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THE EFFECTS OF DIFFERENT SALT DOSES ON YIELD AND NUTRIENT UPTAKE OF TOMATO PLANT

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Abstract

The salinity is a problem in agriculture due to improper use of fertilizer, inadequate irrigation and drainage. This is one of the most important agricultural problems in many parts of the world, especially in arid and semi-arid soil ecosystems. The present study was conducted to investigate the effects of different salt doses on yield and nutrient uptake of tomato plant. The study has been carried out with three replications according to the experimental pattern of randomized plots in the plastic pots with the capacity of 3 kg under the greenhouse conditions. In the study 5 salt doses were applied: 0 dS m^{-1}, 3 dS m^{-1}, 6 dS m^{-1}, 9 dS m^{-1}, 12 dS m^{-1} and NaCl was used as a source of salt. The tomato plants was harvested before flowering and shoot dry weight, macro and micro elements concentrations were determined. The findings have shown that increasing salt doses decreased shoot dry weight of tomato plant. The highest shoot dry weight was determined with 37.33 g pot^{-1} in 0 dS m^{-1} application. Also, N, Ca, Mg, Fe and Cu concentrations were decreased with salt applications. However, the highest P and Zn concentrations were 0.159% P and 30.1 mg kg^{-1} respectively with 12 dS m^{-1} application. Generally, the salt applications didn't affect the yield and macro and micro element concentrations except for P and Zn of tomato plant.

***Key words**: salt, tomato, yield, nutrient uptake.*

INTRODUCTION

Worldwide, more than 800 million ha land area is under the threat of salinity and alkalinity (FAO, 2009). Such problems are experienced over 1.5 million ha land area in Turkey (GDRS, 2011). Salinity is the primary environmental factor limiting and reducing soil fertility and plant yields in various parts of the world, especially in arid and semi-arid regions (Greenway and Munns, 1980). Plants are continuously exposed to various biotic and abiotic stressors and environmental stress factors (Iranbakhsh et al., 2018). The stress factors effecting plants are classified as biotic (plants, microorganisms, animals and anthropogenic impacts) and abiotic (radiation, temperature, water, gases, minerals etc.) stress factors (Larcher, 1995). Salinity is an important abiotic stress limiting plant growth and yields (Zhu, 2016). High soil and water salinity levels significantly restrict agricultural productions in arid and semi-arid regions (Al-Karaki, 2000). It is estimated that salt stress might result in about 50% loss in agricultural productions (Kreps et al., 2002).

Salt stress is generally originated from high soil sodium (Na) and chloride (Cl) concentrations (Ismail et al., 2014). Specific impacts of salt stress on plant metabolism are related to depletion of K and Ca with the accumulation of toxic ions (Na and Cl) (Munns et al., 2002). Soils contaminated with high concentrations of sodium and chloride ions inhibit plant ion uptake and absorption of essential ions (K, Ca, NO_3) through root system (Ashraf and Foolad, 2007). The plants grown in saline ambient have several disadvantages. High salt concentrations of soil solution reduce soil water potential and increase osmotic stress. Increasing sodium (Na) and chloride (Cl) concentrations and Na and Cl accumulation in plant tissue inhibit mineral nutrient uptake of the plants (Marschner, 1995). Salinity is the greatest abiotic stress factor reducing agricultural productivity and influence large area worldwide. Therefore, a need has emerged to grow salt-resistant plants over these lands (Yamaguchi and Blumwald, 2005). Plants have different threshold values against salt stress, some are sensitive (glycosides), some moderately resistant and the rest highly resistant to salinity (halophytes) (Menzel and

Lieth, 2003). Except for halophytes, plant growth and development is negatively influenced by saline conditions (Bewley and Black, 1994). Significant changes are observed in morphologies of the plants grown under salt stress. Effects of salinity on plants generally emerge as smaller leaves, shorter plants, less number of leaves and recessed growth and development. Salinity generally inhibits plant growth and reduce yield levels (Al-Karaki, 2000). Plant sensitivity to saline conditions may vary based on growth stages. Salt has the greatest impact on plant growth and development especially in the germination period (Taiz and Zeiger, 2002). Therefore, salt tolerance of plants should be investigated at different growth stages and threshold values should be determined for each growth stage (Zapata et al., 2004).

Tomato is a significant greenhouse and field crop cultured in semi-arid regions of Mediterranean countries (Sekmen et al., 2005). Tomato (*Solanum lycopersicum* L.) belongs to *Solanaceae* family and has the greatest commercial consumption among the vegetables. Tomato is quite rich in β-carotenenu-cretonne, lycopene, flavonoids, ascorbic acid and other nutrients and all these elements make tomato an effective anti-oxidative and anti-carcinogenic foodstuff (Ahmad et al., 2018). It was proved that 100 gram tomato contained 0.55 mg vitamin B6, 1700 IU vitamin A, 0.10 mg vitamin B1 and 21 mg vitamin C (Sevgican, 1981). With regard to salt tolerance, tomatoes are classified as moderately resistant (Maas, 1986). Knowledge about salt and heat tolerance of the plants to be grown in saline soils will undoubtedly have great contributions to producers both in time and economic aspects (Doğan et al., 2008).

In this study, effects of salt treatments at different doses on yield and nutrient uptake of tomato plants were investigated.

MATERIALS AND METHODS

This study was carried out at greenhouses of Plant and Animal Production Department of Cumhuriyet University Sivas Vocational School. Experiment was conducted in randomized plots design with 3 replications. Experimental soils were taken from 0-20 cm soil profile of experimental fields of the department. Soils were sieved through 2 mm sieve and 3 kg air-dried soils were placed in experimental pots. Soil physical and chemical characteristics are provided in Table 1. Experimental soils were silty-clay-loam in texture, slightly alkaline (pH 7.25), highly loamy (16.2%), unsaline (0.031%), poor in available phosphorus (38.1 kg P_2O_5 ha^{-1}) and sufficient in potassium (942.0 kg K_2O ha^{-1}).

Before sowing, 200 mg N kg^{-1} (in the form of $CaNO_3.4H_2O$), 100 mg P kg^{-1} and 125 mg K kg^{-1} (in the form of KH_2PO_4), 2.5 mg Zn kg^{-1} (in the form of $ZnSO_4.7H_2O$) and 2.5 mg Fe kg^1 (in the form of Fe-EDTA) were applied to each pot as basic fertilizers.

Salt concentrations were arranged as 0 dS m^{-1}, 6 dS m^{-1}, 9 dS m^{-1} and 12 dS m^{-1} by using NaCl. Industrial-type H 2274 tomato cultivar was used as the plant material of the study. Seeds were sown in turf-perlite mixtures (1:1 V/V) in greenhouse, irrigated regularly and seedlings were obtained. Half (1/2) of the salt doses was incorporated into soils during the transplantation of the seedlings into the pots and remaining portion was applied through irrigation water when the seedlings had 7-8 leaves.

Table 1. Physical and chemical properties of experimental soil

Texture	pH	Tuz (%)	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	Organic Matter (%)	Lime (%)	Fe (mg kg^{-1})	Zn (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})
SiCL	7.25	0.031	38.1	942.0	1.2	16.2	3.25	0.42	2.49	1.21

Plant Analyses

Leaf samples were taken from the tomato plants at the beginning of flowering and harvest was performed then. Vegetative parts of the plants were washed through tap water, rinsed respectively through distilled water, 0.1% N HCl solution and twice though again distilled water. They were placed over coarse filter papers and excess water over them was

removed. Plant parts were then placed in separate paper bags and dried at 65°C until a constant weight. Following the measurement of dry weights, dry samples were ground in a plant mill. About 0.2 g of ground samples were wet digested in H_2O_2-HNO_3 acid mixture in a microwave oven.
Resultant slurry was then completed to 20 ml with distilled water and filtered through blue-band filter paper. Samples were then subjected to P colorimetric measured at 882 nm in a spectrophotometer (Murphy and Riley, 1962), K, Ca, Mg, Zn, Mn, Fe and Cu in an AAS (Atomic Absorption Spectrophotometer) (Shimadzu AA-7000) (Kacar and Inal, 2008). N contents were determined with Kjeldahl distillation method (Bremner, 1965).

Data Assessment

Experimental results were subjected to variance analyses (ANOVA) separately in accordance with randomized plots experimental design. SPSS 22.0 Windows software was used for statistical analyses. Means were compared with Tukey's test at $P<0.05$.
Correlation analysis was performed to assess the relationships between the treatments.

RESULTS AND DISCUSSIONS

Effects of different salt treatments on dry matter production of tomato plants were investigated and results are presented in Figure 1.

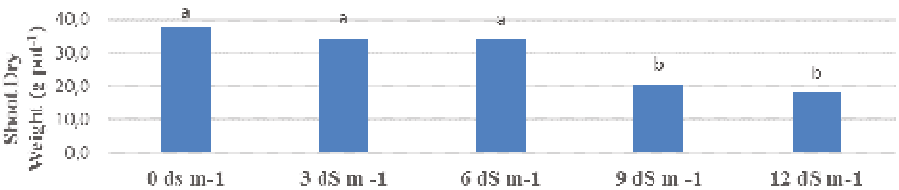

Figure 1. The effects of different salt doses on shoot dry matter production of tomato plant

With regard to shoot dry matter production of tomato plants, the greatest value (37.33 g pot^{-1}) was obtained from the control (0 ds m^{-1}) treatment. Dry matter productions of 3 dS m^{-1} and 6 dS m^{-1} treatments were not significantly different. Decreasing dry matter productions were observed with increasing salt concentrations. Previous researchers also reported decreasing dry matter productions with increasing salt treatments. Al-Karaki (2000) carried out a salt stress study with 3 different tomato cultivars and reported decreasing root dry matter productions with increasing salt concentrations. Cicek and Cakirlar (2002) reported decreasing maize fresh and dry weights with increasing salt stress. Khaled and Fawy (2011) indicated that salt stress negatively influenced maize growth and development and reduced dry matter productions.

Table 2. Effects of different salt doses on N, P and K concentrations of tomato plant (%)

Salt Doses	N	P	K
0 dS m^{-1}	3.10 ±0.02 [a]	0.089 ±0.01 [b]	4.93 ±1.09 [a]
3 dS m^{-1}	2.59 ±0.04 [ab]	0.097 ±0.01 [b]	4.74 ±0.84 [a]
6 dS m^{-1}	2.43 ±0.37 [b]	0.102 ±0.00 [b]	4.33 ±0.41 [ab]
9 dS m^{-1}	2.54 ±0.28 [ab]	0.072 ±0.02 [b]	4.23 ±0.12 [ab]
12 dS m^{-1}	2.88 ±0.57 [ab]	0.159 ±0.03 [a]	3.34 ±0.84 [b]

With regard to N concentrations of tomato plants, the greatest value (3.10%) was obtained from the control (0 dS m^{-1}) treatments as it was in shoot dry matter productions (Table 2). Control treatments was followed by 12 dS m^{-1} treatment with 2.88% N. Yokas et al. (2008) carried out a salt stress study with F1 Target tomato cultivar under greenhouse conditions and reported decreasing N concentrations with increasing salt concentrations. As it was in several studies, Alam (1994) also indicated that

Na intrusion reduced N concentrations. Contrary to N concentrations, P concentrations of tomato plants increased with salt treatments. While P concentration of 0 dS m^{-1} control treatment was 0.089% P, the value was measuredas 0.159% P in 12 dS m^{-1} treatment. The 12 dS m^{-1} treatment was found to be significant with regard to % P concentration as compared to other treatments. With regard to K concentrations of tomato plants, the greatest K concentration (4.93% K) was obtained from 0 dS m^{-1}control treatment. Control treatment was followed by 3 dS m^{-1} treatment with 4.74% K, but the differences between these two treatments were not found to be significant. Kuşvuran et al. (2008) carried a salt stress study with salt-tolerant and sensitive *Cucumis* sp. genotypes and reported significant increases in Na and Cl ions and decreases in K concentrations. Similar findings (decreasing K concentrations) were also reported in various other salt stress studies carried out with tomatoes (Yokas et al., 2008) and soybean (Baran and Doğan, 2014).

Table 3. Effects of different salt doses on Ca and Mg concentrations of tomato plant (%)

Salt Doses	Ca	Mg
0 dS m^{-1}	0.91 ±0.10 ^{a}	0.46 ±0.10 ^{a}
3 dS m^{-1}	0.89 ±0.04 ^{a}	0.46 ±0.07 ^{a}
6 dS m^{-1}	0.81 ±0.03 ^{ab}	0.42 ±0.03 ^{a}
9 dS m^{-1}	0.75 ±0.06 ^{b}	0.36 ±0.03 ^{a}
12 dS m^{-1}	0.76 ±0.04 ^{b}	0.35 ±0.03 ^{a}

With regard to Ca concentrations of tomato plants (Table 3), the greatest values (0.91% and 0.89% Ca) were respectively observed in 0 dS m^{-1} and 3 dS m^{-1} treatments which were placed in the same statistical group. Increasing % Ca concentrations were observed with increasing salt doses. Yakıt and Tuna (2006) applied salt stress to maize plants and reported decreasing Ca concentrations with the intrusion of Na ions. Similar to % Ca concentrations, decreasing Mg concentrations were observed in tomato plants with increasing salt doses. The greatest Mg concentrations were obtained from 0 dS m^{-1} and 3 dS m^{-1} treatments with 0.46% Mg. The changes in plant Mg concentrations under different salt doses were not found to be significant. Similarly, decreasing Mg concentrations were reported for soybean plants with increasing salt doses (Baran and Doğan, 2014).

Table 4. Effects of different salt doses on Fe, Zn, Mn and Cu concentrations of tomato plant (mg kg^{-1})

Salt Doses	Fe	Zn	Mn	Cu
0 dS m^{-1}	126.5 ±15.94 ^{a}	25.3 ±2.72 ^{b}	33.9 ±12.71 ^{ab}	9.4 ±0.23 ^{a}
3 dS m^{-1}	74.3 ±6.22 ^{c}	24.1 ±3.05 ^{b}	31.9 ±3.90 ^{ab}	7.7 ±1.63 ^{b}
6 dS m^{-1}	86.6 ±8.77 ^{bc}	25.6 ±2.59 ^{b}	40.2 ±5.35 ^{a}	8.0 ±0.31 ^{ab}
9 dS m^{-1}	55.9 ±6.47 ^{c}	27.8 ±0.99 ^{ab}	31.4 ±1.17 ^{ab}	8.6 ±0.06 ^{ab}
12 dS m^{-1}	106.4 ±2.97 ^{ab}	30.1 ±0.36 ^{a}	27.2 ±2.15 ^{b}	9.3 ±0.21 ^{a}

With regard to micro element concentrations of tomato plants, Fe concentrations varied between 55.9 mg kg^{-1} Fe and 126.5 mg kg^{-1} Fe with the greatest value (126.5 mg kg^{-1} Fe) in control (0 dS m^{-1}) treatment followed by 12 dS m^{-1} treatment with 106.4 mg kg^{-1} Fe (Table 4). The greatest plant Zn concentration (30.1 mg kg^{-1} Zn) was obtained from 12 dS m^{-1} treatment and the lowest Zn concentration (24.1 mg kg^{-1} Zn) was obtained from 3 dS m^{-1} treatment. With regard to plant Mn concentrations, the greatest value (40.2 mg kg^{-1} Mn) was observed in 6 dS m^{-1} treatment and it was followed by 0 dS m^{-1} control treatment with 33.9 mg kg^{-1} Mn. Different salt doses did not have significant effects on plant Cu concentrations. The greatest value (9.4 mg kg^{-1} Cu) was obtained from 0 dS m^{-1} control treatment and it was followed by 12 dS m^{-1} treatment with 9.3 mg kg^{-1} Cu. Khaled and Fawy (2011) applied different salt doses (0 mM, 20 mM, 60 mM) to maize plants and reported increasing Fe, Cu and Mn concentrations at 20 mM NaCl, but decreasing values at the greatest salt dose of 60 mM.

There was a negative correlation between shoot dry matter production and Zn concentration and there was a positive correlation between N and Fe (Table 5). While there was a positive relationship between Ca and Mg (P<0.01), there was a negative relationship between Ca and Zn (P<0.05). There were also negative correlations between Mg and Zn (P<0.01), positive correlation between Mg and Mn (P<0.05), between Fe and Cu and negative correlations between Zn and Mn and between Zn and Cu (P<0.05).

Table 5. Correlation values of parameters evaluated in the study

Parameters	SDW	N	P	K	Ca	Mg	Fe	Zn	Mn	Cu
SDW	1									
N	.009	1								
P	-.375	.237	1							
K	-.240	.197	.080	1						
Ca	.407	.314	-.276	.288	1					
Mg	.440	.091	-.386	.221	.891**	1				
Fe	.200	.648**	.370	.050	.332	.172	1			
Zn	-.669**	.119	.499	.194	-.624*	-.707**	.110	1		
Mn	.273	-.293	-.415	-.340	.421	.632*	-.124	-.552*	1	
Cu	-.312	.532*	.251	.323	-.019	-.088	.580*	.595*	-.218	1

*Significant at P<0.05 **Significant at P<0.01

CONCLUSIONS

This study was carried out to determine the effects of salt treatments at different doses (0 dS m^{-1}, 3 dS m^{-1}, 6 dS m^{-1}, 9 dS m^{-1}, 12 dS m^{-1}) on yield and nutrient uptake of tomato plants. Present findings revealed that salt treatments reduced yields of tomato plants. Salt treatments had significant effects on P, Zn and Mn concentrations and reduced some macro element (N, K, Ca, Mg) and micro element (Fe, Cu) concentrations. Excessive salinity result in yield and quality losses, thus economic loses. Present findings indicated that a special attention should be paid while selecting plant species to be grown over saline lands and salt-resistant tomato cultivars should be selected in this case to grown tomato over saline soils. Further research is recommended to be carried out about the effects of different salt concentrations on different plants for sustainable agriculture over saline lands.

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