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IMPACT OF WATER QUALITY AND IRRIGATION SYSTEM ON SOME NUTRIENT CONTENTS IN BOTH SOIL AND TOMATO PETIOLES.

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ABSTRACT

Two field experiments were carried out during the two early-summer growing seasons of 2003 and 2004 on a sandy soil at El-Gebeel area, South Sinai to study the effect of both irrigation water quality (WQ) and surface drip (SD) or subsurface drip (SSD) irrigation systems on nutrient levels in soil and tomato petioles. Five water resources with different salinity levels were used (WQ1 = 0.88 dS/m as control, WQ2 = 1.90, WQ3 = 3.98, WQ4 = 6.20, and WQ5 = 10.00 dS/m) for irrigating tomato (*Lycopersicon esculentum* Mill cv. GS).

Data obtained showed that petiole N and P concentrations were significantly increased with increasing salinity levels of the applied irrigation water, while petiole K concentration exhibited an opposite trend. On the other hand, micronutrients (i.e., Fe, Mn, Zn, and Cu) had no specific trend. As for the effect of irrigation system (IS), results revealed that SSD irrigated plants had petiole nutrient concentrations higher than those of SD irrigated ones at any WQ treatment. Distribution and concentrations of the studied nutrients in the soil were significantly influenced by WQ, IS, soil depth, and their interaction effects, with the exception of N and Cu for the later effect.

Keywords: Drip irrigation, Water quality, Tomatoes, Sandy soil.

INTRODUCTION

Under arid and semi-arid climate, water scarcity, high salinity of the available irrigation waters, and sandy soil conditions the drip irrigation system is proved to be the most effective one amongst the irrigation systems (Bucks *et al.*, 1982). Drip irrigation (surface or subsurface system) has grown dramatically during the last decades because it has considerable potential to address some of the pressing concerns related to water and nutrients conservation (Bar-Yosef *et al.*, 1989). However, surface and subsurface drip irrigation systems are intensive management ones in which achieving the benefits require greater attention to details (Hutmacher *et al.*, 1992). Information about petiole nutrient status and nutrients distribution in soil under surface drip (SD) and subsurface drip (SSD) irrigation systems are amongst these details which will improve our understanding of some factors affecting root growth and distribution in the soil and elucidate some processes and conditions, which affect plant development and yield. Thus, the objective of the current research was to study the nutrient status in both soil and tomato petioles at a certain period under SD and SSD irrigation methods using irrigation groundwater with different salinity levels (different qualities).

MATERIALS AND METHODS

Two field experiments were carried out during the two early-summer growing seasons of 2003 and 2004 on a sandy soil at El-Gebeel area in southern Sinai. The soil was sandy in texture and had a pH value of 8.30, low content of organic matter (0.26%) , and low concentrations of macro and micronutrients. Forty m^3 of farmyard manure (FYM), 300 kg calcium super phosphate, and 100 kg potassium sulphate per feddan were applied before planting followed by a 25-30 cm deep ploughing and the beds were then constructed. Iron, Mn and Zn fertilizers as EDTA compounds were added as a foliar application at 0.25 mg/kg each in two doses; i.e., 40 days after transplanting and two weeks after the first one. Tomato seedlings were transplanted on 15th and 18th of February in 2003 and 2004, respectively. Treatments included water resources (WQ) with 5 salinity levels (i.e., WQ1 = 0.88 dS/m as control, WQ2= 1.90, WQ3 = 3.98, WQ4 = 6.20, and WQ5 = 10.00 dS/m) and two irrigation systems (IS); i.e., surface drip (SD) and subsurface drip (SSD) irrigation system. The experiments were designed as split plot randomized complete block with three replicates. The WQ treatments were the main plots and IS treatments the subplots. Analyses of the used soil, FYM, and irrigation waters are shown in Tables (1, 2 and 3). Details of soil, water, and FYM analyses as well as, the added water and fertilizers were presented in a companion paper (Rehan, 2005).

Table 1. Some chemical and physical characteristics of the experimental soil.

Soil depth	pH†	EC‡ dS/m	Soluble cations‡, me/l				Soluble anions, me/l				OM %	Particle size dist. %		
Cm			Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4		Sand	Silt	Clay
00-20	8.30	0.95	2.61	2.59	4.35	0.58	----	2.39	4.87	2.85	0.26	92.60	1.70	5.70
20-40	8.20	0.66	2.79	2.12	1.48	0.52	----	2.19	1.67	3.05	0.30	95.20	2.00	2.80
40-60	8.40	0.51	1.87	1.23	1.61	0.51	----	2.07	1.54	1.61	0.20	96.00	1.60	2.40

† Determined in 1:2.5 soils : water suspension.

‡ Determined in saturation paste extract according to Richards (1954).

Table 2. Chemical composition of the used farmyard manure (FYM)†.

N	P	K	Fe	Mn	Zn	Cu	OC‡
----------------%----------------			-------------------------------ppm-------------------------------				
0.41	0.13	0.62	70.0	60.0	25.0	12.0	30.2

†Total contents as oven dry basis.

‡ OC = organic carbon.

Leaf petiole samples from the fourth mature leaf down from the terminal (a standard position for tomatoes) were randomly selected at the early morning (Phene *et al.*, 1988) on April 1st and April 3rd in the two seasons, respectively (about 45 days after transplanting). The samples were then prepared for NO_3-N, P, K, Fe, Mn, Zn, and Cu analyses according to Chapman and Pratt (1965). The soil was sampled at three depths; 0-20, 20-40, and 40-60 cm from the soil surface and at a lateral distance of 10 cm from the emitter. Soil samples were prepared for the following analyses: mineral N was extracted with 1.0 M KCl (1:5) and determined using the steam-distillation method to include NO_3 and NH_4 ions (Black, 1965), available P was extracted with 0.50 M $NaHCO_3$ solution according to Olsen *et al.* (1954) and determined according to Watanabe and Olsen (1965), available K was extracted with 1.0 M ammonium acetate solution and determined by flame photometer (Richards, 1954), available Fe, Mn, Zn, and Cu were extracted with DTPA solution (Lindsay and Norvell, 1978) and determined by atomic absorption spectrophotometer (Perkin Elmer 3300).

Table 3. Water analyses of the studied groundwater wells and the corresponding potential for expected problems.

Water quality parameter	WQ1	WQ2	WQ3	WQ4	WQ5
PH	7.50	7.45	7.70	7.66	6.82
EC, dS/m	0.88	1.90	3.98	6.20	10.00
Soluble ions, me/L					
Ca	3.54	2.20	5.20	10.00	16.20
Mg	0.46	8.00	17.80	28.75	52.95
Na	4.50	8.90	15.90	29.03	40.17
K	0.25	0.20	0.23	0.42	0.73
CO_3	----	----	----	----	----
HCO_3	1.40	5.20	8.00	12.00	20.50
Cal	5.10	10.00	19.50	42.00	50.25
SO4	2.35	4.10	11.63	13.78	39.25
SAR†	3.14	3.94	4.69	6.60	6.83
Adj. SAR‡	3.08	4.15	5.07	7.38	7.64
SI§	-0.30	+0.45	+1.20	+1.46	+1.12
Total micronutrient, ppm					
Fe	0.02	0.04	0.04	0.04	0.02
Mn	0.03	0.03	0.03	0.04	0.04
Zn	0.04	0.04	0.07	0.03	0.04
Cu	0.06	0.04	0.05	0.05	0.04
Boron, ppm	0.25	0.40	0.26	0.32	1.18
Potential for problems¶					
Salinity problem	(S-M)¶	(S-M)¶	Severe¶	Severe	Severe
Infiltration	None¶	None	None	None	None
Boron toxicity	None	None	None	None	(S-M)
Clogging	-	+	+	+	+

† SAR= sodium adsorption ratio and ‡ = adjusted SAR, both calculated according to Ayers and Westcot (1985). § SI = saturation index ; is an indicator for a tendency for $CaCO_3$ to precipitate from the water and can be used as an indicator for clogging problem. SI is defined as the actual pH of water (pHa) minus the theoretical (pHc) that the water could have if in equilibrium with $CaCO_3$; SI=pHa-pHc (Ayers and Westcot, 1985). Water having positive values (+) should be considered as potential problem water for use through drip systems and the need for preventative measures should be considered in designing the drip system. ¶ water quality is judged on the potential severity of problems that can be expected to develop during long-term use and is divided into three categories; "None" means no restriction on use, (S-M) means slight to moderate range, and (Severe) means severe restriction category.

Statistical analysis was carried out to determine LSD values at 0.05 probability levels for identifying the significance of main plot, subplots and their interaction effects (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Leaf petiole nutrient status

Data in Table (4) revealed that concentrations of NO_3-N, P, K, Fe, Mn, Zn, and Cu in tomato leaf petioles were significantly influenced by WQ, IS, and their interaction effects. In general, increasing salinity levels of irrigation water resulted in an increase in petiole NO_3-N concentration of plants irrigated through either SD or SSD irrigation systems compared to the control (WQ1-SD or WQ1-SSD). However, these increases were not related with the increases in irrigation water salinity; i.e., under SD irrigation system, petiole NO_3-N concentration increased to a maximum value of 3.62% with increasing water salinity to 1.90 dS/m (WQ2) then decreased gradually with increasing irrigation water salinity (Table 5). A similar trend was observed under SSD irrigation system except that the maximum value was attained with irrigation water salinity of 3.98 dS/m (WQ3). At WQ1 Or WQ2, the petiole NO_3-N concentrations were lower in SSD than in SD irrigated plants, increasing the salinity of the irrigation water above 1.90 dS/m (WQ2) resulted in an opposite trend. Bar-Yosef *et al.* (1991a and 1991b) found, using non-saline irrigation water in their studies, that petiole NO_3-N concentrations were lower in SSD than in SD irrigated plants. This contradiction comes from the adverse effect of salts in the applied irrigation water (Kafkafi, 1984). It is noteworthy that petiole NO_3-N concentrations in all treatments and in both the studied seasons were above the deficient level of 0.80 % in this crop development stage. Petiole P concentration followed almost a similar trend as that of petiole NO_3-N concentration.

Table 4. Analysis of variance for the effects of water quality (WQ) and irrigation system (IS) on some nutrient concentrations in tomato leaf petioles in 2003 and 2004.

Source of variance	N	P	K	Fe	Mn	Zn	Cu
	2003						
Replication	NS	NS	NS	*	NS	NS	NS
Water Qual., WQ	***	***	***	***	***	***	***
Irrig. Syst., IS	***	NS	***	***	***	***	*
WQ X IS	***	*	***	*	***	***	*
CV %	4.22	4.47	2.29	3.88	3.70	6.93	13.79
	2004						
Replication	NS	NS	NS	NS	NS	NS	NS
Water Qual., WQ	**	***	***	***	***	***	***
Irrig. Syst., IS	***	***	***	***	***	***	*
WQ X IS	***	***	***	NS	***	***	***
CV %	6.94	4.50	10.32	3.71	5.30	5.36	6.62

*,**,*** Significant at the 0.05, 0.01, and 0.001 probability levels, respectively; NS, not significant.

Contradictory to petiole NO_3-N and P concentrations, petiole K concentration decreased with increasing irrigation water salinity either under SD or SSD irrigation systems. This decrease in petiole K concentration could have stemmed from the reduced root volume under drip irrigation with saline waters (Kafkafi, 1984; Rehan, 2005) in addition to the Na^+-induced K^+ phenomenon as reported by Bower and Wadleigh's (1948), who found that when K^+ was supplied in a sand resin mixture at a constant rate, accumulation of this cation by the root plant was greatly depressed as the proportion of exchangeable Na^+ was increased . Meanwhile, Hecht-Bucholtz *et al.* (1974) suggested that the Ca^{++} present in sufficient concentration is needed to prevent the Na^+-induced K^+ efflux in salt-sensitive plants. This means that Ca^{++} can alleviate the adverse effect of the Na^+-induced K^+ phenomenon that may interpret the inconsistency of decreased petiole K with increasing salinity of the used irrigation waters that were greatly different in their K^+, Na^+ and Ca^{++} concentrations (Table 3). Petiole K concentration in all treatments were far below the reported range for the optimum yield of SD or SSD irrigated tomatoes under non-saline condition; i.e., 38.3 - 48.0 mg/g (Bar-Yosef *et al.*, 1991b) and also far below the deficient level of 30.0 mg/g for tomatoes at the same growth stage (Walsh and Beaton, 1973).

Table 5. Effect of water quality (WQ) and irrigation system (SD or SSD) on NO_3-N, P, K, Fe, Mn, Zn, and Cu concentrations in tomato leaf petioles in 2003 and 2004.

WQ Treatment	N		P		K		Fe		Mn		Zn		Cu	
	SD	SSD	SD	SSD	SD	SSD	SD	SSD	SD	SSD	SD	SSD	SD	SSD
	---------- % ----------						---------- mg kg^{-1} ----------							
	2003													
WQ1	3.60	3.23	0.240	0.235	1.060	1.082	67.30	66.66	55.63	43.00	12.00	14.67	4.83	2.00
WQ2	3.62	3.26	0.272	0.253	1.043	1.040	78.33	73.33	57.00	66.00	17.00	21.67	6.67	7.00
WQ3	3.35	3.91	0.263	0.269	0.813	0.950	65.00	55.33	49.00	32.67	10.33	21.00	4.00	5.00
WQ4	2.99	3.03	0.245	0.260	0.806	0.801	80.23	70.67	72.67	66.00	22.40	24.00	6.30	5.00
WQ5	2.96	3.00	0.210	0.200	0.533	0.500	56.00	42.67	45.67	35.33	12.00	18.00	5.20	3.00
LSD (0.05)														
LSD[†]	0.25		0.045		0.051		4.61		3.52		2.19		1.23	
LSD[‡]	0.23		0.043		0.056		5.03		4.73		1.79		1.30	
	2004													
WQ1	2.33	2.30	0.220	0.217	1.070	0.930	209.3	195.0	20.70	23.30	10.00	20.00	25.70	32.30
WQ2	2.35	2.30	0.243	0.240	0.710	0.830	197.0	164.3	45.30	46.00	4.70	8.30	32.70	28.00
WQ3	2.03	2.74	0.227	0.250	0.650	0.680	149.0	121.0	15.00	21.70	5.40	4.70	21.50	25.70
WQ4	1.99	2.00	0.222	0.223	0.570	0.560	186.3	163.7	17.00	30.30	12.70	34.00	14.70	27.00
WQ5	1.89	1.90	0.190	0.200	0.500	0.510	117.3	96.0	13.70	12.00	2.70	2.80	24.70	13.30
LSD (0.05)														
LSD[†]	0.28		0.045		0.191		NS		2.26		1.03		2.96	
LSD[‡]	0.35		0.043		0.209		NS		2.00		1.18		2.85	

LSD[†] for comparison between two IS means at the same level of WQ treatment, LSD[‡] for comparison between two WQ means at the same or different level of IS

Micronutrient concentrations in tomato leaf petioles (i.e., Fe, Mn, Zn, and Cu) showed no specific trend in response to WQ or IS treatments in spite of the significance of WQ and IS as main effects and their interactions (WQ X IS). This behavior may attributed to the fact that most of the applied micronutrients were added as a foliar application and the rest were derived from the applied FYM. Comparing the petiole micronutrient concentrations with those found in "normal" tomato plants at the same growth stage (i.e., 100-300 mg/kg for Fe, 60-100 mg/kg for Mn, 15-30 mg/kg for Zn, and 4-8 mg/kg for Cu) we can see from Table (5) that petiole Fe concentrations in the first season were less than normal range, while in the second season were within the normal range. Manganese and Zn concentrations showed an opposite trend to that of Fe concentration while petiole Cu concentrations in both seasons were within the normal range.

Available nutrient contents in soil

An analysis of variance for treatment effects on soil nutrient contents in the upper 60-cm layer of the soil revealed that, except for N and Cu concentrations, nutrients concentrations were significantly influenced by WQ, IS and SL (soil layer) treatment main effects and their interaction effects (WQ X IS X SL interaction) as shown in Table (6).

Table 6. Analysis of variance for the effects of water quality (WQ) , irrigation system (IS), and soil layer (SL) on some nutrients concentrations in the soil in 2003 and 2004.

Source of variance	N	P	K	Fe	Mn	Zn	Cu
				2003			
Water Qual., WQ	***	***	***	***	***	***	***
Irrig. Syst., IS	*	***	NS	***	***	***	NS
WQ X IS	*	**	***	***	***	***	NS
Soil layer, SL	***	***	***	***	***	***	***
WQ X SL	NS	***	***	***	***	***	***
IS X SL	**	***	***	***	***	***	NS
WQ X IS X SL	NS	***	**	*	***	***	NS
CV %	12.37	9.38	9.63	8.84	8.91	9.76	22.27
				2004			
Water Qual., WQ	**	***	***	***	***	***	***
Irrig. Syst., IS	NS	***	NS	***	***	NS	***
WQ X IS	*	***	NS	***	***	*	***
Soil layer, SL	***	***	***	***	***	***	***
WQ X SL	**	***	***	***	***	***	***
IS X SL	***	***	***	***	***	***	***
WQ X IS X SL	NS	***	***	***	***	***	NS
CV %	13.37	10.87	9.61	10.84	13.12	14.99	12.04

*,**,*** Significant at the 0.05, 0.01, and 0.001 probability levels, respectively; NS, not significant.

Soil N levels were low through the upper 60-cm soil layer before the initiation of the experiment; i.e., the background N levels ranged from 1.3

to 5.1 mg Nkg^{-1} soil (Table 7). This was expected since the studied soil was sandy in texture and consequently poor in plant nutrients. At any WQ treatment , the N concentration (NO_3-N + NH_4-N forms) under SD irrigation system was higher in the first layer (0-20-cm soil layer); i.e., near the emitter, than in the followed layers and then tended to decrease gradually with depth. For example, at WQ1 level and under SD system, the soil N concentration decreased from 37.8 mg Nkg^{-1} soil in the 0-20-cm soil layer (near the emitter) to 27.8 mg Nkg^{-1} soil in the second soil layer and decreased further to 23.0 mg Nkg^{-1} soil in the third one (40-60-cm). Increasing salinity of the irrigation water resulted in an increase in the corresponding above-mentioned three soil N concentrations at any of WQ treatment (i.e., WQ2, WQ3, WQ4, or WQ5 level).

Table 7.Soil N (NO_3-N + NH_4-N) and available P and K concentrations (mg kg^{-1} soil) as affected by water quality (WQ) and irrigation system (IS) and soil layer (SL) in 2003.

Treatment		N			P			K		
Water quality	Soil layer	Init.¶	SD	SSD	Init.	SD	SSD	Init.¶	SD	SSD
	cm									
WQ1	0 – 20	1.30	37.3	24.0	6.0	29.27	10.19	18.0	140.3	138.7
WQ1	20 – 40	1.40	27.8	32.6	6.0	6.30	14.97	28.0	99.9	172.0
WQ1	40 – 60	1.60	23.0	22.7	4.0	3.60	8.00	45.0	48.2	102.5
WQ2	0 – 20	4.50	45.9	26.3	12.0	28.58	14.54	35.0	241.0	126.7
WQ2	20 – 40	5.10	25.3	38.4	10.0	14.30	22.60	73.0	192.7	194.7
WQ2	40 – 60	3.30	23.5	28.8	10.0	9.97	11.97	100.0	194.0	173.0
WQ3	0 – 20	2.80	48.0	36.5	15.0	54.10	14.57	35.0	155.0	97.2
WQ3	20 – 40	2.40	30.2	40.0	10.0	19.27	22.27	48.0	141.7	134.7
WQ3	40 – 60	2.70	25.4	31.8	10.0	11.60	19.97	80.0	124.7	124.1
WQ4	0 – 20	3.90	50.0	38.4	15.0	38.47	15.93	38.0	177.0	128.5
WQ4	20 – 40	3.90	30.3	43.2	11.0	12.60	28.57	63.0	158.3	234.7
WQ4	40 – 60	2.60	23.0	34.7	10.0	13.27	12.93	80.0	92.5	186.3
WQ5	0 – 20	3.20	53.3	45.6	15.0	41.27	28.97	155.0	242.7	204.3
WQ5	20 – 40	3.10	32.0	47.76	14.0	20.53	34.53	95.0	237.5	252.7
WQ5	40 – 60	1.91	27.2	38.2	10.5	16.97	13.93	108.0	222.0	226.3
LSD (0.05)										
LSD†		---	NS		---	3.07		---	26.4	
LSD‡		---	NS		---	3.50		---	27.4	
LSD§		---	NS		---	2.64		---	22.9	

¶ = Background concentration in the soil at the init. of the exp., † = LSD for comparison between two SL means at the same combination of WQ and IS , ‡ = LSD for comparison between two IS means at the same combination of WQ and SL, and § = LSD for comparison between two WQ means at the same combination of IS and SL.

Under SSD irrigation system, the pattern of soil N concentration distribution in the soil profile (0-60 cm depth) at all the WQ treatments exhibited different show than that under SD system (Tables 7and 8) ; i.e., soil N concentration was maximal in the 20-40-cm soil layer, where the emitters were placed in SSD system. Bar-Yosef *et al.* (1991b) and Phene *et al.* (1988) found also, but under non-saline irrigation water conditions, that the soil N concentration was maximal near the emitter and they attributed the relatively high N concentration in the top layer under SSD system, which was also noticed in the current study (Tables 7 and 8), to the decomposition of the organic materials (plant residues). Soil available P and K concentrations followed almost the same trend as that of N concentration with different magnitudes.

Table 8.Soil N (NO_3-N + NH_4-N) and available P and K concentrations (mg kg^{-1} soil) as affected by water quality (WQ) and irrigation system (IS) and soil layer (SL) in 2004.

Treatment		N			P			K		
Water quality	Soil layer	Init.[¶]	SD	SSD	Init.[¶]	SD	SSD	Init.[¶]	SD	SSD
	cm									
WQ1	0 – 20	1.30	60.0	48.1	6.0	14.97	7.73	18.0	269.0	172.8
WQ1	20 – 40	1.40	35.7	54.1	6.0	9.00	9.96	28.0	135.5	178.0
WQ1	40 – 60	1.60	32.2	57.7	4.0	6.93	5.00	45.0	78.9	152.7
WQ2	0 – 20	4.50	66.4	48.1	12.0	22.47	19.97	35.0	242.7	161.7
WQ2	20 – 40	5.10	39.0	50.7	10.0	19.97	30.97	73.0	216.7	294.7
WQ2	40 – 60	3.30	34.0	37.9	10.0	5.00	6.00	100.0	180.0	166.5
WQ3	0 – 20	2.80	51.7	32.0	15.0	35.00	16.70	35.0	167.0	156.5
WQ3	20 – 40	2.40	34.3	43.5	10.0	12.60	22.50	48.0	148.1	173.9
WQ3	40 – 60	2.70	20.4	27.7	10.0	11.00	18.85	80.0	153.0	154.0
WQ4	0 – 20	3.90	63.3	48.0	15.0	45.04	20.00	38.0	156.6	146.0
WQ4	20 – 40	3.90	35.4	59.7	11.0	23.00	38.01	63.0	134.0	145.0
WQ4	40 – 60	2.60	24.9	36.9	10.0	17.52	15.01	80.0	122.5	140.0
WQ5	0 – 20	3.20	59.0	33.0	15.0	74.98	32.51	155.0	437.0	269.6
WQ5	20 – 40	3.10	31.6	48.8	14.0	35.00	40.96	95.0	355.4	369.6
WQ5	40 – 60	1.91	27.4	27.9	10.5	24.72	28.63	108.0	269.3	341.9
LSD (0.05)										
LSD†		----	NS		----	4.00		----	32.2	
LSD‡		----	NS		----	3.77		----	32.5	
LSD§		----	NS		----	3.06		----	26.4	

¶ = Background concentration in the soil at the init. of the exp., † = LSD for comparison between two SL means at the same combination of WQ and IS , ‡ = LSD for comparison between two IS means at the same combination of WQ and SL, and § = LSD for comparison between two WQ means at the same combination of IS and SL.

However, the background levels of these two nutrients at the initiation of the experiment were quite high and differed greatly with depth and from site to site (Table7). It is noteworthy that all the three macronutrient concentrations; i.e., N, P, and K, at the time the soils were sampled (45 days after transplanting), were in the sufficient ranges. The increases in these nutrient concentrations in the soil with increasing salinity of the irrigation water may be due to the reduced root system (Rehan, 2005), which may reduce their absorption rate.

Micronutrient concentrations (;i.e., Fe, Mn, and Zn) in the soil profile, in general , decreased with soil depth (Tables 9 and 10). of the high-salinity applied irrigation waters (Bucks *et al.*, 1982).

Table 9. Soil available Fe, Mn, and Zn concentrations (mg kg^{-1} soil) as affected by water quality (WQ) and irrigation system (IS) and soil layer (SL) in 2003.

Treatment		Fe			M			Zn		
Water quality	Soil layer	Init¶.	SD	SSD	Init.	SD	SSD	Init.	SD	SSD
	cm									
WQ1	0 – 20	2.11	1.78	2.41	1.98	0.90	2.04	2.66	2.10	2.91
WQ1	20 – 40	1.62	1.13	0.44	1.00	0.47	0.65	0.18	0.58	1.16
WQ1	40 – 60	2.93	0.89	0.64	1.83	0.64	1.49	0.89	0.21	1.06
WQ2	0 – 20	3.29	1.49	1.56	3.78	0.61	1.08	1.16	0.58	1.88
WQ2	20 – 40	2.11	1.31	1.42	1.53	0.56	0.97	1.79	0.26	0.54
WQ2	40 – 60	1.47	1.52	1.03	1.76	0.61	1.06	1.66	0.25	0.22
WQ3	0 – 20	2.07	0.77	0.74	1.30	0.73	0.79	2.77	0.66	3.06
WQ3	20 – 40	1.84	0.88	0.75	0.89	0.55	0.82	0.48	0.15	0.24
WQ3	40 – 60	1.86	0.72	0.70	1.01	0.96	0.97	0.28	0.14	0.39
WQ4	0 – 20	2.36	1.78	1.29	1.77	1.53	2.17	2.34	0.66	1.76
WQ4	20 – 40	1.37	0.69	1.10	0.87	0.67	0.84	0.35	0.18	0.30
WQ4	40 – 60	0.77	0.60	0.51	1.26	0.48	0.82	0.68	0.98	0.27
WQ5	0 – 20	2.22	0.81	0.42	1.65	1.18	0.70	0.12	0.82	3.78
WQ5	20 – 40	0.67	0.54	0.17	0.69	0.96	0.75	0.12	0.55	0.35
WQ5	40 – 60	1.38	0.72	0.17	2.32	1.24	0.76	0.99	0.34	0.19
LSD (0.05)										
LSD†			0.15			0.14			0.12	
LSD‡			0.15			0.14			0.13	
LSD§			0.13			0.12			0.10	

¶ = Background concentration in the soil at the Init. of the exp., † = LSD for comparison between two SL means at the same combination of WQ and IS , ‡ = LSD for comparison between two IS means at the same combination of WQ and SL, and § = LSD for comparison between two WQ means at the same combination of IS and SL.

Table 10. Soil available Fe, Mn, and Zn concentrations (mg kg^{-1} soil) as affected by water quality (WQ) , irrigation system (IS) and soil layer (SL) in 2004.

Treatment		Fe			Mn			Zn		
WQ	Soil layer	Init.	SD	SSD	Init.	SD	SSD	Init.	SD	SSD
WQ1	0 – 20	2.11	3.040	2.894	1.98	2.880	1.286	2.66	2.430	2.894
WQ1	20 – 40	1.62	2.380	0.866	1.00	1.190	0.361	0.18	0.650	0.860
WQ1	40 – 60	2.93	2.229	1.571	1.83	1.690	1.590	0.89	1.110	1.570
WQ2	0 – 20	3.29	2.007	1.671	3.78	3.016	2.159	1.16	2.077	1.671
WQ2	20 – 40	2.11	2.402	0.767	1.53	0.971	1.270	1.79	1.181	0.770
WQ2	40 – 60	1.47	1.027	1.263	1.76	2.860	1.599	1.66	1.230	1.270
WQ3	0 – 20	2.07	2.040	1.780	1.30	3.088	1.310	2.77	2.820	1.780
WQ3	20 – 40	1.84	1.840	1.389	0.89	1.298	1.819	0.48	0.280	1.339
WQ3	40 – 60	1.86	1.780	0.910	1.01	2.280	1.580	0.28	1.042	0.910
WQ4	0 – 20	2.36	2.650	0.820	1.77	1.590	1.849	2.34	1.830	0.820
WQ4	20 – 40	1.37	2.650	0.900	0.87	1.150	1.499	0.35	0.330	0.800
WQ4	40 – 60	0.77	2.349	0.800	1.26	1.750	2.750	0.68	1.339	0.900
WQ5	0 – 20	2.22	2.089	1.030	1.65	2.130	1.570	0.12	1.910	1.030
WQ5	20 – 40	0.67	1.885	1.099	0.69	1.699	2.595	0.12	0.595	1.099
WQ5	40 – 60	1.38	1.670	0.931	2.32	1.710	2.400	0.99	0.619	0.931
LSD (0.05)										
LSD†			0.304			0.397			0.313	
LSD‡			0.306			0.403			0.322	
LSD§			0.247			0.304			0.266	

¶ = Background concentration in the soil at the init. of the exp., † = LSD for comparison between two SL means at the same combination of WQ and IS , ‡ = LSD for comparison between two IS means at the same combination of WQ and SL, and § = LSD for comparison between two WQ means at the same combination of IS and SL.

However, no consistent trends regarding the difference between SD and SSD irrigation system or as affected by WQ treatment levels were recognized. These results were expected since these nutrients were foliarlly applied rather than through the irrigation system (fertigation) for fear of the expected interactions between these elements and the constituents

Regarding the available Cu concentration and distribution in the soil, data in Table (6) show that WQ X IS X SL and IS X SL interaction effects were insignificant. So, data were averaged across IS treatments and presented in Table (11). At any WQ treatment level, the soil available Cu concentration was higher in the upper soil layer (0-20 cm) and decreased with the depth. Like Fe, Mn, and Zn concentrations, no consistent trend in response to irrigation water salinity was observed.

Table 11. Available Cu concentration in the soil as affected by water quality (WQ) and soil layer (SL), averaged across irrigation systems in 2003 and 2004.

Soil layer	2003					2004				
	Water quality treatment					Water quality treatment				
	WQ1	WQ2	WQ3	WQ4	WQ5	WQ1	WQ2	WQ3	WQ4	WQ5
00 – 20	0.370	1.239	0.272	0.158	0.053	0.414	0.378	0.435	0.401	0.330
20 – 40	0.042	0.147	0.048	0.033	0.060	0.176	0.174	0.350	0.190	0.192
40 – 60	0.004	0.055	0.138	0.10	0.037	0.020	0.234	0.230	0.209	0.190
LSD(0.05)										
LSD†	0.037					0.037				
LSD‡	0.046					0.039				

† LSD for comparison between two SL means at the same level of WQ.

‡ LSD for comparison between two WQ means at the same or different soil layer.

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تأثير نوعية المياه و طرق الرى على محتوى كل من التربة و أوراق الطماطم من بعض المغذيات.

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أقيمت تجربتين حقليتين خلال الموسمين الصيفيين لعامى ٢٠٠٣، ٢٠٠٤ على أرض رملية بمنطقة الجبيل – جنوب سيناء لدراسة تأثير استخدام نوعيات مختلفة الصلاحية من المياه الجوفية لمنطقة الدراسة وكذا نظامى الرى بالتنقيط السطحى و تحت السطحى على محتوى كل من التربة وأوراق الطماطم من بعض العناصر الغذائية (النيتروجين، الفوسفور، البوتاسيوم، الحديد، المنجنيز، الزنك والنحاس). وقد استخدمت مياه خمسة أبار مختلفة الملوحة (٠,٨٨ ديسيسيمنز/م كمعاملة كونترول، ١,٩٠ ، ٣,٩٨ ، ٦,٢٠ ، ١٠,٠ ديسيسيمنز/م).

ولقد أظهرت نتائج الدراسة ما يلى :

- تأثر محتوى أوراق الطماطم من العناصر الغذائية تحت الدراسة معنويا بكل من ملوحة مياه الرى ونظام الرى وكذا التفاعل بينهما، حيث ازداد محتوى الأوراق من النيتروجين والفوسفور بزيادة ملوحة مياه الرى بينما انخفض محتواها من البوتاسيوم، بينما لم يظهر تركيز العناصر الصغرى داخل الورقة اتجاها محددا حيث أن هذه العناصر قد تمت اضافتها بطريقة الرش وليس من خلال نظام الرى بالتنقيط.
- أدى استخدام نظام الرى بالتنقيط تحت سطح التربة (٢٠ سم اسفل سطح التربة) الى زيادة محتوى الاوراق من هذه العناصر مقارنة بنظام الرى بالتنقيط السطحى، وذلك عند أى مستوى من مستويات ملوحة مياه الرى.
- تأثر محتوى التربة من العناصر الغذائية تحت الدراسة تأثرا معنويا بكل من ملوحة مياه الرى ونظام الرى والعمق من سطح التربة والتفاعل بينهم (ملوحة مياه الرى X نظام الرى X عمق التربة) فيما عدا النيتروجين والنحاس؛ حيث لم يتأثرا بالتفاعل الثلاثى فى موسمى الدراسة.