



The effect of water quality and irrigation methods on moisture and salinity distribution of soil

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ABSTRACT

Current study was carried out with aim to evaluate the effect of pressurized irrigation methods and furrow irrigation method with municipal effluent on distribution of salinity and moisture in the soil profile. The experimental study was designed by split plot layout with three irrigation methods including furrow, surface drip (SD) irrigation and subsurface drip irrigation (SSD) and two water qualities (municipal effluent and fresh water) in a sugar beet field located in Corbal plain, Iran. Soil sampling was conducted in two sessions (prior to irrigation and after harvesting) at three depths of 0-20, 20-40, 40-60 cm and 15 points around areas where water leaked. Variance analysis of salinity showed a significant difference ($p < 0.01$) between irrigation methods, also between two water qualities in terms of salinity concentration, for three sampled depths of soil. The maximum value of salinity was found at the depth of 0-20 cm in subsurface drip irrigation by 1.66 dS/m, and the minimum value of salinity was found at the depth of 20-40 cm in furrow irrigation by 0.92 dS/m. Irrigation by municipal effluent caused a higher salinity concentration in the soil compared to fresh water regardless to the amount of water. Leaching operations, reducing the irrigation period and increasing the irrigation frequency, conducting researches and promoting the use of effluent are recommended in conclusion.

Key words: Salinity, Effluent, Surface Drip Irrigation, Subsurface Drip Irrigation, Furrow Irrigation.

INTRODUCTION

Fresh water is necessary for human existence. While only 3% of the earth water is fresh water of which two third exists as frozen water in poles. Therefore, only 1% of the earth water is usable as surface water and groundwater so that groundwater has a 65% portion of fresh water (USEPA, 2002). Rapid urbanization and industrialization have increased the pressure on limited existing fresh water to meet the growing needs for food production (Hassanli *et al.*, 2009). Also, water shortages and poor water quality

are critical issues in many areas throughout world. With rapid increases in population, rising standards of living and shortage of water resources in urban areas, use of alternative water resources such as municipal reclaimed water and other sources of non-potable waters to irrigate landscapes is unavoidable (Genhua and Raul, 2010). While Iran has serious problems related to fresh water resources, and water crisis would be a considerable issue in long time, attention to non conventional water resources is an unavoidable necessity. Concentration of industrial and population centers make a huge volume of municipal effluent (Bouri *et al.*, 2008). Some studies have shown that, the best way for effluents disposal after the primary treatment stages is to use them in agriculture (Pescod, 1992). Unconventional waters such as saline drainage waters and effluents can be effective to fill the gap between accessible fresh water sources and demand for fresh water (Murtaza, 2006). Some impacts of even treated effluent on the soil considering its quality include; increasing microbiological contamination of soil, increasing heavy metals and organic matter and particularly increasing salinity in the soil. Considering when water becomes wastewater, its minerals would increase 300-800 mg/L (Hassanli *et al.*, 2009); water salinity can cause soil salinization, soil toughness, and can decrease soil productivity. A potential concern is the elevated salt levels in alternative waters (Genhua and Raul, 2010) and the main obstacle for extending their use is resulted from their quality (Fernandez-Galvez *et al.*, 2010). Since, salinity is a limiting factor of plant growth and considered as a desertification index, understanding how salt is distributed in soil profile can be helpful to reduce local impacts of salinity on plants. Drip irrigation methods may play an important role in efficient use of water but there is still limited information about their use in arid countries such as Iran (Hassanli *et al.*, 2009). Therefore, it seems an essential issue to evaluate the processes of salinity changes by various irrigation methods especially when using unconventional waters in order to select a proper management to use such water quality particularly in arid, semi-arid areas and sensitive regions to desertification. History of the effluent use in Europe back to 1800 AD: dating of farms irrigated by effluent in Paris, France back to 1868 AD. The area of agricultural lands irrigated by effluent was appropriately 1000 ha. In 1904 since Seine River had been dry, more than 5000 ha of marginal lands was irrigated by domestic effluent. Hassanli *et al.* (2009) implemented an experiment to evaluate the effects of irrigation method and water quality on sugar beet yield, percentage of sugar content and irrigation water use efficiency (IWUE). Statistical testing indicated that the irrigation method and water quality had a significant effect (at the level of 1%) on sugar beet root yield, sugar yield, and IWUE. In addition, irrigation by effluent led to an increase in the net sugar yield due to the increase in the sugar beet root yield. Identifying the effects of irrigation by effluent on soil pollution has been recommended at the end of this study. Genhua and Raul (2010) conducted a review on salt tolerance of landscape plants and their physiological responses to salinity stress. They reported that plant species, dominant salt type, substrate, irrigation method and management, and environmental conditions affect plant responses to salinity stress. Perez (2003) irrigated a wide area and showed that, various amounts of water salinity have a significant effect on soil specifications especially on soil salinity. He also believes that using effluent with weak treatment can have harmful effects on environment and can accelerate desertification. Klay *et al.* (2010) examined seven irrigated sub-perimeters and seven profiles which differed by soil composition, texture and structure and irrigation periods (from zero to 14 years). They announced that soil salinization is caused by high wastewater salinity and increases in irrigation period. Heavy metal content increases with irrigation period, especially for Pb (1010– 1890 mg/kg) and Cd (2–20 mg/kg). The pH values of the water and soil are slightly basic. The metals' migration will especially depend on the organic carbon concentration and the soil nature. Ghadir *et al.* (2001) evaluated the effect of irrigation by saline water (2.9 dS/m) on soil salinity and acidity. They announced that after an irrigation session by saline water, soil salinity increased and the salinity in upper 15 cm of the soil surface was higher. Hassanli *et al.* (2007) evaluated the use of municipal effluent for 14 tree species within 25 months in Southern Iran from 2003 to 2005. They indicated that the applied effluent had no adverse effect on soil properties. The soil salinity decreased

from 8.2, 6.8 and 7.0 dSm⁻¹ to 1.07, 1.12 and 3.5 dSm⁻¹ in the soil layers of 0–30, 30– 60 and 60–90 cm respectively. Reuse of municipal treated effluents is highly recommended in irrigation particularly in arid and semi arid regions for plantations by drip systems. Pescod (1992) compared advantages and disadvantages of various irrigation methods while operation of municipal effluent and reported that, drip irrigation mitigates the problems caused by using effluent. Abduljavad *et al.* (2005) studied the effect of management of irrigation by saline water and salt tolerant tomato species. They mentioned that, drip irrigation is much more proper in terms of efficiency and saline water use. Hassanli *et al.* (2005) irrigated 14 various tree species during 25 months and announced that, soil salinity at depths of 0-30, 30-60 and 60-90 cm reduced from 8.2, 6.8 and 7 dS/m to 1.07, 1.12 and 3.5 dS/m respectively.

MATERIALS AND METHODS

In order to evaluate the effect of two water qualities (treated municipal effluent and fresh water) and three irrigation methods (surface drip irrigation or tape, subsurface drip irrigation and furrow) on salinity and moisture distribution in sugar beet cultivation, an experiment was conducted in the refinery station of Marvdasht, Iran with 340 mm annual precipitation and 2585 mm annual evaporation. The experiment was performed by split plot layout with three main factors (subsurface drip irrigation, surface drip irrigation and furrow) and two sub-factors (municipal effluent and fresh water) and three replications (totally 18 plots with size 6m by 7m) in a sugar beet field. For furrow irrigation method equipped by hydroflume, water entered the furrows by a 6 inch pipe and through an aperture which had been made in front of each furrow. In surface drip irrigation (SD) method which has some advantages such as high efficiency, to reduce evaporation and capability to mitigate environmental impacts while irrigation by municipal effluent, water was distributed through 16 mm lateral pipes along the plants. In subsurface drip irrigation (SSD) which in addition to advantages of surface drip irrigation, can prevent direct contact between human and wastewater, water was given the plants by plastic 16 mm pipes which were placed under the soil surface and at a depth of 15-20 cm, through automatic droppers. Diameters of polyethylene main pipes, manifold pipes and lateral pipes were respectively 50, 32 and 16 mm. Droppers of both pressurized irrigation methods were automatic and were placed with 30 cm distance from each other with 1.33 L/S water flow rate. Irrigation systems and considered plots were designed and performed after determining the location of each treatment and corresponding plots. Some characteristics of two studied water qualities have been presented in Table 1. and some soil characteristics of the experimental field before planting have been shown in Table 2.

Table 1. Chemical characteristics of irrigation water

Type of water	EC(dS/m)	pH	SAR	CO ₃ H ⁻	Cl ⁻	SO ₄ ⁻²	Ca ⁺²	Mg ⁺²	Na ⁺	K ⁺
							(meq/L)			
Effluent	1.52	7.62	4.29	8.46	4.76	1.83	3.41	3.14	7.77	0.134
F.Water	0.509	7.77	0.89	3.47	1.5	0.83	3.03	1.05	1.28	0.027

Table 2. Soil chemical and physical characteristics before planting

Depth (cm)	Clay (%)	Silt (%)	Sand (%)	EC dS/m	pH	Organic carbon(%)	SAR	N(%)	P (ppm)	K (ppm)
0-20	45	43.3	11.3	0.703	8.33	0.996	0.359	0.091	18.79	550
2-40	46	44	10.6	1.086	8.3	0.76	0.508	0.07	16.71	445
4-60	49.3	40	10.6	1.278	8.3	0.57	1.425	0.0735	14.62	410
60-80	50	45	10	2.353	8.28	0.76	2.529	0.065	9.61	340

15 soil samples were taken at each sampling step after determining the middle point of each plot close to the water leaking point in pressurized irrigation methods and with distances of 15 and 30 cm. Soil sampling was carried out in 2 steps including, before planting and after harvesting sugar beet with 8 months interval. Soil samples were produced weighing 300-400 gr and transferred by especial plastic containers to the laboratory. Taken samples were immediately transferred to the laboratory and were divided into two parts to measure the soil moisture, salinity and acidity. To measure the weighted soil moisture, prepared samples were weighted by a digital scale (model: sartorus GM 3101) with 0.1 gr accuracy. Then soil samples were kept in an oven for 24 hours under 105 °C temperature to determine their dry weight. After 24 hours, samples were weighted again. The weighted soil moisture was determined by calculating the difference between dry weight and wet weight divided by the weight of dry soil (Equation 1).

$$\theta = \frac{M_w - M_d}{M_d} * 100 \quad (1)$$

Where

θ : Percentage of weighted soil moisture

M_w : The weight of wet soil

M_d : The weight of dry soil

Electrical conductivity (EC) was used in order to determine the amount of salinity.

To measure EC of saturated extract, firstly a saturated extract of soil sample was produced then, soil salinity was measured by a digital EC Meter (model: JENWAY 4150) for all samples. Statistical analysis was accomplished by SAS software.

RESULTS AND CONCLUSION

1. Soil moisture

Comparing mean amounts of moistures showed that in the first sampling step, the maximum amount of soil moisture among pressurized irrigation methods occurred at the depth of 40-60 cm with a weighted moisture by 16% in surface drip irrigation while, at the depth of 40-60 cm of furrow irrigation method there was a significant increase in the amount of soil moisture (16.5%) compared with other methods that probably is due to greater volume of used water in this method than other methods, leaking and more percolation of irrigation water. In the second sampling, the most amount of soil moisture was found at the depth of 0-20 cm in surface drip irrigation with a weighted moisture of 17.4% while, and at greater depths, the maximum amount of soil moisture was found in furrow irrigation method at the depth of 40-60 cm with an average of 19.6% weighted moisture. As it can be seen in Table 3. the amount of soil moisture at the deeper points (40-60 cm) in furrow method is greater than others. Totally, furrow irrigation method caused more soil moisture increase in lower depths due to greater volume of used water (11400 m³) during the growth period comparing other methods (8200 m³). Also the minimum amount of soil moisture in the soil surface was found in furrow method that surface evaporation is the reason of this happening.

Table 3. Comparison of soil weighted moisture means in various layers of the soil affected by different irrigation methods

Irrigation Method	Soil weighted moisture (%)			Soil weighted moisture (%)		
	(First sampling step)			(Second sampling step)		
	0-20	20-40	40-60	0-20	20-40	40-60
(cm)						
Furrow	11.8 a*	15.2 ab	16.6 a	15.5 c	18.7 a	19.6 a
S.S.D	12.3 a	15.5 b	15.8 b	16.2 b	17.3 b	17.7 b
S.D	11.5 a	13.8 b	16 ab	17.4 a	15.5 c	17.6 b

*: Means with dissimilar letters in each column have significant difference at the level of 5% based on Duncan Test.

Soil moisture variations in various treatments and depths in the first and second sampling steps have been shown in figure 1. and figure 2. As the figures suggest, in the first sampling the amount of surface soil moisture was less than the depth of 20-40 cm and at the depth of 20-40 cm soil moisture was less than 40-60 cm depth and it was true for all treatments. The same situation is seen in figure (2) with less difference. Based on this figure despite of the first sampling step, soil moisture was higher in the soil of surface drip irrigation plot for both used water qualities.

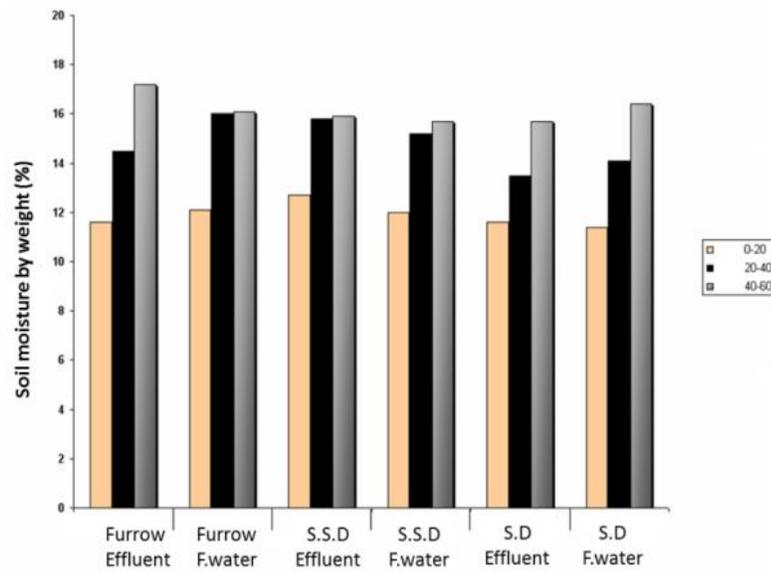


Figure 1. Soil moisture variations in various treatments and depths in the first soil sampling step

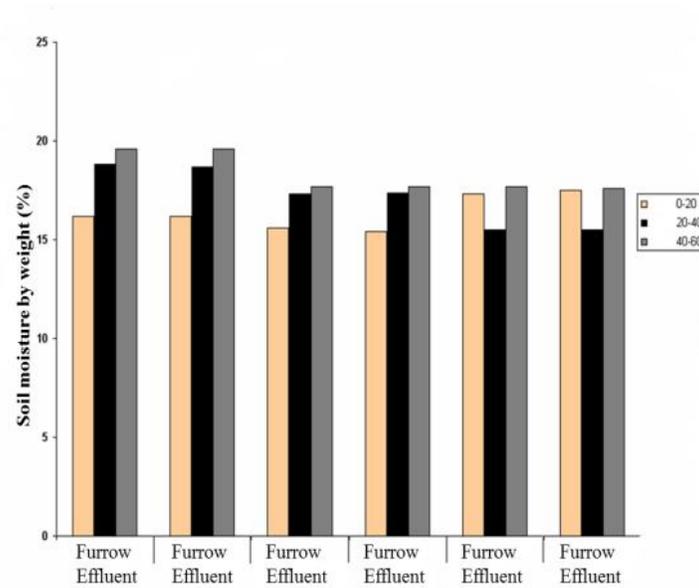


Figure 2. Soil moisture variations in various treatments and depths in the second soil sampling step

2. Soil salinity

Secondary salinity is a serious problem in irrigated crop lands in arid and semi-arid regions so, evaluating the salinity distribution in various irrigation methods can be effective for salinity management. In the first sampling step, the plots irrigated by furrow method with the average salinity of 1.2, 1.07 and 1.09 dS/m respectively at the depths of 0-20, 20-40 and 40-60 cm had a significant decrease comparing the amount of salinity accumulation in other irrigation methods. In the second soil sampling also, the minimum amount of soil salinity (EC) was found in furrow irrigation by 1.32, 0.92 and 1.1 dS/m at the depths of 0-20, 20-40 and 40-60 cm respectively.

Table 4. Comparison of salinity means (dS/m) in various soil layers affected by irrigation methods

Irrigation Method	EC (Ds/m)			EC (Ds/m)		
	(First sampling step)			(Second sampling step)		
	0-20	20-40	40-60	0-20	20-40	40-60
	(cm)					
Furrow	1.2 b*	1.07 b	1.09 b	1.32 c	0.92 c	1.1 c
S.S.D	1.7 a	1.25 a	1.27 a	1.66 a	1.29 b	1.58 a
S.D	1.9 a	1.38 a	1.17 ab	1.53 b	1.39 a	1.45 b

*: Means with dissimilar letters in each column have significant differences at the level of 5% based on Duncan Test.

In total, furrow irrigation method caused less salinity (EC) in the soil due to using more water volume comparing other irrigation methods. Comparison of surface drip irrigation and subsurface drip irrigation methods in the first sampling step showed higher salinity (EC) at the depths of 0-20 and 20-40 cm in surface drip irrigation method and at 40-60 cm depth in subsurface drip irrigation method. However, there was not statistically a significant difference between these two irrigation methods at the depths of 0-20 and 20-40 cm. In the second sampling step, the maximum amount of EC (1.66 dS/m) was found at the depth of 0-20 cm in subsurface drip irrigation. On the other hand, the minimum measured soil salinity was in furrow irrigation method with 0.92 dS/m of electrical conductivity at the depth of 20-40 cm. In 40-60 cm depth also, subsurface drip irrigation showed less soil salinity comparing other methods. Irrigation with municipal effluent caused to increase soil salinity in both soil samplings and all three depths compared to fresh water. Maximum amount of salinity caused by irrigation by municipal effluent was seen at the depth of 0-20 with 1.82 dS/m of EC (Table 5).

Table 5. Comparison of salinity means (dS/m) in various layers of soil affected by water quality

Type of water	EC (dS/m)			EC (dS/m)		
	(First sampling)			(Second sampling)		
	0-20	20-40	40-60	0-20	20-40	40-60
(cm)						
Effluent	1.82 a*	1.57 a	1.46 a	1.6 a	1.3 a	1.4 a
F. water	1.38 b	0.9 b	0.89 b	1.4 b	1.08 b	1.28 b

*: Means with dissimilar letters in each column have significant difference at the level of 5% based on Duncan Test.

Generally, regardless to irrigation method, irrigated plots by municipal effluent showed greater salt accumulation in all three studied depths. There was a significant interaction between irrigation methods and water quality treatments. The maximum soil salinity of interaction treatments was measured at the depths of 0-20 cm in a treatment including subsurface drip irrigation – municipal effluent with 1.97 and 1.78 dS/m of EC in the first and second soil sampling steps respectively. The minimum measured EC of interaction treatments was at the depth of 20-40 cm of a treatment including furrow irrigation – fresh water with 0.7 and 0.76 dS/m in the first and second sampling steps respectively (Table 6).

Table 6. Mean salinity in the soil layers for various components of the interaction of irrigation methods and water quality

Evaluated Treatments	EC (dS/m)			EC (dS/m)		
	(First sampling step)			(Second sampling step)		
	0-20	20-40	40-60	0-20	20-40	40-60
(cm)						
Furrow-Effluent	1.5	1.44	1.41	1.39 bc*	1.07 b	1.27 c
Furrow-F.water	0.9	0.7	0.77	1.25 c	0.76 c	0.9 d
SSD-Effluent	1.97	1.6	1.55	1.78 a	1.4 a	1.65 a
SSD-F.water	1.4	0.9	1	1.55 ab	1.18 b	1.51 ab
SD-Effluent	2	1.67	1.44	1.46 ab	1.4 a	1.49 ab
SD-F.water	1.8	1.1	0.9	1.41 bc	1.32 ab	1.4 b

*: Means with dissimilar letters in each column have significant difference at the level of 5% based on Duncan Test.

As it can be found from achieved data in table (6) although initial soil salinity at different depths was approximately same, the amount of soil salinity at different depths changed after irrigating by effluent for a year due to higher salinity of municipal effluent comparing fresh water and using various irrigation methods. All treatments irrigated by municipal effluent became more saline than plots irrigated by fresh water at all three depths of soil samplings. Also, pressurized irrigation methods made soil more saline than furrow irrigation method.

As it is observed in figure (3) and figure (4), in all treatments and both soil sampling steps, salinity of soil surface (0-20 cm) was higher than deeper layers. These two figures obviously show the effect of using municipal effluent on soil salinity.

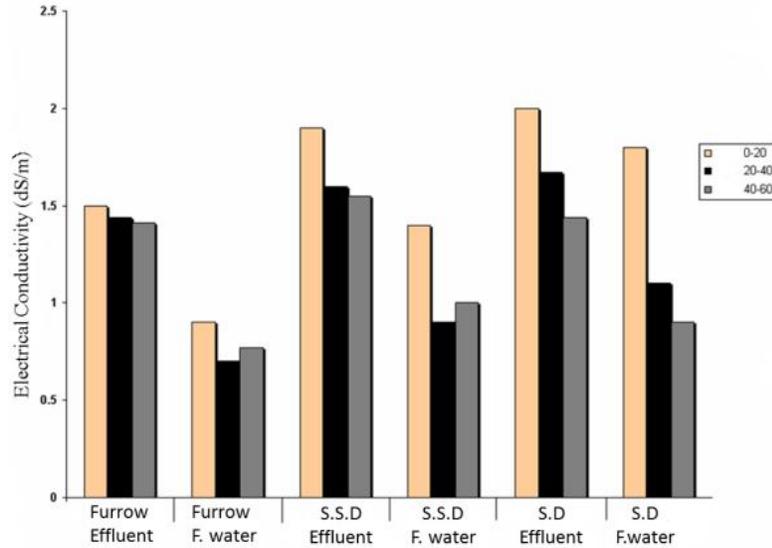


Figure 3. Soil salinity variations in various treatments and depths in the first soil sampling step

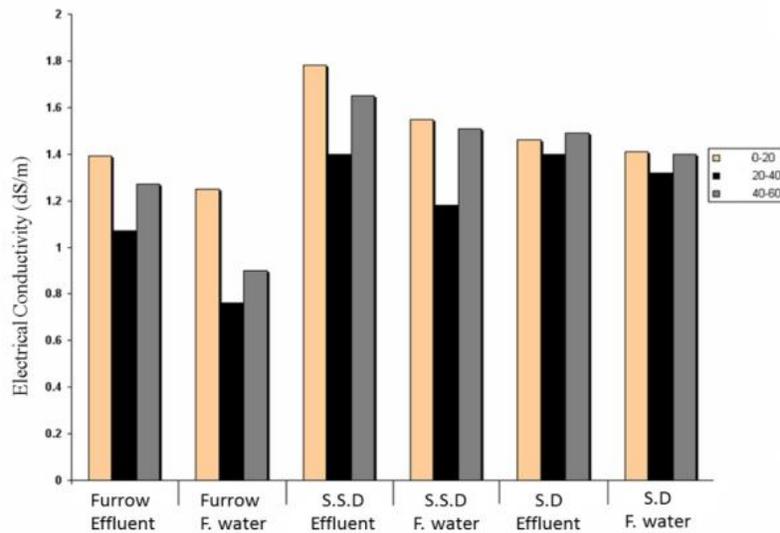


Figure 4. Soil salinity variations in various treatments and depths in the second soil sampling step

3. Salinity distribution

In subsurface drip irrigation method, the maximum amount of salinity was found at the distance of 30 cm from the dropper and at the depth of 0-20 cm. Lower salinity was seen closer to the dropper. Also, the minimum salinity was shown at the depth of 20-40 cm and in line with dripper. According to figure 5, the maximum amount of salinity was indicated on the soil surface.

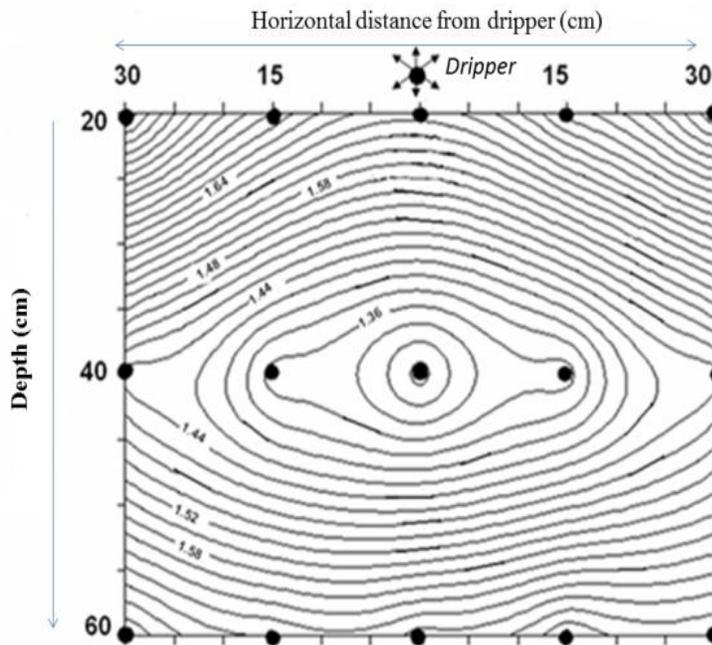


Figure 5. Distribution of salinity in the soil profile in subsurface drip irrigation method

In surface drip irrigation method, the highest salinity was found at the depth of 0-20 cm (soil surface) (Figure 6) and with increasing distance from the dropper, soil salinity increases. In fact, there was more salinity at longer distances from droppers since, less leaching is occurred. In furrow irrigation method, the most value of salinity was obtained at the top of the heap of furrow (0-20 cm) (Figure 7). Also, the bottom of the furrow showed the lowest salinity.

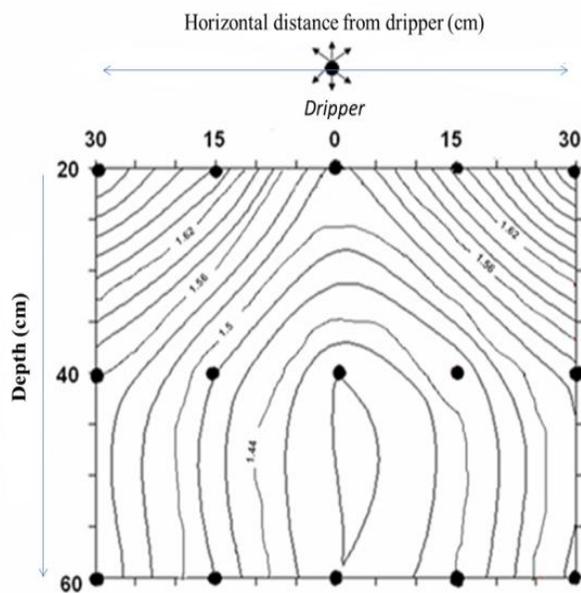


Figure 6. Distribution of salinity in the soil profile in surface drip irrigation method

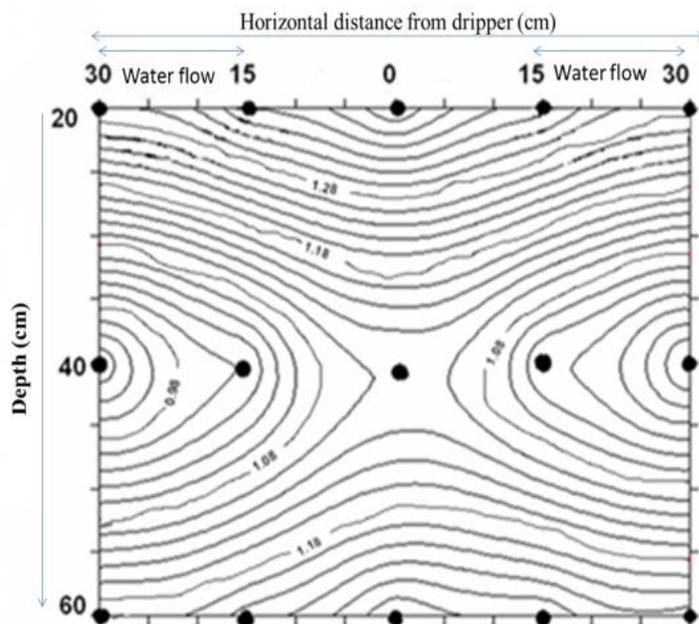


Figure 7. Distribution of salinity in the soil profile in surface furrow irrigation method

With regard to the results of this study, some points in using wastewater effluent are recommended as below:

- In irrigation methods with relatively high efficiency, salt accumulation increases in soil surface due to reduction of water losses of depth that result in impossibility of leaching. Therefore, leaching operation by high quality waters while using effluent for irrigation is recommended particularly in pressurized irrigation methods.
- Groundwater level control is required when wastewater effluent is used due to probability of groundwater pollution.
- Environmental impacts of effluent must be considered and studied.
- Reducing the irrigation period and increasing the irrigation frequency are recommended because wastewater effluents have much higher salinity than fresh waters.
- In drip irrigation method, it is recommended to activate the irrigation system when rainfall is occurred. It can be effective to improve leaching.
- More researches on the accumulation of various elements in the soil and around the water source can reveal more facts about the use of effluent in irrigation.

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