



RESEARCH PAPER

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**Effects of using subsurface drip irrigation and treated municipal wastewater on olive (*Olea. europaea* L.)**

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**Key words:** Olive, sub surface drip irrigation, wastewater.

**Abstract**

The aim of this study was to evaluate and validate the effects of using treated wastewater on the vegetative growth and nutrients content of three years old zard olive (*Olea. europaea* L.) trees. The experiments were carried out for 4 years (2009 – 2013) in random complete blocks in three treatments with six repetitions. The treatments were: subsurface drip irrigation with wastewater (T<sub>1</sub>), subsurface drip irrigation with wastewater in 15 cm depth (T<sub>2</sub>) and subsurface drip irrigation with wastewater in 30 cm depth (T<sub>3</sub>). Wastewater from the treatment plant of the Boroujerd, Iran was used. The present study was designed to determine the effect of subsurface drip irrigation with wastewater in 30 cm depth as compared to other treatments had higher growth parameters, nutrients content and had seen significant difference. Another important finding was that drip irrigation T<sub>1</sub> with wastewater, had lower growth parameters as compared to another treatments. In T<sub>3</sub>, plants absorb water and essential elements, better than other treatments because irrigation source is near the root zone.

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## Introduction

In most arid and semiarid regions of the world, including the lands of Iran (above 80%) water crisis is considered as one of the main problems on the path of sustainable agriculture (Galavi *et al.*, 2010). The use of treated wastewater for irrigation is one of the most-readily-available alternative water sources when natural resources are scarce (Hamilton *et al.*, 2007). In view of recent advances in water management, irrigation and drainage methods, it becomes feasible to use low quality water for irrigation with minimum adverse impacts on plant growth and productivity (Chartzoulakis *et al.*, 2005). Availability of good quality water for irrigation is limited worldwide and thus agriculture is likely to be forced to make increasing use of municipal wastewater (Palese *et al.*, 2009).

Drip systems result in increased productivity and nutrient saving. However, the system has problems of seasonal labor requirement in spreading and collecting the laterals in addition to its deterioration because of its exposure to above soil surface condition particularly in sunny hot climates. To solve these problems, subsurface drip irrigation is being studied. This system has additional advantages over surface irrigation including placement of both water and nutrients at the center of the root system with water content being relatively high and steady with time (Phene & Howell, 1984; Thompson *et al.*, 2002), and decreased evaporation of water from soil surface resulting in increased water availability to plants (Martinez Hernandez *et al.*, 1991), and movement of nutrients in larger volume around the emitter in spherical volume, while in the case of surface application the movement is restricted to a semispherical volume below the drip (Phene *et al.*, 1986). Recent evidence suggests that marketable and total ear yields of corn for subsurface trickler were higher than for surface tricklers. Total fresh weight, dry matter production and plant height during the growing season were greater for subsurface than for surface content at the center of the rootzone. This increased P and K uptake rates resulted in higher dry

matter production and commercial yield relative to surface trickler placement (Martinez *et al.*, 1991). Oron *et al.* (1992) used wastewater in experiment fields in the Palestine and concluded that the contamination of soil and plant surfaces is the lowest when drip irrigation system is used, but when sprinkling irrigation is applied the contamination rate was at its maximum level. In addition to that, in relation to the effect of the application of wastewater in irrigation of corn, Oron *et al.* (1999) realized that the functioning of corn in subsurface drip irrigation is better than that in surface drip irrigation system. Najafi (2006), showed 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 wastewater for irrigation. That research indicates that estimating the effects of using treated municipal wastewater and subsurface drip irrigation in the same condition of this research will be offered on the others agriculture crops for further investigation.

The objectives of this study were to evaluate the effect of subsurface drip irrigation with municipal wastewater on growth parameters of young olive trees (*Olea europaea* L. -cv Zard).

## Materials and methods

### Area study

The effect of municipal wastewater on the growth and nutrients content in leave of young trees (*O. europaea* L.-cv Zard) was investigated by precise lysimetric experiments. The experiments were carried out for 3 years (2009 – 2013) in random complete blocks in three treatments with six repetitions. The climate in the area is classified as semi-arid, and the annual rainfall of 561 mm (mean 1999–2012) falls mostly in the winter, the mean annual temperature ranges from 14.9 to 17.1 °C. The studies were done using Entisols sampled to a depth of 0-30 cm from agricultural fields in Boruojerd province (33°54' N, 48°40' W; 1620 m above sea level) in Iran.

*Treatments*

The treatments were: surface drip irrigation with wastewater(T1), subsurface drip irrigation with wastewater in 15 cm depth (T2) and subsurface drip irrigation with wastewater in 30 cm depth (T3). In all of the drip irrigation treatments, in line emitters were selected with 4 L hG1 discharge, wastewater from the treatment plant of the Boruojerd, Iran was used. The

lysimetric experiments were conducted in zero-tension circular lysimeters of 1 m diameter and 1.7 m height from the bottom. The bottom of the lysimeter was covered by geo-textile, overlaid with 0.1 m river sand with 0.5-1 mm grain size, then with 1 m subsoil and 0.4 m topsoil. The soil of the experimental grove is a clay loam(table 1).

**Table 1.** Soil analysis result for chemical characteristic.

Depth (cm)	Ec (dSm <sup>-1</sup> )	pH	OM (g kg <sup>-1</sup> )	Micro and macro elements (mg kg <sup>-1</sup> )							
				N	P	K	Ca+Mg	Fe	Mn	Zn	Cu
0 - 40	1.14	7.7	1.53	1.88	0.69	66.1	50.3	1.87	0.77	0.10	0.009
40 - 100	1.42	7.65	0.1	0.1	0.47	78.33	43.85	1.11	0.76	0.08	0.005

*wastewater analysis*

Wastewater was sampled three times during each experimental year's irrigation season. Wastewater samples were collected randomly in the field from 5

to 8 emitters using 1000 mL sterile glass bottles and stored at 4°C before analysis (table 2). The odour test was performed on the water samples according to the APHA, AWWA, WEF methodology (1995).

**Table 2.** Analysis of municipal wastewaters used for irrigation.

Parameters	unit	wastewater	Agriculture application	Water resources
pH	dSm <sup>-1</sup>	7.5	6 – 8.5	6 – 8.5
EC	mgL <sup>-1</sup>	1.41	< 3	< 3
Total -N	mgL <sup>-1</sup>	39.22	--	--
Total P	mgL <sup>-1</sup>	69.1	--	6
K	mgL <sup>-1</sup>	27.1	--	--
Mg	mgL <sup>-1</sup>	83.8	100	100
Ca	dSm <sup>-1</sup>	90.3	--	75
Fe	mgL <sup>-1</sup>	0.18	3	3
Zn	mgL <sup>-1</sup>	0.01	2	2
Mn	mgL <sup>-1</sup>	0.018	1	1
Cu	mgL <sup>-1</sup>	0.008	1	1

*Plant analysis*

Regarding the effect on vegetative growth, trunk circumference for each tree was tagged and measured at the beginning and the end of the experiment. Percent of net increase of trunk circumference was calculated. In addition, fifty mature leaves per tree from tagged shoots were collected randomly and the leaf area were measured using portable leaf area meter . Volume index was calculated using the equation for one-half of a prolate spheroid as follows:

**V= 0.5236.H<sup>2</sup>.D**

where, V is the volume index, (m<sup>3</sup>), H is the canopy height (m) and D is the canopy diameter (m). At first

of October, sample of 100 leaves (one-year old) was collected randomly from each tree at a constant height and at all direction of the trees for analysis. Each leaf sample was divided into two portions. In the first portion, leaves were washed with tap water, distilled water, air-dried then oven dried at 65°C to a constant weight. The dried samples were ground and then digested with concentrated sulfuric acid +30% hydrogen peroxide . Total N was determined by micro-Kjeldahl method (Jackson, 1973). Phosphorus was determined according to the method of Murphy and Riley (1962). Potassium determined by Flame Photometer (Jackson, 1973). Leaf contents of calcium, magnesium and micronutrients (Fe, Mn, Cu and Zn) were determined by atomic absorption

spectrophotometer (Carter, 1993). In the other portion of each leaf sample (fresh leaf material), total chlorophyll content was determined according to Moran and Porath (1980). Relative Water Content (RWC) were determined by the method of Weatherly (1950).

#### *Statistical analysis*

Collected data were analyzed via SAS Institute Inc. 6.12. First of all data were analyzed by ANOVA to determine significant ( $p \leq 0.05$ ) treatment effect. The significant difference between individual means was determined by Duncan Multiple Comparison Test.

### **Results and discussion**

#### *Vegetative growth*

One question that needs to be asked, however, is whether Irrigation system did not have significant effects on vegetative growth parameters: percent of increase in trunk circumference, percent of increase in tree height, volume index and leaf area. Previous studies have reported that crop yield and water use efficiency (WUE) were slightly higher when applying water through subsurface drip than through surface drip (El-Gindy and El-Araby, 1996). Such increments may be due to that increasing water supply improved the root function, consequently enhanced nutrients uptake and metabolic processes that led to increase tree growth (Mengel and Kirkby, 1987). Total fresh weight, dry matter production and plant height during the growing season were greater for subsurface than for surface content at the center of the rootzone. This increased P and K uptake rates resulted in higher dry matter production and commercial yield relative to surface trickler placement. The effect of water regime on increasing olive trees growth was confirmed by Andria and Morelli (2002). Girona *et al.* (2002) studied the response of young olive trees to different water supplies. Irrigation treatments were based on crop coefficients (Kc), 0.25, 0.38, 0.50, 0.57, 0.64, 0.71 and 0.85. Trees that received higher Kc grew faster and comparatively received substantially more water than the expected solely by Kc's. Dichio *et al.* (2002)

studied the soil water availability and relationship between canopy and roots in young olive trees (cv. coratina). The ratio between root and leaf dry weight was always greater in non-irrigated plants compared to irrigated ones. Also, the study showed that increased canopy growth by 67% compared to irrigated plants. In non-irrigated plants, canopy growth (but not root growth) was drastically reduced, as a defiance strategy against water deficit, making for a better root/leaf ratio and consequently greater water availability for leaves.

This finding is in agreement with Najafi (2006), showed 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 wastewater for irrigation. That research indicates that estimating the effects of using treated municipal wastewater and subsurface drip irrigation in the same condition of this research will be offered on the others agriculture crops for further investigation. Also Asgari *et al.* (2007) in the same condition of this research on sunflower reported same results. These findings of the current study are consistent with those of Rahil and Antonopoulos (2007) examined the effects of irrigation with reclaimed wastewater and nitrogen fertilizer applications on plant growth, water and nitrogen distribution in the soil profile, water and nitrogen balance components and nitrogen leaching to groundwater. They concluded that municipal wastewater reclaimed by activated sludge and nitrification/denitrification can be used as valuable source of irrigation without contaminating groundwater. However, this quality of wastewater can replace only a small portion of plant N requirements.

#### *Leaf area index*

Leaf Area Index (LAI) fluctuation trend of the treatments revealed that about 30 days after sprouting, a slow growth in the leaf area index was observed. Probably it resulted from meristematic cells

and small leaf area. Then with a fast and linear growth until 90 days after planting, it reached the maximum growth and until the end of the growth, it had a declining trend due to the fall of the leaves. Of course, slight differences were observed among different treatments when they reached their maximum leaf area. The leaf area index fluctuation trend for different treatments during the growing seasons suggests that T<sub>3</sub> treatment has produced more leaf area index compared to other treatments during the growing seasons. That is T<sub>3</sub> gained more significant leaf area index compared to other treatments when leaf area index reached its maximum point. The results suggest that in T<sub>3</sub> treatment, more water has been absorbed and larger leaf area formed due to the nearness of rhizosphere to water and nutrient and made an appropriate moist bulb, up to 60 cm deep. Also added that high concentration of N, K and P in the wastewater compared with common water and its nearness to rhizosphere for absorption by the plant in T<sub>3</sub> treatment resulted in an increase in the leaf area index. Asgari *et al.* (2007) in the same condition of this research on sunflower reported that sunflower under the same irrigation condition has same LAI index. Such increments may be due to that

increasing water supply improved the root function, consequently enhanced nutrients uptake and metabolic processes that led to increase tree growth (Mengel and Kirkby, 1987). The effect of water regime on increasing olive trees growth was confirmed by Andria and Morelli (2002), Hussein (2008) and Erel *et al.* (2008).

*Leaf water contents and leaf total chlorophyll*

The results (table 3) show that T<sub>2</sub> and T<sub>3</sub> had the highest leaf water contents, but there is no significant difference between them. The data obtained clearly indicate that T<sub>3</sub> treatment significantly increased leaf content of total chlorophyll (Table 3). Such increase may be due to improve the tree growth as a result of more water absorption and more uptakes of N, Mg and Fe, such elements have close association in chlorophyll biosynthesis (Raghavendra, 2000). Also, such increases might be due to increase photosynthesis rate as a result of more absorption of available nutrients, which cause an increase in growth and photosynthesis efficiency (Therios, 2006). These results agreed with those reported by Palese *et al.* (2009) and Hussein (2008).

**Table 3.** Effect of wastewater treatment on Zard olive trees grown.

Treatment	Percent of increase in trunk circumference (%)	Percent of increase in tree height (%)	Volume index (m <sup>3</sup> )	Leaf area (cm <sup>2</sup> )	RWC (%)	Chlorophyll (mg g <sup>-1</sup> F W)
T <sub>1</sub>	270.8	223.0	0.398	4.86	76.1	0.29
T <sub>2</sub>	289.95	252.88	0.4030	5.1501	76.1	0.284
T <sub>3</sub>	298.78	274.03	0.5009	5.4012	76.2	0.321
Significance treatments	ns	ns	*	*	ns	*

ns: not significant, \*: significant at P = 0.05

*Leaf nutrients content*

The results indicate that in (T<sub>3</sub>) subsurface Drip irrigation treatment, less weed grew to compete with the plant and less water evaporated from the soil surface with more dry weight were due to the nearness of irrigation water source and nutrients present in the wastewater around the rhizosphere to be absorbed. subsurface drip irrigation with wastewater in 30 cm depth (T<sub>3</sub>), significantly increased leaf content of nutrients (N, P, K, Fe, Zn,

Mn and Cu), (Table 4). Such increase may be attributed to the increase of vegetative growth and improvement of water and nutrients absorption. The beneficial effect was noticed at the highest levels of water (T<sub>3</sub>), in which it improved the nutrients status of olive leaves (Hussein, 2008). These results are in harmony with those obtained by Bahati and Singh (2003), Hussein (2008) and Palese *et al.* (2009). Kiziloglu *et al.* (2008) investigated the effects of irrigation with untreated, and preliminary and

primary treated wastewater on macro and micronutrient distribution within the soil profile, yield and mineral content of cauliflower and red cabbage plants grown on a calcareous soils. They reported that wastewater irrigation affected

significantly plant nutrient content. In addition, application of wastewater increased yield as well as N, P, K, Ca, Mg, Na and Fe contents of cauliflower and red cabbage plants.

**Table 4.** Effect of wastewater on leaf nutrients content of olive trees.

treatments	Macronutrients leaf content (%)					Micronutrients leaf content (%)			
	N	P	K	Ca	Mg	Fe	Zn	Mn	Cu
T <sub>1</sub>	1.8266	0.172	0.964	1.07	0.841	79.81	5.15	7.9	5.8
T <sub>2</sub>	2.0761	0.207	1.175	1.11	0.861	84.37	5.82	8.03	6.3
T <sub>3</sub>	2.568	0.282	1.321	1.12	0.902	90.31	6.88	9.08	6.95
Significance treatments	*	*	*	ns	ns	*	*	*	*

ns: not significant, \*: significant at P = 0.05

**Conclusions**

The most obvious finding to emerge from this study is that, the application of wastewater due to the presence of nutrients results in an increase in the product growth indices in ordinary situations (Asgari *et al.*, 2007; Meli *et al.*, 2002; Ramirez-Fuents *et al.*, 2002). It was also shown that, the most dry matter rate and product functioning was observed to be performed by subsurface drip irrigation treatment at a depth of 30 cm (Asgari *et al.*, 2007). This shows the supply of moisture and nutrients in the rhizosphere development environment. Third, when the surface evaporation rate in subsurface drip irrigation is reduced, the efficiency of water consumption in T<sub>3</sub> increases meaningfully. As a general conclusion, irrigation with wastewater through drip method at a depth of 30 cm of soil is a suitable method for the irrigation (Najafi, 2006). Due to the formation of moist bulb in suitable depth and reduction in soil surface evaporation leads to more access of the plant to water and nutrients. In 2003, Lamm and Troien reported that a successful application of subsurface drip irrigation for 10 years in Kansas, USA, reduced the irrigation water-use for corn by 35-55% compared with traditional forms of irrigation. In addition, less use of herbicides and reduction of the danger of environmental contamination, all result in a better control of weeds growing between the planting rows. Also, due to the dryness of the planting rows which provide suitable conditions for the movement of

agricultural machinery in the best gain is attained. Future studies on the current topic are therefore recommended.

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