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Effects of Using Subsurface Drip Irrigation and Treated Municipal Waste Water in Irrigation of Tomato

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Abstract: Whenever good quality water is scarce, water of marginal quality will have to be considered for using in agriculture. Municipal waste water is marginal quality water and using of this for irrigation can be an important consideration when its disposal is being planned in arid and semi-arid regions. In this study, secondary municipal effluent was used for irrigation of tomato. This effluent is using activated sludge process to treat the municipal wastewater. Five different irrigation treatments were designed with three replications. The treatments were as follows: T1: Furrow irrigation with drinking water network. T2: Surface drip irrigation (DI) with treated wastewater. T3: Sub surface drip irrigation (SDI) in 15 cm depth with treated wastewater. T4: Sub surface drip irrigation (SDI) in 30 cm depth with treated wastewater. T5: Furrow irrigation with treated wastewater. Crop water requirement was determined by ET-HS model. Also, in this study, chemical and microbiological characteristics of soil, water and crops have been analyzed. The results of this study indicated that application of DI and SDI could be control environmental contamination and in comparison surface irrigation, decreases the pollution problems in the soil. Also, the highest yield was obtained from T2 and T3, which was about 52 tons ha^{-1} (18 tons ha^{-1} higher than the average yield of the T1). A part of this increased yield can be related to better soil moisture and increased available nitrogen in the root zone. Additionally, with regard to health problem, minimum contact was generated between the effluent and the workers or the aerial plant parts. But the microbiological tests indicated that among of effluent treatments, T3 had better microbiological quality of tomato.

Key words: Municipal waste water, subsurface drip irrigation, tomato, waste water reuse, water use efficiency, environmental contamination

INTRODUCTION

The continuous growth of world population along with industrial and agricultural activities for increasing the supply of food in one way and consecutive drought in recent years on the other hand has caused that the consumption of the existing surface reservoir to reach to its maximum in the dry belt zone and further depletion beyond the standard level. IRAN is among the Middle East countries, which experienced 20-25% drop in annual rainfall comparing to average annual rainfall between 1961-1990 in the year of 2000 (Abedi and Najafi, 2001). In addition, Iran is among the countries, which the consumption of its water reservoirs is beyond the international standard. So, in the case where the country is suffering severely from the shortage of consumptive water and critical problems of water reservoir, this is considered as a serious problem. It is inevitable and necessary to pay attention to the abnormal consumption of reservoirs (Najafi, 2002).

On the other hand, concentrations of industrial and densely populated centers in various locations have caused the formation of high capacity amount of sewage. Having no attention for better method of desorption has caused environmental problems in the vicinity of these locations. The study has shown that the best way for usage of wastewater after treatment is in the agriculture (Pescod, 1992).

Since the wastewater is considered as the non-ordinary resources of water, its usage in agriculture demands a unique management, which in addition to its appropriate utilization, it has neither threat on environment and health of plant soil nor on the surface and subsurface reservoirs. On this field, Pescod (1992) has compared the advantages and disadvantages of different methods of irrigation at the time of utilizing the wastewater and concluded that drip irrigation is the only method that solves the particular problem of using wastewater.

In addition to that, Lauver (2000) in a research done on mass balance of nitrate contamination in the case of using municipal wastewater in Arizona, USA has found that the possibility of ground water contamination is high without having control on the above-mentioned waste water. While, Phene and Ruskin (1989) in another research showed that the application of surface drip irrigation and subsurface drip irrigation have been successful in the case of closed nitrate movement comparing to the soil condition, water and in the conditions of root expansion.

Oron *et al.* (1992) by using the waste water on the experimental farms have concluded that when drip irrigation system is utilized the contamination of soil surface and plants would be minimum while it would be maximum in the case of sprinkler irrigation. The result of these experiments also shows that in subsurface irrigation system the amount of nitrogen in the depth of 30-60 cm would be less compare to surface drip irrigation. As the result nitrogen and phosphor are absorbed to the roots whenever the water supply is nearby.

On the other hand, Korom and Jepson (1994) in a study showed that at the time of surface irrigation with waste water, 24% of existing nitrogen has been leached from the accessibility of the root plant.

In another research, Oron *et al.* (1999) showed that by using two methods of surface and subsurface drip irrigation, the amount of contamination of soil is less in the case of subsurface drip irrigation. In this study, the amount of produced corn has also estimated to be more in the subsurface drip irrigation.

In addition to these, concerning the utilization of waste water for irrigation of tomatoes, Erfani *et al.* (2001) showed in a research that utilization of treated municipal waste water has caused an increase in the products comparing with irrigation of products with the well water. The result of this research also showed that microbial contamination of products has been increased in the case of using treated waste water in comparison with the ordinary condition. In another study, Hanson and May (2004) reported that subsurface drip irrigation in the fine-textured salt-affected soils can increase yield and profit of tomatoes compared to sprinkler irrigation with acceptable levels of soluble solids. Drip irrigation also can control subsurface drainage to the shallow ground water.

MATERIALS AND METHODS

The southern sewage treatment plant is located in the southeast of Isfahan, Iran. This plant treats sewage of approximately 800,000 people of Isfahan, which in turn part of waste water damped into the Zayandehrood River and small portion of it is used for irrigation of suburban farms and gardens. This treatment plant is using activated sludge processor and this process is done in there completely.

For the purpose of research, in the vicinity of the treatment plant, a plot was selected somehow the treated waste water be accessible. A drip irrigation pumping station was designed and connected to the output of waste water. The filtration of drip irrigation includes a sand filter, screen filter and two layers of fine and medium sand filters which the upper layer with effective diameter of 0.5 mm and thickness of 60 cm and bottom layer with effective diameter of 1 mm and thickness of 30 cm.

Screen filter is cascaded with a 100 micron (150 mesh) steel screen in series with the sand filter. Maximum hydraulic load of 2.5 m^3 h^{-1} m^{-2} is assumed with 4.75 dripper per square meter.

For the purpose of checking the impacts of the above-mentioned drip irrigation model, five different irrigation treatments were selected and a randomized complete block design of three replications was employed for irrigation of tomato. These treatments were as follows:

- T1 : Furrow irrigation and ridge with drinking water network.
- T2 : Surface drip irrigation with treated waste water
- T3 : Subsurface drip irrigation in the depth of 15 cm with treated waste water.
- T4 : Subsurface drip irrigation in the depth of 30 cm with treated waste water.
- T5 : Furrow irrigation and ridge with the width of 75 cm with treated waste water.

According to the above treatments, tomato was planted from the beginning of May 1st by October 25th of 2001. The amount of the water necessary for the plant and irrigation schedule were defined based on ET-HS Model (Najafi, 2002). For this purpose maximum and minimum of the temperature were measured daily and filled in the model. Finally the consumed water of the plant was defined.

RESULTS AND DISCUSSION

After three times of harvesting from various treatments of tomato product, all different treatments were defined with maximum yield. Figure 1 shows the conclusion of yield from the above treatment per hectare, which had been compared by Duncan test. Based on this figures the first treatment had the least yield compare to other treatments while second and third treatments had the most yield. Comparison of these figures based on Duncan test showed that the yield of second and third treatments have significant difference of 5% in level with the first and fourth treatment. With the reference to the amount of irrigation and product yield the Water Use

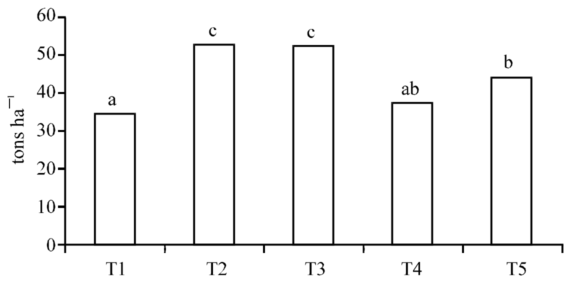

Fig. 1: Amount of average yield in different treatments

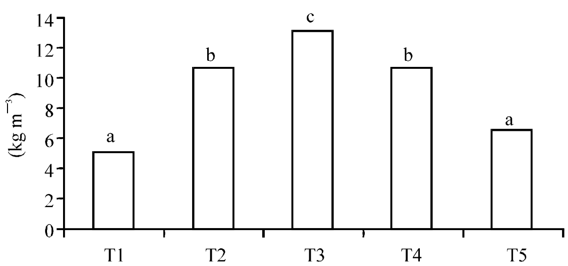

Fig. 2: Comparison of WUE in different treatments

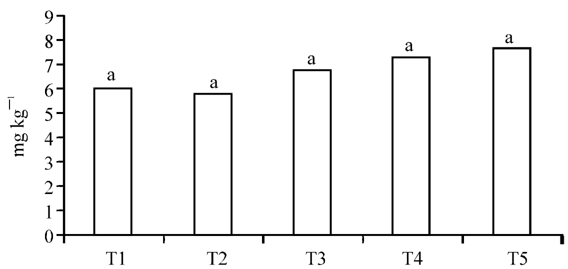

Fig. 3: Average concentration of N-NO_3 in tomato samples in different treatments

Efficiency (WUE) was calculated per treatment. Figure 2 shows the rate of WUE in the sample under the study. Based on this figure third treatment has had the most efficient use of water in the production somehow has shown substantial difference with other treatments. The second and forth treatments were also classified in next order while the first and fifth treatment have had the least efficiency of water usage.

Checking this study showed that due to the accumulation of nitrates in tomato, no significant difference in 5% level was observed (Fig. 3). Meanwhile the figures obtained in production of the treatments under the study are much less than the toxic threshold of nitrates in tomatoes (Najafi, 2002). Figure 4 also shows the nitrate movement in different layers of soil for planting the tomatoes. Based on this figure in special condition in second and third treatments, maximum accumulation of nitrates is observed up to the depth of

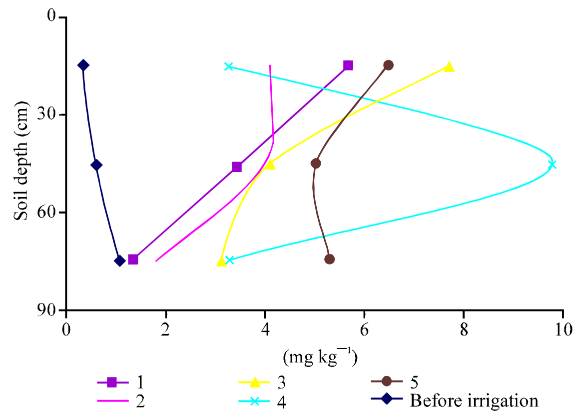

Fig. 4: Nitrogen movement in different layers of soil

Table 1: Average of heavy metal concentration in soil of different irrigation treatments (g/ha/y)

Treatment	Fe	Zn	Cu	Mn	Cd	Pb
T1	338	338	68	68	68	135
T2	246	246	49	49	49	99
T3	199	199	40	40	40	80
T4	176	176	35	35	35	70
T5	338	338	68	68	68	135
Critical limit	-	140000	75000	-	1900	15000

30 cm. In the fifth treatment which barley and ridge method was utilized, the nitrate has moved down to the 90 cm depth.

Another important parameter at the time of using waste water in agriculture is the amount of heavy elements entering into soil and its accumulation in the product. Table 1 show the density of Iron, Copper, Zinc, Manganese, Lead and Cadmium elements entering into the soil with reference to the amount of irrigated water next to the annual permissible limit of these elements based on US-EPA standard (Hung and Iskandar, 2000). With comparison of these values with standard references, the permissible amount of these elements can be determined. Among the sewage treatment the third treatment has had the least injection amount of heavy elements into soil. The same elements have been analyzed in tomatoes and based on the obtained result, the amounts of above-mentioned elements have been below their critical limits (Erfani *et al*., 2001) and no impermissible accumulation of elements is observed (Fig. 5).

Figure 6 shows the amount of nematodes in tomato samples in different treatments under the study. Figure 7 shows the amount of measured fecal coliform separately in different treatments. These two parameters have been compared at 5% level based on Duncan test. The result shows that there is no substantial differences among the first, third and fourth treatments. The second treatment is classified next in row and the fifth has had the most contaminated condition among the treatments.

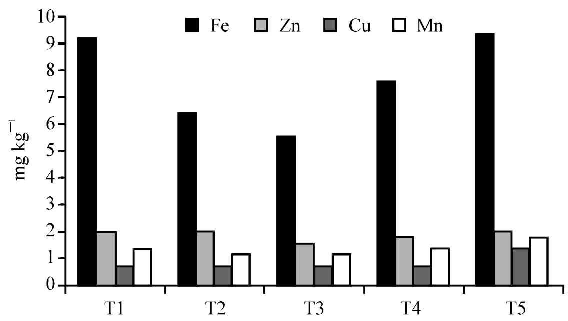

Fig. 5: Average concentration of heavy metals in tomato samples in different treatments

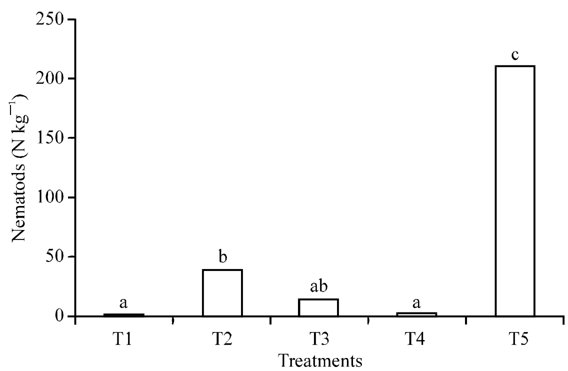

Fig. 6: Amount of nematodes in tomato samples in different treatments

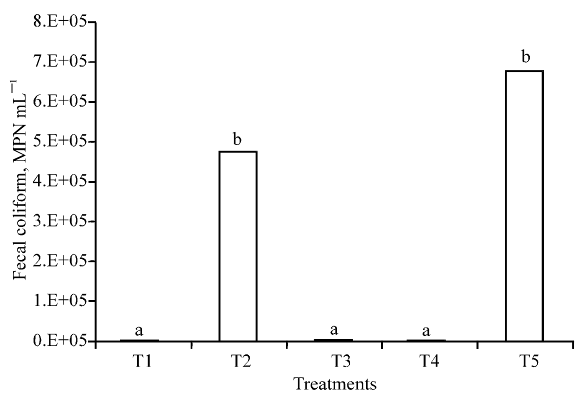

Fig. 7: Amount of fecal coliforms in tomato samples in different treatments

By checking the result obtained from the product evaluation, it can be concluded that first usage of waste water has caused considerable increase in the amount of products due to existence of nutritious elements along with irrigation. Previously, Mara (1995) showed that waste water reuse caused increasing of crops product as compared to fresh water. Secondly, among the waste water treatments the best product functioning is observed for surface and subsurface drip irrigation in the depth of 15 cm, showing the supply of moisture and nutritious elements in the root development area. Hanson and May (2004) were showed that the tomato yield increases of 12.90-22.62 Mg ha^{-1} were found for the drip systems compared to the sprinkler systems with similar amounts of applied water. Thirdly, with attention to that the amount of surface evaporation in subsurface drip irrigation method decreases, the efficiency of water consumption in the third treatment or subsurface drip irrigation in the depth of 15 cm has increased substantially.

The result of this study also showed that in the case of subsurface drip irrigation due to minimal leaching, prevalence contamination due to usage of waste water in depth and to water reservoir is minimized.

In addition on the condition that there is enough moisture exists around the root, the available nitrogen in waste water is absorbed to the plant, which in turn increases the growth and efficiency of the product (Oron *et al*., 1999). Moreover, the result of this study shows that in the case of subsurface drip irrigation, the contamination of soil surface and product is minimum, which in this case there would be less concern about the usage of waste water for irrigation of special product. In also minimizes the contact of farm workers with sewage.

Even though the density of heavy element is much less than toxic threshold of these elements in soil and plant, this study showed that with reference to increase in efficiency of water usage, the density of toxic elements like lead and cadmium to soil is minimum.

In an overall study, it can be concluded that the subsurface drip irrigation in the depth of 15 cm, in the case of design and implementation of ET-HS model for measuring of crop water requirement, the best condition is achieved for tomatoes when using the municipal waste water for irrigation.

Finally estimating the effects of using treated municipal waste water and subsurface drip irrigation in the same condition of this study will be offered on the others agriculture crops for further investigation. In addition finding the relationship between soil texture, root zone area and microbiological pollution on soil surface and crops will be suggested for future study.

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