1	62.3	5.2±0.45^{hijk}	1011±156^{efgh}	1.66±0.326^{ef}	3.219±0.336^{abcd}
EC 4 X 1	214.6	67.2	4.5±0.43^{k}	967±39.46^{efgh}	1.83±0.0792^{cdef}	2.477±0.228^{d}
EC 4 X 2	225.4	70.8	4.6±0.18^{jk}	1056±81.98^{defgh}	1.64±0.226^{f}	2.883±0.405^{bcd}
EC 4 X 3	219.7	70.7	5.2±0.37^{ijk}	956±117.8^{fgh}	1.73±0.0967^{def}	2.978±0.078^{abcd}
EC 4 X 4	201.6	66.0	5.3±0.24^{hij}	1101±121.1^{defg}	1.60±0.142^{f}	3.377±0.415^{abcd}
EC 4 X 5	240.3	69.3	4.9±0.23^{ijk}	1116±125.2^{defg}	1.57±0.0752^{f}	3.176±0.254^{abcd}
EC 8 X 1	171.0	64.7	5.5±0.47^{hi}	941±139.5^{gh}	2.09±0.167^{bcdef}	2.645±0.351^{cd}
EC 8 X 2	170.8	64.4	5.5±0.18^{hi}	1094±48.64^{defg}	2.06±0.154^{bcdef}	2.714±0.244^{bcd}
EC 8 X 3	165.9	63.2	6.0±0.25^{gh}	1113±202.5^{defg}	1.95±0.261^{bcdef}	3.138±0.438^{abcd}
EC 8 X 4	154.5	59.7	7.2±0.44^{def}	1356±198.2^{bcde}	1.90±0.174^{bcdef}	3.826±0.521^{ab}
EC 8 X 5	89.3	50.2	6.5±0.17^{efg}	1452±304.6^{abcd}	1.77±0.0259^{def}	3.676±0.0443^{abc}
EC 12 X 1	112.9	56.8	6.5±0.17^{fg}	918±166.8^{gh}	2.42±0.273^{abc}	2.707±0.3^{bcd}
EC 12 X 2	94.6	52.3	7.2±0.51^{def}	1339±71.43^{bcdef}	2.28±0.446^{abcd}	3.276±0.756^{abcd}
EC 12 X 3	80.7	50.2	7.3±0.17^{cde}	1252±274.7^{cdefg}	2.45±0.147^{ab}	3.007±0.244^{abcd}
EC 12 X 4	85.0	50.2	7.7±0.056^{bcd}	1779±329.8^{a}	2.25±0.362^{bcde}	3.529±0.717^{abcd}
EC 12 X 5	74.9	48.3	7.6±0.30^{cd}	1699±140^{ab}	2.09±0.34^{bcdef}	3.765±0.585^{abc}
EC 16 X 1	58.0	48.3	7.9±0.37^{abcd}	1088±179.4^{defg}	2.38±0.16^{abc}	3.357±0.365^{abcd}
EC 16 X 2	83.6	51.5	7.9±0.12^{abcd}	1431±99.38^{abcd}	2.42±0.361^{abc}	3.344±0.535^{abcd}
EC 16 X 3	71.2	48.3	8.7±0.13^{a}	1615±147.9^{abc}	2.33±0.367^{abcd}	3.815±0.519^{ab}
EC 16 X 4	67.9	47.9	8.1±0.13^{abc}	1622±113.4^{abc}	2.16±0.479^{bcdef}	4.032±1.191^{a}
EC 16 X 5	57.3	45.0	8.5±0.12^{ab}	1810±238.5^{a}	2.85±0.123^{a}	2.983±0.172^{abcd}
p-value	0.43	0.08	<.001	<.001	0.011	0.05

Table 4. Effect of interaction of salt stress and level of leaf on leaf size, specific weight, SPAD and thickness.

Treatment	Leaf size (cm)	Leaf specific weight	SPAD	Leaf thickness (mm)
Factor 2: Salt treatment (S)				
EC 2	44.12±3.813a	0.4792±0.0988c	67.4±3.594ab	0.5936±0.0675c
EC 4	42.81±5.111ab	0.5045±0.0945c	67.05±3.227b	0.5974±0.0594c
EC 8	40.5±5.217b	0.5858±0.1b	67.86±2.916ab	0.6912±0.0702b
EC 12	36.45±4.282c	0.6166±0.127ab	68.36±3.5ab	0.7188±0.104ab
EC 16	30.66±2.837d	0.6591±0.133a	68.61±3.718a	0.7548±0.129a
***p*-value**	<.001	<.001	0.013	<.001
Factor 2: Leaf level (L)				
Leaf under truss 1	34.63±5.989a	0.7109±0.0942a	72.26±2.018a	0.7092±0.107b
Leaf under truss 2	38.42±5.586ab	0.6429±0.115b	69.7±1.982b	0.7709±0.115a
Leaf under truss 3	39.15±6.555ab	0.5336±0.1c	67.47±1.697c	0.6585±0.0969c
Leaf under truss 4	41.05±6.921b	0.4793±0.0678d	65.9±1.24d	0.6242±0.0721cd
Leaf under truss 5	41.31±5.478c	0.4785±0.0695d	63.95±1.865e	0.593±0.0501d
***p*-value**	<.001	<.001	<.001	<.001
Interaction (S x L)				
EC 2 X 1	41.88	0.7675	71.96	0.598±0.0867[de]
EC 2 X 2	44.90	0.684	69.44	0.67±0.0557[bcde]
EC 2 X 3	43.90	0.619	67	0.576±0.0611[de]
EC 2 X 4	44.90	0.4869	65.9	0.576±0.0378[de]
EC 2 X 5	45.00	0.5256	62.72	0.548±0.0295[e]
EC 4 X 1	39.17	0.8333	71.61	0.652±0.0507[cde]
EC 4 X 2	40.38	0.7558	68.84	0.6425±0.0526[cde]
EC 4 X 3	42.25	0.6355	66.53	0.5825±0.0589[de]
EC 4 X 4	47.62	0.5477	65.26	0.555±0.0287[e]
EC 4 X 5	44.62	0.5229	63.02	0.555±0.0229[e]
EC 8 X 1	33.20	0.6088	73.35	0.716±0.0602[bcd]
EC 8 X 2	40.60	0.5433	69.68	0.776±0.0541[abc]
EC 8 X 3	42.50	0.427	67.73	0.65±0.05[cde]
EC 8 X 4	42.30	0.3915	66.26	0.656±0.0737[cde]
EC 8 X 5	43.90	0.4254	64.76	0.658±0.0164[cde]
EC 12 X 1	31.17	0.6389	70.68	0.774±0.065[abc]
EC 12 X 2	34.50	0.5613	70.2	0.858±0.0363[a]
EC 12 X 3	36.80	0.4461	68.16	0.708±0.054[bcd]
EC 12 X 4	39.60	0.4505	65.71	0.648±0.0669[cde]
EC 12 X 5	40.20	0.4257	64.53	0.606±0.0391[de]
EC 16 X 1	27.72	0.7059	73.68	0.806±0.119[ab]
EC 16 X 2	31.70	0.6702	70.35	0.908±0.0526[a]
EC 16 X 3	30.30	0.5401	67.92	0.776±0.0868[abc]
EC 16 X 4	30.80	0.5162	66.38	0.686±0.0586[bcde]
EC 16 X 5	32.80	0.4966	64.73	0.598±0.0449[de]
p-value	0.27	0.382	0.876	0.007

References

Agius, C., von Tucher, S., Rozhon, W. (2022): The effect of salinity on fruit quality and yield of cherry tomatoes. Horticulturae 8, 59. https://doi.org/10.3390/horticulturae8010059

Al Hassan, M., Martínez Fuertes, M., Ramos Sánchez, F.J., Vicente, O., Boscaiu, M. (2015): Effects of salt and water stress on plant growth and on accumulation of osmolytes and antioxidant compounds in cherry tomato. Notulae Botanicae Horti Agrobotanici Cluj-Napoca 43, 1–11. https://doi.org/10.15835/nbha4319793

Azarmi, R., Taleshmikail, R.D., Gikloo, A. (2010): Effects of salinity on morphological and physiological changes and yield of tomato in hydroponics system. Journal of Food, Agriculture and Environment 8, 573–576.

Eckert, C., Sharmin, S., Kogel, A., Yu, D., Kins, L., Strijkstra, G.J., Polle, A., (2019): What makes the wood? Exploring the molecular mechanisms of xylem acclimation in hardwoods to an ever-changing environment. Forests 10, 358. https://doi.org/10.3390/f10040358

Ghoname, A., Fawzy, Z., El-Bassiony, A. (2019): Adverse positive effect of salinity stress on tomato fruit quality. Acta Scientific Agriculture 3, 66–69. https://doi.org/10.31080/asag.2019.03.0565

Hoffmann, J., Berni, R., Sutera, M.F., Gutsch, A., Hausman, J.F., Saffie-Siebert, S., Guerriero, G. (2021): The effects of salinity on the anatomy and gene expression patterns in leaflets of tomato cv. Micro-Tom. Genes 12, 1165. https://doi.org/10.3390/genes12081165

Kamrani, M.H., Khoshvaghti, H., Hosseinniya, H. (2013): Effects of salinity and hydroponic growth media on growth parameters in tomato (*Lycopersicon esculentum* Mill.). International Journal of Agronomy and Plant Production 4, 2694–2698.

Lu, J., Shao, G., Cui, J., Wang, X., Keabetswe, L., (2019): Yield, fruit quality and water use efficiency of tomato for processing under regulated deficit irrigation: A meta-analysis. Agricultural Water Management 222, 301–312. https://doi.org/10.1016/j.agwat.2019.06.008

Oztekin, G.B., Tuzel, Y. (2011): Comparative salinity responses among tomato genotypes and rootstocks. Pakistan Journal of Botany 43, 2665–2672.

Parvin, K., Ahamed, K.U., Islam, M.M., Haque, M.N. (2015): Response of tomato plant under salt stress: Role of exogenous calcium. Journal of Plant Sciences 10, 222–233. https://doi.org/10.3923/jps.2015.222.233

Rosadi, R.A.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, 7–12. https://doi.org/10.18005/jaeb0201002

Safi, A., Rachid, G., El-Fadel, M., Doummar, J., Abou Najm, M., Alameddine, I. (2018): Synergy of climate change and local pressures on saltwater intrusion in coastal urban areas: effective adaptation for policy planning. Water International 43, 145–164. https://doi.org/10.1080/02508060.2018.1434957

Shabala, L., Mackay, A., Tian, Y., Jacobsen, S.E., Zhou, D., Shabala, S. (2012): Oxidative stress protection and stomatal patterning as components of salinity tolerance mechanism in quinoa (*Chenopodium quinoa*). Physiologia Plantarum 146, 26–38. https://doi.org/10.1111/j.1399-3054.2012.01599.x

Siddiky, M., Khan, M., Rahman, M.M., Uddin, K.M. (2015): Performance of tomato (Lycoperscon esculentum Mill.) germplasm to salinity stress. Bangladesh Journal of Botany 44, 193–200. https://doi.org/10.3329/bjb.v44i2.38507

Siddiky, M., Sardar, P., Hossain, M., Khan, M., Uddin, M.K. (2012): Screening of different Tomato varieties in saline areas of Bangladesh. International Journal of Agricultural Research, Innovation and Technology 2, 13–18. https://doi.org/10.3329/ijarit.v2i1.13989

Singh, J., Sastry, E.V.D., Singh, V. (2012): Effect of salinity on tomato (*Lycopersicon esculentum* Mill.) during seed germination stage. Physiology and Molecular Biology of Plants 18, 45–50. https://doi.org/10.1007/s12298-011-0097-z

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. https://doi.org/10.7831/ras.4.46