J. King Saud Univ., Vol. 6, *Agric. Sci.* (1), pp. 163-170 (A.H. 1414/1994).

Response of Two Tomato Varieties to Irrigation with Sulphate Waters

A.S. Modaihsh and A.A. Alsadon
Department of Soil Science and Department of Plant Production, College of Agriculture, King Saud University, Riyadh, Saudi Arabia

Abstract. Tomato (*Lycopersicon esculentum* Mill, (Var, Marmande and Pearson) plants were grown under greenhouse conditions, in a loamy sand calcareous soil ($CaCO_3$, 26.5%) to study the growth and yield of tomatoes irrigated with SO_4^{2-} waters (15, 30 and meq/l).

Results indicated that total fruit weight and average fruit weight were not affected by SO_4^{2-} level. Fresh weight (FW), dry weight (DW) and maximum length (ML) of root system as well as total soluble solids (TSS) and acidity of fruit were significantly ($P \leq 0.05$) increased by high SO_4^{2-} level (45 meq/l).

The results also revealed that in Marmande cultivar, at the second stage (69 days) – the uptake of N, P, K, SO_4, Fe, Zn, Mn and Cu was significantly ($P \leq 0.05$) increased as SO_4^{2-} level increased. Also, soil SAR and pH were significantly increased.

The results suggest that under prevailing conditions of the experiment, irrigating tomatoes with SO_4^{2-} waters having concentration in the range of (15-45 meq/l) can be tolerated by tomato plant and it would not restrict its growth and yield.

Introduction

Sulphur is often added in excess to plant needs in arid and semi-arid regions. This is because irrigation is a common practice and in some of these areas the sulphate $(SO_4)^{2-}$ is the predominant anion in the irrigation water. This is the case in some cultivated areas of Saudi Arabia, particularly the central region (e.g. Aljelh, Tebrak).

The limited information concerning the effect of sulphate waters on plants and soils show a great deal of contradictions in results [1-3]. In general, use of high SO_4^{2-} waters may lead to gypsum precipitation. This is considered beneficial to soils because of the limited solubility of gypsum (31.35 meq/l in pure $CaSO_4$ system at 25°C) which does not create saline conditions in the soil [4,5]. However, an adverse effect may occur due to precipitation of Ca^{++} with SO_4^{2-} leading to an increase in concentration of Na^+ which raises the soil solution sodium adsorption ratio (SAR) [6]. These changes, which may cause beneficial or harmful effects, are greatly influenced by soil properties and the applied ionic composition [7-9]. The use of high SO_4^{2-} waters may also cause extensive accumulation of sulphur (S) in the soil. Therefore, some S-toxicity problems may arise [1].

Because of the limited information and apparent contradictions in the literature regarding the effect of sulphate waters on plants and soils and the presence of significant amounts of SO_4^{2-} in the ground waters in some areas of Saudi Arabia, the present study was undertaken to evaluate the effect of SO_4^{2-} waters on the soils and tomatoe growth and yield.

Material and Methods

A greenhouse experiment was carried out at the College of Agriculture, King Saud University (with moderate temperatures ranging from 17-22°C min. and 24-28 °C max.). Seeds of two cultivars; Marmande and Pearson, were raised in seedling flats under greenhouse conditions. When the seedlings reached the four true leaf stage, 48 seedlings of each cultivar were transplanted to plastic pots 30 cm in diameter containing 16 kg of soil. The soil used was a loamy sand (Torrifluvent, calcareous soils $CaCO_3$, % 26.5) obtained from The Agricultural Research and Experimental Station at Dirab, 25 km south west of Riyadh (24° 42', 46° 44'E, Alt 600 m). Some of the physical and chemical properties of the soil are presented in Table 1.

Each pot received an equivalent of 220 kg N/ha as urea splitted into three doses (110, 55 and 55 kg N/ha). Also equivalent of 180 kg P_2O_5/ha and 120 kg K_2O/ha were added to each pot in the form of KH_2PO_4. Micronutrients were added at rates of 10 ppm Fe as Fe EDDHA, 10 ppm Zn as Zn-EDTA and 5 ppm Mn as Mn-EDTA. Irrigation was carried out on weekly basis by top addition of water and it was planned to give 0.3 leaching fraction at each irrigation. Irrigation water was prepared by dissolving mixture of Na, Ca and Mg salts in distilled water in such a way as to give waters of different SO_4^{2-} concentrations (15, 30 and 45 meq/L) but with equal electrolyte concentration (EC=5 mmohs/cm) and SAR=7 (Table 2). Pots were arranged in a completely randomized design with four replicates. Plants were harvested 46, 69 and 104 days after planting, oven dried at 70°C for 48 h; and dry weight (DW) was recorded. Plant materials analysis was carried out for N, P, K, SO_4, Fe, Mn, Zn and Cu according to the methods described by Chapman and Pratt [10] and Black [11]. Also, data were recorded for tomato yield, total acidity, ascorbic acid, total soluble salt (TSS) and pH. At the end of the study, soil samples were taken from each pot and soil pH, EC and SAR were determined using standard methods [10,11].

Table 1. Characteristics of the soil under investigation

Soil property	Dirab soil
Great soil group	Torrifluvent
pH, (H_2O) 1:1	7.50
EC, dS/m	1.30
$CaCO_3$, %	26.50
Organic matter, %	0.10
NH_4^+, ppm	17.90
NO_3^-	21.20
K^+, NH_4OAC (ppm)	188.00
Sodium bicarbonate soluble-P ppm	3.40
DTPA extractable Fe ppm	1.36
DTPA extractable Mn ppm	0.76
DTPA extractable Zn ppm	0.50
DTPA extractable Cu ppm	0.41
Sand%	80.00
Silt%	9.00
Clay%	11.00
Soil texture	Loamy sand

Table 2. Composition of the irrigation waters

SO_4^{2-} conc. meq/l	Conc. of the used salts meq/l
15	15.0 Na_2SO_4 7.25 NaCl 13.87 $CaCl_2.2H_2O$ 13.87 $MgCl_2$
30	22.26 Na_2SO_4 7.74 $MgSO_4.7H_2O$ 6.13 $MgCl_2$ 13.87 $CaCl_2.2H_2O$
45	22.26 Na_2SO_4 13.87 $MgSO_4.7H_2O$ 8.87 $CaSO_4.2H_2O$ 5.00 $Cacl_2.2H_2O$

Results and Discussion

Total yield and yield components of tomato fruits as affected by SO_4^{2-}level are shown in Table 3. Total fruit weight and average fruit weight were not affected by SO_4^{2-} treatments, whereas the number of fruits/plant was significantly reduced by increasing SO_4^{2-} concentration from 15 to 45 meq/l. In a similar study, Cedra *et al.* [1] determined the effect of SO_4^{2-} on tomato plants (*Lycopersicon esculentum* Mill. var. 6C-204) using wider range of SO_4^{2-} concentrations (0-105 meq/l). They found out that fruit yields were negatively affected by both S-deficiency and high SO_4^{2-} levels (45, 75 and 105 meq/l). Reduction in yield was attributed, under S-deficiency conditions, to the abortion of flower buds and in high SO_4^{2-} concentration treatments to high osmotic concentration or enhanced excess uptake of certain ions, which could contribute to reduced Ca^{++} transport to fruits. Noticeable yield reduction was observed only at S-deficiency and/or high SO_4^{2-} (45-105 meq/l). Also, Haward and Long [12] pointed out that reduction in tomato fruit weight was not large at Na salt concentration of 40 meq/l (75% as SO_4^{2-}) but was decreased sharply at Na concentration of 80 meq/l (60 meq/l SO_4^{2-}). Therefore, the SO_4^{2-} concentrations in the range used in this study (15-45 meq/l) did not result in harmful effect on tomato plants. Also, the results are in agreement with the previous studies and confirm the conclusion that tomato plants were able to grow under wide range of SO_4^{2-} without considerable yield reduction.

Table 3. Total yield and yield components of tomato fruits as affected by sulfate level in the irrigation water

SO_4^{2-} meq/l	Total yield g/plant	No. of fruit/plant	Avg. fruit wt. g
15	115.0 a	6.9 a	19.7 a
30	129.1 a	5.4 ab	25.7 a
45	96.3 a	4.4 b	23.7 a

Means in each column followed by the same letter are not significantly different at $P \leq 0.05$.

Table 4 shows the fresh weight (FW), dry weight (DW) and maximum length (ML) of root system as affected by SO_4^{2-} levels. High SO_4^{2-} level (45 meq/l) resulted in an increase in FW, DW and Ml of roots. This result is in line with the same observation reported by Cedra *et al.* [1]. They mentioned that, the top growth was more negatively affected by excess SO_4^{2-} than root growth.

Table 4. Fresh weight, dry weight, and maximum length of root system as affected by SO_4^{2-} levels in the irrigation water

SO_4^{2-} meq/l	*FW (g)	**DW (g)	***ML (cm)
15	3.96 b	1.36 b	29.71 ab
30	4.01 b	1.34 b	26.34 b
45	7.11 a	2.31 a	40.11 a

Means in each column followed by the same letter are not significantly different at P≤0.05.
* FW : Fresh weight
** DW : Dry weight
***ML : Maximum length of root system.

Nutrients uptake

Data presented in Table 5 show that in Marmande cultivar at the second stage, the uptake of all nutrients (N, P, K, SO_4, Fe, Zn, Mn, Cu) was significantly (P≤0 05) increased by increasing SO_4^{2-} concentration. However, with Pearson cultivar, this response was inconsistent. The nutrients uptake were not significantly different at the first and third stages for both cultivars (data not shown). The pronounced effect of SO_4^{2-} treatment at the second stage may be attributed to the fact that plant at this stage were at their highest physiological activity, flowering and fruit set were progressing. Therefore, plants uptake of nutrients were reflecting the effect of SO_4^{2-} level.

Table 5. Effect of SO_4^{2-} level in the irrigation water on macro and micro nutrient uptake by two tomato cultivars

Cultivar	Treatment SO_4^{2-} meq/l	N	P	K	SO_4	Fe	Zn	Mn	Cu
		mg/pot							
Marmande:	15	75.0	10.3	91.0	21.6	1.2	0.29	0.29	0.04
	30	165.6	17.6	225.9	49.3	2.2	0.58	0.59	0.08
	45	266.0	23.2	373.6	62.1	2.4	0.92	0.71	0.13
Pearson:	15	183.4	26.1	278.4	53.3	2.2	0.71	0.76	0.12
	30	124.4	12.1	185.1	42.0	2.6	0.49	0.53	0.07
	45	209.8	18.6	323.9	55.6	1.9	0.70	0.73	0.12
	LSD(0.05)	17.4	3.5	48.9	6.9	1.0	0.18	0.15	0.12

Soil EC, SAR and pH

Table 6 shows the final EC, SAR and pH of soils. Data show that the increase in SO_4^{2-} level resulted in a significant ($P \leq 0.05$) increase in soil SAR and pH. Also, higher accumulation of salts occurred by increasing SO_4^{2-} level from (15-30 meq/l) but further increase in SO_4^{2-} resulted in a drop in soil EC (Table 6). Apparently, this can be partially attributed to precipitation of gypsum at higher SO_4^{2-} level. Papadopoulos [2] reported that salt accumulation was substantially less with only SO_4^{2-} in irrigation water than with 1:1 mixture of $NaCl+CaCl_2$ having comparable EC. Also, it seems that soil SAR was not high enough to affect the yield of tomato plants (8.45 – 12.73) (Table 6).

Table 6. Effect of SO_4^{2-} level on soil SAR, pH and EC at the end of the experiment.

SO_4^{2-} level meq/l	SAR	pH	EC dS/m
15	8.45 c	7.52 c	6.33 b
30	11.26 b	7.66 b	8.87 a
45	12.73 a	7.86 a	7.97 a

Means in each column followed by the same letter are not significantly different at $P \leq 0.05$.

Total soluble solids (TSS) and the fruit acidity (Table 7) significantly increased at high SO_4^{2-} level (45 meq/l). Such increase in acidity by sulfate may be attributed to the acidity effects of SO_4^{2-} stored in leaves and fruits as mentioned by Thomas [13] and Zidan *et al.* [14].

Table 7. Acidity, vitamin C, TSS and pH of tomato juice as affected by SO_4^{2-} levels

SO_4^{2-} level meq/l	Acidity%	*V.C.%	**TSS% dS/m	pH
15	0.92 b	20.62 ab	8.96 b	3.73 a
30	0.83 b	17.47 b	9.43 b	3.77 a
45	1.34 a	21.80 a	11.37 a	3.80 a

Means in each column followed by the same letter are not significantly different at $P \leq 0.05$.
* V.C. : Vitamin C
**TSS : Total soluble solids

In conclusion, it is suggested that water having SO_4^{2-} concentration in the range of (15-45 meq/l) can be easily tolerated by tomato plants. Considering that SO_4^{2-}concentration in the irrigation waters in the Kingdom of Saudi Arabia rarely exceed these values. It is expected that it would not restrict tomato plant yield and could be used safely.

Acknowledgement. The authors wish to thank Dr. Safwat Khalil, Dr. Ahmed Al-Shal and Mr. Mohammed Osman for their technical help and supervising greenhouse work.

References

[1] Cedra, A.; Martinez, V.; Caro, M. and Fernandez, F.G. "Effect of Sulphur Deficiency and Excess on Yield and Sulphur Accumulaiton in Tomato Plants." *J. Plant Nutrition,* 7(1984), 1529-1541.

[2] Papadopoulos, I. "Effect of Sulphate Waters on Soil Salinity, Growth and Yield of Tomatoes." *Plant and Soil,* 81 (1984), 353-363.

[3] Papadopoulos, I. "Soil Salinity as Affected by High Sulphate Water." *Soil Scien,* 140 (1985), 376-383.

[4] Doneen, L.D. *Studies on Water Quality Criteria.* Univ. Calif. Water Resources Center. (1958), 46-56.

[5] Doneen, L.D. and Handerson, D.W. "Quality of Irrigation Water and Chemical and Physical Properties of Soil." *Trans. 7th Int. Congr. Soil Sci.* 1(1960), 516-522.

[6] Cedra, A.; Fernandez, F.G.; Caro, M. and Gruillen, M.G. "Growth and Mineral Composition of Two Lemon Varieties irrigated with Saline Waters." *Agrochimica.* 23 (1979), 387-396.

[7] Rhoads, J.D.; Ingralson, R.D.; Tuckar, J.M. and Clark, M. "Salts in Irrigation and Drainage Waters. 1. Effect of Irrigation Water Composition, Leaching Fraction and Lime of the Year on the Salt Compositions of Irrigation Drainage Waters." *Soil Sci. Soc. Am. Proc.* 37(1973), 770-774.

[8] Rhoades, J.D.; Usler, J.D. and Ingralson, R.D. "Minimizing the Salt Burdens of Irrigation Drainage Waters." *J. Environ. Qual.* 3(1974), 311-316.

[9] Tang, K.K. and Biggar, J.W. "Specific Conductance Model for Natural Water and Soil Solutions of Limited Salinity Levels." *Water Resources Research.* 8(1972), 145-153.

[10] Chapman, H.D. and Pratt, P.F. *Methods of Analysis of Soil Plant and Waters.* Univ. Calif. Div. Agric. (1961).

[11] Black, C.A. *Methods of Soil Analysis.* Madison, Wisc.: Amer. Soc. Agron., 1965.

[12] Haward, H.E. and Long, E.M. "Some Effects of Sodium Salts on the Growth of Tomato." *Plant Physiol.* 18(1943), 556-569.

[13] Thomas, M.D. "Agricultural Research with Radioactive Sulphur and Arsinic." *Proc. Auburn. Conf. Radioactive Isotopes in Agricultural Research. Alabama Polytechnic Institute, (1947). Cited after Beaton, J.D. Soil Sci. 101 (1966), 267-282.*

[14] Zidan, E.A.; Al-Shal, M.A.; Khalf-Allah, A.M. and Rabiea Gacal, M. "Yield and Quality of Tomatoes as Affected by Methods and Levels of Sulphur Application." *Proc. 4th Veg. Res. Conf. Alex. Univ. Egypt.* (1973), 157-166.

استجابة صنفين من الطماطم للري بالمياه الكبريتية

عبدالله سعد المديهش و عبدالله عبدالرحمن السعدون

قسم علوم التربة وقسم الإنتاج النباتي، كلية الزراعة، جامعة الملك سعود،

الرياض، المملكة العربية السعودية

ملخص البحث. تمت هذه الدراسة في أصص تحت ظروف الصوبة الزجاجية لمعرفة تأثير الري بمياه كبريتية ذات تركيزات مختلفة من الكبريتات (١٥، ٣٠ و ٤٥ ملليمكافىء/لتر) على نمو وإنتاجية صنفين من الطماطم Pearson و Marmande في تربة جيرية (٢٦,٥٪ كربونات كالسيوم) رملية طميية.

دلت النتائج على أن الوزن الكلي للثمار ومتوسط وزنها لم يتأثرا معنويًا بالري بالمياه الكبريتية في حين كانت الزيادة معنوية ($P \leq 0.05$) لكل من وزن الجذور وأقصى طول للجذور والحموضة و TSS للثمار عند المستوى العالي من الكبريتات (٤٥ ملليمكافىء/لتر).

أظهرت الدراسة أيضًا أن امتصاص عناصر النيتروجين، الفوسفور، البوتاسيوم، الكبريتات، الحديد، الزنك، المنجنيز، النحاس من قبل صنف Marmande كان معنويًّا ($P \leq 0.05$) في الطور الثاني من النمو (٦٩ يومًا). كما تبين من الدراسة أن الري بالمياه الكبريتية قد زاد بشكل معنوي من pH و SAR التربة.

تحت ظروف هذه الدراسة اتضح أنه عند ري نباتات الطماطم بمياه ذات مستوى تركيز من الكبريتات يتراوح بين ١٥-٤٥ ملليمكافىء لتر فإنه يمكن لنباتات الطماطم تحمل تلك التركيزات بدون أن تحد من نموها أو إنتاجيتها.