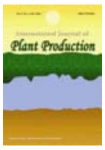

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Effects of salinity and irrigation water management on soil and tomato in drip irrigation

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Abstract

In this research, the effects of irrigation with saline and fresh water through drip irrigation method and using two irrigation management strategies: M_1, M_2 (M_1 is irrigation with fresh water in alternative with saline water, M_2 is saline water in first half time of each irrigation event and fresh water in the second half), on the yield, water productivity (WP), soil salinity, plant height and diameter, fruit water content, fruit density, "L", "a" and "b" colorimetric factors, textures, strength, sodium, calcium and nitrogen concentrations were investigated. The experiments were conducted in a randomized completely block design as split plot with three replications in which management strategies were the main plots and subplots were different levels of salinity, 0.68, 2, 4, 6 and 8 dS/m (S_0, S_1, S_2, S_3, S_4, respectively). Highest and lowest yields were in M_1S_1 (59.12 t/ha) and M_2S_4 (18.81 t/ha) treatments, respectively. The yield difference between M_1 and M_2 management strategies were significant at 5% level of probability and the average yield of M_2 was 24.20% less than the M_1 treatment. Applied irrigation water was decreased with increasing salinity levels because leaf area and leaf transpiration was reduced. Therefore, water productivity was increased, so that the highest water productivity was in the M_1S_4 treatment. To evaluate the use of saline water on soil, EC_e was measured in each plot at four layers in soil. Highest EC_e was in the S_4 salinity level in both management strategies. Based on soil salinity and crop yield, M_1 and M_2 management strategies were suitable at lower levels of salinities (0.68 and 2 dS/m) and salinities over 4 dS/m, respectively. Furthermore, M_1 management strategy, due to more efficient leaching in the surface layers of soil, was more appropriate than M_2 management strategy.

Keywords: Salinity; Irrigation management; Tomato; Water productivity.

Introduction

Because of increasing world population and thereafter increasing demand for food, use of fresh water resources has increased (Wallace, 2000). On the other hand, the world's fresh water resources are limited; that forced farmers to use low quality waters. About 12% of Iran's surface waters are saline; so the role of saline and brackish waters in the future would be undeniable (Anonymous, 2009).

In general, water quality has significant effect on yield and application of saline water has reduced the amount of yield (Murtaza et al., 2006). Appropriate irrigation methods and irrigation management strategies can reduce the effects of salinity of irrigation water on soil and crop and increase water productivity. Pasternak et al. (1986) used drip irrigation system with brackish (EC_i=6.2 dS/m) and fresh (EC_i=1.2 dS/m) waters over a period of three growing seasons to were about 44% less than fresh water. Field experiments were conducted on a sandy loam soil by Narsh et al. (1993) to evaluate the changes in soil water and salinity when conjunctive irrigation method with fresh (0.6 dS/m) and saline (12 dS/m) waters were applied in various cyclic/mixing modes. Relative yield with saline water was reduced to 60%. The yield in cyclic irrigations with fresh and saline waters was 7-11% more than mixing method in equal proportions. It was concluded when conjunctive use of fresh and saline waters were applied for the production of wheat, water productivity was higher than cyclic use of fresh and saline waters, when fresh water was applied at the initial stages (pre-irrigation and/first post-sowing irrigation) and saline water was applied at the later growth periods when it can tolerate the salts. Pasternak (1995) studied the tomato irrigation management with saline water. Results showed that when tomatoes were irrigated with saline water (7.5 dS/m), the total yield was reduced by 60% relative to the control. However, when irrigation with saline water started at the appearance of the fourth or the eleventh leaf, a water salinity of 7.5 dS/m reduced the yield by only about 30%. Malash et al. (2005) studied the effect of two water management strategies i.e. alternate and mixed supply of fresh water and saline water in six ratios applied through drip and furrow method on tomato yield and growth. Results showed that the highest yield obtained (3.2 Kg/plant) was the result of the combination of drip system and mixed management practice using a ratio of 60% fresh water with 4% saline water. Effects of drip irrigation using saline water on the production of tomato, in silt loam soil texture and semi-humid climates in China were investigated by Wan et al. (2010). Results showed that salinity in the range of 1.1-4.9 dS/m had little impact on yield and had the greatest impact on the cumulative amount of water used by plant and water productivity. Therefore, with increasing salinity, water productivity increased. Malash et al. (2008) studied there sponse of tomato to irrigation with saline water applied by different irrigation methods and water management strategies. The results indicated that salinity (at 3 dS/m and above) significantly reduced leaf area, height and dry weight of plant as well as fruit weight and number and hence total yield, but increased fruit T.S.S. content. Water use efficiency (WUE) was increased by using water with low and moderate salinity levels (2 and 3 dS/m) as compared to those obtained with non-saline water (0.55 dS/m) or the highest salinity level (4.5 dS/m). Salinity increased Na, Cl and Mg contents as well as dry matter percentage, but decreased N, P, K and Ca contents in leaves of plants. Drip irrigation enhanced tomato growth, yield and WUE under both saline and non-saline conditions, but showed more advantages under saline conditions as compared with furrow irrigation. Drip irrigation method did not allow salt accumulation in root zone (wetted area beneath the emitters and the plants). Using saline water up to 3 dS/m produced yield that was not significantly differ than that produced by non saline water if applied by drip irrigation and blended water management.

In this research, effects of saline and fresh water in drip irrigation under two irrigation management strategies M_1, M_2 (M_1 is alternative irrigation with fresh water and saline water, M_2 is saline water in first half of each irrigation event and fresh water in the second half), on the yield and quality parameters of tomato, water productivity (WP), soil salinity, plant height and diameter, fruit water content, fruit density, "L", "a" and "b" colorimetric factors, textures, strength, sodium, calcium and nitrogen concentrations were investigated.

Materials and Methods

This research was conducted in the College of Agriculture Shiraz University, located 16 km north of Shiraz (latitude 36^o 29, longitude 32^o 52 and altitude 1810 m) in 2010. Soil physical characteristics and irrigation water analysis are shown in Tables 1 and 2, respectively. The field area was 319 m^2 including 30 plots with dimensions 2×3 m with three replications. To prevent water seepage from a plot to adjacent plots, 1 m spacing was considered between plots (Figure 1). Experimental design was split plot, in which, water management strategy was the main plots (M_1, alternative irrigation with fresh water and saline water; M_2, is saline water in first half time of each irrigation event and fresh water in the second half) and subplots were four salinity levels of irrigation water i.e. 0.68 (control), 2, 4, 6, 8 dS/m as S_0, S_1, S_2, S_3, S_4, respectively. The soil moisture was measured by neutron probe and irrigation interval was 3 days. All treatments were irrigated with fresh water until the appearance of the fourth or the eleventh leaf and then saline irrigation water treatments were applied. For preparing the saline waters two reservoirs (one for saline water and another for fresh water) was considered. The saline water was performed by Nacl and $cacl_2$. The irrigation water was mixed of saline and fresh water until the desired salinity was obtained. For the control of this mixing the valves were considered and the E_c of mixed water were measured by E_c-meter before each irrigation. The variation of E_c was ±5%. Irrigation water was applied by surface drip irrigation. Tomatoes were Transplanting on the 13th of April, at 3 rows in each plot, with a distance of 60 cm between rows. The amount of soil moisture was measured by the Neutron probe. Irrigation depth was determined according to following equation:

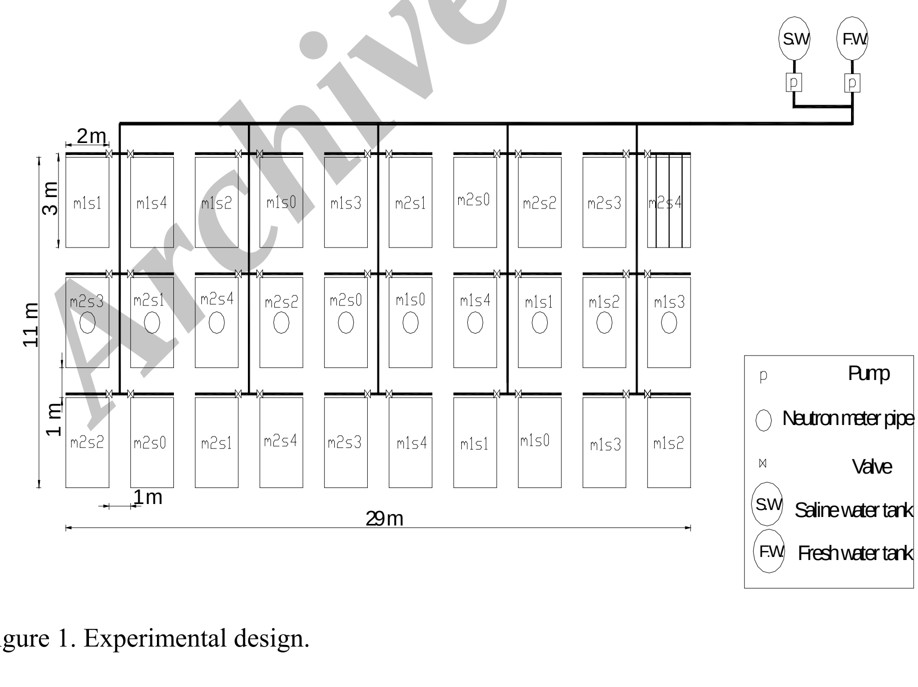

Figure 1. Experimental design.

Table 1. Soil physical properties in different soil depth.

Depth (cm)	Soil texture	Particles(%)			$\rho_b(g.cm^{-3})$[1]	$PWP(cm^3.cm^{-3})$[2]	$FC(cm^3.cm^{-3})$[3]	$EC(ds/m)$[4]	pH	$OC\%$[5]
		Clay	silt	sand						
0-30	Silty clay loam	55	35	10	1.23	0.12	0.27	0.686	7.68	0.844
30-60	Silty loam	49	12	39	1.46	0.16	0.31	0.476	7.54	0.591
60-90	Silty loam	60	11	29	1.46	0.16	0.31	0.471	7.41	0.493
90-120	Silty loam	63	11	26	1.46	0.16	0.31	0.450	7.4	0.410

1- Bulk density, 2- Permanent wilting point, 3- Field capacity, 4- Soil electrical conductivity, 5- Organic carbon.

Table 2. Chemical analysis of fresh irrigation water.

Quantity	Parameters
7.65	pH
0.679	EC (dS/m)
1.7	Chloride (meq/l)
2.9	Calcium (meq/l)
5.2	Magnesium (meq/l)
0.76	Sodium (meq/l)
0.015	Potassium (meq/l)
7.4	Bicarbonate (meq/l)

$$d = \frac{(Fc - \theta_v) \times Rz}{100} \quad (1)$$

Where: d is the irrigation water depth (cm); θ_v is the volumetric soil water content within the root depth before irrigation (%); FC is the volumetric soil water content at field capacity (%); R_z is the root depth (cm). In Eq. (1) R_z is varied with time and obtained from the following equation (Borg and Grimes, 1986):

$$Z_r = RD_m\,[0.5 + 0.5 \sin(3.03\, DA_s/DT_m - 1.47)] \quad (2)$$

Where: Z_r is the root depth of the given day; DA_s is the number of days after planting, DT_m is the number of days to reach the maximum root depth and RD_m is the maximum depth of plant roots. Values of DT_m and RD_m, were considered 80 days and 90 cm, respectively. Nitrogen was applied with a rate of 150 kg ha^{-1} urea through irrigation water (70 kg ha^{-1} at 5 June 2010 and 80 kg ha^{-1} at 22 June, 2010). Tomatoes yield were harvested from middle row of each plot at two times (6 and 26 September, 2010) and fruits weight were determined. Furthermore, plant height and canopy diameter were measured. At the end of the growing season, after the last irrigation with saline water for both irrigation management strategies, soil was sampled in each plot from 0-30, 30-50, 50-70 and 70-90 cm depths and for each layer, electrical conductivity of saturated extract (EC_e) was determined. In order to evaluate the tomatoes quality, fruit water content, fruit density, colorimetric characteristics, tomato texture strength and the amount of sodium, calcium and total nitrogen concentration were measured.

Measurement of plant parameters

Plant height and canopy diameter

To evaluate the effect of treatments on plant height and canopy diameter, when the vegetative growth stopped, these parameter were measured in three randomly selected plants from middle row of each plot (Table 3).

Fruit water content

On average 93% of tomato weight is water (Holland et al., 1991). In higher water content, the tomato texture strength and durability reduce and its transportation is difficult. To determine the water content of fruits, three medium sized tomatoes per plot were selected randomly and the fresh weight was measured and then dried inside oven (65 ^oC) in paper envelope. After drying, fruit weights were measured again. Fruit water content obtained from the following equation:

$$w = \frac{w_1 - w_2}{w_1} \times 100 \qquad (3)$$

Where: w is the water content (%), w_1 is the fresh fruit weight (gr) and w_2 is the dried fruit weight (gr).

Fruit density

One common use of tomato is in paste and sauce production. The fruits with higher density are more suitable for these purposes. To determine the fruit density, three medium sized tomatoes per plot were selected randomly. Tomatoes were placed in a box with known volume and weight and then their total weight was measured. The box was filled by a substance with known density (e.g., canola small rounded seed, 0.676 g/cm^3), that was suitable for filling the empty volume of the box and were weighted again to determine canola's weight. Fruit density obtained from the following equation:

$$\rho_t = \frac{\rho_c - w_t}{(\rho_c \times v_b) - w_c} \qquad (4)$$

Where: ρ_t is the tomato density (gr/cm^3), ρ_c is the canola density (gr/cm^3), w_t is the tomato weight (gr), w_c is the canola seed weight (gr) and v_b is the box volume (cm^3).

Table 3. Tomato characteristics in different salinities and irrigation management strategies.

Irrigation water (EC_i) salinity (ds/m)	Plant height (m)	Plant diameter (m)	Water content (%)	Density (g/cm^3)	L "Factor"	a "Factor"	b "Factor"	Texture strength (load gram)	Sodium concentration (ppm)	Calcium concentration (ppm)	Nitrogen concentration (%)
Irrigation management, m_1											
S_0 (0.68)	53.33	48.33	96.57	0.94	46.67	57.00	51.67	599.00	7.04	970.33	3.19
S_1 (2)	51.67	50	96.55	0.92	42.67	58.67	49.67	663.83	7.35	891.67	3.06
S_2 (4)	50	48.33	96.38	0.92	40.33	54.67	47.00	742.67	7.38	734.00	2.97
S_3 (6)	48.33	45	96.29	0.94	43.00	58.00	48.67	787.17	9.37	700.00	2.62
S_4 (8)	41.67	38	95.28	0.90	41.00	55.67	47.33	780.00	17.87	673.67	2.61
mean	49^a	45.9^a	91.46^a	0.924^a	42.93^a	57.73^a	48.86^a	758.8^a	9.8^a	793.93^a	2.94^a
Irrigation management, m_2											
S_0 (0.68)	53.33	45	96.97	0.90	45.33	58.67	48.67	642.00	6.88	1049.67	3.32
S_1 (2)	51.67	55	96.73	0.91	41.33	56.00	47.67	695.17	8.04	1037.33	3.33
S_2 (4)	51.67	43.33	96.50	0.93	43.67	59.00	50.33	734.00	8.48	916.00	2.74
S_3 (6)	51.67	40	95.98	0.90	42.67	59.00	49.33	834.00	10.24	817.00	2.62
S_4 (8)	51.67	38.33	95.87	0.93	40.00	56.00	47.33	887.50	15.26	667.67	2.68
mean	52^a	44.33^a	96.35^a	0.914^a	43.66^a	56.8^a	48.66^a	729.07^a	9.78^a	897.53^a	2.88^a
Mean of m_1 and m_2											
S_0 (0.68)	53.33^a	46.66^{ab}	96.77^a	0.92^a	46^a	57.83^a	50.17^a	620.67^c	6.96^b	1010^a	3.25^a
S_1 (2)	51.67^a	47.15^a	96.64^{ab}	0.915^a	42^{ab}	57.33^a	48.67^a	679.83^{bc}	7.69^b	964.5^a	3.2^a
S_2 (4)	5.83^a	45.83^{bc}	96.43^{bc}	0.925^a	42.67^{ab}	56.83^a	48.66^a	729.33^{abc}	7.92^b	825^a	2.83^{ab}
S_3 (6)	50^a	42.50^{bc}	96.14^{bc}	0.92^a	42.83^{ab}	58.5^a	49^a	811^{ab}	9.8^b	758.5^a	2.65^b
S_4 (8)	46.67^a	38.17^c	95.92^c	0.915^a	40.5^b	55.83^a	47.33^a	878.83^a	16.57^a	670.67^a	2.62^b

Different letters in columns and rows indicate a statistically significant difference at 5% probability.

Colorimetric characteristics

Color and appearance of vegetable, is the first parameter that is considered by the consumers. Human eye has ability in detecting colors, so that it can detect minimal changes in the transparency and light. But this ability is variable in different people. The more conventional way to measure color of food is Lab or L^* a^* b^* method. L^* a^* b^* or CIELab is a global standard that was published by International Lighting Commission where L is luminance, expressed as a percentage (0 for black to 100 for white) and "a" and "b" are two color ranges, from red to green and from yellow to blue, respectively, with values ranging from -120 to +120 (Larrain et al., 2008). To determine the colorimetric characteristics, color photo of tomatoes was taken under the same lighting conditions in a chamber with a white background using high resolution digital camera. Then images were processed by Photoshop software to determine Lab.

Tomato firmness

One of the important characteristics in tomato fruit is good texture and resistance to mechanical damage resulting from transportation. To measure the tomato texture strength TA device (STEVENS-LFRA texture analyzer) was used (Marrs, 1980). Tomato texture strength was measured with the incoming force to crush the fruit.

Concentration of sodium and calcium

To measure the sodium and calcium concentrations in tomato fruit, samples which dried to determine water content were used. The dried samples were powder and passed through the sieve (No. 200) and then ash was made. Five ml HCl per one gram of powder was added to the ash and after passing through filter paper, the volume of sample was brought to 50 cm^3 by boiling distilled water. After preparing plant samples, the sodium and calcium concentrations were measured by Flame Photometer at wavelength of 589 nm and atomic absorption (GBC 932, Perkin Elmer, USA) at wave length of 422.7 nm, respectively (Pauwels et al., 1997).

Nitrogen concentration

To measure the nitrogen concentration in tomato, fruit samples which dried to determine water content were used. Then samples were powder and passed through the sieve (No. 200). The nitrogen was measured by Kjeldahl method (Bermner and Mulvaney, 1982).

Table 4. Fresh tomato yield (t/ha), in the different irrigation management strategies and salinities.

Irrigation water salinity (EC_i) (ds/m)	irrigation management strategies Alternative In season (M_1) Yeild (t/ha)	Alternative In event (M_2) Yeild (t/ha)	mean Yeild (t/ha)
S_0 (0.68)	43.06^{AB*}	32.95^{BCDE}	38.02^{B}
S_1 (2)	54.12^{A}	40.19^{BC}	47.15^{A}
S_2 (4)	27.48^{DEF}	32.30^{BCDE}	31.57^{BC}
S_3 (6)	21.33^{EF}	29.37^{CDE}	25.35^{CD}
S_4 (8)	18.81^{F}	23.58^{DEF}	21.20^{D}
mean	32.97^{A}	31.67^{A}	

[*] Mean followed letters in columns and rows are not statistically different, according to LSD test at 5% level of probability.

Results and Discussion

Fresh tomato yield

Based on the amount of fresh tomato yield (t/ha) in different treatments (Table 3), analysis of variance was performed. The results showed that the salinity and interaction of salinity and irrigation management strategies on tomato yield, was significant at 5% level of probability. The irrigation management strategies showed no significant effect on tomato yield. The maximum and minimum of yield were obtained in M_1S_1 (54.12 t/ha) and M_1S_4 (18.81 t/ha) treatments, respectively. Fresh tomato yield in M_1S_1 and M_2S_1 treatments were 25.7% and 22.0% more than the control salinity level (S_0), respectively. According to Table 3 and Figure 2, maximum yield in both irrigation management strategies were in S_1 salinity level (2 dS/m). In S_1, S_2, S_3 and S_4 salinity levels, the changes of yields relative to control treatment (S_0) were +25.7, -36.2, -50.5, for M_1 treatments and -56.3%; +22.0, -2.0, -10.9, -28.4%; for M_2 treatment and +23.8, -19.1, -30.7, -42.4%, for mean of M_1 and M_2 treatments, respectively.

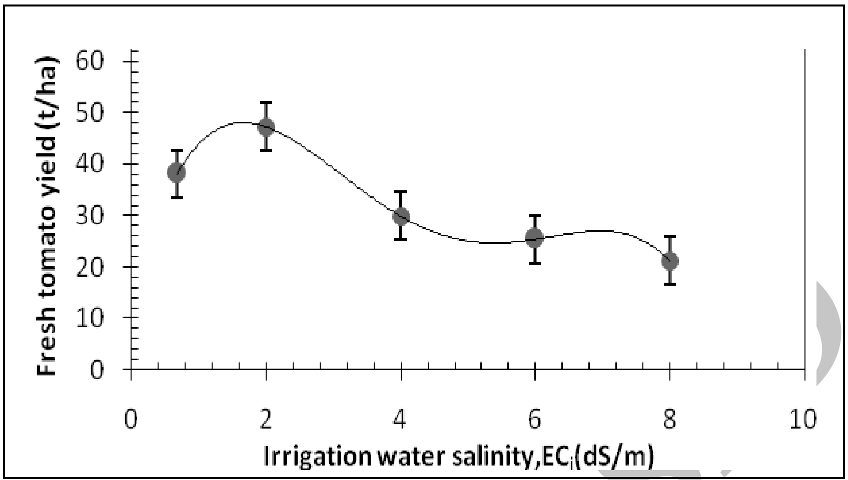

Figure 2. Relationship between Fresh tomato yield and salinity levels of irrigation water at mean of M_1 and M_2 treatments.

Yield salinity relationship

Relationship between fresh tomato yield and water salinity at two irrigation management strategies are as follow:

For mean of alternate in season (M_1) and alternate in event (M_2) treatments:

$$y = -0.196EC^4 + 3.669EC^3 - 22.81EC^2 + 49.05EC + 14.089 \quad (5)$$
$$n = 30 \quad R^2 = 0.69 \quad Se = 6.78 \quad P - value = 3.93 \times 10^{-6}$$

For alternate in season (M_1) treatments

$$y = -0.281EC^4 + 5.279EC^3 - 32.644EC^2 + 68.491EC + 9.980 \quad (6)$$
$$n = 15 \quad R^2 = 0.81 \quad Se = 6.43 \quad P - value = 2.07 \times 10^{-4}$$

For alternate in event (M_2) treatments

$$y = -0.111EC^4 + 2.059EC^3 - 12.980EC^2 + 29.6008EC + 18.198 \quad (7)$$
$$n = 15 \quad R^2 = 0.77 \quad Se = 3.56 \quad P - value = 2.83 \times 10^{-3}$$

Where: y is the fresh yield of tomato (t/ha) and EC_i is the electrical conductivity of irrigation water (dS/m). In Eq. (5), until the salinity of 2 dS/m, yield was increased and then with increasing salinity, yield was decreased. The trend of yield reduction is high until the salinity reached-5 dS/m and then it become low-at salinity of 8 dS/m. According to Figure 2, for mean of M_1 and M_2 strategies, EC_i values that reduce 10, 25, 50, 75 and 100% of yield relative to control were 2.4, 3.3, 5.2, 8.5 and 8.92 dS/m, respectively.

Water Productivity

Water productivity (WP) was obtained from division of the fresh tomato yield (kg/ha) by amount of irrigation water applied to the farm during the growing season (mm). The plant yield (kg/ha) and water productivity for different treatments are shown in Table 5. The amounts of applied water with increasing salinity levels were reduced. Therefore, with increased salinity, WP increased. In general, in M_1 treatment WP was higher than M_2 treatment. Therefore, the WP of M_1S_0, M_1S_1 and M_1S_4 treatments were 30.7, 49.4 and 9.6% higher than M_2S_0, M_2S_1 and M_2S_4 treatments, respectively. However, in M_1S_2 and M_1S_3 treatments WP were 11.8 and 12.3% lower than M_2S_2 and M_2S_3 treatments, respectively. Therefore, M_1 treatment in low (S_0, S_1) and high (S_4) salinity levels, showed higher WP. However, in medium salinity levels (S_2, S_3), M_1 treatment resulted in lower WP than M_2 treatment.

Table 5. Yield and water productivity in different treatments.

Water Productivity (WP) (kg/m^3)	Applied water (mm)	EC_i (dS/m)		Management Strategy
3.417	1260	0.68	S_0	(M_1)
5.306	1020	2	S_1	
3.523	780	4	S_2	
3.949	540	6	S_3	
6.272	300	8	S_4	
2.615	1260	0.68	S_0	(M_2)
3.550	1132	2	S_1	
3.995	892	4	S_2	
4.504	652	6	S_3	
5.722	412	8	S_4	

Soil salinity (EC_e)

Figure 3 shows the values of soil saturated extract (EC_e) at the end of growing season for each treatment at different soil depths. In all soil layers, the lowest EC_e was in M_1S_0 treatment. Highest EC_e in all soil layers was-with S_4 level. Further, in the first (0-30 cm) and second layers (30-50 cm) EC_e was highest in M_2, however, in third (50-70 cm) and fourth layers (70-90 cm) it was highest in M_1 treatment. In salinity of 0.68 and 2 dS/m, M_1 treatment and in salinity levels over 2 dS/m, M_2 treatments have lower mean EC_e Similar to WP, for soil salinity the M_2 treatment is appropriate management at high water salinity levels.

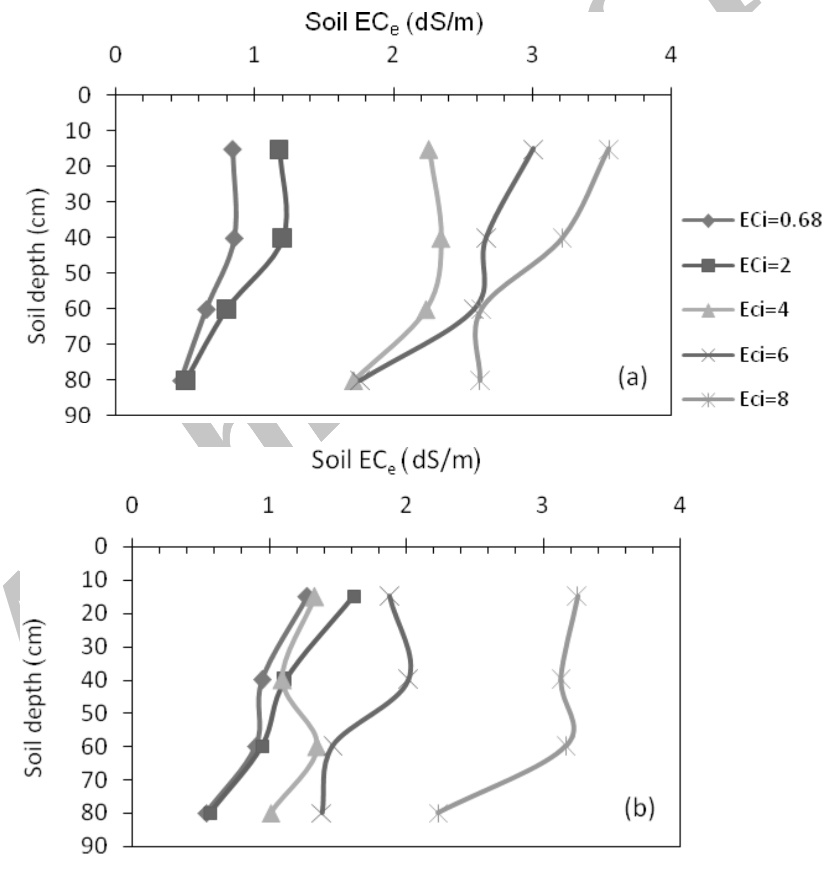

Figure 3. EC_e in different soil depths and management strategies: a) M_1 strategy, b) M_2 strategy.

According to Figure 3, the use of saline water to irrigate crops in all growing season increased EC_e for both management strategies. For salinity between 0.68-6 dS/m, EC_e in M_2 treatment were close to each other, however, for salinity of 8 dS/m, the EC_e increased considerably. The EC_e in M_2 treatment for all salinity levels is less than M_1 treatment due to more effective leaching in M_2 management strategy. Salts were accumulated in 0-50 cm layer and the EC_e was decreased in depth lower than 50 cm due to the presence of a layer with low hydraulic conductivity in this depth. In general, M_2 management strategy, due to more efficient leaching in the upper layers, is more appropriate than M_1 for tomato plant and may be for growing shallow root crops.

Plant height and canopy diameter

Statistical results were showed that salinity, irrigation management strategies and the interaction of salinity and irrigation management strategies has no significant effect on plant height at 5% level. The maximum of plant height was in M_1S_0 and M_2S_0 (53.3 cm) and the minimum was in M_1S_4 (41.7 cm) treatments, respectively. For canopy diameter, the results showed that salinity has a significant effect at 5% level while the irrigation management strategies and the interaction of salinity and irrigation management strategies have no significant effect ($P<0.05$). The maximum and minimum of canopy diameter were in M_2S_1 (55 cm) and M_1S_4 (38 cm) treatments, respectively. Similar to behavior of yield response to salinity levels, the maximum canopy diameter in both management strategies was in S_1 salinity level and for salinity over 2 dS/m; canopy diameter was reduced with increasing salinity level. In general, the osmotic pressure of soil solution increases. Therefore, the amount of energy that plant spent to absorb water increases with increasing salinity level. This is why, the yield and canopy diameter were reduced with increasing salinity.

Tomato water content

Based on analysis of variance, salinity showed a significant effect while the irrigation management strategies and the interaction of salinity and irrigation management strategies have no significant effect on tomato water content at 5% level of probability. The maximum and minimum values of tomato water content were in M_2S_0 (97.0%) and M_2S_4 (95.9%) treatments, respectively. Tomato water content reduced with increasing the salinity level. The average of tomato water content in M_1 management strategy at low and medium salinity levels (0.68, 2 and 4 dS/m) was lower than M_2 treatment, but at high salinity levels (6 and 8 dS/m) was higher than M_2 treatment. According to these results, the S_4 salinity level and M_1 management strategy was increased the tomato water content.

Fruit density

Statistical results showed that salinity, irrigation management strategies and the interaction of salinity and irrigation management strategies have no significant effect on fruit density at 5% level of probability. Therefore, changes in fruit density, has not a specific trend with respect to salinities and management strategies. The maximum and minimum values of fruit density were in M_1S_3 (0.94 g/cm^3) and M_1S_4 (0.90 g/cm^3) treatments, respectively.

Colorimetric characteristics

Based on analysis of variance, salinity level has a significant effect while the irrigation management strategies and the interaction of salinity and irrigation management strategies have no significant effect on "L" factor at 5% level of probability. The maximum and minimum values of "L" factor were in M_1S_0 (46.7) and M_2S_4 (40.0) treatments, respectively. The "L" factor reduced with increasing the salinity level.

The interaction of salinity and irrigation management strategies has a significant effect while the salinity and irrigation management strategies have no significant effect on "a" factor at 5% level of probability. The maximum value of "a" factor was in M_1S_0 and M_2S_0 (59.0) and the minimum was in M_1S_4 (54.7) treatments, respectively. Higher value of "L" and "a" factors represent premature fruit (Larrain et al., 2008).

There is not a trend between salinity, irrigation management strategies and interaction of salinity and irrigation management on "b" factor. The maximum and minimum values of "b" factor were in M_1S_0 (51.7) and M_1S_2 (47.0) treatments, respectively. The M_1S_2 was also the optimum treatment according to "L" and "a" factors. Therefore, salinity has significant effect on the just "L" factor. The irrigation management strategies and interaction of salinity and irrigation management have not significant effect on the "L", "a" and "b" factors. According to these results the S_4 salinity level has the positive effect on the "L" and "a" factors. In general, the tomato fruits that were irrigated with saline water had been riper. Therefore, use of saline water can be considered the optimal method to precocity of fruits.

Tomato firmness

Based on analysis of variance, salinity showed a significant effect while the irrigation management strategies and the interaction of salinity and irrigation management strategies have no significant effect on tomato texture strength at 5% level of probability. The maximum and minimum values of tomato texture strength were in M_2S_4 (887.5 load gram) and M_1S_0 (559 load gram) treatments, respectively. In general, the tomato texture strength increased with increasing salinity levels. In S_1, S_2, S_3 and S_4 levels the tomato texture strength was 10, 18, 31 and 42% higher than the control treatments, respectively. These results were in agreement with results obtained on tomato water content. The tomato water content was reduced and then the texture strength was increased with increasing salinity levels. According to these results the S_4 salinity level has the positive effect on the texture strength.

Sodium, calcium and nitrogen concentration

Based on analysis of variance, salinity showed a significant effect just on sodium and nitrogen concentration while the salinity for calcium and irrigation management strategies and the interaction of salinity and irrigation management strategies have no significant effect at 1% level of probability on sodium, calcium and nitrogen concentration. Sodium concentration increased with increasing salinity levels. For M_1 and M_2 treatments, the sodium concentrations in S_1, S_2, S_3 and S_4 salinity levels were increased 4.4, 4.8, 33.1, 153.8% and 16.9, 23.2, 48.8, 121.8% relative to control (S_0), respectively. Therefore, increasing sodium concentration in S_1, S_2 and S_3 salinity levels in M_1 treatment was lower than those in M_2 treatment. However, it was inverse in S_4 salinity level. The maximum and minimum values of sodium concentrations were in M_1S_4 (17.9 µg/g) and M_2S_0 (6.88 µg/g) treatments, respectively.

The nitrogen and calcium concentrations were decreased with increasing salinity levels. In M_1 and M_2 treatments, calcium concentration in S_1, S_2, S_3 and S_4 salinity levels were decreased 8.1, 24.4, 27.9, 30.6% and 1.2, 12.4, 22.2, 36.4% relative to control (S_0), respectively. The maximum and minimum values of nitrogen concentration were in M_2S_1 (3.3%) and M_1S_4

(2.6%) treatments, respectively. In saline conditions, increased concentrations of salts prevent the natural nutrition in plants. Nitrogen is one of the most important elements that limiting plant growth. Nitrogen uptake is reduced more than any other nutrient elements when plants are under salt stress. In saline conditions, many factors are effective in the reduction of nitrogen uptake by plants such as reduction of the permeability of plant roots, reduction of the microbial activity and subsequent loss of soil mineralization of organic compounds, high concentrations of chloride in the root zone and reduction of the nitrification. According to these results the S_4 and S_1 salinity levels and M_1 management strategy have the positive effect on the sodium and nitrogen concentrations, respectively.

Conclusion

With increasing salinity levels, canopy diameter, fruit water content, "a" and "L" factors of colorimetric characteristics and nitrogen concentration were decreased. However, sodium concentration and texture strength were increased. Plant height, "b" factor in the colorimetric characteristics and calcium concentration, were not influenced by salinity levels. Highest and lowest fresh yield were obtained in M_1S_1 (54.12 t/ha) and M_1S_4 treatments (18.81 t/ha), respectively. Tomato fresh yields in M_1S_1 and M_2S_1 treatments were 25.7% and 22.0%, higher than the yield in the control salinity, respectively. Therefore, in both irrigation management strategies, in S_1 salinity level (2 dS/m), yield was higher than S_0 (0.68 dS/m). Water productivity increased with increasing salinity, so that highest water productivity was obtained in M_1S_4 treatment. However, the acceptable WP with good yield was obtained in M_1S_1 treatment. The M_1 management strategy in low (S_0, S_1) and high (S_4) salinity levels showed higher WP. However, medium salinity levels (S_2, S_3) have lower WP than M_2 treatment. In terms of impact on soil salinity and crop yield similar to WP, at lower levels of salinity (0.68 and 2 dS/m) the M_1 management strategy and at salinity levels over 4 dS/m, the M_2 strategy is an appropriate management strategy. In general, M_1 treatment has better results than M_2 treatment.

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