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SURFACE AND SUBSURFACE DRIP IRRIGATION METHODS AND WATER QUALITY EFFECT ON ROOT AND SHOOT GROWTH AND FRUIT QUALITY OF TOMATO

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ABSTRACT

Two field experiments were conducted during two successive early summer seasons of 2003 and 2004 on a sandy soil of El-Gebeel farms, South Sinai, Egypt, to evaluate the effect of using the regional high salinity groundwater from representative wells (WQ1= 0.88 dS/m as cntrol, WQ2= 1.90, WQ3= 3.98, WQ4= 6.20, WQ5= 10.00 dS/m) in surface drip (SD) and subsurface drip (SSD) irrigation of tomato (*Lycopersicon esculentum* Mill., cv. GS) . Tomato rooting depth, shoot weight, fruit weight, fruit height, and fruit diameter significantly decreased with increasing salinity of the irrigation water relative to the control (WQ1). The reductions were about 16.3, 19.4, 25.8, and 58.1% for root length, respectively; while the corresponding reductions were 4.4, 8.7, 44.0, and 69.1% for shoot weight; and 16.9, 25.9, 55.9, and 64% for fruit fresh weight. Fruit height and fruit diameter exhibited a similar trend but in a lesser magnitudes. On the other hand, fruit total soluble solids (TSS) and vitamin C concentrations significantly increased with increasing salinity and were attributed to the reduction in fruit dry weights. Subsurface drip irrigation (20 cm below bed surface) significantly increased rooting depth and shoot weight compared to the SD one. Simple correlation coefficients among the studied parameters revealed that fruit weight or fruit size were significantly and positively correlated with root length and shoot weight and negatively with irrigation water salinity.

Keywords: Drip irrigation, subsurface drip irrigation, Water quality, Sandy soils, Tomatoes, South Sinai, Groundwater

INTRODUCTION

Sinai Peninsula, the northern gate of Egypt, has been left without development until the last two decades. Many great projects have been planned and executed to achieve this goal, especially through increasing the habitants of this important area. Since in most of the early civilization, as in many today's nations, irrigated agriculture has provided and continues to provide the agrarian basis of society (Gulhati and Smith, 1967), the transfer of Nile water to Sinai is the utmost one of these projects. However, the Nile water cannot be reached to every location in Sinai because of its vast area (≈61000 km^2) and the nature of its topography, so the groundwater is considered the only resource of water in such locations, which also receive very few, if any, precipitation. Generally, the groundwater of South Sinai is high saline (Mahmoud, 1997). Thus, and under South Sinai conditions (i.e., sandy soil, arid climate, and high saline water) the drip irrigation has the greatest potential (Bucks *et al.*, 1982). They reported three reasons for the possible improvement in salinity management with drip irrigation; i.e., (1) frequent drip irrigation can help maintain a high total soil water potential (high soil matric and osmotic potential), (2) drip irrigation with high saline irrigation water does not cause foliar damage compared with sprinkler irrigation and (3) leaching can be closely controlled. However, irrigation, practiced without restraint or knowledge of basic factors governing soil, irrigation water requirements, salinity and plant use may lead to ecological disaster (Phene *et al.*, 1990). So, greater attention to details is required to achieve the benefits of drip irrigation in general and subsurface drip irrigation in particular.

The importance of water quality evaluations for irrigation in general and drip irrigation in particular has been emphasized in a number of publications (Richards, 1954; Gupta, 1979; Bucks *et al.*, 1980; Bucks *et al.*, 1982; Ayers and Westcot, 1985). These articles emphasize the need to evaluate the irrigation water to assess the possible problems associated with the soil salinity, soil permeability, toxicity, emitter plugging, and compatibility with the chemical or nutrient solution additions through drip irrigation systems.

Tomato is considered one of the most important vegetable crops grown in newly reclaimed sandy soils (Merghany, 1997) and water plays a crucial role in determining its yield and quality (Rudich and Luchinsky, 1987).

Traditionally, tomatoes have been irrigated by furrow, sprinkler, or sub irrigation (seepage irrigation), however, several research have been carried out with surface drip (SD) and/or subsurface drip (SSD) irrigation. These research revealed that (1) for both SD and SSD irrigation systems, most of the tomato root system was concentrated in the top 40 cm of the soil profile (Machado *et al.*, 2003) and that SD or SSD did not restrict the depth of root expansion in a deep soil (Bar-Yosef *et al.*, 1991a), (2) surface drip, SD, or SSD have improved water management of tomatoes with corresponding increases in productivity, fruit quality, and in water and fertilizer use efficiencies (Locascio *et al.*, 1981; 1985; Phene *et al.*, 1988; Locascio, 1989 ; Phene *et al.*,1990 and Clark *et al.*, 1991), (3) root dry weight, shoot weight, fruit weight, and concentration of vitamin C of fruit juice were higher in SSD compared to SD irrigated tomato plants , while the total soluble solids (TSS) of tomato fruits showed a reverse trend (Merghany, 1997) on the other hand , Machado *et al.* (2003) found that tomato fruit quality was not significantly affected by emitter depth, and (4) saline water of 3 dS/m did not limit tomato yields, whereas yields did decline by 35% with water of 10 dS/m (Singh *et al.*, 1978) and that the adverse effect of saline irrigation water on tomatoes was more pronounced with furrow or sprinkler than with drip irrigation systems (Bernstein and Francois, 1973), also Seifert *et al.* (1975) found that although salt concentrations increased significantly throughout the soil profile as the irrigation water salinity increased, yields did not decline until the water quality decreased to 3.6 dS/m. It is noteworthy that data referred to in 1, 2, and 3 are of research carried out with non-saline irrigation waters except Merghany (1997) who used a groundwater of 1.7 dS/m. Thus, the objective of the current study was to evaluate the effects of using the regional high saline groundwaters of South Sinai in SD and SSD irrigation on root length, shoot weight, and fruit quality of tomato.

MATERIALS AND METHODS

Two field experiments were carried out during the early summer growing seasons of 2003 and 2004 at El-Gebeel area in South Sinai, Egypt, to evaluate the effect of water quality (WQ) and irrigation system (IS) and their interaction on root length, shoot weight, and fruit quality of tomato (*Lycopersicon esculentum* Mill., cv. GS). The treatments were arranged in a randomized split plot design and were replicated three times. The main treatments were the WQ at five 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). The sub treatments were the IS at two levels (i.e., surface drip (SD) and subsurface drip (SSD) irrigation methods). 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 N and micronutrients. The complete soil analysis is shown in Table (1) and was determined according to Black (1965) and Lindsay and Norvell (1978).

Soil preparation, prior to the installation of the irrigation lines, consisted of an addition of 40m^3/fed of farmyard manure (FYM), 300 kg calcium super phosphate, and 100 kg potassium sulphate per feddan followed by a 25-30 cm deep ploughing. Analysis of the used FYM is shown in Table (2). The remaining fertilizers (NPK) were applied through the irrigation system starting two weeks after transplanting as recommended for drip irrigated tomatoes in Egyptian sandy soils (Merghany, 1997). The same rates of fertilizers were added in the both seasons except the FYM which was not added in the second season. The experimental units were then constructed as 4 beds space 150 cm from center to center, each bed with a length of 7.0 m (6x7 m^2). The surface and subsurface drip irrigation lines were installed in the center of each bed at the top and at a depth of 20 cm from the surface of the bed. Iron, Mn and Zn fertilizers were foliarly-sprayed as EDTA compounds at 5 mg kg^{-1} soil each in a solution concentration of 500 ppm in two doses (40 days after transplanting and two weeks after the first one). The drip lines were made of polyethylene and had emitters spaced 50 cm apart with a flow rate of 4L/h. A single line per row and one emitter per plant system was used.

Forty-day-old tomato seedlings were transplanted on 15th and 18th of February in 2003 and 2004 growing seasons, respectively. The applied irrigation water was estimated from ETc (crop evapotranspiration) assuming the drip irrigation efficiency is 90% (Eid *et al.*,1999). ETc was estimated using the following formula:

$$ETc = ETo \times Kc \quad , \text{ where}$$

ETo = reference crop evapotranspiration (mm/day) calculated using a meteorological data from El-Tor weather station and according to the modified Penman method (Doorenbos and Pruitt, 1977),

Kc = crop coefficients were the average values for the following crop stages (Doorenbos and Pruitt, 1977): 0.75 for development stage (from transplanting to the beginning of fruit set =45 days); 1.1 for mid-season (from the beginning of fruit set to blooming =70 days); and 0.6 for late season.

A leaching fraction of 0.10 of the estimated ETc was added to each experimental unit.

A random sample of 10 plants per experimental unit was chosen at random to determine root length and shoot weight. The plants were carefully pulled out, washed out of soil, and separated into shoot and root. Average fruit weight, fruit diameter, and fruit height were determined using a sample of 100 ripe fruits. Fruit juice quality;i.e., acidity as pH or as citric acid content; TSS%; and vitamin C were determined in a sub sample representing three harvest dates in both seasons following the methods reported in AOAC (1965).

Water samples were collected and analyzed according to the methods reported in APHA (1989).

Analysis of variance (ANOVA) was used to determine the significance of main effects and their interactions. Least significant difference (LSD) values were calculated, when significant treatment effects were detected, for comparison between two IS means at the same or different level of WQ and for comparison between two WQ means at the same level of IS (Gomez and Gomez, 1984). Differences were determined at the 5% level of probability. Correlation coefficients were calculated using the data averaged across seasons, IS, and replications to determine the relationships between water salinity and each of the studied parameters and among these parameters as well. All analyses were performed utilizing the MSTAT-C Statistical Package (Freed *et al.*, 1989).

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

Soil depth Cm	pH†	EC‡ dS/m	Soluble cations‡, me/l				Soluble anions, me/l				OM %	Particle size dist. %		
			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

† In 1:2.5 soil : water suspension.
‡ 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‡
------------%------------			--------------------mg/kg----------------				%
0.41	0.13	0.62	70.0	60.0	25.0	12.0	30.2

† Total contents as oven dry basis.
‡ Organic carbon

RESULTS AND DISCUSSION

Climatic data for the experimental area are shown in Table (3). The most pronounced aspect of climatic parameters relative to the crop yields is the great difference between pan evaporation and precipitation rate either during the studied period or as an average of 48 years (from 1919 to 1967). Data reveal also that there was no great variation in the climatological parameters from year to year during the studied period.

Table 3: Selected climatic parameters for the studied area[†]

Month	Monthly rainfall	Pan evaporation	Mean daily air temperature, C°	
	Mm	mm/day	minimum	maximum
Feb.	1.3 (1.3)[‡]	7.8 (7.8)[‡]	9.7	21.7
March	1.2 (1.2)	9.0 (9.2)	12.6	24.2
April	0.2 (0.2)	9.9 (10.2)	16.5	27.9
May	0.2 (0.2)	10.6 (11.1)	20.5	20.7

† Data collected from El-Tor Meteorological Station

‡ Data in brackets are the mean values for the period 1919-1967.

Water quality assessment

Data in Table (4) exhibit the main characteristics and the corresponding suitability assessment of the used irrigation waters from the standpoint of potential severity of problems that can be expected to develop during long-term use.

Table 4: Water analyses of the studied groundwater wells and the corresponding potential for expected problems

Water qual. 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, meq/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	nil	nil	nil	nil	nil
HCO_3	1.40	5.20	8.00	12.00	20.50
Cl	5.10	10.00	19.50	42.00	50.25
SO_4	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 problem	None[¶]	None	None	None	None
Boron toxicity	None	None	None	None	(S-M)
Clogging problem[§]	-	+	+	+	+

† 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.

These problems are those related to salinity, water infiltration rate, toxicity, and clogging of drip emitters (Ayers and Westcot, 1985). In general, soil salinity and emitters clogging are the pronounced problems that can be expected to develop due to long-term use of these waters in irrigation, especially WQ3, WQ4, and WQ5 groundwater resources. No infiltration or toxicity problems are expected to develop due to using the studied irrigation waters, except WQ5 which rated as "Slight to Moderate" restriction in use in regard to Boron toxicity problem.

Root and shoot growth

Root length and shoot weight were significantly influenced by WQ and IS in the both growing seasons, except shoot weight in the first season which was not significantly affected by IS main effect. The WQ X IS interaction effects on both parameters were not detected (Table 5).

Table 5: Analysis of variance for root length, shoot weight, and fruit quality parameters in 2003 and 2004.

SOV	Root length	Shoot wt.	Fruit wt.	Fruit ht.	Fruit diam.	pH	Citric acid	Vit. C	TSS
					2003				
Replication.	NS	NS	NS	NS	NS	NS	NS	NS	NS
Water quality, WQ	***	***	***	NS	*	NS	*	*	*
Irrig. System, IS	*	NS	NS	***	NS	NS	*	***	NS
WQ X IS	NS	NS	NS	***	NS	NS	***	***	NS
CV %	20.73	22.89	25.85	0.82	20.34	17.4	4.47	11.76	14.9
					2004				
Replication.	NS	NS	NS	NS	NS	NS	NS	NS	NS
Water quality, WQ	***	***	***	*	***	NS	NS	NS	†
Irrig. System, IS	**	*	*	**	NS	NS	***	**	NS
WQ X IS	NS	NS	NS	*	NS	NS	***	†	NS
CV %	15.21	17.08	7.35	6.10	14.61	7.72	2.41	11.73	13.5

†,*,**, *** Significant at 0.10, 0.05, 0.01, and 0.001 probability levels, respectively; NS, not significant.

A consistent decline in root and shoot growth with increasing irrigation water salinity were observed. Reductions in root length, averaged across IS treatments, were about 16.3, 19.4, 25.8, and 58.1% relative to the control (WQ1) in the first season, respectively (Table 6). Regarding the effect of IS on root length, SSD irrigation system stimulated root growth deeper in the soil profile than SD one. The average root length, across WQ treatments, was 38.4 cm for SSD compared to 32.3 cm for SD treatment. Shoot weight followed almost the same trend as that of the root length, where the corresponding reductions in shoot weight relative to the control were 4.4, 8.7, 44.0, and 69.1%. Subsurface drip, SSD, irrigation system produced plants that had shoot weight greater than those under SD irrigation system. Root length and shoot weight data of the second season exhibited similar trends as those of the first season (Table 7). However, the adverse effects of irrigation water salinity on root and shoot growths were greater in the second season than in the first one. For example, the root length and shoot weight of plants irrigated with QW1 treatment (control), averaged over IS treatments, were reduced from 46.5 cm and 810.3 gm/plant in the first season to 35.5 cm and 735 gm/plant in the second season (about 23.6 and 9.3% reduction, respectively). A comparable trend was existed in almost all the studied WQ treatments (Tables 6 and 7). Root growth enhancement is considered to be an important criterion, it is a dynamic process responding to signals from both soil environment and shoot, and any reduction in root growth ultimately reduces shoot development and realization of yield potentials (Burke and Upchurch, 1995). The reduction in root length observed in the current study, and consequently the reduction in shoot weight, was expected due to the high soil matric potentials which resulted from the high saline irrigation waters (data of soil matric potentials were not determined in the current study). These results are in agreement with those of Bernstein and Francois (1973) who found that root growth under drip irrigation was adversely affected by irrigation water salinity, Bar-Yosef *et al.* (1991b) and Merghany (1997) who found that SSD irrigated tomato plants had root and shoot weights greater than those SD irrigated plants. They attributed that to the low soil moisture level in SD irrigation system due to the high water evaporation rate. These results are in agreement also with those of Machado *et al.* (2003) who found that for SD and SSD irrigation systems and for two cultivars of tomato most of the root system was concentrated in the upper 40 cm of the soil profile. The negative relationship between irrigation water salinity and root length or shoot weight as well as, the positive relationship between root length and shoot weight were further confirmed by the significant correlation coefficients ($r = -0.980^{***}$, $r = -0.962^{*}$, and $r = 0.904^{*}$, respectively) as shown in Table (8). The increases in reduction in root length and shoot weight in the second season compared to the first one may be attributed to one or more of the followings: (1) salt accumulation in the periphery of the wetted zone and in the soil surface between drip emitters resulted from the first season and during the second one which may be leached into the root zone (Bernstein and Francois, 1975), (2) the absence of the beneficial effects of the applied FYM, which was added in the first season and was not repeated in the second season, and (3) the possible incidence of emitters clogging which may clog or reduce discharge rate relative to the nominal value (Bar-Yosef *et al.*, 1991a). However, the clogging problem was not investigated in the current study.

Fruit quality

Fruit quality parameters responded differently to the studied treatments as was declared by the statistical analysis (Table 5). Fruit juice acidity determined as pH was not significantly affected by any of the studied treatments. Some parameters were significantly influenced by WQ only (i.e., fruit weight, fruit diameter, and TSS). Others were significantly affected by WQ, IS treatments, and their interaction (i.e., fruit height, citric acid and vitamin C concentrations of fruit juice). Fruit size as represented by fruit weight, Fruit height, and fruit diameter were consistently decreased with increasing salinity of the irrigation water. The reductions in the three parameters, averaged across IS treatments, due to irrigation with WQ2, WQ3, WQ4, and WQ5 relative to the control were, respectively, 19.6, 25.9, 55.9, and 64.0% for fruit weight; 9.3, 16.0, 21.3, and 33.3% for fruit diameter; and 7.7, 15.4, 32.3, and 35.4% for fruit height (Table 6).

Table 6: Root length, shoot weight, and fruit quality parameters as affected by water quality (WQ) and irrigation system (IS) in 2003.

Treatment		Root L. cm	Shoot wt gm/plant	Fruit wt . gm/frt.	Fruit diam. Cm	Fruit ht. cm	pH	Cit. acid mg/100g	Vitamin C mg/100g	TSS %
WQ	SD	39.0	800.	175.	7.	6.3	3.9	0.40	15.30	6.
	SS	54.0	820.	179.	7.	6.6	4.0	0.50	12.67	6.
WQ	SD	35.7	750.	136.	6.	5.7	3.9	0.60	15.27	7.
	SS	42.0	800.	148.	7.	6.2	4.1	0.63	14.23	7.
WQ	SD	35.0	700.	129.	6.	5.7	3.9	0.70	11.93	7.
	SS	40.0	780.	133.	6.	5.2	3.9	0.73	12.23	7.
WQ	SD	33.0	439.	76.2	5.	4.3	3.8	0.73	12.70	8.
	SS	36.0	460.	80.2	6.	4.5	3.9	0.73	15.77	8.
WQ	SD	19.0	239.	64.1	4.	4.2	3.9	0.67	14.77	8.
	SS	20.0	260.	63.7	5.	4.2	3.9	0.77	14.83	8.
LSD†		NS	NS	NS	N	0.1	NS	0.06	0.48	N
LSD‡		NS	NS	NS	N	1.9	NS	0.16	4.49	N
WQ										
WQ1		46.5	810.	177.	7.	6.5	3.9	0.45	13.99	6.
WQ2		38.9	775.	142.	6.	6.0	4.0	0.73	14.75	7.
WQ3		37.5	740.	131.	6.	5.5	3.9	0.62	12.08	7.
WQ4		34.5	450.	78.2	5.	4.4	3.8	0.73	14.24	8.
WQ5		19.5	250.	63.9	5.	4.2	3.9	0.72	14.80	8.
LSD§		5.9	110.	26.7	1.	NS	NS	------	----	1.
IS means										
SD		32.3	586.	116.	6.	5.2	3.8	0.67	14.00	7.
SSD		38.4	624.	121.	6.	5.3	3.9	0.63	13.95	8.
LSD§		6.0	9.16	NS	N	----	NS	----	----	N

† LSD for comparison between two IS means at the same level of WQ.
‡ LSD for comparison between two WQ means at the same or different level of IS.
§ calculated only when WQ X IS interaction was insignificant.

However, the response of fruit height to WQ treatments was affected by IS treatments (i.e., the WQ X IS interaction on fruit height was significant, Table 5). This interaction justifies the comparison between any two WQ treatments at the same level of IS (i.e., SD or SSD irrigation systems) and the comparison between SD and SSD at any level of WQ treatments. Briefly, the WQ1-SSD irrigated plants had the greatest fruit height values followed by WQ1-SD irrigated ones (6.6 cm and 6.3 cm), while the smallest fruit height value was associated with WQ5-SD or WQ5-SSD treatment (i.e., 4.2 cm, Table 6).

Table 7: Root length, shoot weight, and fruit quality parameters as affected by water quality (WQ) and irrigation system (IS) in 2004.

Treatment		Root L. cm	Shoot wt. g/plant	Fruit wt. gm/frt..	Fruit diam. cm	Fruit ht. cm	PH	Cit. acid mg/100g	Vit. C mg/100gm	TSS %
QW1	SD	29.00	710.0	131.66	6.72	5.52	4.10	0.63	19.70	7.13
	SSD	42.00	760.0	147.20	6.97	6.62	4.10	0.67	19.23	8.10
QW2	SD	29.00	680.0	107.37	5.98	5.33	4.10	0.82	19.53	8.17
	SSD	41.86	740.0	107.47	6.90	5.34	4.19	0.90	13.73	8.52
QW3	SD	28.00	600.0	85.83	5.74	4.37	4.10	0.75	21.83	8.67
	SSD	33.00	654.3	87.83	6.00	4.97	4.00	0.83	18.00	10.10
QW4	SD	26.99	229.9	52.49	5.67	4.21	4,00	0.77	17.40	9.06
	SSD	29.99	401.5	64.51	5.67	4.21	4.00	0.98	18.67	10.75
QW5	SD	16.99	209.9	48.41	4.92	3.81	4.00	0.76	24.45	9.83
	SSD	18.49	386.5	51.68	5.00	3.98	4.00	0.87	17.89	8.53
LSD†		NS	NS	NS	NS	0.54	NS	0.06	4.07	NS
LSD‡		NS	NS	NS	NS	1.17	NS	0.19	4.59	NS
WQ means										
WQ!		35.50	735.0	139.4	6.85	6.07	4.10	0.65	19.47	7.61
WQ2		35.43	710.0	107.4	6.44	5.34	4.15	0.86	16.63	8.35
WQ3		30.50	626.7	86.83	5.87	4.67	4.05	0.79	19.92	9.39
WQ4		28.49	315.7	58.50	5.67	4.21	4.00	0.88	18.03	9.91
WQ5		17.74	298.2	50.05	4.96	3.90	4.00	0.81	21.17	9.18
LSD§		4.46	68.4	24.1	0.81	----	NS	----	----	1.68
IS means										
SD		26.00	486.0	85.15	5.81	4.65	4.06	0.75	20.58	8.57
SSD		33.07	588.3	91.74	6.11	5.02	4.06	0.85	15.50	9.20
LSD§		3.66	74.6	5.29	NS	----	NS	----	----	NS

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

‡ LSD for comparison between two WQ means at the same or different level of IS.

§ calculated only when WQ X IS interaction was Insignificant.

Total soluble solids (TSS) parameter is an important one in the yield consideration. In general, soluble solids of about 5 % is considered acceptable for processing (Ayars *et al.*, 1992). Total soluble solids significantly increased with salinity of the applied irrigation waters. The increases were about 19, 22, 27, and 29% relative to the control (WQ1), respectively. These increases could be attributed to the decreases in fruit weights (a dilution effect) due to irrigation water salinity as discussed earlier in this section and were confirmed by the positive correlation coefficient between WQ and TSS (i.e., r = 0.765), and the negative correlation coefficient between TSS and fruit weight (i.e., r =-0.946**, Table 8). Emitter placement (SD or SSD) did not significantly affect TSS. This is in agreement with the observations of Bar-Yosef *et al.* (1991a) and Machado *et al.* (2003) who found that irrigation system did not significantly affect TSS content of tomato fruits.

Citric acid concentration of tomato fruit increased with increasing the salinity of the applied irrigation water either under SD or SSD irrigation system. The increases due to using WQ2, WQ3, WQ4, and WQ5 waters under SD system were about 50, 75, 83, and 68% relative to the control, respectively. The corresponding increases under SSD system were 26, 46, 46, and 54%. Emitter placement (i.e., SD or SSD) significantly affected the citric acid concentration, where the SSD irrigated plants had higher concentrations than SD irrigated ones at any level of WQ treatment.

Vitamin C content of fruits followed a comparable trend as that of citric acid concentration (Tables 6 and 7). These results are partially in agreement with those of Fattahalla (1992), Tan (1995), and Merghany (1997) who found that tomato fruit TSS and vitamin C concentrations were strongly influenced by irrigation system.

Table 8: Simple correlation coefficients between water salinity (WQ) and botanical components and among the botanical components as well.

Parameter	Root length	Shoot weight	Fruit weight	Fruit diam.	Fruit height	Citric acid	Vit. C	TSS
WQ	-0.980***	-0.962**	-0.945**	-0.983***	-0.949**	0.219	0.685	0.755
Root L.		0.904*	0.888*	0.966**	0.886*	-0.165	-0.738	-0.685
Shoot wt.			0.949**	0.920*	0.942**	-0.273	-0.632	-0.745
Fruit wt.				0.963*	0.996***	-0.504	-0.423	-0.910*
Fruit diam					0.968**	-0.341	-0.567	-0.847*
Fruit ht.						-0.467	-0.429	-0.920*
Citric acid							-0.504	0.692
Vitamin C								0.062

,**, Significant at 0.05, 0.01, and 0.001 probability level.**

Conclusion

Water quality assessment of the representative groundwater of the studied area for irrigation showed that soil salinity and emitter clogging were the problems most expected to develop during long-term use. Irrigation with the studied waters through SD or SSD resulted in a gradual decrease in root length either with water salinity or with time (two seasons). The reduction in root length reached to about 58.1% with the highest salinity water (WQ5 = 10.0 dS/m) relative to the control (WQ1 = 0.88 dS/m). The reduction in root growth was reflected on shoot growth and fruit quality. The increase in vitamin C and TSS concentrations were due to the reduction in fruit weight. The adverse effect of water salinity was more pronounced under SD system than under SSD one.

Data of the second season not only confirmed those of the first one , but also did draw attention toward the possible cumulative adverse effect of the used irrigation water supplies during the long-term use, which threaten the sustainability of irrigated agriculture in the studied area unless proper managements be studied and adopted.

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تأثير نظامى الرى بالتنقيط السطحى و تحت السطحى باستخدام مياه جوفية مختلفة الجودة بجنوب سيناء على نمو المجموع الجذري والخضري وصفات الجودة لثمار الطماطم

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تهدف الدراسة ألي تقييم استخدام المياه الجوفية مختلفة الجودة (الملوحة) في الري بالتنقيط السطحى وتحت السطحى (٢٠ سم تحت سطح التربة) للطما طم فى أرض رملية بمنطقة الجبيل بجنوب سيناء على طول الجذر ووزن المجموع الخضرى ومواصفا ت الثمرة (وزن الثمرة، قطر الثمرة، ارتفاع الثمرة، محتوى الثمرة من vitamin-C و المواد الصلبة الذائبة TSS وكذلك حموضة عصير الثمرة). حيث زرعت الطماطم صنف GS خلال الموسمين الصيفيين ٢٠٠٣-٢٠٠٤ و تم اختيار ٤ آبار تمثل المياه الجوفية لمنطقة الدراسة (ملوحتها على الترتيب :١,٩٠، ٣,٩٨، ٦,٢٠، ١٠,٠ د يسيسيمنز/م) بالإضافة إلى مصدر للمياه منخفضة الملوحة كمعاملة مقارنة(٠,٨٨ د يسيسيمنز/م) صممت التجربة بنظام القطع المنشقة حيث كانت معاملات المياه فى القطع الرئيسية وانظمة الرى فى القطع الفرعية وتكررت ثلاث مرات. وأظهرت الدراسة النتائج التالية.

انخفض كل من طول الجذر ووزن المجموع الخضرى ووزن الثمرة وقطر الثمرة وارتفاعها انخفاضا معنويا بزيادة ملوحة مياه الرى مقارنة بالكنترول حيث بلغ هذا الانخفاض١٦,٣٪ ، ١٩,٤٪، ٢٥,٨٪، ٨٥,١ ٪ فى طول الجذر، بينما بلغ الانخفاض في وزن المجموع الخضري حوالي ٤,٤٪ ، ٨,٧ ٪ ، ٤٤٪ ، ٦٩,١ ٪ وكان الانخفاض في وزن الثمرة حوالي ١٩,٦ ، ٢٥,٩ ، ٥٥,٩، ٦٤,٠ ٪ على الترتيب. كما أظهرت نتائج كل من ارتفاع الثمرة وقطرها نفس الاتجاه ولكن بقيم أقل . من ناحية أخرى ازداد تركيز كل من vitamin C و TSS زيادة معنوية بزيادة ملوحة مياه الرى ويعزى ذلك آلي انخفاض الوزن الجاف للثمرة نتيجة التأثير الضار لملوحة مياه الرى.

أدى الرى بالتنقيط تحت سطح التربة ألي زيادة معنية في طول الجذر ووزن المجموع الخضري مقارنة أترى بالتنقيط السطحي، بينما لم يكن هناك أي فروق معنوية بين نظامى الرى فيما يتعلق ببقية الصفات تحت الدراسة. كما أظهرت نتائج الارتباط البسيط بين ملوحة مياه الرى والصفات تحت الدراسة و بين الصفات بعضها البعض أن كلا من طول الجذر ووزن المجموع الخضري قد ارتبط ارتباطا معنويا وعكسيا مع ملوحة مياه الرى ، وأن وزن وحجم الثمرة قد ارتبطا ارتباطا معنويا عكسيا مع ملوحة مياه الرى وطرديا مع كل من طول الجذر ووزن المجموع الخضرى.