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The effects of water salinity and potassium levels on yield, fruit quality and water consumption of a native central anatolian tomato species (*Lycopersicon esculantum*)

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Abstract

The effects of four irrigation water salinities (0.25, 2.5, 5 and 10 dS m^{-1}) and three potassium fertilizer levels (0, 5 and 10 mmol l^{-1}) on yield and some quality parameters of a native Central Anatolian tomato species (*Lycopersicon esculentum*) were investigated under greenhouse conditions. A fully randomized factorial experiment was conducted between 13th of June and 11th of October 2002 at the Faculty Agricultural Experimental Station of Ankara University. Yield, fruit quality, drainage water salinity and evapotranspiration data were collected. It was found that both salinity and potassium fertilizer levels affected fresh fruit yield. The yield decreased with increasing salinity starting at salinity level of 2.5 dS m^{-1} and continued to 10 dS m^{-1} treatment. The interaction between salinity and K levels was significant, $p < 0.05$, but the changes in yield did not exhibit any clear result to state that K^{+} levels had a direct effect on salinity–induced yield decrease. Plant biomass was affected only by the salinity levels of the irrigation water: the biomass decreased with increasing salinity. Increasing salinity levels resulted in smaller fruit size, higher soluble solid content (SSC) and decreased the pH of the fruit juice.

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Water consumption decreased with increasing salinity. Increasing salinity levels led to a decrease in water use efficiency (WUE).

Keywords: Salinity; Tomato; Potassium fertilization; Yield; Fruit quality

1. Introduction

Open-field tomato production is concentrated in a few warm and rather dry areas where irrigation is essential for high yield. Natural soil hydrological processes in these regions frequently produce saline soils (Cuartero and Fernandez-Munoz, 1999). Hence, in the areas with optimal climate for tomato, salinity is a serious constraint. It is difficult to cultivate or increase tomato yields in areas with salt affected soils, and/or to irrigate with saline water~~s~~. One approach to control salinity is leaching of soluble salts from the root zone soil by giving an additional amount of irrigation water known as leaching fraction. This practice is no longer feasible in certain areas because of the limited fresh water resources and the rise of saline water tables. Alternative approaches include (1) plant breeding, selection and introduction of salt tolerant cultivars and (2) the use of soil amendments and cations that could possibly alleviate the detrimental effects of salt and specific-ion stress on plants (Satti and Lopez, 1994).

Saline conditions have been found to disrupt several physiological processes leading to reduction in growth (Flowers et al., 1977; Greenway and Munns, 1980; Satti and Ahmad, 1992; Öztürk, 2002) and in fruit size and fruit yield (Ehret and Ho, 1986; Adams, 1991; Cornish, 1992; Satti et al., 1993). On the other hand, it has been reported that irrigating tomato with saline water can improve its fruit quality (Mizrahi, 1982; Adams, 1987; Mizrahi et al., 1988; Hao et al., 2000; Inal, 2002).

A major objective of salinity–fertility studies is to test if fertilizing salt-stressed plants either alleviates the growth-limiting effect of salinity or actually increases crop salt tolerance (Grattan and Grieve, 1994). Bernstein et al. (1974) defined salinity—nutrient impact on plant salinity tolerance level as: (a) no effect; (b) increase; and (c) decrease in salt tolerance. Grattan and Grieve (1999), on the other hand, prefer to define the interactions based on plant performance at optimal fertility relative to the performance at suboptimal fertility.

Maintenance of adequate potassium levels is essential for plant survival in saline habitats. Potassium is the most prominent inorganic plant solute, and as such makes a major contribution to lower the osmotic potential in the stele of roots that is a prerequisite for turgor-pressure-driven solute transport in xylem and the water balance of plants (Marschner, 1995). Despite the presence of significant amount of data showing reduced uptake and translocation of potassium by plants grown in high Na substrates, there is very little information showing that the addition of potassium to sodium-dominated soils improved plant growth or yield (Grattan and Grieve, 1999). Various investigators (Bernstein et al., 1974; Bar-Tal et al., 1991; Cerda et al., 1995) concluded that despite the beneficial effects of increasing K/Na within the plant, K fertilization did not reduce the deleterious effects of salinity. Tomato could act as a model crop for saline land recovery and use of poor-quality water as there is a wealth of knowledge on the physiology and genetics of this species (Cuartero and Fernandez-Munoz, 1999).

The main objectives of this study were to investigate the possibility of reducing the negative effects of irrigation water salinity by K applications, and the effect of different salinity and potassium fertilization levels on the fruit yield, water consumption, water use efficiency, biomass, fruit size, pH, and total soluble solids of a tomato species which is widely cultivated in Central Anatolia.

2. Materials and methods

The experiment was carried out in a greenhouse at the Experimental Station of Faculty of Agriculture of Ankara University, between 13 of June and 11 of October 2002. A native Central Anatolian species, H2274-Oturak, was selected for the experiment. The fruits of this well-known species are tough and suitable for transporting and have unique flavour and smell. The tomato plants were grown in polyethylene lysimeters, 40 cm in diameter and 50 cm deep. Each lysimeter was filled with 52 kg of air-dried soil and contained a single plant. Table 1 shows the characteristics of the experimental soil.

Irrigation water salinity levels were as follows: $T_0 = 0.25$, $T_1 = 2.5$, $T_2 = 5$ and $T_3 = 10$ dS m^{-1}. These salinity levels were obtained by dissolving NaCl and $CaCl_2$ salts in non-saline water. Potassium fertilizer levels were: $K_0 = 0$, $K_1 = 5$ and $K_2 = 10$ mmol K^+/lysimeter. The experiments were carried out in a fully randomized factorial experimental design with three replications. For all salinity levels, the sodium adsorption ratios (SAR values) of the irrigation water kept below one. Potassium was applied in the form of KNO_3 since the other forms, such as KCl, could change the salinity levels with their anions. Other macro and micro nutrients were applied equally to all lysimeter. The amount of N applied in form for KNO_3 was taken into consideration when calculating the amount of N to be

Table 1
Physical and chemical characteristics of the soil used for the experiment

Bulk density (g cm^{-3})	1.24
pH	7.69
EC (dS m^{-1})	0.4
P (mmol/kg)	1.25
K (mmol/kg)	10.0
N (mmol/kg)	107
Organic Material (%)	1.06
Texture (%)	Sandy clay loam
Sand	55
Clay	24
Silt	21
$CaCO_3$	10.69
Field capacity (%)	24
Wilting point (%)	19

Table 2
The analysis of irrigation water used in the experiment

	EC dS m^{-1}	SAR $(me\ l^{-1})^{1/2}$	Cation (me l^{-1})				Anion (me l^{-1})				
			Na	K	Ca + Mg	Total	HCO_3	CO_3	Cl	SO_4	Total
T_0	0.26	0.35	0.37	0.07	2.20	2.640	0.91	–	0.710	1.02	2.64
T_1	2.4	0.68	2.30	0.09	22.80	25.19	1.10	0.1	20.75	3.24	25.19
T_2	4.8	0.62	3.01	0.07	47.23	50.31	0.90	0.3	50.78	1.33	53.31
T_3	9.7	0.65	4.53	0.08	95.74	100.34	0.90	0.1	98.86	0.48	100.34

added as NH_2CONH_2. Phosphorus was applied in the form of H_3PO_4, calcium in form of $CaSO_4{\cdot}2H_2O$ and magnesium in form of $MgSO_4{\cdot}7H_2O$ the amounts were 7.50, 8.6 and 34.5 g/plant, respectively. The amount of potassium was divided into three equal parts. The first part was applied on 31 June, the second on 22 July and the rest on 29 August, except for the control treatment which did not receive any additional potassium. Table 2 shows characteristics of the irrigation water.

Evapotranspiration rates were determined by weighting the lysimeter with a digital scale at 2 day intervals. Plants were irrigated when 50% of available soil water was extracted. Additional 20% of irrigation requirement was added for leaching purpose (Ayers and Westcot, 1989). After each irrigation, drainage water was collected in a pot, and the electric conductivity (EC) was measured in order to monitor root zone salinity.

The plant biomass was determined by weighting the plants after being oven-dried at 70 °C. To evaluate the physical quality aspects of the tomatoes, the size, height and diameter, of the fruits were measured while to evaluate the chemical quality aspects, soluble solid content (SSC) and pH values of the fruit juice were determined. Water use efficiency (WUE) was calculated by dividing water used for evapotranspiration by total fresh (economical) yield (Doorenbos and Kassam, 1979).

MINITAB statistical analysis software was used for analysis of variance, ANOVA and Duncan test. Significance of the effects of the salinity levels and potassium levels was statistically evaluated at $p < 0.05$ and <0.01 significance levels.

The Duncan test has been applied to determine how significant the differences between the averages of groups are. The latter are described using the alphabets A, B, C, a, b, c, etc. AB, BC, or ab, ac, indicate that these averages (for example in AB, average A and average B) can be put together in one group however, they are both different from the C, D, etc. The studied variations were mainly due to water salinity and potassium levels.

3. Results and discussion

3.1. Yield and biomass

The fruit yield results are given in Table 3. The average yield of tomato ranged between 215 g/plant and 1880 g/plant for the treatments T_3K_2 and T_0K_0, respectively. In the 0 mmol K^+ treatments, increasing salinity from 0.25 to 10 dS m^{-1} resulted in a decrease in yield

Table 3
Tomato fresh yields according to the salinity and K levels

Irrigation water salinity levels (dS m^{-1})	0 mmol K^+/ plant-lysimeter	⇒	⇓	5 mmol K^+/ plant-lysimeter	⇒	⇓	10 mmol K^+/ plant-lysimeter	⇒	⇓	Average	⇓
0.26	1880	a	A	1261	b	A	1394	b	A	1512	A
2.4	1157	ab	B	918	b	B	1218	a	A	1098	B
4.8	633	a	C	744	a	B	604	a	B	660	C
9.7	268	a	D	223	a	C	215	a	C	235	D
Average	985	a		787	b		858	ab			

⇒ shows the horizontally Duncan test results, the K levels effects on the fresh yield; ⇓ shows the vertically Duncan test results, the salinity levels effects on the fresh yield. A, B, C, a, b, c, etc. shows the different Duncan groups of the yield results.

from 1830 to 268 g/plant. In presence of 5 mmol K^+, both 2.5 and 5 dS m^{-1} salinity levels are in the same Duncan group. In one hand, at 5 mmol K^+ level, the treatment of 2.5 dS m^{-1} salinity level resulted in less yield than 0 mmol K^+ level, on the other hand, at 5 mmol K^+ level, the treatment of 5 dS m^{-1} salinity level resulted in higher yield than 0 mmol K^+ level. In presence of 10 mmol K^+ level, the yield decreased significantly for all salinity treatments, except 2.5 dS m^{-1} salinity level, which resulted in higher yield than 0 mmol K^+ level.

The results for biomass are given in Table 4. The biomass yield was affected only by salinity ($p < 0.01$ significance level). The biomass yield did not show any response to potassium fertilizer levels. The results showed that the biomass yield was already reduced at the 2.5 dS m^{-1} salinity level and the reduction continued to increase as the salinity increased from 2.5 to 10.0 dS m^{-1}. The average decrease in biomass yield caused by an increase in salinity from 2.5 to 5.0 dS m^{-1} was approximately 37%, as the salinity increases further to 10.0 dS m^{-1} a further yield reduction of approximately 60% was obtained.

3.2. *Fruit size*

Fruit diameter and height were determined for each fruit, the results are shown in Table 5. Potassium fertilizer levels did not have any effect on fruit size. Salinity levels, however, strongly affected the fruit height and diameter, and these parameters decreased linearly with increasing salinity levels that it is seen through the Duncan test results. Both parameters exhibited similar response to salinity levels, as the analysis put them together in the same statistical group.

Table 4
Duncan test results for the biomass yield of tomato in relation with the salinity treatments

Treatment (dS m^{-1})	Biomass (g/plant-lysimeter)
0.26	253.3 a
2.4	224.8 a
4.8	149.2 b
9.7	94.4 c

Table 5
Duncan test results for the fruit height, diameter, and the total soluble solids of tomato fruits

Treatments	0.25 (dS m^{-1})	2.5 (dS m^{-1})	5 (dS m^{-1})	10 (dS m^{-1})
Fruit diameter (mm)	52.4 a	48.8 b	46.4 b	39.7 c
Fruit height (mm)	53.0 a	47.3 b	46.2 b	41.4 c
TSS (Brix) (%)	5.43 c	5.71 c	7.51 b	10.4 a
pH	4.51 a	4.5 a	4.4 a	3.9 b

3.3. Total soluble solid content (TSS)

TSS or Brix (Brix is total soluble solids or soluble solid contents of tomato juice measured by refractometer, and its unit is %, i.e. grams of matter in 100 ml of solution) of tomato fruits ranged between 10.36% and 5.43% for the 10 and 0.25 dS m^{-1} salinity levels, respectively (Table 5). The TSS was not affected by low salinities (2.5 dS m^{-1}) but subsequently, it showed a great increase with increasing salinity levels. Compared with the control, the 10 dS m^{-1} salinity level caused a 100% increase in TSS of the fruit. On the other hand, potassium fertilizers did not have any statistically significant effect on SSC. Duncan test results showed that TSS was strictly related to the irrigation water salinity levels, at $p < 0.01$ significance level.

3.4. pH of fruit juice

Results for the pH of the tomato juice are given in Table 5. The pH of the juice was not significantly affected by potassium application. Salinity only had a significant effect at 10 dS m^{-1}, decreasing the pH from 4.5 to 3.9; a 12% decrease.

3.5. Water consumption and water use efficiency (WUE)

While potassium levels did not have any statistically significant effect on water consumption and water use efficiency however, these parameters showed a strong relation to salinity at $p < 0.01$ significance level (Table 6). The biggest amount of water, 175.8 l per plant-lysimeter, was applied to the control treatment. The amount of water applied to the treatments with 2.5, 5.0 and 10.0 dS m^{-1} salinity levels were 144.3, 113.7 and 76.7 l per plant-lysimeter, respectively. Compared with the control, the decrease in water consumption was 21%, 35% and 56% for the 2.5, 5.0 and 10 dS m^{-1} salinity levels, respectively.

Potassium fertilizer levels did not have any statistically significant effect on water use efficiency (economical yield/water consumption) however, WUE decreased with increasing salinity levels at $p < 0.01$ significance level. Compared with the control, the

Table 6
Duncan Test results for the water consumption and WUE

Treatments	0.25 (dS m^{-1})	2.5 (dS m^{-1})	5 (dS m^{-1})	10 (dS m^{-1})
WUE (fresh yield)	8.5 a	7.6 b	5.8 c	3.07 d
Water consumption liter/plant-season	175.8 a	144.3 b	113.7 c	76.7 d

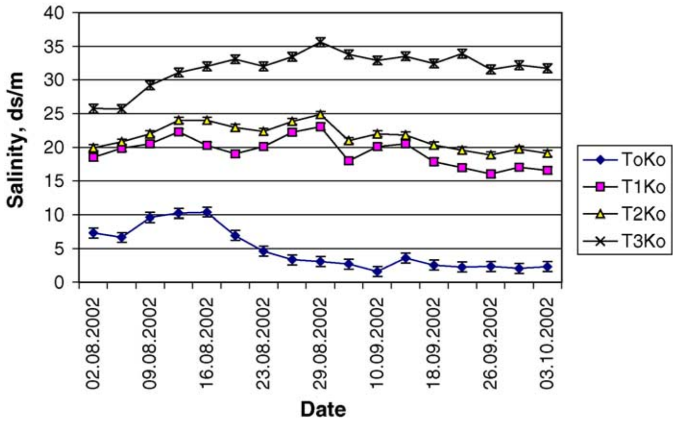

Fig. 1. Drainage water salinity changes in time.

decrease in WUE was 11%, 31% and 64% for the 2.5, 5.0 and 10.0 dS m^{-1} salinity levels, respectively.

3.6. Electrical conductivity of the drainage water

During the experiment, the drained water was collected after each irrigation and the electrical conductivities of these waters were measured. The changes in drainage water salinity with time are illustrated in Fig. 1. The salinities of drainage water, EC_d, increased with increasing the irrigation water salinities, EC_i. When the irrigation water salinity changed from 0.25 to 2.5 dS m^{-1}, the drainage water salinity increased on average from 5 to 18 dS m^{-1} but when the irrigation water salinity changed from 2.5 to 5 dS m^{-1}, the increase of the drainage water salinity increased from 18 to 22 dS m^{-1} only. This is because at higher irrigation water salinity level, the total irrigation water requirements is less and consequently the total drained water is decreased. Less leaching water amount resulted progressively in less salt leaching. Fig. 1 shows drain water salinities for the highest irrigation water salinity treatment (10 dS m^{-1}), which exceed 22 dS m^{-1} (the range is from 30 to 35 dS m^{-1}).

4. Conclusion

The effects of different salinity and potassium levels on yield, water use efficiency, biomass, fruit size, pH and TSS of a native Central Anatolian tomato species (*Lycopersicon esculentum*) were evaluated. While the salinity levels had statistically significant effects on all these parameters, potassium levels only had statistically significant effects on yield but this effect was not enough to state that K^+ levels have a positive effect against salinity-induced yield decrease, it might be only a simple fertilizer effect. Increasing salinity levels caused a certain decrease in all of the examined parameters, except TSS which increased in response to increasing salinity levels.

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