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EFFECT OF IRRIGATION WITH TREATED INDUSTRIAL EFFLUENT ON GROWTH AND BIOCHEMICAL CONSTITUENTS OF OLIVES

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Abstract

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The suitability of treated industrial effluent came from Al-Husseun Bin Abdullah II Industrial Estate (HUIE) wastewater Treatment Plant for irrigation of olive (*Olea europaea* L.) was investigated during two complete vegetative cycles. The plants were nonbearing transplants under controlled conditions and bearing trees grown in the field. Irrigation with six electrical conductivities (EC = 0.78, 1.0, 2.0, 3.0, 4.0 and 5.0 dS m^{-1}, respectively T_0, T_1, T_2, T_3, T_4, T_5) were compared in the greenhouse experiment. The olive trees under field conditions were trickle irrigated with treated effluent or potable water. Regardless of the cultivar, length and number of new shoots, diameter of the main trunk, leaf area and dry weight of the plants significantly enhanced under the influence of different treatments. A considerable variation in the studied cultivars was noticed. 'Improved Nabali' was the most positively affective one. The leaf biochemical contents from proline and total chlorophyll contents showed no variations among the treated effluent treatments and studied cultivars. Proline content was enhanced by irrigation with treated effluent only under the field condition. Olive oil acidity and peroxide value were not affected by treatments. These results indicate that this kind of effluent is suitable for application to olive orchards under irrigation with continuous monitoring of mineral levels.

Key words: irrigation, olives, industrial effluent, biochemical constituents

Introduction

Water is a resource that is becoming increasingly scarce and needs to be sustained, globally and locally. Recycled effluent usage for irrigation is becoming an increasingly popular practice in many areas of the world, particularly in arid and semiarid regions, where supplies of good-quality water are limited or nonexistent. In many parts of the world, treated municipal wastewater reuse has been successfully practiced for the irrigation of various crops including forests (Al-Jamal, 2002 and Bhati and Singh, 2003) agronomic (Oron and DeMalach, 1987; Tsadilas, 1997 and Burun et al., 2006) and horticultural (Brito et al., 1997; Murillo et al., 2000; Al-Lahham et al., 2003; Carter et al. 2005 and Lopez et al., 2006) crops. The main obstacle for extending the use of of effluents for the irrigation of crops has resulted from their quality. The effluent from different industrial sources has dif-

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ferent impacts on the plants because of the different chemical constituents. Jordan is restoring to use reclaimed wastewater as a principle source of water for irrigating crops as a sensible approach to alleviating the water problem and to improve the water quality of inland surface waters. Moreover, this irrigation source could be reused if concentrations of all trace elements were found to be low and within guidelines for irrigation of agricultural crops (Shatanawi and Fayyad, 1996). However, irrigating plants with wastewater of salinity higher than the crop can tolerate will result in reduction in vegetative growth, yield loss and may decrease crop quality. The various species and cultivars vary greatly in their tolerance to irrigation with such water. Wastewater damage to plants is produced by a combination of several causes, including mainly osmotic injury (Briccoli et al., 1994) and specific ion toxicity (Maas and Hoffman, 1977; Zeid and Abou El Ghate, 2007). Plant adaptation to wastewater conditions can depend on the mechanism of salt avoidance as well as to an increase in specific organic solutes (mainly proline) which help in osmoregulation and in preventing salt accumulation within the cells. However, particular care needs to be directed when using this water for irrigation regarding avoiding accumulation of certain trace elements (e.g., Pb, Cd, and Ni), microbial contamination and deterioration of soil physical conditions (Toze, 2006).

Olive is the leading economic fruit crop of Jordan, which is widely planted at all regions of the country. Despite the current wide use of wastewater for irrigation, there are relatively few data available that confirms or disputes the beneficial or determinal use of industrial wastewater for production of local olive cultivars. The first experimental data concerning using this source of irrigation on local olive cultivars concluded that fruits responded to long-term effluent irrigation from Samra Treatment Plant by exhibiting higher fruit fresh weight and higher fat content compared with trees irrigated with potable water (Al-Gazzaz, 1999). In Tunsia, the olive trees gave an important yield and high rate of oil when they were irrigated with treated wastewater (Charfi et al., 1999). Furthermore, soil salinity increased oil content and did not affect acidity and peroxide value of 'Arbequina' olives (Royo et al., 2005). However, the irrigation with such water has the disadvantages of damaging the soil and of decreasing the yield on the long term.

The response to stress differes greately among various olive genotypes. 'Frantoio' has been consistently reported more tolerant than 'Improved Nabali' to salt stresses (Al-Absi et al., 2003). Supplying the water with seawater until a saline concentration of 10.7 and 15.0 dS/m was obtained, leaded to death of all tested cultivars, whereas Coratina cultivar showed greater resistance (Wallace et al., 1979). However, using brackish water of E. C. of 5.97dS/m, as source of irrigation on Carolea, Nocellara del Belice olive cultivars, did not produce any variations in their growth (Briccoli et al., 1994). Concerning floricultural crops, the reuse of treated effluents becomes a viable option for their irrigation. Irrigation with treated sewage water of roses did not affect the percent and distribution of the flowering stems as well as postharvest quality of the flowers (Bernstein et al., 2006). On the contrary, all phenotypic measurements showed an overall decrease as wasterwater salinity increased for *Celosia argentea* (Carter et al., 2005).

Proline is the most prevalent organic solute that has been accumulated in plants. Extensive research has demonstrated that proline accumulation is a common metabolic response of higher plant to abiotic stresses, including salt stress (Gunes et al., 1996 and Taylor, 1996). The decline in osmotic potential in response to salinity is achieved by accumulation of solutes within the cell and leaving of water from the vacoule. Using fourteen cultivars of olive, El-Sayed et al. (1995) observed remarkable increases in leaf proline content of all tested cultivars as irrigation water salinity inceased.

This research work aimed at evaluating the potential utilization of saline treated industrial effluent from Al-Husseun Bin Abdullah II Industrial Estate (HUIE), as a source of water and its effect on vegetative growth, leaf proline and chlorophyll contents and oil quality of three olive cultivars under partially controlled conditions and two cultivars under field conditions during a 2-year period.

Materials and Methods

Experimental sites

This investigation was carried out in two locations. The first (pot) experiment was carried out at a partially controlled glasshouse, in which temperature and ventilation, can be controlled, located at the College of Agriculture, University of Mutah, Al-Karak, Jordan, while the second (field) experiment was carried out at the olive orchard of Al-Hussein Bin Abdullah II Industrial Estate (HUIE), located about 20 km east of Karak city, during the period March 2004 - January 2006.

Water source

The treated industrial effluent used in this study was taken from the HUIE wastewater Treatment Plant that was built in 1999. This water was mainly generated by textile firms and mixed with municipal domestic effluent. The current flow of the treated water was 500 m^3d^{-1}. Sampling was performed once every two months and the electrical conductivity of the water in each experiment was also measured bimonthly. Ten samples of the treated effluent were collected during the investigation time. The chemical characteristics of the treated effluent and potable water are shown in Table 1.

Plant material and growing conditions

Greenhouse experiment

Uniform, nonbearing, two years old 'Improved Nabali' (locally known as Nabali Muhassan), 'Nabali', and 'Manzanillo' olive transplants were used. The transplants (average diameter 9.1 mm) were

Table 1

Average, minimum and maximum quality characteristics of the treated effluent and average quality characteristics of potable water used in the experiments as well as guideline limits of water quality for irrigation

Constituent	Treated wastewater				Potable water		Recommended max. conc.**
	Min	Max	Mean	Std. dev	Mean	Std. dev	
pH	7.3	8.2	7.8	0.3	7.6	0.17	8.4
NO_3-N (ppm)	2.4	6.4	3.9	1.42	3.4	0.23	30
NH_4-N (ppm)	2.3	9.3	4.1	2.07	2.1	0.12	10
PO_4 (ppm)	6.8	10.5	8.6	1.39	0.08	0.012	-
K (ppm)	14.9	29.3	22.4	6.01	6.73	0.67	-
Ca (ppm)	58.3	144.5	99.03	31.2	51.8	7.02	400
Mg (ppm)	58.4	114.1	84.19	17.92	28.3	3.39	60
Na (ppm)	190.4	351.2	275.25	55.22	50.7	8.05	207
Cl (ppm)	58.3	124.1	93.2	23.69	82	8.82	350
Fe (ppm)	0.54	0.95	0.72	0.13	0.097	0.0187	5
Mn (ppm)	0.046	0.082	0.061	0.012	ND*		0.2
Zn (ppm)	0.033	0.046	0.039	0.004	0.104	0.012	2
Cu (ppm)	0.06	0.14	0.09	0.03	0.01	0.0028	0.2
Pb (ppm)	0.016	0.035	0.023	0.006	ND		5
Ni (ppm)	0.007	0.014	0.01	0.002	0.101	0.0086	0.2
Cd (ppm)	ND	ND	ND	-	ND		0.01

* : Not detectable.

** : Ayers and Westcot, 1985.

Table 2
Chemical and physical properties of the soils used in the greenhouse and Al-Hussein Bin Abdullah II Industrial Estate (HUIE) orchard experiments at the beginning of the experiment

Properties Texture	College greenhouse Sandy clay loam	HUIE orchard Sandy clay loam
pH	7.4	8.1
E.C. (dS/m)	1.12	1.4
Organic matter (%)	0.64	0.81
N (%)	0.15	0.22
P (ppm)	155	224
K (ppm)	269	154
Ca (ppm)	472.1	326.2
Mg (ppm)	33.8	37.7
Na (ppm)	1.47	2.1
Fe (ppm)	6.3	4.9
Mn (ppm)	4.1	8
Zn (ppm)	1.1	3.2
Cu (ppm)	1.4	2.5
Pb (ppm)	ND*	0.24
Ni (ppm)	ND*	ND*
Cd (ppm	ND*	ND*

* : Not detectable.

planted in March 2004 in 8-liter plastic pots (25 cm diameter, 25 cm depth) containing a sandy clay loam soil. They were supplied with half-strength Hoagland nutrient solution (Hoagland and Arnon, 1950) once every three days for 40 days before treated effluent application began. The nutrient solution contained the major nutrient salts $Ca(NO_3)_2$, $MgSO_4$, KNO_3, and KH_2PO_4, in concentrations of 2.5, 1.0, 2.5 and 0.5 mmol L^{-1}, respectively; the minor nutrient salts $ZnSO_4$, $MnSO_4$, $CuSO_4$, H_3BO_3, and MoO_3 in concentrations of 0.4, 4.6, 0.2, 23.4 and 0.1 µmol L^{-1}, respectively; and 38.4 mg L^{-1} of Sequesterene containing 13% (w/w) NaFe. The chemical properties of the soil were determined according to the standard procedures of the USSL (1954). These properties are shown in Table 2. One transplant was planted in each pot. The transplants were trained to 3-4 shoots per plant two weeks after planting.

Irrigation with six electrical conductivities (EC = 0.78, 1.0, 2.0, 3.0, 4.0 and 5.0 dS m^{-1} in treatments T_0, T_1, T_2, T_3, T_4, T_5, respectively) were compared in the greenhouse experiment. The aqueous solutions were obtained by diluting treated effluent (average EC = 4.2 dS m^{-1}) with tap water until a saline concentration of the target E.C was obtained, or by adding a multicomponent electrolyte solution (comprising Ca, Mg, Na, SO_4, Cl and HCO_3) with a Cl to SO_4 ratio of 1:1 at a fixed SAR of 5 while the stoichiometric ratio of Ca to Mg was kept at a constant value of 1. T_0 represents the control treatment irrigated with potable water.

Five representative pots, from the different treatments, were supplied with 15 cm-long tensiometers filled with the target solutions to be irrigated. All solutions were applied by flood irrigation in an amount sufficient to bring about 30% leaching fraction when the tensiometer reading reached about 30 kPa at the 15 cm-depth. Potable water and effluents were applied to the plants at 4-day intervals with an average of 1 L per pot.

Greenhouse environmental conditions were recorded at a single point above the plant canopy at hourly intervals using a hygrothermograph from March 2004 to November 2005. Daily air temperatures ranged from 18.5 to 39.4 ^{0}C with a mean of 29.0 ^{0}C, whereas night temperatures ranged from 7.6 to 28.6 ^{0}C with a mean of 18.1 ^{0}C. Relative humidity during day time ranged from 33.7 to 48.0% with a mean of 40.9%.

Field experiment

Five years old trees (average height of 1.86 m, average diameter of 7.2 cm) of 'Improved Nabali' and 'Nabali' olives were used. These cultivars were selected for their widespread planting in orchards and nurseries, both private and public. The trees were spaced at 7 m within and 7 m between rows. The trees were irrigated with tap water (average EC = 0.82 dS m^{-1}) or treated industrial effluent (average EC = 4.2 dS m^{-1}) using a drip irrigation system with one emitter per plant, each delivering 4L h^{-1}. The irrigation lasted about 120 min per day and was applied during 2 days per week from April to October and weekly from November to March.

Length of young shoots, number of young shoots/plant, number of leaves per young shoot, leaf area, dry weight of leaves and roots as well as relative growth rate (RGR) were recorded fourteen and seventeen months after treatments for the greenhouse and HUIE field experiment, respectively. Trunk diameters 20 cm above soil surface were measured with caliper.

Proline content was colorimetrically estimated in fresh leaf samples from the two cultivars ten months after beginning of the investigation according to the method of Bates et al. (1973). Chlorophyll content was determined according to Harborne (1973). Olive oil will be extracted using soxhlt apparatus. Olive oil acidity and peroxide value were measured according to Sandia and Martinez (1997).

Statistical design and analysis

Data from each experiment were analyzed separately. The pot experiment was laid out as a randomized complete block design with three replicates in 3 x 6 factorial arrangements. Each replicate was represented by two transplants. On the other hand, randomized complete block split plot experimental design consisted of two cultivars, two irrigation water qualities and four replicates was used for HUIE field experiment. Statistical assessments of differences between mean values were performed by LSD test at P: 05 according to Snedecor and Cochran (1980) using MSTATC statistical package (Michigan State Univ., East Lansing, MI).

Results and Discussion

Treated effluent quality

The results of the analysis of Al-Hussein Bin Abdullah II Industrial Estate (HUIE) treated wastewater used in the two experiments are presented in Table 1. The analysis shows that it is low in toxic pollutants such as heavy metals (Table 1). In general, levels of most metals were below the recommended maximum concentrations and within guidelines for irrigation of agricultural crops (Ayers and Westcot, 1985). It is clear that the treated effluent was found to be basic in reaction and had higher concentrations of sodium and magnesium than the recommended maximum limit (Ayers and Westcot, 1985). On the contrary, the levels of calcium, manganese, zinc, cupper, iron, lead and nickel were within the sufficiency range. The level of cadmium was below the detection limit.

Soil analysis

The results of selected chemical properties of the soils used in this study are given in Table 2. The soil textures of both soils were sandy clay loam. It is clear that the two soils used in pot and field experiments tend to have relatively high pH values. Soil analyses have shown that both soils have low E.C. (1.02- 1.4 dS/m) and low organic matter content (0.64% and 0.81% for pot and field experiments, respectively).

The total nitrogen of greenhouse and orchard soils was between 0.15% - 0.22% while the available P was between 155-224 ppm which is considered optimal for most crops (Walsh and Beaton, 1973). Exchangeable cations (K, Ca and Mg) were enough. Heavy metal concentrations were so low. There was no salinity problem in the soils at the beginning of the experiment.

Growth parameters

The data presented in Figures 1a, 1b, 1c, 1d, 1e and 1f revealed that length and number of new shoots, diameter of the main trunk, leaf area, dry weight of leaves of the various cultivars varied considerably under the influence of different treated effluent treatments at the greenhouse experiment. Generally, the greater concentration of treated effluent used, the

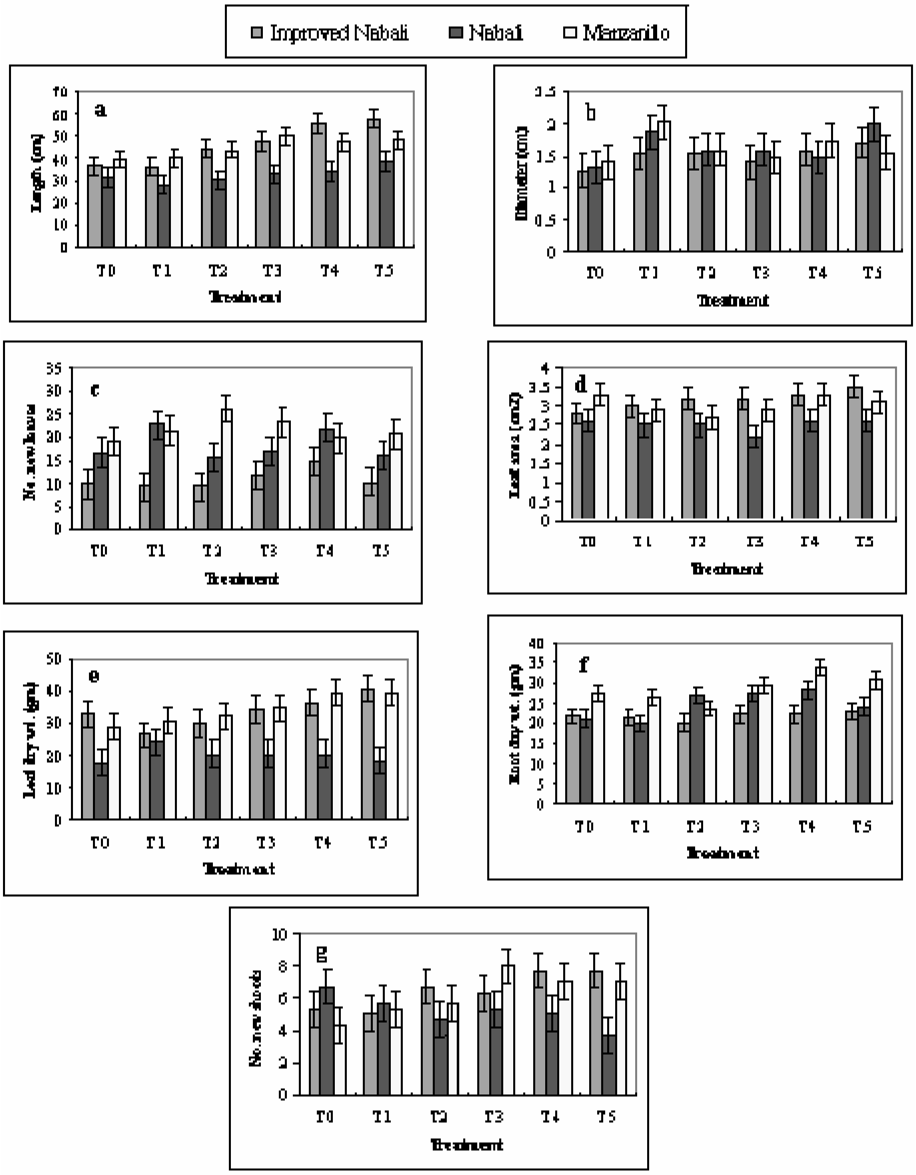

Fig. 1. Average length of young shoots (a), diameter of the main trunk (b), number of new leaves (c), leaf area (d), dry leaf weight (e), dry root weight (f) and number of new shoots (g) of 'Improved Nabali', 'Nabali' and 'Manzanillo' olives grown under greenhouse conditions as influenced by wastewater treatments

higher growth observed. Length of new shoots responded linearly to increasing treated effluent concentration and ranged from 36.7 and 39.5 cm with control treatment to 58.0 and 48.7 cm with application of 5.0 dS m^{-1} treatment for 'Improved Nabali' and 'Manzanillo', respectively. T_5 treatment (5.0 dS m^{-1}) results a significant increase in young shoots length, number of new shoots and leaf area of 'Improved Nabali'. The increase was 58.0%, 45.3%, 25.0% and 33.5% for the previous parameters, respectively, than that of the control treatment (T_0). The different levels of treated effluent did not significantly influence the number of new leaves per shoot of the studied cultivars although highest numbers of 'Improved Nabali' and 'Manzanillo' leaves were obtained with higher concentrations of irrigation water.

Concerning diameter of the main stem (Figure 1b), it is evident that the three cultivars did not follow the same trend. In 'Improved Nabali' and 'Manzanillo', the trunk diameter was not significantly influenced by E.C. of treated effluent treatments. The increase in growth even at about 5.0 dS m^{-1} confirms the findings of Maas and Hoffman (1977), Therios and Misopolinos (1988) and Al-Absi et al. (2003) who classified olive as a moderately salt tolerant plant. Data reported concerning the influence of irrigation water salinity on olive growth appear to be contradictory. Plant growth improvement caused by textile wastwater application has been reported in the literature (Bhati and Singh, 2003). The results obtained confirm the findings of Charfi et al. (1999) who recorded that leaf area as well as weights of fruit and pulp of olive trees irrigated with treated effluent was higher than those of the control. Furthermore, it was previously reported, that irrigation with intermediate saline water (4.2-5.97 dS m^{-1}) did not significantly affect vegetative growth of Carolea, Nocellara del Belice (Briccoli et al., 1994) and Barnea (Weisman et al., 2004) olives. In addition, higher yield of 'Manzanillo' olive was obtained when they were irrigated with 7.5 dS m^{-1} water (Klein et al., 1994). In the current investigation, the salt stress of the used treated effluent did not reach a point that cause a reduction in growth by causing osmotic stress, specific ion toxicity or ion imbalance (Greenway and Munns, 1980). In addition, despite the high concentration of Na in irrigation water, the specific toxicity of sodium seems to have no negative effect on depression of water absorption and, in turn, on growth parameters of olives.

The data presented, also, showed a reasonable genotypic variability among the three tested olive cultivars, in response to treated effluent application. Our results show that the lowest adverse effect of treated effluent application on olive growth was relevantly clear on the semi-vigrous cultivar 'Nabali'. Considering these data, we may conclude that 'Nabali' is most tolerant to treated effluent salinity than the other tested cultivars. Otherwise, it is noted that in spite of the relatively high salinity content of the highest treated effluent treatments, the transplants of 'Nabali', and

Table 3

Vegetative growth parameters of mature 'Improved Nabali' and 'Nabali', olives grown at Al-Husseun Bin Abdullah II Industrial Estate as influenced by treated effluent treatments

Parameter	Improved Nabali		Nabali	
	Control	Wastewater	Control	Wastewater
Length of young shoots (cm)	63.4 a	71.0 a	51.3 a	58.5 a
Trunk diameter increase (mm)	2.6 a	4.2 a	3.6 a	2.8 a
Number of leaves / shoot	22.4 b	35.8 a	30.1 b	37.8 a
Leaf area (cm^2)	3.2 a	3.0 a	2.8 a	3.0 a
Number of young shoots	7.4 a	6.4 a	8.3 a	9.2 a

Means within rows of each cultivar followed by the same letter are not significantly different at P=0.05 (T test).

'Manzanillo' did not show salt injury symptoms, while those of 'Improved Nabali' manifested simple leaf burn symptoms when irrigated with the highest effluent concentration. The substanial genotypic variation in growth in response to salinity has been extensively investigated (Therios and Misopolinos, 1988; Tattini et al., 1992 and Briccoli et al., 1994).

Under the open field conditions, the analysis of data show that there is no significant difference in length of new shoots, leaf area and trunk diameter of 'Improved Nabali' and 'Nabali' between the treated and control treatments (Table 3). However, with the application of treated effluent, a significant increase was seen in number of new leaves over that of the control. Insignificant response to olive cultivar was obtained in terms of the growth parameters. The greater growth of the trees obtained by treated effluent application may be due to the sufficient availability of essential nutrients in the treated effluent which might have enhanced growth parameters and did not reach a point causing a decrease in the diffusion pressure gradient between the plant and the medium (Therios and Misopolinos, 1988) or ion toxicity and ion imbalance or a combination of any of these adverse effects (Greenway and Munns, 1980). In fact, the effect of wastewater treatments on plant growth is largely dependent on its quality (Bhati and Singh, 2003). The latter study highlighted the potential importance of mixing textile effluent with municipal effluent for improvement of biomas production of *Eucalyptus camaldulensis*. Many investigators have reported a substantial increase in plant growth and biomass production upon recycled effluent application on several species (Shukkry, 2001; Al-Lahham et al., 2003; Bhati and Singh, 2003 and Bernstein et al. 2006) as well as on olive (Charfi et al., 1999). The effluent-irrigated olive trees gave higher average fruit flesh weight than albeit well water-irrigated ones (Al-Gazzaz, 1999). In Jerusalem artichoke, it was found that biomass yields (tops and tubers) recorded under recycled effluent usage are equal to and in many cases higher than those obtained for crops grown elsewhere under more favorable conditions (Parameswaran, 1999). On the contrary, the morphological features of Celosia argentea tended to show an overall decrease as salinity of wastewater increased (Carter et al., 2005).

These findings enable one to state that treated effluent effluents of HUIE wastewater Treatment Plant was unhazardous for olive growth and could be considered, under controlled conditions, as a source of irrigation reuse. This recommendation is based on the fact that this water is generated by textile firms mixed with municipal domestic effluent that characterized by its high nutritive value and low concentrations of toxic minerals. Furthermore, the results indicated that the response to treated effluent may vary according to variety, salinity level and ionic composition of the effluent. However, further investigations are required to determine the possibility of accumulation of toxic elements in soils and plant tissues.

Biochemical constituents

Concerning the greenhouse experiment, irrigation with treated effluent tended to have no clear effect on proline and total chlorophyll contents of 'Improved Nabali'and 'Nabali'. However, 'Manzanillo' chlorophyll concentration increased with increasing salinity of the treated effluent (Figure 2a). Manzanillo and Nabali olive cultivars under the greenhouse conditions exhibited differences in chlorophyll content among the treatments. Chlorophyll content of 'Improved Nabali' and 'Nabali' did not affected by the treated effluent treatments. The resulting positive influence to the photosynthetic apparatus as result of the higher treated effluent concentrations in the current investigation may explain the clear increase in plants growth. 'Nabali' accumulated less proline and more chlorophyll than the other tested cultivars. Under field conditions, however, the results obtained did not agree with the pot experiment concerning proline accumulation. Tissue proline concentrations of 'Improved Nabali' and 'Nabali' significantly increased by using treated effluent as source of irrigation (Table 3). A highly positive correlation (av. R= 0.57) was observed between leaf praline content and growth parameters of Manzanillo. The reasonable increase in proline concentration at wastewater treated plants is due either to inhibition of proline oxidation or the breakdown of proline from its

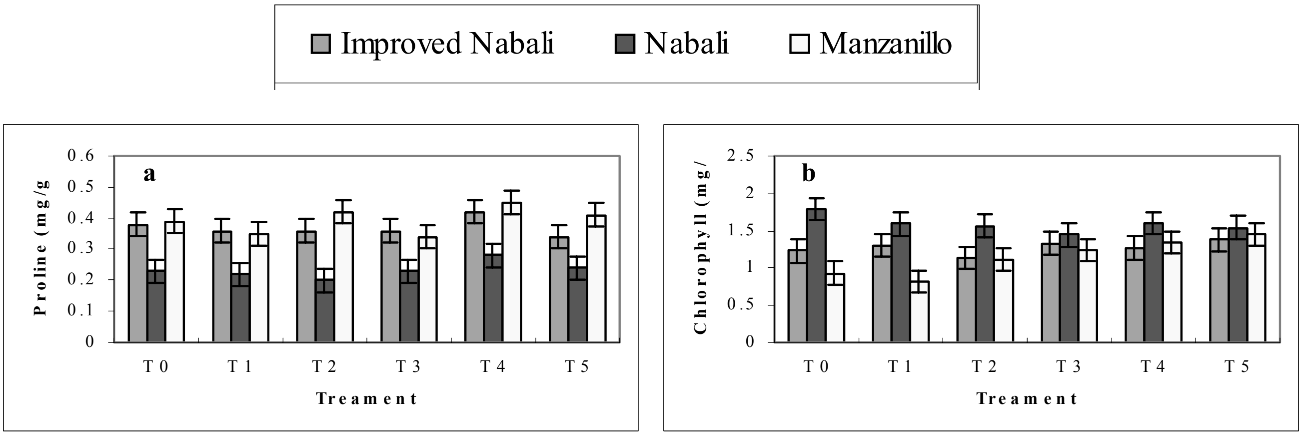

Fig. 2. Leaf proline (a), and chlorophyll (b) contents of 'Improved Nabali', 'Nabali' and 'Manzanillo' olives grown under greenhouse conditions as influenced by wastewater treatments

precursors (Delauney and Verma, 1993). The genotypic variation in proline content may be used for evaluation of tolerance or sensitivity of plants to salt stress (Greenway and Muuns, 1980). These results indicated that proline accumulation in olives is a symptom of the salt stress rather than an indicator of tolerance and no relation is found between proline level and stress tolerance. Under saline environments, proline accumulation in plants increased for the osmoregulation (Gunes et al., 1996). In fact, accumulation of proline under normal conditions may act as a nitrogen reservoir in olive leaves during the summer when all the amino acids are dramatically reduced (Drossopoulos and Niavis, 1988). It has been previously suggested that proline accumulation is related to the maintenance of a more favorable K/Na ratio in the roots of the treated plant (Colmer et al., 1996). Greenway and Muuns (1980) findings of the enhancement of proline content by the crops under salinized conditions supports this result. Furthermore mannitol accumulation, rather than proline, has been considered the compound responsible for olive defence reaction under abiotic stress conditions (Rejskova et al., 2007).

Oil quality

In agreement with previous report (Wiesman et al., 2004), data illustrated in Table 4 showed that olive oil acidity and peroxide values of both cultivars were unaffected by treated wastewater irrigation. This result of selected routine analysis of the oil samples suggest

Table 4

Leaf biochemical contents, olive oil acidity and peroxide value of mature 'Improved Nabali' and 'Nabali', olives grown at Al-Husseun Bin Abdullah II Industrial Estate as influenced by treated effluent treatments

Parameter	Improved Nabali		Nabali	
	Control	Wastewater	Control	Wastewater
Leaf proline (mg/gm fresh wt.)	0.47 b	0.99 a	0.27 b	0.64 a
Leaf total chlorophyll (mg/gm fresh wt.)	0.94 a	1.22 a	1.13 a	1.08 a
Olive oil acidity (% Oleic acid)	0.44 a	0.40 a	0.68 a	0.70 a
Peroxide value (meq O_2/Kg)	5.2 a	4.8 a	6.8 a	6.5 a

Means within rows of each cultivar followed by the same letter are not significantly different at P=0.05 (T test).

that the oil produced from olives irrigated by treated effluent has the same quality measures of that of potable water, since HUIE wastewater Treatment Plant satisfies the international olive oil standards (IOOC 1995). On the contrary, it has been reported that oil composition of 'Frantoio' olives indicated an accelerated ripineng of fruits induced by salinization (Cresti et al., 1994). The oliec/linoliec acid ratio dropped by salinity. Klein et al. (1994) reported that olive oil composition is significantly affected by salinity treatments. Percent oil and oil yield per unit fruit weight of both 'Manzanillo' and 'Uovo di Piccione' olives were significantly increased.

Conclusion

In conclusion, the present experimental results have shown the progressive effect of irrigation with treated industrial effluent on growth and reduction of fertilizers need of olives without affecting oil quality, but to a different extent in each cultivar. In addition, the overall results indicate the importance of the variety choice used because of the genotypic variation in response of the olive cultivars to the treated effluent salinity. Under conditions of this investigation, it is suggested that "Nabali' was the most tolerant cultivar for both osmotic stress and sodium toxicity. It can therefore be asserted that it is possible to irrigate non-bearing and bearing olive trees using treated effluent with a salt concentration of E.C. of about 5 dS m^{-1} or less with a continuous monitoring of the effluent quality to avoid specific toxicity of ions and contamination with heavy metals. However, it is of prime importance to emphasize that this statement must be limited to the the chemical composition of the treated effluent used and to the olive cultivars tested.

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