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EFFECTS OF RECYCLED WATER ON SOIL STRUCTURE AND GROWTH OF TOMATO GROWN ON A SALINE SOIL

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ABSTRACT

This study was conducted to evaluate the effects of irrigation water quality on some soil physical properties and plant growth of tomato grown in saline soil. Recycled water (1.5 dS/m) and mains water (0.62 dS/m) were used. The experiment was laid out as a randomized complete block design. The results showed that using mains water for irrigation under saline soil conditions induced clay dispersion; as a result soil structure destruction was more evident in soil irrigated with mains water. Regarding plant growth, recycled water reduced both total leaf area and above-ground dry biomass. Water use efficiency (WUE) was greater when mains water was applied. Blossom End Rot (BER) was more evident with recycled water plants. Thus, yield of tomato was reduced with increasing salinity.

Key words: Saline soil, Recycled water, Soil physical properties, Plant growth, Blossom End Rot.

INTRODUCTION

Salinity is considered a significant factor inhibiting plant growth and hence agricultural productivity. Salinization is becoming a universal issue and a threat to global food security as 20% of world lands classified as salt affected soil (20). Salinity can occur naturally in soil, in particular, in arid and semiarid areas where rainfall is not enough to leach access salt down the root zone or through the use of low quality water for irrigation over time such as recycled water (3) which causes accumulation of soluble salts in soils or waters such as sodium chloride which is the dominant salt in many saline soils of the world (13). Salinization causes different stresses on plant growth; osmotic stress, ionic toxicity and nutrient deficiency that may interfere with all plant functions, and even lead to plant death (8, 15). Salinity may also cause secondary effects on plant growth through degradation of soil structure when high sodium in soil is present (2). In the Northern Adelaide Plains (NAP), Australia, using recycled water over 32 years has made its soil saline, sodic and lacking in organic matter (19). This has resulted in destruction of the soil structure and reduction of plant growth. This study was to evaluate the effects of recycled water (1.5 dS/m) and mains water (tap water, 0.62 dS/m) on soil physical properties and plant growth of tomato grown in the NAP soil.

MATERIALS AND METHODS

Soil and experimental pot set up

A saline soil ($EC_{1:5}$ 3.9 dS/m) was blended and steam-sterilized before the usage to ensure that it was free of plant pathogens. 10 white plastic 20 L buckets (inner dimensions: top diameter= 28.5, bottom diameter= 24.5 cm, height= 38.5) were lined at the bottom with 1 kg of stones covered by geo-textile fabric to prevent blockage of drainage holes.

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Crops

A pot experiment was conducted in a glass-house at the Waite Campus of the University of Adelaide from August to December 2011. Seedlings (10 cm high) of the tomato (*Lycopersicon esculentum* L.) variety were planted on September 30. The plants were individually staked and pruned to a single stem. Prunings were dried (70 C°, 48 h) and weighed. At the end of the experiment (110 days), the plants were harvested and dried (70 C°, 48 h). The total dry weight was the dry weight of the plant and the prunings.

EXPERIMENTAL DESIGN AND TREATMENTS

The experiment was laid out as a randomized complete block design. Irrigation water quality treatment was tested. Recycled water (EC 1.5 dS/m) and mains water (EC 0.62 dS/m) were applied to tomato plants. The treatment was replicated five times.

Soil analysis

The soil texture was clay, consisted of 52% clay, 20% silt and 5% sand. The electrical conductivity ($EC_{1:5}$) of the soil was 3.91 dS/m at the beginning of the experiment. At the end of the experiment the $EC_{1:5}$ of soil treated with mains water was 2.1 and $EC_{1:5}$ of soil treated with recycled water was 3.2 dS/m. $pH_{1:5}$ was 8.23 when the experiment commenced and still consistent until the end of the experiment.

Hydraulic conductivity

The saturated hydraulic conductivity (K_{sat}) of the sterilized soil was measured in the laboratory, before the experiment commenced using Darcy's Law (Equation 1) with three replicates. 150 gm of soil was placed in a cylinder (height =10 cm, diameter= 5.5 cm) and saturated with water of three different salinities, 1.5 dS/m (simulating CARW), 0.7 dS/m (mains water) and 0.01 dS/m (sterilized water). Steady flow was obtained and K_{sat} was calculated. At the end of the experiment, K_{sat} was measured again directly in situ in pots before the soil was disturbed and also in the laboratory by taking intact soil cores from pots.

$Q/t = AK_s \times P/L_s$ "Equation 1"

Where Q/t, the volume of water per unit of time moving through the soil volume, A, the cross-sectional area of the column through which the water flows, K_{sat} , the saturated hydraulic conductivity, P, water potential between the ends of column and L_s , the length of the soil column.

Table 1: Means K_{sat} values measured with three different types of water in three ways using three replications before and after the experiment (repacked soil was before the experiment, intact soil core and in situ were directly after the experiment finished, the coefficient of variation (cv) ≈ 0.25, n.a (not available).

Measurement methods	K_{sat} (cm/hour)		
	Artificial recycled water	Mains water	sterilized water
Before experiment In the laboratory (repacked soil)	30	10	3.7
After experiment In the laboratory (intact soil core)	7.6	3	0.8
In situ (in pots)	6.2	2.4	n.a

Mean bulk density (ρ_b), gravimetric water content (θ_M) and volumetric water content (θ_V) at field capacity of *in tact* soil cores measured at end of experiment (110 days) on pots irrigated with mains water or recycled water

(Equations, 2,3,4). Total soil porosity (ε) was calculated from the mean Bulk density assuming an average Particle density of 2.65 g/cm^3 (Equation 5) ; volumetric air content (ε_r) was calculated by difference between Total porosity and volumetric water content (Equation 6).

P_b = dry soil weight / volume of soil "Equation 2"

Where volume of soil is (solids + pores)

θ_M = (wet soil weight – dry soil weight) / dry soil weight "Equation 3"

$\theta_V = \rho_b \times \theta_M$ "Equation 4"

$\varepsilon = 1 - (\rho_b / \rho_s) \times 100$ "Equation 5"

$\varepsilon_r = \varepsilon - \theta_V$ "Equation 6"

Properties of the NAP irrigation water

Two types of water were used in the experiment, mains water and artificial recycled water to simulate class A recycled water (CARW) used in the NAP. The source of recycled water in the NAP is from the Bolivar Wastewater Treatment Plant that collects waste water from urban areas and then produces CARW. Water quality properties of both mains water and artificial recycled water are shown in Table (2).

Table 2: Mains and artificial recycled water properties

properties	Mains water	Artificial recycled water
pH	7	8
TDS (mg/L)	397	960
EC (dS/m)	0.62	1.5
Sodium (mg/L)	71	230
Calcium (mg/L)	30	43
Magnesium (mg/L)	19	33

Fertilizer requirement, insect control

The fertilizer requirement of the crop was supplied using 15 gm of "Hortico All Purpose Compound Fertilizer" (N: 12.2%; P: 5.1%; K: 13.7%; Ca: 4.5%; Mn: 1.1%; Zn: 0.01%) to each pot before the first irrigation event. The fertilizer was buried in three different places in each pot 5 cm below the soil surface around the edge of the pot to provide nutrients.

Collecting data

Growth and development parameters such as plant height, number of flowers and leaves were recorded from individuals at weekly intervals. WUE was estimated by the weight of dry biomass per plant divided by the total amount of water applied during the experiment. Productive parameters such as number and weight per fruit from each plant were recorded from fruits harvested over different dates as they ripened on the plants.

Data analysis

The data collected were subjected to an analysis of variance using two way ANOVA model procedure for a randomized complete block design employing GenStat version 5.

RESULTS AND DISCUSSION

Soil physical properties

Soil physical characteristics are summarized in Tables (3) and Figure (1), which show that soil treated with mains water had slightly greater bulk density (thus lower total porosity) and air-filled porosity than soil treated with recycled

water; these differences, however, were not statistically significant at P=0.05. The saturated hydraulic conductivity (K_{sat}) significantly decreased in the pots irrigated with mains water. This is probably because the soil was sodic (19). Using high quality water such as mains water to irrigate sodic soil induces clay dispersion (6). Dispersed clay particles block soil pores and hence increase bulk density but decrease K_{sat}. These findings are consistent with those of Shainberg et al. (17) and of Frenkel et al. (6).

Table 3: Mean Bulk density and Volumetric water content at field capacity, Total porosity and Volumetric air content were measured on pots irrigated with Mains water or Recycled water (3 replications)

Factor	Bulk density (g/cm^3)	Volumetric water content (cm^3/cm^3)	Total porosity (cm^3/cm^3)	Volumetric air content (cm^3/cm^3)
Mains water*	1.14	0.34	0.57	0.23
Recycled water*	1.11	o.30	058	0.28
LSD(5%)	n.s.	n.s.	n.s.	n.s.

* $EC_{1:5}$ for soil irrigated with Mains water = 2.1 dS/m; irrigated with Recycled water = 3.2 dS/m.

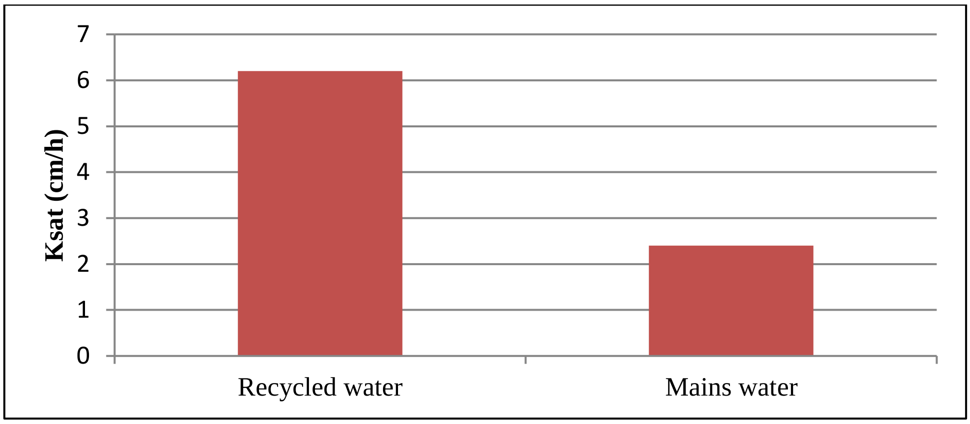

Figure 1: Mean saturated hydraulic conductivity (3 replications) of undisturbed soil in pots at the end of the experiment (110 days) using Recycled or Mains water, the coefficient of variation (cv) ≈ 0.27.

Plant growth and yield parameters

Salinity of the irrigation water had a significant effect on the vegetative growth characteristics of tomatoes: plant height, number of leaves per plant, and above-ground dry biomass were all significantly reduced in the soils irrigated with recycled water compared with those irrigated with mains water (Table 4, Figure 2). As a result, the water use efficiency (WUE) for biomass production was significantly lower for the recycled-water plants. Similar observations were reported by Lopez etal. (7), Munns and Termaat (14) and Reina et al. (16). The reduction of dry biomass with increasing salinity was explained by Malash et al., (10) and Mudgal et al. (12), who report that saline water reduced water uptake, stomatal density, transpiration and net CO_2 assimilation, which in turn reduced the growth and transfer of nutrients into the plants.

In addition, the plants irrigated with the recycled water had significantly lower reproductive growth characteristics relative to the mains water plants: the

number of fruits per plant, the weight per fruit and the total weight of fruit per plant were all significantly lower (Table 4). A reduction in the weight of tomatoes caused by increased salinity was also reported by Adams & Ho (1), Cruz et al. (4) and Sonneveld & Welles (18). The reason is that high salinity lowers water potential in the plant which reduces the water flow into the fruit and therefore the rate of fruit expansion (5). Also, the incidence of blossom end rot in tomato fruits (BER) which is caused by calcium deficiency was significantly greater for the recycled water plants. Sodium increases and calcium decreases in the fruit linearly with increasing salinity causing BER (1).

Table 4: Mean Vegetative and Reproductive growth characteristics for tomato as affected by water quality.

Factor	Vegetative growth				Reproductive growth			
	Height (cm)	No. Leaves / plant	Dry bio-mass (g)	WUE (g.biomass /L)	No. fruit / plant	Weight / fruit (g)	Weight / plant (kg)	No. Fruit with BER*
Mains water*	181	15.4	67	1.4	32	80	2.57	0.90
Recycled water*	162	14.2	56	1.2	26	71	1.87	2.4
LSD (5%)	7	0.8	2.6	0.05	0.8	5	0.44	0.36

*** BER = Blossom end rot, * $EC_{1:5}$ for soil irrigated with Mains water = 2.1 dS/m; irrigated with Recycled water = 3.2 dS/m.**

Figure 2: The difference in height and biomass of plants as affected by salinity treatment, (*left*) plant grown in recycled water, (*right*) plant grown with mains water.

The reduction in number and weight of tomatoes and BER incidence were more evident with increasing height of fruits on the stem (Figure 3). Similar

observations were reported by Magán et al. (9). Possible explanation is that the fruits in higher trusses are more likely to be weaker than those in the lower trusses due to less water and nutrient uptake available to the highest trusses, which make them fewer, smaller and more subject to BER. So, our results suggest that a short cycle of crops in which four to six trusses is recommended under salinity conditions.

Figure 3: Number and weight of fruit decrease, but BER increases with increasing the height of truss on the stem.

Leaf tissue concentrations of Na, Ca, K, and P were significantly affected by salinity treatment (Table 5). Leaf Na concentration increased and Ca, K and P decreased with recycled water plants. Na has been reported to increase and Ca and K decrease slightly in the leaf tissues with increasing salinity in most tomato species (1). The accumulation of Na in the leaf of tomato occurs at the expense of K, and Ca (3). Parida (15) reported that under salt stress the uptake of Na competes with other nutrient ions uptake such as K and Ca, leading to nutrient deficiency in particular K deficiency. This is because salt stress disturbs the ion homeostasis mechanisms of the plant. Under salt stress, the similar channel of Na and K make it difficult for transport proteins to distinguish between these two ions and thus substantial uptake of Na through K transporter (12).

Table 5: Salt accumulation in tomato leaves as affected by salinity treatment

Factor	Na (g/kg)	Mg (mg/kg)	Ca (g/kg)	K (g/kg)	P (g/kg)
Mains water*	9.8	7.80	28	24	2.56
Recycled water*	13.4	7.77	27	22	2.34
LSD (5%)	1.200	n.s.	0.34	0.45	0.18

* $EC_{1:5}$ for soil irrigated with Mains water = 2.1 dS/m; irrigated with Recycled water = 3.2 dS/m.

Increased salinity was noticed to hasten tomato fruit ripening. This is because salinity hinders fruit development but stimulates all the parameters of the fruit ripening process (11). Salinity was also observed to improve perceived fruit flavour. Total soluble solids, acids and sugars increase with increasing salinity, resulting in improved fruit taste (9, 18). However, the enhancement in the ripening process and the taste are accompanied by reductions in weight and number of fruits and there are more important in marketing.

It can be concluded that salinity is a critical issue decreasing crops productivity and it is globally increasing. In this study efforts were made to evaluate the negative effects of salinity on soil structure and plant growth of tomato. Our results showed that the usage of mains water to irrigate saline soil slightly affected the soil physical properties because of clay dispersion. In relation to plant growth, the recycled water plants were more affected by salt stress compared to the mains water plants. Total leaf area and aboveground biomass for plants irrigated with mains water were greater compared with those irrigated with recycled water. BER incidence was more evident on the fruits of the recycled water plants. A decline in both size and number of fruits was noticed when recycled water applied. Furthermore, the adverse effects of salinity on number and weight of fruits and BER incidence increased with increasing the height of the fruits on the stem. Our results suggest that short tomato crops cycle in which four to six trusses is recommended under salinity condition.

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مجلة الزراعة العراقية (البحثية) مجلد١٨ عدد١ ص ٢٠٩-٢١٧ تشرين الثاني/٢٠١٣

تأثيرات المياه المعادة في بناء التربة ونمو نبات الطماطة في تربة ملحية

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روبرت مري** كاميرون كرانت**

الملخص

تمت دراسة اثر استعمال المياه المعادة على بناء التربة وعلى نمو نبات الطماطة. اجريت الدراسة في الترب المالحة التي تم تجهيزها من السهول الشمالية لمدينة اديلايد استراليا وباستخدام نوعين من مياه الري: المياه المعادة بملوحة ١,٥ ديسيسمينز/م والمياه العذبة 0.62 ديسيسمينز/م. استغرقت التجربة ١١٠ يوم. لتحديد معنوية النتائج تم استخدام التصميم العشوائي الكامل. اظهرت النتائج ان استخدام مياه الشرب لأرواء اراضي ذو ملوحة عالية اذا ماقورن باستخدام المياه المعادة يؤدي الى تشتت التربة وبالتالي تناقص التوصيل الهيدوليكي المشبع. اما إنتاج الطماطة، فان النتائج أظهرت بأن استخدام المياه المعادة قد ادت الى تناقص الانتاج الخضري لنبات الطماطة بالاضافة الى تناقص محصول الطماطة اذا ماقورن باستخدام المياه العذبه لأرواء الاراضي المالحة. وقد لوحظ بان عدد وحجم الطماطة تتناقص مع ازدياد عمر النبات. لذا نوصي بقصر دورة انتاج الطماطة في الاراضي المالحة.

جزء من رسالة الماجستير للباحث الاول.

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