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The effect of irrigation with treated waste water on olive growth, yield and quality.

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Dedication

To the soul of my mother Adiba, who was impatiently waiting for me to finish this work but unfortunately she died before seeing it.

To my kind father who deserves my great love and respect.

To my beloved wife Shefaa who created the good atmosphere for me to finish this work.

To my brothers and sisters for their encouragement.

To my beloved daughter Sireen.

Declaration

I Certify that this thesis submitted for the degree of Master is the result of my own research, except where otherwise acknowledged, and that this study (orany part of the same) has not been submitted for a higher degree to any other University of institution.

Signed

Saleh Musleh Saleh Ali

Date: / /

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List of Abbreviations

B	Boron
Ca	Calcium
Cl	Chloride
COD	Chemical oxygen demand
EC	Electrical conductivity
FFA	Free fatty acid
K	Potassium
Mg	Magnesium
N	Nitrogen
Na	Sodium
NO3	Nitrate
OMC	Organic matter content
P	Phosphorus
pH	Hydrogen ion concentration
SAR	Specific Absorption Rate
UV	Ultraviolet
WC	Water content

Abstract

This study investigated the impact of reusing treated wastewater for irrigating olive trees on the trees growth and production, as well as its impact on the main physical and chemical properties of the produced olive. Furthermore, the study investigated the impact of applying the treated wastewater on soil properties.

This study was conducted in tow orchards grown with 'Nabali Mohasan'- ('Improved Nabali') olive grown so far under the rain-fed system, located in Sir village northwest of the west bank. The experiment included two treatments of twenty olive trees each of the first treatment included 10 trees irrigated with treated wastewater generated from Sir Treatment plant, whereas the other 10 trees were kept under conventional rain-fed system. And each treatment replicate for five times and each replicate have two measured trees. The selected olive trees were identical in age, size and the planting distances.

The treated wastewater applied to the trees through a drip irrigation network, three successive seasons during the period from 2010 to 2012 started in April and ended on September. In each irrigation period, each olive tree received 96-100 liters in each cycle whereas three irrigation cycles were applied during the week.

The results of the experiment showed that the vegetative growth of irrigated olive trees was higher compared with the non-irrigated trees. Regarding the fruits production, the result showed a significant production increase irrigated trees. The results also showed irrigated with treated wastewater fruits water content increase, whereas the oil content in fruits didn’t change significantly between the 2 treatments. However, free fatty acids(FFA) in oil is significantly increased for irrigated trees whereas the ploy-phenols concentration was found to be significantly lower for the irrigated trees compared to the non-irrigated ones.

Moreover, irrigating olive trees with treated wastewater has also affected the leaf mineral content. The concentrations of K, Na, N, Ca and Cl in the leaves of irrigated trees were

found to be significantly higher that the non-irrigated trees, whereas the concentrations of P and Mg were significantly lower in the leaves of irrigated trees.

This study showed that the soil analyses results in spring showed that the concentration of most minerals was relatively lower than what it was in autumn, as well as the EC values, mainly because of soil mineral leaching during the fall season, whereas no significant change in soil PH was recorded, Furthermore, the concentration of most soil minerals was significantly higher in irrigated plots except for magnesium where the data showed the same concentrations in both treatments at both soil depths where's organic matter content was also higher in irrigated treatments in both soil layers.

Related to olive oil properties the study showed The oil extracted from fruits of irrigated has a higher FFA content than the fruits harvested from non-irrigated trees, where's The peroxide value was the same in both treatment and it is below the ceiling value of the IOOC, while the poly- phenols content in oil of non-irrigated trees was found to be very high compared to oil of irrigated trees.

Results provided a positive indicator of the possibility of using this type of treated water to olive trees irrigation under the conditions of the experiment**.**

1. Chapter One

Introduction

1.1. General

The Middle East is renowned as a water scarce region. The severity of the problem in Palestine is not a result of climatic misfortune, however, but of regional political problems: specifically, shortage has been caused by the Israeli occupation policies. Palestinians' water supplies are currently insufficient to cater for demand, and are increasingly degraded. Projected regional population and demand increases are high, rendering coming to grips with the water shortage urgent. Any attempt at resolution should consider three related areas within a single integrated water management formula. Firstly, attempts must be made to resolve allocation disputes, governed by principles of international water law; secondly, supplies must be enhanced, either through water import or water catchment; and thirdly, conservation and appropriate utilization must be emphasized. Only if the water shortage is analyzed in such an integrated manner will it be possible to ensure full resolution of the Palestinian-Israeli hydro political dispute.

Water resources in West Bank are very limited since full Israeli control on the Palestinian water resources; the Israeli occupation forces issued many military orders which state the full right of Israel to capture the Palestinian water resources. So the gap between water demand and water supply increases, and the agriculture is the main consumer of groundwater. (Tubail.K, 2002). Construction of the wall will mean the removal of tens of thousands of trees and will effect the hydrology of the watersheds. This will cause changes in water quantity and quality, stream channel morphology and groundwater levels. Surface water flow will be altered, and there will be an increase in erosion and sedimentation.

The impacts on the region’s water supplies around the wall are also of serious concern. The climate of Palestine is semi-arid, and water sources are precious. In villages around Qalqilya and Tulkarm, more than 30 wells will be lost in the first phase of the wall. These wells, located in the western groundwater basin, were drilled prior to the 1967 occupation of Palestine by Israel. As a result, Palestinians will lose nearly 18 percent of their share of the basin’s water. (John Reese, 2010).

The agricultural sector represents the main products in the West Bank, the amount of the cultivated land in the fifteenth years estimated at 2435000 donum, which is 40% of the total cultivated area in the West Bank.

The Palestinians' water agricultural consumption in the West Bank amounts 90 million cubic water (MCM) annually. This amount is used for irrigating about 1.8 million donums (Various kinds of agriculture).

In 2009 the majority of crops in the Palestinian territories are rain-fed crops, which constitute 89.4% the territory of rain-fed crops.

Olive tree cultivation is a significant part of land use in Mediterranean countries. The olive tree agriculture and the process of olive oil production have important environmental, social, and economic considerations. It’s constituted the main source of nutritional fats, their most valuable export product and was identified with their culture. Mediterranean countries produce 95% of the total world production of olive oil, which is estimated to reach 2.4 million metric tons per year (Paraskev. C A, 2007).

Planting olives are the most planted trees in Palestine; it contributes with 50% of the total agricultural income, while Citrus occupied 51% of the total income(Agriculture in the West Bank and the Gaza strip (1967-1994).

Olives are a centuries-old mainstay of the Palestinian economy, and are in peak season for harvest from the middle of October to the beginning of November. Forty-five percent of

Palestinian agricultural land (224,565 acres /89,862 hectares) is planned with olive trees. Many local Palestinian economies depend on the olive harvest to survive. Olive trees make up 80% of tree land in West Bank and Gaza. The amount of olive to be produced is 162,585 metric tons in 2010. (FAO AND UNDP, 2010)

All over the world, Wastewater reuse in agriculture has been shown as one important management issue for sustainable use of the limited freshwater resource and had this importanc because of the potential economic and environmental benefits (Abu-Madi. M, 2009).

Wastewater reuse could be an option to cover part of the demand (Tubail. K, 2002) and the best solutions for reducing the current pressure on water resources (Environmental Technologies Action Plan, 2010).

Waste-water is not only sewage as common in the thinking of many people but it also produced from many sources, such as dwellings, commercial or industrial facilities and institutions, in addition to any ground water, surface water and storm water.

The total agricultural area in the West Bank is around 165,000 hectares (62%fruit trees, 11%vegetables, and 27%field crops) (Palestinian Central Bureau of Statistics, 2007). Around 93 MCM/yr of water is used for irrigation, or 70%of the total water resources. Irrigated agriculture represents 37%of total agricultural production compared to only 24%from rain fed agriculture (Birzeit University, 2009). The use of properly treated wastewater would represent a significant increase in available water, and would be much better for the environment than the direct discharge of raw sewage.

Standards for wastewater effluent quality for various uses have been established by the Palestinian Ministry of the Environment, but they are often not enforced (WHO, 2009). The regulations establish four classes of water from Class A (high quality) to Class D (low quality). Multiple barriers (zero to four) are needed depending on the class of effluent water and type of reuse. Fourteen kinds of barriers are listed, including disinfection, distance between irrigation water and crops, and inedible peel/shell on the crop (Palestinian Environmental Quality Authority).

1.2. Problem statement

Israelis receive most of their water from two principal water sources: the Mountain Aquifer and the Jordanian Basin. Under international law, these sources are international water resources shared by Israel and the Palestinians. The division of water from these sources is patently unfair, in Israel's favor. As a result, Palestinians in the West Bank suffer a permanent water crisis, making it impossible for them to meet their basic needs.

The water crisis causes particularly great distress in towns and villages that do not have a network to households with running water. Two hundred and eighteen communities in the West Bank are not connected to a water network, compelling their approximately 197,000 residents to seek alternative water sources. The extensive restrictions on freedom of movement that Israel has imposed during the current intifada, together with the sharp deterioration of the Palestinian economy, impede Palestinians' access to water and aggravate their already grave situation.

Irrigation may be defined as the application of water to soil for the purpose of supplying the moisture essential for plant growth. Irrigation plays a vital role in increasing crop yields and stabilizing production. In arid and semi-arid regions, irrigation is essential for economically viable agriculture, while in semi- humid and humid areas, it is often required on a supplementary basis.

Wastewater can be considered as a resource. Wastewater and its nutrient content can be used extensively for irrigation and other ecosystem services. Its reuse can deliver positive benefits to the farming community, society, and municipalities.

The reuse of treated wastewater in agriculture can be a sustainable solution for water scarcity. A two-year field experiment was conducted in order to investigate the short-term effects of treated wastewater on olive growth, yield and concentration of total nitrogen (N_t), potassium (K), phosphorous (P) in olive leaves. Olive trees were subjected to the following irrigation treatments: (1) trees irrigated with well water and (2) trees irrigated with treated wastewater. For both treatments, the treated wastewater and well water were applied at a rate of $4.5\ m^3\ day^{-1}\ tree^{-1}$ ($5000\ m^3\ ha^{-1}\ year^{-1}$). After two years, non-significant injuries caused by salts and/or heavy metals were observed on shoot growth of trees irrigated with treated wastewater. The application of treated wastewater significantly increased concentration of N_t, P and K in the leaves.

The importance of the olive crop, which is olive tree annual, rain-fed agriculture crop depending on the different seasons and the quantity of annually rainfall and limited water resources and the control of the Israeli occupation, which cause varying production from year to year; we must find ways to raise the worth of olive crop by supplementary irrigated water to increase efficiency, productivity and improve the type and characteristics.

1.3. Objectives

The aim of this research is to study the effect of the use of treated wastewater for olive irrigation. The study will also investigate the effect of using treated wastewater on:

1. Soil physical and chemical properties.
2. Olive growth and yield, olive oil quality.
3. Characteristics of the fruit, weight of olive fruit, flesh to pit ratio.
4. Microbial contamination in the fruits.
5. Quantity of water needs to have a high quality mature fruit.
6. Oil quality data.

1.3.1 Specific objectives

In this research we will study:

- The effect of irrigation with treated wastewater on olive growth and yield
- The effect of irrigation with treated wastewater on olive oil quality.

1.4.Thesis Outline

Chapter One introduces a general background about the treated wastewater reuse; it identifies the water research statement, and describes briefly the main and specific objectives. Chapter Two provides the study area description, beside literature review for previous researches in the same core. Chapter Three shows the methodology followed, and the analysis of the samples. Chapter Four provides the data analysis and results. Chapter Five presents the final conclusion and recommendations resulted from the research.

2. Chapter Two

2.1 Literature Review

2.1.1 Irrigation of olives

"Olive tree is remarkably resistant to drought. This has been emphasized by many researchers e.g.: Leon and Bukovch (1978) but nevertheless it strongly responds to additional irrigation. This has been shown by many authors whatever the method used (Spiegel, *et al.,* 1958).

The effect of four irrigation regimes with five olive cultivars was studied during three successive years, the water levels were; 0, 33, 66 and 100%. The response to irrigation of the cultivars was evident in terms of plant growth, production and the main qualitative parameters of the fresh product. 66% of water consumption proved to obtain production similar to the 100% water level (D’Andria, 2009).

Increased vegetative growth, better flowering buds, higher percentage of fruit set, greater size of fruits and higher oil production per tree have been reported as beneficial effects of an adequate water supply (Michelakis, 1994b and 1998). It was found that the root density of the “Kalamon” table variety was 6-7 times denser at the most wetted areas near to the dripper (up to 60 cm) than at the less or no wetted areas at longer distances, (120-300 cm) from the dripper. At the fairly wetted intermediate areas (60-120 cm form the dripper) only 3 times denser root system has been developed. Root system density was generally reduced with the depth, independently on the distance form the dripper. Most of the root system, about 60% of the total, was concentrated at the upper 40 cm of soil layers adequate water was found to be important during the early period for abundant as studied Spiegel (1957) and Samish and Spiegel (1961) who claimed that the tendency to alternate bearing was reduced by encouraging vigorous growth in the spring. It was found that irrigation increases the fruit size of olive trees with low and medium yield but it does not affect significantly the fruit size of trees with high yield (Michelakis, 1994).

A twelve year-old olive cv. Kalamon trees irrigated at soil water potential ranged of -0.08 to –0.012 MPa were compared with non-irrigated trees in Crete. Soil moisture reached wilting point at the end of July in the non- irrigated treatment (Michelakis, et al., 1946).

A field experiment was conducted to examine the effect of drip irrigation using wastewater from a table olive industry on physiological, nutritional and yield parameters of olive trees. Two types of wastewater were used, first with SAR and EC values (12 - 56 and 3.5 – 4.5 ds/m, respectively and the second 73-90 and 4.3-6.0 dsm-1). Olive trees responded rapidly to wastewater application, however, the more saline wastewater caused decreases in leaf water potential and caused a rapid, significant reduction in leaf N concentration and subsequently reduces olive yield (Marillo et al. , 2000). A better response to an improved water supply was found during stages I and Ш, while no obvious response was observed during stage Ц (Fig 1). Spiegel (1957) found that, irrigation during the early stages of development of the olive had no material effect on fruit size, but that after the stone had hardened irrigation increase fruit volume considerably although it delayed maturity and coloring (Samish and Spiegel, 1961). Also found that late summer drought reduced the size of olives (Cucurachi, 1959).

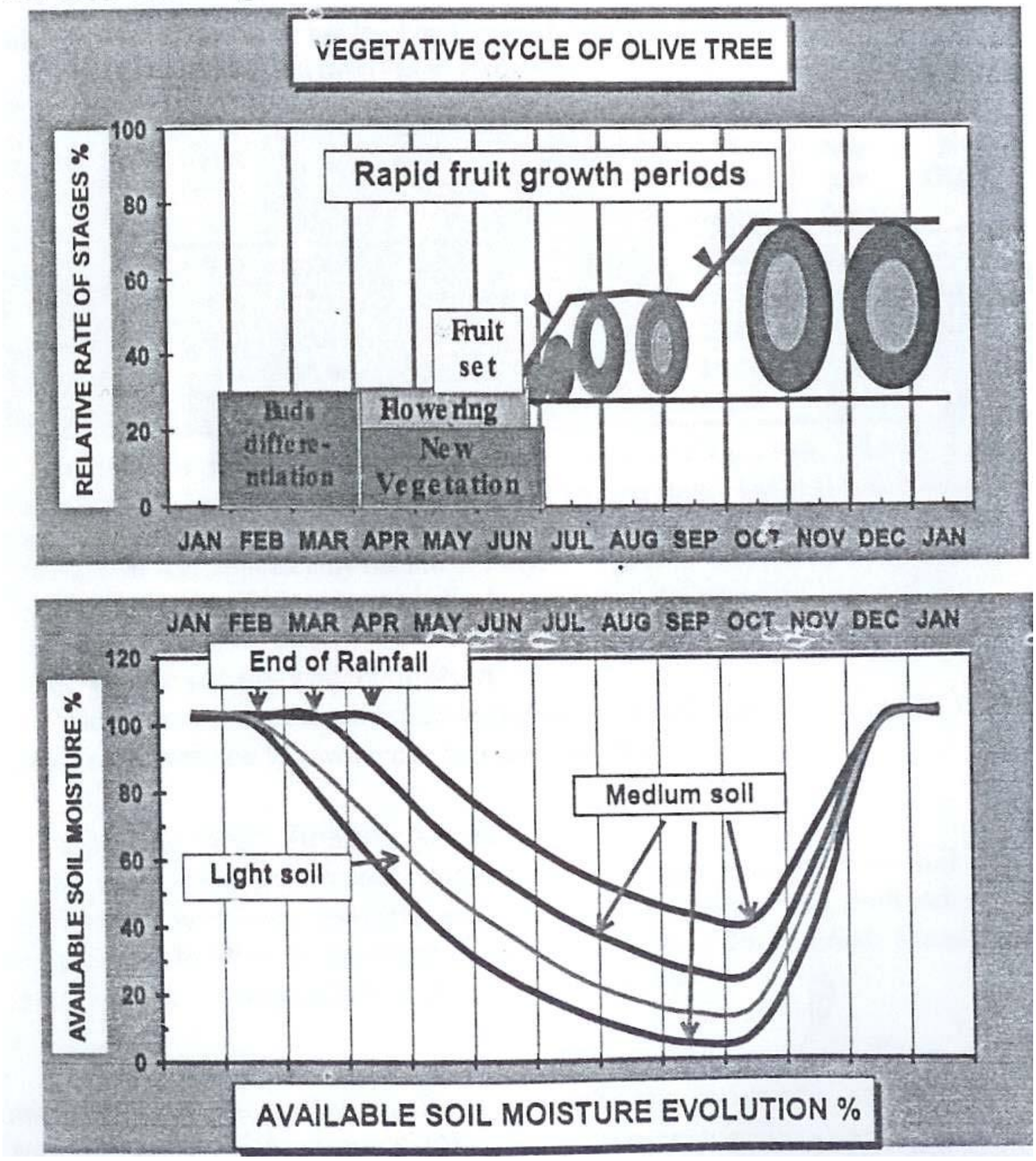

Figure (3.1): Schematic representation of the vegetative cycle of olive tree in relation to the available soil moisture (Michelakis, 1998).

Therefore, it is clear that appropriate fruit size is necessary after the stone hardening stage. Consequently, it is obvious the importance of irrigation for the table varieties during the late summer period.

It was found that the fruit yield (kg/tree) increased with the water use level due to the higher number of fruits per tree rather than to the increase in fruit size (Michelakis, 1998).

Since the beginning of the 1980s many countries have been using untreated or partially treated wastewater for agricultural irrigation. Treated wastewater is used for agricultural irrigation directly and indirectly. In direct reuse, the treated effluent is taken from the wastewater treatment plants (WWTPs) to the irrigation site. In indirect reuse, the treated effluent is discharged into surface water or groundwater aquifers. (Abu-Madi. M, 2004).

Due to the scarcity of water resources and the importance accorded to effluent reuse, several studies are focusing on the use of treated wastewater for irrigation purposes. One is investigating the suitability of bananas for irrigation by treated wastewater because of this crop's relative salt resistance and its high demand for nutrients, coupled with the possibility of using drip irrigation, thus preventing direct contact between water and fruit. Another is checking the effects of sub-surface trickle irrigation of selected field crops using treated wastewater (Israel Ministry of Foreign Affairs, 2007).

Today in LA, around 400 m^3/per second of raw wastewater flows into surface waters and nearly 500,000 hectares of agricultural land are irrigated with wastewater, mostly raw water. In Colombia, water reuse is informal rather than planned. Only 8% of the 6 million m^3 of daily raw wastewater is treated. Rapidly growing populations in developing countries, the effect of pollution on surface and underground water, unequal distribution of water resources and serious droughts have forced water agencies to look for new innovative sources of supply. Wastewater becomes another way to respond to water demand, linking water supply to the development of sewerage and issues of urbanization (IRC, 2005).

The study in Mexico City describes and illustrates the problems related to wastewater treatment in mega-cities of the developing world. Here reuse in agriculture is used as a possibility to get rid of the wastewater without treatment. Untreated wastewater of about 75 m^3/s and the raw sewage of Mexico City is used to irrigate 85,000 ha of agricultural land in the neighboring state of Hidalgo. Besides the positive effects of freshwater conservation and higher agricultural production, which feeds and provides income to the local population, this method evokes a lot of diseases. The high content of organic matter and plant nutrients in the water has improved the physical and chemical conditions of the soils. Soil organic matter increased and so did the crop harvest: the crop yield increased by 94 – 150 %. The irrigated area receives over 80kg/ha of nitrogen per year. Nevertheless a high prevalence of enteric and parasitic diseases among more than 100,000 workers had to be noticed so here it can be seen that agricultural reuse is being advocated, but coupled with the need for secondary treatment prior to distribution (Kretschmer. N., et.al, 2002).

Not only in particular semi-arid or arid regions reuse projects are realized, In Belgium reuse has been implemented because of water quality issues (water scarcity isn't a problem there). A food processing industry, which freezes locally grown garden market products, has recycled all its wastewater by irrigating 550 ha of crops located around the factory. By adopting this solution, the processing plant was able to avoid paying a tax. Here the soil is only used as purification facility for the industrial effluent which consists of wastewater from washing and processing the vegetable and cleaning the building (Kretschmer. N., et.al, 2002).

An interesting example for wastewater reuse, although not only related to agriculture, is the project in Sharjah, United Arab Emirates. It is one of the most water-poor states in the world, but its waste water recycling programme has enabled it to expand its green spaces and to conserve valuable groundwater supplies. The recycled wastewater is used for landscape and horticulture irrigation. To protect public health Sharjah established conditions and regulations for the safe use of recycled wastewater for irrigation. Implemented projects, public acceptance and the willingness to implement such projects are highly connected with the grade of water scarcity andsalinity in the country (Kretschmer. N., et.al, 2002).

The use of recycled water in the UAE, however, is limited to irrigation of landscape areas, parks and streets in major cities. The recycled water is not used for agricultural purposes, particularly due to concerns over health and environmental hazards, as well as public and social attitudes towards the use of crops irrigated by recycled or treated wastewater.

(W. Al-Zubari, "Towards the establishment of a total water cycle management and re-use program in the GCC countries,2009)

Trying to specify all interesting reuse projects would go beyond the scope of reuse wastewater. There are certainly a number of examples in the Mediterranean region (arid and semi arid climate) such as Israel, Palestine and Jordan, but also in Europe where temperate climate prevails (Kretschmer. N., et.al, 2002).

The Italian authorities, together with the European Union, have funded a project to identify feasible technical solutions in the field of water management, restoration and reuse. In this context, wastewater was studied for potential use for irrigation purposes. Two solutions were studied, with the actual use of the resulting water for crop irrigation (Environmental Technologies Action Plan, 2006).

In a first experiment, municipal wastewater was submitted to membrane filtration instead of the chemical disinfection commonly used as the last step of water treatment. The resulting water was used to irrigate tomatoes, fennel and salads. In terms of microbiological safety, the treated wastewater was comparable to the local irrigation water. One drawback appeared: irrigation with membrane filtered effluents caused an increase of salts in the soil (Environmental Technologies Action Plan, 2006).

Another experiment submitted wastewater to simplified treatments by skipping biological processes in order to preserve the agronomic potential of organic matter occurring in urban wastewater. The treated water was then successfully used in an olive orchard. Compared to olive trees grown in rain-fed conditions (which are the local standard) irrigation with treated effluents caused a yield increase, with a 50% improvement in the characteristics of the fruit such as weight and flesh to pit ratio. No significant microbial contamination was observed in the fruits (Environmental Technologies Action Plan, 2006).

This project is especially relevant from a market perspective, since the researchers show that there are two technological solutions with immediate potential applications for wastewater reuse in agriculture and that they are specifically suited to southern Italy. The most promising system consists of olive tree watering with water submitted to simplified treatments. Membrane filtered wastewater should be used carefully for vegetable irrigation because of risks of bacterial contamination, as confirmed by the presence - although in very low count - of total coliforms on the crops used in the experiment (Environmental Technologies Action Plan, 2006).

The quality of French ground and surface water resources have steadily deteriorated to the extent that many rivers were recently reported to be affected by excessive eutrophication. The main factors of water quality deterioration are pollution from agricultural origin, wastewater treatment deficiencies due to under capacity and unreliable WWTP infrastructure. (Brissaud. F, 2005).

Many wastewater reuse projects in France are driven by the aim of protecting receiving waters from microbial pollution and recovering rivers affected by eutrophication (Brissaud. F, 2005).

For illustration, irrigation of vegetables to be eaten raw with quality grade A water is allowed, but methods that reduce the direct contact of irrigation water with vegetables and fruits are highly recommended. Irrigation of public green spaces with the same quality of water A is allowed, and it is done by short range sprinklers. Also, sprinklers should be more than 100 m from houses, sports and recreational areas. This last requirement applies also to aspersion of cereal, fodder crops, nurseries with B quality water. The most prominent restrictions added to the WHO's guidelines are mainly aimed at protecting people from aerosol risks. Reuse of C quality water by drip or underground irrigation is limited to areas closed to public access (Brissaud., 2005).

France treats about 4000 MCM of sewage per year. Presently, there are at least 30 water reuse projects in France, half of which use treated water for agricultural irrigation covering more than 3000 ha; the other 15 projects use treated water for golf courses and urban area irrigation (Juanicó. M, Salgot., 2005).

The largest irrigated area is 700 hectares at Clermont Ferrand. The mean irrigated surface is just about 100 ha. In tourist areas located along the Mediterranean and Atlantic coastlines, the irrigated crops are: market gardening (potatoes, cabbages, carrots, onions,.), orchards, meadows and corn, or lawns of golf courses. Corn is the most frequent crop irrigated in hinterland projects (Brissaud., 2005).

Water resources are limited temporally and spatially in Greece, thus there are 25 MWTPs 8.5% of the plants where effluents are reused for irrigation of agricultural land mainly in olive trees and cotton. This quantity constitutes 5.2% of the total produced effluents (Karamanos., et.al, 2004).

It should be noted that there are plants that discharge to fleeting rivers and after infiltration there is pumping through adjacent wells by farmers for irrigation. This is a way indirect reuse for irrigation. The effluents produced from 7.5% of the MWTPs are used for irrigation of forested land and fire protection purposes. This quantity constitutes 2.4% of the total produced effluents (Karamanos. A, et.al, 2004).

Spain is presently reusing about 300 million m^3/y of wastewater. The main approved uses are agriculture and golf courses irrigation, and secondarily groundwater recharge and industrial reuse. There is also a strong pressure for discharging treated wastewater into rivers, but after advanced treatment in order to improve running water quality. Recycling systems are today relying on tertiary classical technologies (coagulation-filtration plus disinfection) and extensive natural technologies (wetlands, lagooning and infiltration-percolation. The areas where recycling and reuse are most operative at present are Balearic Islands (golf courses, urban parks and groundwater recharge), Canary Islands (golf courses and agriculture) and the entire Mediterranean coastline (agriculture, golf courses and leisure activities other than golf) and Vitoria in the Basque country where municipal wastewater is treated and reused for agricultural purposes (Juanicó. and, Salgot., 2005).

Many horticulture activities can be found in Tunisia: fruit growing (olive trees cover about 80% of the total fruit area), vegetables, and flowers. Olive tree growth (rain fed) is spread widely in the country. Citrus and grape production is located mainly in the Cap Bon area and dates are produced in the oases located in the south. Other fruit species are cultivated in the northern and the central areas. Vegetables production is spread along the coast and the inland irrigated perimeters in the north and central zones, treated effluents is used to irrigate about 6,750 ha of orchards (citrus, grapes, olives, peaches, pears, apples, and pomegranate), fodder, cotton, cereals, golf courses and lawns. Surface irrigation techniques are mainly practiced on the schemes with complementary irrigation and some sprinkler irrigation is used on cereals in case of a severe rainfall deficit and on fruit trees during the early years of their development (Abu-Madi. M, 2004).

Al-Wardanin reuse scheme located southeast of Tunis and utilizing 800-1,000 m^3/d of treated effluent from Wardanin WWTP. A reservoir with a capacity of 500 m^3 is followed by a pumping station adjacent to the WWTP. About 50 ha are equipped for irrigation with treated wastewater. About 95% of the treated wastewater is used to irrigate fruit trees. (Abu- Madi. M, 2004).

The Jordanian Treated Wastewater team limited there projects to the cultivation of crops which are not for direct human consumption, including exotic fodders like ryegrass; Zerqa River Basin Scheme is the largest reuse system in operation in Jordan. There are four treatment plants located in the basin that discharge its treated effluent to Zerqa River where it is collected downstream at King Talal Dam and used for restricted irrigation in the southern section of the Jordan Valley (Abu-Madi. M, 2004).

The largest treatment plant is As-Samra treating about 60MCM where most of it joins the flow at Zerqa River. A small portion (2%) of this effluent is used in on-site irrigation of about 1000 hectares planted with olive trees, fodder crops and forest trees. All of the other research activities, dealing with testing low treatment technologies, have reuse components. Survey and analysis comparing olive trees irrigated with fresh water with those irrigated with wastewater over 12 years are being investigated (UNEP, 2007).

Another project, grey water-treatment system was installed in 25 homes in Al Baida, Jordan, and household's members were taught how to set up efficient gardens. The project has exceeded expectations. The grey water effluent meets standards for restricted irrigation, and households are using it to irrigate eggplants, herbs and olives (Faruqui.N, 2002) which represent more than two thirds (87%) of the beneficiaries separate treated graywater and utilization (Surani.E, 2003).

All beneficiaries believed the graywater separation and collection was worth the effort, and showed intention of pursuing this practice in the future. About two thirds of the beneficiaries planned and had the desire to separate graywater from other sources, i.e., laundry and shower. The percentage of graywater collected was reasonable. About half of the beneficiaries used all their produce for home consumption or for social gifts to relatives and neighbors (Surani.E, 2003).

Irrigation with treated effluent is being performed in some areas in Israel for more than 30 years; in fact wastewater reuse in irrigation was pioneered in the Jeezrael Valley (MarjIbnAmer) south of the Lower Galilee (Kretschmer. N., et.al, 2002) the major farming regions of Israel. It is mostly irrigated agriculture occupies land stretching about 170 kilometers from north to south, and about 20 kilometers wide. The area corresponds to a south-to-north rainfall gradient of 400 to 600 millimeters, and is characterized by relatively well developed soils, mainly grumosols and lithosols, in some places mixed with sand (ICARDA, 2007). It is forecasted that in the near future, treated effluents from various treatment schemes will form 80% of all irrigation water used in the previous mentioned valley, due to the increase in raw sewage production combined with a decrease in the amount of freshwater allocated for irrigation (due to freshwater shortages). In previous project municipal wastewater is treated as irrigation water. The preliminary results were effluents of high quality. When operating with all components the system is expected to release effluent of unrestricted irrigation quality (Kretschmer. N., et.al, 2002). Within this area the Israeli Treated Wastewater program compared irrigation using treated wastewater with irrigation using fresh water on some 70 agricultural and experimental plot parts. In the rainier segments of the area, mainly in the north, Avocado plantations were the focus of most of the experiments, as well as corn and other field crops in the MarjIbn Amer. In the somewhat drier central and southern sections, the effects of different water qualities on citrus orchards were the major concentration. On these sites the Israeli Treated Wastewater team was able to test the effects of treated wastewater on the full range of low altitude, coastal and valley systems that account for the bulk of agricultural production in Israel (ICARDA, 2007).Salination is one of the sustainability related problems of long-term massive water reuse. The country has implemented several measures to reduce the concentration of salts and Boron in municipal sewage (Juanicó. and, Salgot., 2005).

Cyprus has developed an official policy defining treated wastewater as an integral part of their water resources, Cyprus has no rivers with perennial flow while rainfall is highly variable and droughts occur frequently. Since groundwater is reliable, clean and most importantly cheap, water resources development in Cyprus initially focused on groundwater. Reuse of treated sewage effluent amounts for only about 3 MCM, from which 2 MCM for agriculture and the rest for landscape irrigation (Juanicó. M, Salgot. M, 2005).

Cyprus is facing two major obstacles in its continued development: a growing scarcity of water resources in the semi-arid regions of the country and, degradation of water at its beaches. The government has recognized that a water reuse program would address both problems. In addition, it is expected that treated water will provide a reliable alternative resource for irrigation, which draws about 80 percent of the total water demand (Juanicó. and, Salgot., 2005).

Although Turkey is situated in a large Mediterranean geographical location where climatic conditions are quite temperate, the diverse nature of landscape and in particular the existence of the mountains that run parallel to the coasts result in drastic regional differences in climatic conditions. While the coastal areas bear relatively mild climates, the inland Anatolian plateau has a continental climate with hot, dry summers and long lasting, cold winters with limited rainfall (Juanicó. M, Salgot. M, 2005).

Irrigation with wastewater has been estimated in 50 MCM/y in 2008. But the country has not a reuse policy and agricultural irrigation with wastewater is not conducted officially (Juanicó. M, Salgot. M, 2010).

Wastewater agricultural irrigation is widely spread in South East Anatolia, mainly for the irrigation of vegetables. For example, in Siverek, located in South East Anatolia, domestic wastewater discharged into streams is being reused for agricultural applications on cotton, wheat and various vegetables including eggplants, peppers, tomatos, cabbage, carrots and spinach. The total area irrigated with wastewater is 165 ha and the consumption of irrigation water was 1.9 MCM in 2009. In tourist villages and resorts, the major form of reuse is irrigation of gardens and parks (Juanicó. M, Salgot. M, 2005).

Greece has renewable freshwater resources evaluated about 70,000 MCM per year. So water resources are abundant at the national level and the water stress index is very low. However, Greek geography is “complicated” with hundreds of islands, isolated peninsulas and valleys separated by a mountainous topography. Water scarcity at the local level is a common problem in numerous places within the country (Juanicó. M, Salgot. M, 2005).

More than 80% of the treated effluents in Greece are produced in regions with deficient water balance. Thus, wastewater reuse in these areas would satisfy a real water demand. The distribution of treated domestic wastewater effluents in deficient water balance regions, as a function of the average distance from the agricultural land which is available for irrigation, have been analyzed: about 90% of the treated effluents are discharged from WWTP’s which are located at a distance of less than 5 km from the available farmland. Therefore, the additional cost for transport to the irrigation fields is low (Juanicó. M, Salgot. M, 2005).

Malta has suffered from acute water stress for decades; the renewable water resources (30MCM per year of groundwater) hardly cover half of the water demand.

Because agriculture is the main source of income, wastewater is practiced since the late 1980s. Since 1983, the effluent of the SantAntnin sewage treatment plant has been used for irrigation. The effluent is used to irrigate 600 ha of crops by furrow and spray irrigation. The effluent quality is suitable for unrestricted irrigation and is used to produce potatoes, tomatoes, broad and runner beans, green pepper, cabbages, cauliflower, lettuce, strawberries, clover, etc (Juanicó. M, Salgot. M, 2005).

Despite the high salinity, there are no problems with crops. This is probably associated with high permeability of the calcareous soil. Soil monitoring has shown a salt accumulation in the top soil during the irrigation season followed by leaching to the groundwater with the winter rains (Juanicó. M, Salgot. M, 2005).

Egyptian Treated Wastewater Re-use project sites were located in the Nile delta, where most of the country's agricultural production and most of its use of marginal water takes place (ICARDA, 2007).

One way of alleviating the increasing water shortage is the reuse of the irrigation drainage water, which is significantly more saline than the Nile water entering the irrigation system. To reduce salinity, drainage water is blended with freshwater prior to reuse at 20 pumping stations. This preponderance of irrigation drainage water treatment and reuse between 3 and 8 billion cubic meters annually distinguishes Egypt from the other four countries in the Initiative, where sewage is the principal source of treated wastewater. Activities of the Egyptian Treated Wastewater reuse program were carried out in the Kafr el Sheikh governorate in the far north of the middle delta. Lysimeter experiments were used to irrigate selected crops with various qualities of mixed drainage and fresh water (ICARDA, 2007).

In recent years, the Ministry of State for the Environment developed a plan to preserve natural resources and reduce pollution by established forest and planting multiple types of trees to produce wood (Ecosystems, 2005).

In the West Bank there is only one major wastewater treatment plant, in El Bireh, results obtained on the analysis of irrigated grass grown under greenhouse conditions show a safe use of treated effluent for agricultural purposes (pine trees, ornamental flowers, olive trees, grape stocks, sweet corn). A drip irrigation system used to irrigate about 6000m^2 area planted with various types of trees and vegetables (Al-Sa`ed. R., 2007)

3. Chapter Three

3.1 Methodology

3.1.1 Water analysis.

Sampling: Water tests are divided into two main groups:

1. Physical and Chemicals characteristics tests which have a certain sample collection method.
2. Biochemical oxygen demand (BOD) and Chemical oxygen demand (COD) tests has a sample collection method which is different from the first one, and it has been done in a specific day according to the deal with the lab.

The procedure for wastewater sampling consisted of drawing about 250 ml from wastewater before being treated and another 250 ml from treated wastewater after treatment process, all the bottles were clean and autoclaved before used.

Table (3.1): Methods of analysis for wastewater.

BOD	Standard method
COD	Closed reflux, calorimetric method
NO3	Photometric method
CL	Ergonometric titration method

3.1.2 Soil analysis

The soil was sampling and analysis was done twice a year. The results in spring showed that the concentration of most minerals was relatively lower than what it was in autumn, as well as the EC values, mainly because of soil mineral leaching during the fall season, where as no significant change in soil pH was recorded. However, the soil of irrigated treatments still has a higher salinity (in terms of EC index) than the soil non-irrigated treatment (Table 3). Furthermore, the concentration of most soil minerals was significantly higher in irrigated plots except for magnesium where the data showed the same concentrations in both treatments at both soil depths.(Table 3). Furthermore, organic matter content was also higher in irrigated treatments in both soil layers (Table 3).

Table (3.2): Soil properties and mineralogy analysis

Parameter	**Unit**	**0-30 cm**		**30-60 cm**	
		Rain-fed	**Treated wastewater**	**Rain-fed**	**Treated wastewater**
pH	-	7.21a	7. 39a	7.42a	7.78a
EC	µS/cm	1968b	3210a	1830b	2610a
Na^+	mg/Kg	27.2b	82.3a	14.2b	32.0a
K^+		7.8b	32.0a	9.1b	29.5a
Ca^{2+}		39.5b	62.1a	52.0b	80.4a
Cl-		172.1b	214.8a	1	190.6a
Mg^{2+}		18.5a	22.8a	31.4a	32.2a
NO3-		74.2b	108.2a	65.5b	98.7a
P		18.1b	48.6a	16.1b	52.6a
OMC	%	2.56b	3.73a	3.22b	4.04a

3.1.3 Study Area

Experimental plot located at Sir –about 11 Km east of Qalqilya-, the traditional -'Nabali- ('Improved Nabali') is being studied. The experiment utilizes treated wastewater from Sir Wastewater treatment plant which has been operating since 2006. About 200m east the plant there is a large olive orchard 4.627dounm (86 olive trees) with average 5m between each, (similar-sized tree about 25 years old).

Altitude of Sir Village is 450 m, the elevation difference between the plant and the orchard is about 43 m, a pump has been installed near the treatment plant in order to raise water to the orchard. There are 50 houses connected to Sir Treatment plants (around 212 households beneficiaries), the average daily flow rate from houses is 14.0 m^3/day. The treatment plants components include Septic tank retrofitted with the trickling filter, effluent from the septic/recirculation trickling filter is applied to an up flow filter and sludge from the trickling filter is returned to the septic tank. Moreover, there is a storage tank with a total volume of 38 m^3.

Photo (3.1): Landscape view of the waste water treatment plant in Sir-Qalqilya and nearby olive orchard *(April, 2011)*

Photo (3.2): Landscape view of the wastewater treatment plant in Sir-Qalqilya. *(April, 2011)*

3.1.4 The experimental design:

Every tree was given a traceability number consists of 9 digits the first 3 digits represent the district which is Qalqilia and its code 300, the next 3 digits represent project code which is wastewater reuse, whereas the last 3 digits represent the tree number which is series numbers from 1-20.

There were 20 samples from each tree irrigated and non irrigated, each sample was 2 kg olive fruit and it was pressed and analyzed for physical and chemical properties as maturity index, oil acidity, and peroxide, and organoleptic analysis, UV absorbance and total polyphenols in order to determine oil stability using Folin - Ciocalteu' schlorimetric analysis.

The olive trees in Sir Orchard are not irrigated previously ; there were two treatments in our experiment:

1. Traditional (not irrigated); the even number plots

2. Irrigated with treated wastewater; the odd number plots

The experiment design is shown below, each treatment replicates for 5 times and in each plot 2 measured trees are under study.

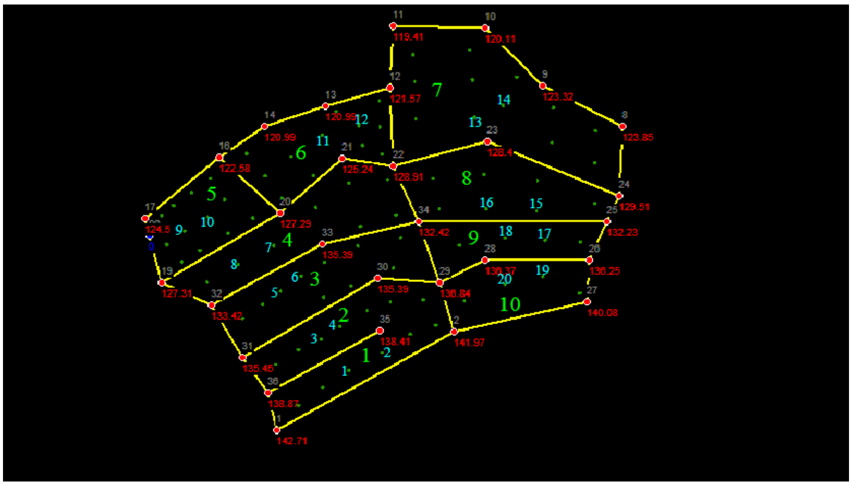

Figure (3.2): The experimental design in Sir, the map show the plots, odd plot number for irrigated trees and even plot number for non irrigated trees, also the 20 olive trees under study are shown in small turquoise font

The irrigation network was established in the first week of May 2008, it was designed by specialized Company, and the irrigation started directly after its establishment. The irrigation network is pressurized because there is about 40 m difference in level between the treatment plant and the highest point in the orchard.

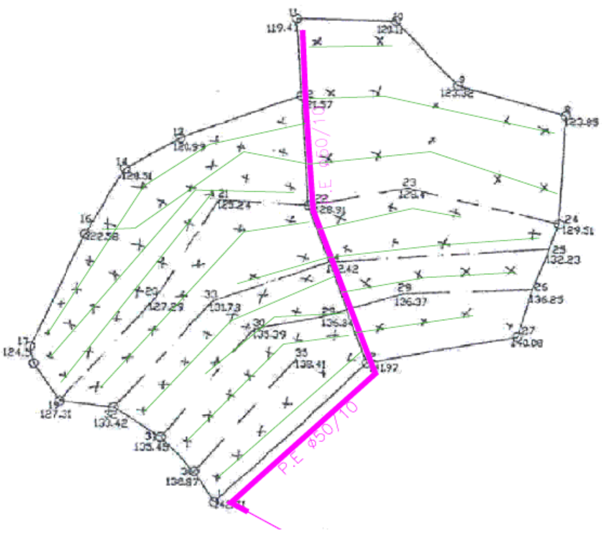

Figure (3.3): The irrigation network.

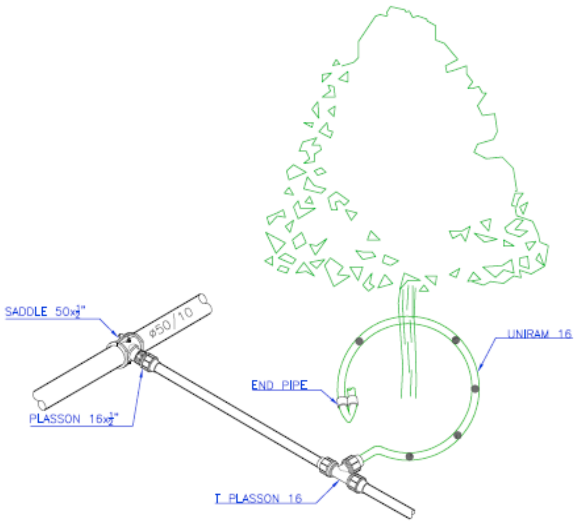

Figure (3.4): The irrigation network around each olive tree.

Collection of data and experiment period was completed during 3 years starting in 2010 till 2012. All the data collected and experiment results was together in database and analyzed in scientific manner in order to have comparison between options of olive cultivated management.

3.1.5 Soil tests, root-zone soil (Initial characterized of soil)

Soil tests were sampled 2 times per year (autumn and spring) in each plot using a sampling method. Of each orchard from depths (0-30cm, 30-60cm). Sampling point was located between midway between trees, 40 cm from the emitter line. They had been put in wood bucket, then in plastic one with a label showing the following details: No. of sample, No. of plot, depth and date, in addition to the name of the person who took the sample, the sample had been sent to laboratory for analysis.

3.1.6 Vegetation growth measurement (Shoot growth)

The vegetation growth for the measured trees have been determined by taking a new branch that has new leaves and back 15cm from the latter point of branch and tying it with a tape. Shoot growth measured after finished.

3.1.7 Fruit set percentage (level)

Flower were taken per stem. There must be about 100-150 buds, the stems were taken, and the buds in each were counted; in average it is 25 buds per stem. Then, tapes with different colors were tied after about 5 blooms; the average of fruit after blooming is 2-3.

3.1.8 Estimation of bearing

Bearing is theact,capability,orperiodofproducingorbringingforth. The bearing mark is given as a score from 0-5, 0 means no flowering and 5 full flowering and so between, the estimation of bearing is in proportion with the size of tree.

3.1.9 Leaves mineral analysis

The following criteria were considered in analysis leaves samples:

1. Selection of leaves expressing strong growth and avoiding those with old leaves.
2. Select leaves only from healthy, undamaged branches.
3. Leaves that are in full sun locations are best.
4. Always test at least 2-3 leaves displaying prominent symptoms.

Leaves were rinsed with distilled water, dried at 60 C, and then grinded.

- Total N, P, K, Ca, Na, B and Cl contents of the leaves were determined after appropriate digestion techniques (sulfuric acid, peroxide, nitric acid, water).
- The concentration of N and P were determined with an Auto analyzer which is a machine that analyze the amount of N and P.
- Na and K contents were determined by an atomic absorption spectrophotometer and flame photometer.
- Chloride will be determined using a chloridometer which is (**ChloroChek)** machine**.**

3.1.10 Olive and Oil Tests

The following procedure was used for oil tests:

- Each treatment harvested according to its appropriate ripening stage, ripening level determined according to fruit skin color (50% black) and fruit hardiness.
- Each examined tree harvested separately, fruit weight and olive size measured using electronic balance and a caliber.

3.1.11 Determine physical and chemical properties steps

Not all the fruit in an orchard, or even on the same tree, will ripen and turn color at the exact same time, so a maturity index was developed to help producers numerically categorize their fruit's maturity level. A

maturity index number allows producers to evaluate their varieties under their own specific growing conditions over a number of years. This helps determine when each variety should be harvested in order to obtain the oil style the producer wants. If a particularly good oil was produced, a maturity index number can help the grower repeat that oil style in successive years by harvesting at the same fruit maturity index each time. An oil's flavor is not due to fruit maturity alone, and the maturity index is not perfect, but it is a simple way of documenting the level of fruit maturity from year to year.

- A sample of olives, weighting one kg was taken from each tree sample.
- One hundred olive fruits were taken randomly and ranked according to the degree of ripening on especial sheet (Maturity Index, Figure below).
- Separating fruit stake place according to ripening degrees calculated by the following equation:[(Number of olive fruits in each cell*cell) / total number of olive fruits] *100%
- Oil percentage measured from each replicate by chemical extraction.
- Quality of the virgin olive oil determined as defined by the regulation and standards of both the international olive oil council and the EU.

Maturity Index

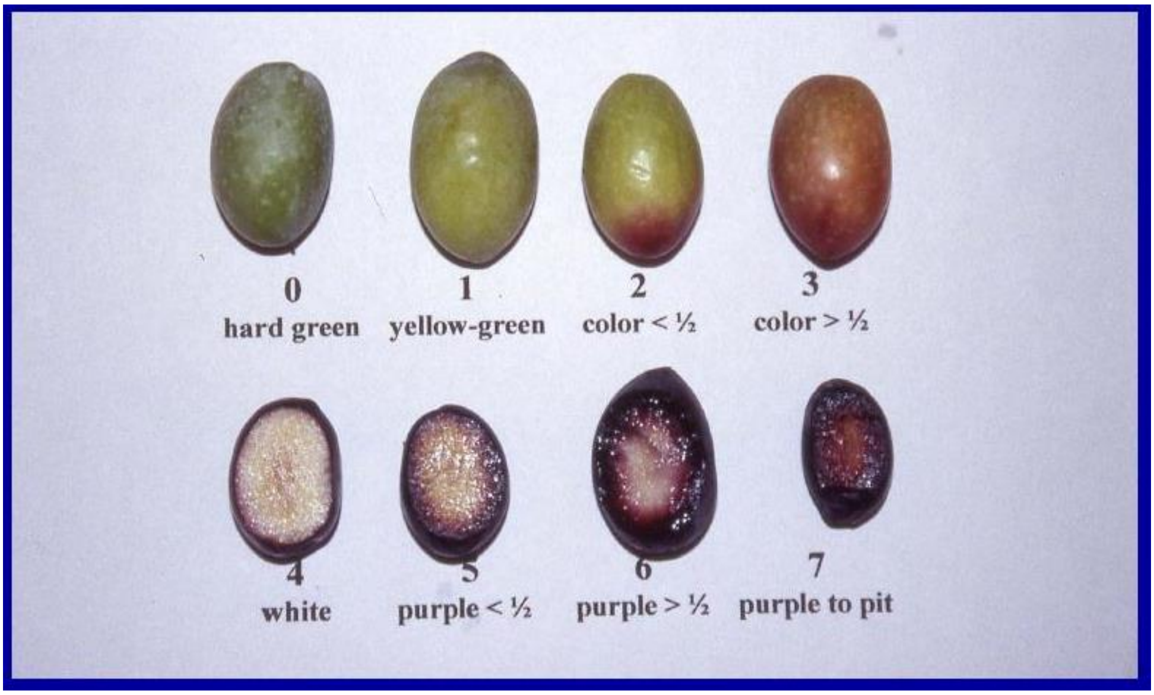

Figure (3.5): The Maturity Index

- 0 = Skin color deep green – fruit hard
- 1 = Skin color yellow-green – fruit starting to soften
- = Skin with < half the fruit surface turning red, purple, or black
- = Skin color with > half the surface turning red, purple, or black
- = Skin color all purple or black with all white or green flesh
- = Skin color all purple or black with < half the flesh turning purple
- = Skin color all purple or black with > half the flesh turning purple
- = Skin color all purple or black with all the flesh purple to the pit

4. Chapter Four

4.1 Results

All data were analyzed by SPSS descriptive and the paired sample T-test method for means comparison.

4.1.1 Irrigation schedule and Wastewater analysis

Olive trees were irrigated twice a week through a drip irrigation system. The average amount of applied treated wastewater was 280 Liters/tree weekly during May-June 2012. The irrigation process continued till the end of September 2012.

Effluent quality assessment has been investigated through 4 analysis cycles during May-September. The data show an improvement in effluent quality compared to the previous season.

Table (4.1): Characteristics of treated effluent applied for olive irrigation

Parameter	Unit	Value	Palestinian
PH	-	7.83	6-9
EC	µS/cm	2635.00	2500
BOD	mg/L	53.20	60
COD	mg/L	82.17	150
TSS	mg/l	38.85	60
Na^+	mg/L	53.12	200
K^+	mg/L	4.40	5
Ca^{2+}	mg/L	14.08	200
Mg^{2+}	mg/L	67.9	60
Cl^-	mg/L	132.24	100
NO_3^-	mg/L	39.00	45

4.1.2 Impact of olive irrigation on shoot growth and fruit set

The effect of irrigating olive trees with different level of both rain-fed and treated wastewater are shown in table 2. When the trees were irrigated by rain-fed, the increase in shoot growth was 5.23 cm, but after using the treated wastewater the shoot growth increase about 77.66%. This means that treated wastewater have an effect on shoot growth. These differences are significant. Concerning the fruit index, it was 1.2 when irrigated by rain-fed and increased to 3.2 after using treated wastewater. These differences are significant.

Table (4.2): Average shoot elongation and fruit set index.

Treatment	Increase in shoot growth*		Fruit set index***
	(cm)**	%	
Rain-fed	5.23 b	34.86 b	1.2 b
Treated wastewater	11.6 a	77.66 a	3.2 a
Irrigated			5.3 a
Non-irrigated			4.1 b

* Growth was measured for the period May-October (2009)

** The base shoot growth was 15 cm

***Fruit set index is for 2009 season

4.1.3 Fruit set

Fruit set data showed irrigated plots had a significantly higher fruit set % than the rain-fed trees (5.3 % and 4.1% respectively) However, The fruit set data in both treatments indicated a good production season (Table 4).

4.1.4 Leaf Analysis

Analysis results showed no significant differences in K, Na, P, Cl, Ca, and Mg concentration in olive leaves of two treatments, as shown in leaves sample. While the concentration of NH_4^+, was significantly higher in olive leaves of treated wastewater treatment (Table 5).Plant growth, fruit set, yield and fruit measurements. The trees of irrigated treatments showed significantly higher growth rate compared to rain-fed trees during 2009 growth season. However, rained trees had a significantly higher fruit set average than the irrigated trees during the same period (Table 5).

Table (4.3): Leaf analysis of minerals.

Mineral (% fresh weight)	Irrigated	Non-irrigated
K	0.68a	0.61a
Na	0.05a	0.04a
N	1.54a	1.34b
P	0.15a	0.16a
Ca	0.94a	0.72b
Mg	0.09b	0.21a
Cl	0.20 a	0.19 a

Difference between means is significant at $t \leq 0.05$ in K, Ca and Mg.

Analysis results for leaf samples taken fall 2011 showed no significant difference in K, Na, P, Cl, and P concentration in olive leaves of tow treatments (in terms of %of fresh weight), whereas the concentration of N and Ca was significantly higher in leaves of irrigated trees. However, the data shows that the Mg content in eaves of non-irrigated trees was significantly higher that the irrigated ones (Table 5).

4.1.5 Oil properties

The results of oil analysis for the season 2011/2012 has are presented in table according to these results, water content (WC) in fruits of irrigated trees was significantly higher (by 30%) compared to WC of non-irrigated trees, whereas the oil content in both treatment was the same when chemical extraction is used, while it is significantly higher in non-irrigated treatment when mechanical extraction is used (Table 6) because the mechanical extraction result is accurate. This indicates that irrigation has significantly increased water content in olive fruit but at the same time, oil % in fruits was reduced.

Regarding the basic chemical properties of oil, the oil extracted from fruits of irrigated has a higher FFA content than the fruits harvested from non-irrigated trees. This doesn’t mean that the acidity will rise.

However, the peroxide value was the same in both treatments and it is below the ceiling value of the IOOC, while the poly- phenoles content in oil of non-irrigated trees was found to be very high compared to oil of irrigated trees (Table 6).

Table (4.4): Oil properties analysis

Parameter	Unit	Irrigated	Non-irrigated
Oil content (NIR)	%	26.36 a	28.78 a
Oil content (Soxht)	%	25.92 a	28.48 a
Oil content (Aben)	%	20.66 b	25.8 a
Water Content (weighing)	%	38.85a	29.49b
FFA content	%	1.51 b	0.60 a
Peroxide	(mmole/kg)	6.9 a	6.34 a
Poly-phenols	(mg/kg)	182.3 b	265.1 a

Difference between means is significant at $t \leq 0.05$

From the above table, it appears that the oil content in the non-irrigated olive trees greater than that in the irrigated olive trees, which is logical, where because of the irrigation, the olive fruit size increase and the water content increase as (which shown in the above table), for this and as a result in the percentage basis , when the water content increase , the olive oil content decrease.

Free fatty acid in the irrigated olive appear to be higher than that in the non-irrigated olive, which is a result of the water used for irrigation which is mainly acidic water and affect the fatty acid composition in the olive oil and increase free fatty acid.

The peroxide value in both olive oil from irrigated and non-irrigated olive trees nearly the same with small increase in the irrigated one , which is due to some hydrolysis oxidation in the irrigated olive because of high water content.

Finally, the polyphenol content in the olive oil comes from non-irrigated olive is greater than that from the irrigated olive, this is due to the percentage basis, where , when the water content increase the polyphenol concentration decrease.

4.1.6 Olive yield

The data below clearly indicated the results of yield quality and quantity measurements.

The yield in rain-fed was 1.6 kg/ tree, when irrigated with treated wastewater, it increased to 9.54 kg/tree. This show that treated wastewater contains high nutrients that made a big difference between the yield in rain-fed and treated wastewater. Differences between yield kg/ tree and the average yield kg/donum is significant but the maturity index, weight ratio (pit/pulp) not significant.

Table (4.5): Impact of irrigation with treated wastewater on fruit yield and fruit and pit characteristics

Parameter	Rain-fed	Treated wastewater
Yield (Kg/tree)	1.60b	9.54a
Average yield Kg/donum *	28.8 **	171.72
Maturity index	2.90	3.03
Fruit weight (g)	2.31a	2.10 b
Pit weight (g)	0.76 a	0.72 a
Weight Ratio (Pit / Pulp)	0.329	0.343

* Planting density is 18 tree/dunum

** Bad season fruit yield average is 54 kg/dunum (MOA. Ministry of Agriculture)

Table (4.6): Impact of irrigation on Water and oil contents in olive fruits

Treatment	Water content %		Oil content %		
	NIR	Oven	Mill	NIR	Soxhlet
Rain-fed	26.89	28.63	19.91a	29.42 a	26.51 a
Treated wastewater	29.57	30.48	19.48 a	25.96 b	24.32

4.1.7 Impact of olive irrigation of oil quality

Table (4.7) : Free fatty acids content in olive oil for irrigated and non-irrigated trees

Parameter	Rain-fed	Treated wastewater
Free fatty acids %	1.51b	0.60a

Free fatty acid, is one of the main quality parameter in the olive oil and according to it, the olive oil quality classified, for this it is important to analyze it and identify the effect of irrigation on it, which is mainly analyzed by titration with sodium hydroxide with presence of ethyl alcohol and phenolphthalein indicator according to the IOOC method of analysis.

Table 10: Fatty acids composition of olive oil for irrigated and non-irrigated trees

Fatty acid	% of oil fatty acids composition		
	Rain-fed	Treated wastewater	Standards For Olive Oil (IOOC-1996) (EU-2002)
Myristic acid C 14:0	0.0105a	0.0107a	Max 0.05
Palmitic acid C 16:0	12.002 a	11.469b	7.5-20.0
Palmitoleic acid C 16:1	0.472 a	0.541a	0.3-3.5
Heptadecanoic acid C 17:0	0.145a	0.174a	Max 0.3
Heptadecenoic acid C 17:1	0.200a	0.240a	Max 0.3
Stearic acid C 18:0	4.295a	3.860a	0.5-5.0
Oleic acid C 18:1	72.924a	74.388a	55.0-83.0
Linoleic acid C 18:2	8.614a	8.129a	3.5-21.0
Linolenic acid C 18:3	0.663a	0.757a	Max 1.0 (EU-0.9)
Arachidic acid C 20:0	0.474a	0.374b	Max 0.6
Gadoleic acid C 20:1	0.200a	0.059b	Max 0.4

From the above table , it can be shown that all the fatty acids within the fatty acid profile standards according to the IOOC.

The main fatty acid in olive oil is Oleic acid, which is mono unsaturated fatty acid , this acid can be increased by irrigation, this appear clearly in the above table where Oleic acid in irrigated olive higher than that in the rain-fed olive. This is opposite for the second fatty acid, the Palmitic acid which is saturated fatty acid, where composition of Palmitic acid in the rain-fed olive higher than that in the irrigated olive , this due to the dissociation or dilution of the saturated fatty acid with high quantity of water in the irrigated olive, also this is the same for Stearic acid which is saturated fatty acid.

The main poly unsaturated fatty acid, linoleic acid appear higher in the rain-fed olive than that in the irrigated olive which due to some hydrolysis oxidation of the unstable double bonds in linoleic fatty acid because of the increase in the water content in the irrigated olive.

5. Chapter Five

5.1 Results

The study aims to show the effect of the use of treated waste water in the growth and production of olive trees as well as soil physical and chemical qualities.

Hypothesis of study as the following:

5.1.1 Effect of treated waste water on the shoot growth on olive trees.

Average annual shoot growth in olive trees irrigated with treated wastewater was found to be significantly higher than in the rain-fed trees. It was obvious in this study that the shoot growths of rain-fed trees were less than the trees irrigated with treated waste water. Before using treated waste water, the shoot growth was 5.23 cm, but it rose to 11.6 cm after being irrigated by treated waste water. This means an average increase by 77.66% . Therefore, there are significant differences after using treated waste water on the shoot growth of olive trees on the significant level of ($t \geq 0.05$).

The results of vegetative growth strongly indicated the important effect of supplementary irrigation with (WWR) on olive trees. The increase of shoot vegetation and fruit set is clearly shown in the experiment table (2) page 24. Vegetative growth improved when treated water irrigation was applied as compared to rain-fed. This could be attributed to the higher nutrient contents of treated gray water. The vegetative growth of any year is the base for the next year flowering and copping (Michelakis, 1998). Therefore, application of (WWR) assists in achieving higher and more stable annual yield of olives.

Previous studies by SamishandSpiegel (1961) showed that the tendency of alternate bearing was reduced by irrigation. Alternate bearing in olive is enhanced by the low vegetative growth during a heavy crop. Therefore, the enhancement of supplementary irrigation on vegetative growth will improve the production in the next year. Thus, it reduces the tendency of alternate bearing. Nitrogen is another important factor that encourages vegetative growth. The higher nitrate content of treated wastewater 39.00 (Table 1) could explain the superiority of vegetative growth of the olive trees irrigated with this water compared to rain-fed

Average yield, fruit weight, fruit length were significantly higher in trees irrigated with treated wastewater. As it appears in the (table2), the fruit set index was affected. The average value of olive fruit size irrigated by treated waste water was bigger than fruit size in rain-fed irrigation. The value was 1.2,an increase by 2 and this shows that there are differences with significant statistical between fruit set index in treated waste water olive trees and in rain-fed olive trees for olive trees irrigated by treated waste water on the significant level of $\infty \leq 0.05$.

5.1.2 Effect of treated waste water on olive trees production.

It appears from the study that fruit set as measured for olive trees irrigated by treated waste water was 5.3, and for rain-fed olive trees, it was 4.1. These significant differences in the statistical function ($t \geq 0.05$) for the olive trees irrigated by treated waste water. The increase in the production is clear between the two treatments, it increased in the irrigated olive trees by 0.1270.

Regarding to previous studies, Olive production (kg/fruit) is a function of several factors, among those is primarily fruit set. Fruit set in olives is strongly influenced by soil moisture that available during this period. This could be the reason of higher fruit set and therefore subsequently higher production. In addition the higher mineral contents of treated gray water mainly nitrogen is also an important factor that known to improve fruit set. This result is consistent with the finding of other researchers (Spiegel, 1957; Smaish and Spiegel, 1961; Nichelakis, 1998).

Moreover, the study shows that the quantity of the yield was 1.6 , 9.54 for the rain-fed trees and the irrigated trees by treated waste water respectively. These differences has statistical significant of $t \geq 0.05$ for the irrigated olive trees with treated waste water. In addition, the production ratio (kg/dunum) was 28.8 kg in rain-fed trees and 171.72 kg in trees irrigated by treated waste water. The statistical analysis shows there are differences in the statistical significant function $t \geq 0.05$ for the irrigated trees by an average increase of 318% compared with bad season average according to the Ministry of Agriculture.

Irrigation with treated waste water caused a highly significant increase of the yield in both years. Treated waste water worked as fertilization supplying N, P and K in large amounts

Maturity Index for rain-fed trees is 3.9 and for irrigated trees with treated waste water is 3.03. These averages are close to 3 which indicates that olive trees in both systems haven't shown any statistical differences according to maturity index.

It's also apparent that there are no significant differences in the fruit weight which was 2.3 gm in rain-fed trees and 2.1 gm in irrigated treated waste water trees.

The weight of the pit in irrigated trees was 0.76 gm and in rain-fed trees was 0.72 gm the difference between them was only 0.49 and this is significant difference $t \geq 0.05$.

The study also shows that there were no statistical differences between the weight average of the pit to the pulp in fruit. The average weight of the pit to the pulp was 0.329 in rain-fed trees and the pulp weight forms 0.671. And the pit weight average to the pulp in the irrigated trees was 0.657 for pulp weight with average decrease 0.0140 and this scale indicates that irrigation of trees using treated waste water has no influence on the pit and the pulp average.

5.1.3 Effect of treated waste water on olive oil properties

The result of water quantity analysis in fruit of the irrigated trees by treated waste water was bigger 30% compared with fruit in rain-fed trees. But oil content for both of them was very close when making chemical extraction. Whereas there was a difference in oil for them both too, after making mechanical extraction for oil due to table 6. This indicated that water average in the fruit of the treated waste water irrigated trees has increased while the oil average has decreased. After testing the chemical characteristics of oil, it was clear that the average of fruit fat acid for treated waste water irrigated trees was bigger that rain-fed trees. And this may be the cause of the high infection of the fruit fly in the trees that are irrigated by treated waste water. The average of peroxide value in both of them was similar and the poly-phenols content in the fruit of rain-fed trees was smaller than the fruit in the treated waste water irrigated trees. Table 6 clarifies that oil content of FFA is 1.51 , 0.60 in the irrigated trees and rain-fed trees respectively, and this is a high average because the difference between them is 0.91. It was also clear in the study that oil content according to NIR analysis was 26.36%, 28.78% for irrigated fruit olive trees and rain-fed fruit trees respectively, which means an increase by 2.42% on the fruit of rain-fed trees. After testing the olive fruit according to SOXHR analysis, the average was very close to the NIR analysis. But when testing the olive fruit in the irrigated trees test, the increase ratio was 9.36% compared with fruit in the rain-fed trees. The ratio of FFA in oil content was 1.5% in the olive oil of treated waste water trees fruit, whereas the ratio of oil from the rain-fed trees fruit was 0.60% which has a less average of 0.90% than in treated one. This indicates that the amount of FFA increases when irrigate trees by treated waste water

This happens because of the high average of treated waste water content from nutrients that can be absorbed by trees. Regarding the study, the average of Poly-Phenols in the irrigated olive oil is smaller than rain-fed olive oil trees. In the irrigated tree, the average was (mg/kg 183.3) in the olive oil. In rain-fed olive oil, the average was (mg/kg 265.1) and this indicates that the quality of oil increases when irrigated with treated waste water. These differences have a statistical function to $t \leq 0.05$.

The average of peroxide in the irrigated olive oil was (m mole /kg 6.9) an increase by 0.56 from the rain-fed olive oil. When the average of Peroxide increases in oil, its quality will fall (be less), but according to EU, if the average of Peroxide is less than 10, it's acceptable.

After FFA analysis for the fruit oil in the irrigated and non-irrigated trees, it was clear as in the following figure, that the average of FFA in both trees was close. It was 0.55 in rain-fed trees and 0.54 in the irrigated trees. This explains that there is no significant effect on the irrigated trees by treated waste water. In another word, there is no change in FFA ratio when trees are irrigated by treated waste water. but when FFA was analyzed, it was clear that most of FFA contents weren't bigger than the approved by IOOC and EU.

The existing differences between FFA are non-significant although there was a little increase in FA in the irrigated trees.

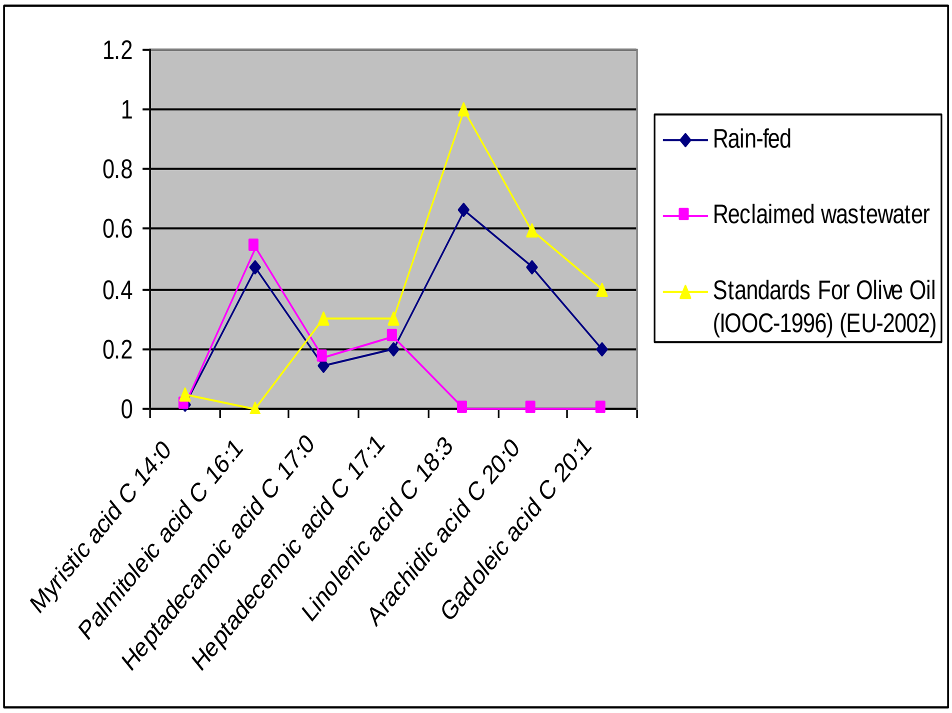

Figure ( ): The ratio of FFA of olive oil for rain-fed and treated wastewater compared with the standards of olive oil.

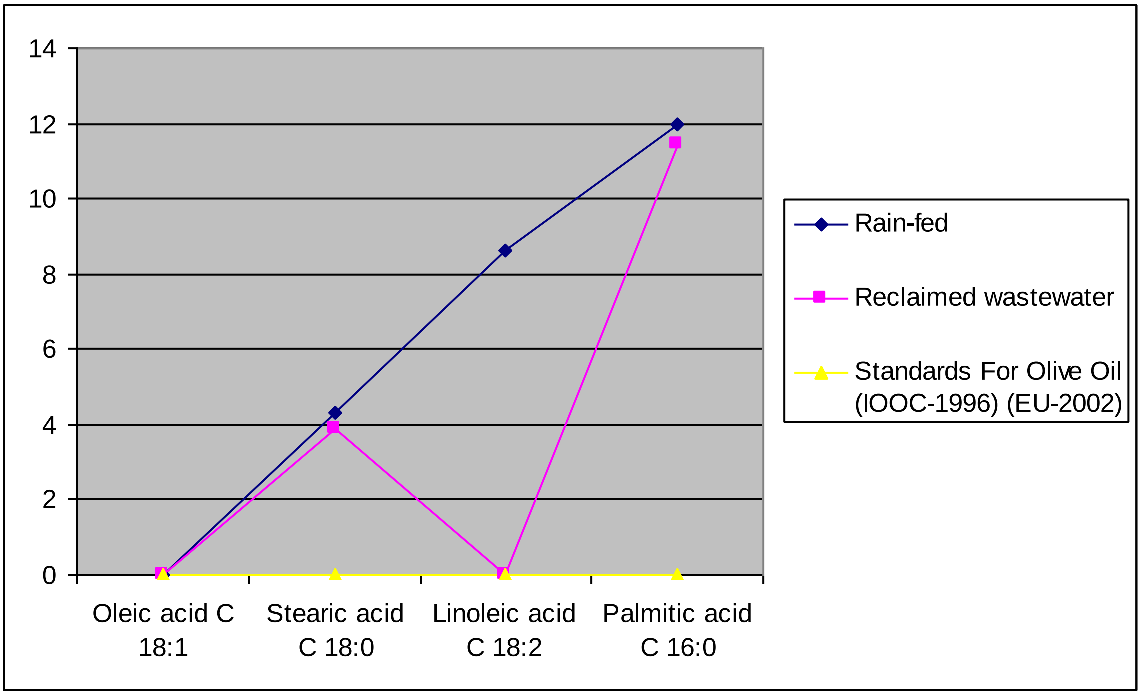

Figure14: The ratio of FFA of olive oil for rain-fed and treated wastewater compared with the standards of olive oil.

5.1.4 Effect of treated waste water on the physical and chemical qualities of soil

After the analysis that was made twice a year, the salinity of soil in the irrigated trees was higher than soil in rain-fed trees, and this is because of the contents of treated waste water irrigated to trees. The organic matters in the irrigated soil were higher than soil in rain-fed trees.

Samples of soil have been taken on the depth from 0-30 cm and 30-60 cm. It was clear that pH scale on the depth from0-30 cm was 7.39 in the irrigated trees, and 7.21 in rain-fed trees, with an increase of 0.18 in treated waste water. But when samples were taken from the depth of 30-60 cm, the pH scale was 7.42 in rain-fed and 7.76 in treated waste water, with an increase of 0.39. This is a big difference that it can affect the trees and it's a significant difference.

The study also shows that there was a significant increase in N, which is an important element in soil. It was 74.21 (mg/kg) in rain-fed soil, and 108.2 (mg/kg) in treated waste water soil on the depth from 0-30 cm.

On the depth from 30-60 cm, N was 65.5 (mg/kg) in rain-fed soil, and 98.7 (mg/kg) in treated waste water soil. All these differences are significant ones, and this explains the shoot increase in the irrigated soil by treated waste water compared with rain-fed.

A significant increase of N was reported in roots of trees irrigated with treated waste water. This significant was the consequence of N supply by treated waste water and its greater absorption by fine roots. In general, results showed significant differences for all the periods of the year between irrigated and non-irrigated trees.

Results showed that irrigation with treated waste water led to a significant increase of roots P concentration. The significant increase was attributed to high root P absorption as a consequence of P accumulation in soil solution

The rate of P, which is an important element for shoot growth, leads to increase the growth of the roots, and so the increase of water and nutrients absorb. This clarifies the increase of fruit size and the rate of water in the fruit. The amount of P in rain-fed on the depth from 0-30 cm was 18.1 (mg/kg), and in treated waste water, it was 48.6 (mg/kg) and this is a significant difference.

On the depth from 30-60 cm, the amount of P in rain-fed was 16.1 (mg/kg), and 52.6 (mg/kg) in treated waste water. And this is also a significant difference. Therefore, irrigate trees by treated waste water leads to significant increase for P in soil.

After the analysis, the amount of K in rain-fed from 0-30 cm depth was (mg/kg) 7.8, and in treated waste water, it was 32.0, a four-time increase for the treated waste water, which is also a significant difference.

The rate of K in rain-fed from 30-60 cm depth was (mg/kg) 9.1, and in treated waste water, it was (mg/kg) 29.5 and this is also a significant difference. This explains the increase of fruit size in the irrigated trees.

The analysis also shows that the rate of small elements in the treated waste water was higher than rain-fed on the depth from 0-30 cm, 30-60 cm, and these are significant differences.

5.1.5 Effect of treated waste water on leaf minerals content

Analysis results showed no significant differences in K, Na, P, Cl, Ca, and Mg concentration in olive leaves of two treatments. While the concentration of NH_4^+, was significantly higher in olive leaves of treated wastewater treatment (Table 5).Plant growth, fruit set, yield and fruit measurements. The trees of irrigated treatments showed significantly higher growth rate compared to rain-fed trees during 2009 growth season.

However, rained trees had a significantly higher fruit set average than the irrigated trees during the same period (Table 5).

Analysis results for leaf samples taken fall 2011 showed no significant difference in K, Na, P, Cl, and P concentration in olive leaves of two treatments (in terms of %of fresh weight), whereas the concentration of N and Ca was significantly higher in leaves of irrigated trees. However, the data shows that the Mg content in eaves of non-irrigated trees was significantly higher that the irrigated ones

6. Chapter Six

6.1 Conclusions and Recommendations

Referring to the data analysis the main findings of this research can be summarized as follows:

- Shoot growth and fruit set was higher in the trees irrigated with treated wastewater than the rain fed trees.
- The soil analyses results in spring showed that the concentration of most minerals was relatively lower than what it was in autumn, as well as the EC values, mainly because of soil mineral leaching during the fall season, whereas no significant change in soil PH was recorded.
- Organic matter content was also higher in irrigated treatments in both soil layers
- Fruit set data showed irrigated plots had a significantly higher fruit set % than the rain-fed trees.
- Analysis results of showed no significant differences in K, Na, P, Cl, Ca, and Mg concentration in olive leaves of tow treatments
- The concentration of NH_4^+, was significantly higher in olive leaves of treated wastewater treatment
- The oil extracted from fruits of irrigated has a higher FFA content than the fruits harvested from non-irrigated trees
- The peroxide value was the same in both treatment and it is below the ceiling value of the IOOC, while the poly- phenoles content in oil of non-irrigated trees was found to be very high compared to oil of irrigated trees

6.2 Recommendations

- Conduct more studies regarding the olive and oil properties that affect the olive yield and oil quality.
- It is recommended to have a one reference in one publication for the research result. This publication will be the reference of other researchers and decision makers for planning and management to reduce risks and costs of olive irrigation practices.
- Farmers and ministry of Agriculture must adopt the irrigation with treated wastewater in order to improve the olive and oil properties and exploits the wastewater treatment plants effluent.

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اثر استخدام المياه المعالجة في ري اشجار الزيتون على النمو، الانتاج، والجودة

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الملخص

هذه الدراسة تهدف الى التحقق في إعادة استخدام المياه المعالجة في ري أشجار الزيتون وأثرها على نمو الأشجار والإنتاج, بالإضافة عن تأثيرها على الخواص الفيزيائية والكيميائية الرئيسية للزيوت المنتجة, علاوة على ذلك قام الباحثون بدراسة تأثير تطبيق مياه الصرف الصحي المعالجة على خواص التربة.

وقد اجرت الدراسة على اثنين من بساتين أشجار الزيتون صنف النبالي المحسن في قرية صير شمال الضفة الغربية بحيث كانت هذه الأشجار حتى لحظة بدء التجربة تنمو بطريقة غير مروية (بعلية). هذه التجربة شملت قطعتين كل قطعة تحوي على 10 أشجار زيتون بحيث كانت القطعة الأولى تسقى في المياه المعالجة من محطة صير والأخرى تسقى من مياه الأمطار, وتم تكرار كل معالجة 5 مرات وفي كل معالجة تم حساب شجرتين.

مياه الصرف الصحي المعالجة المطبقة على الأشجار من خلال شبكة الري بالتنقيط، بدأت منذ ثلاثة مواسم متتالية خلال الفترة 2010-2012 في ابريل نيسان وانتهت في سبتمبر ايلول. في كل فترة الري، تلقت كل شجرة الزيتون 96-100 لتر في كل دورة في حين تم تطبيق ثلاث دورات الري خلال الأسبوع.

أظهرت نتائج التجربة أن النمو الخضري للأشجار الزيتون المروية كان أعلى مقارنة مع الأشجار غير المروية. فيما يتعلق بإنتاج الثمار وأظهرت نتيجة لزيادة الإنتاج في الأشجار المروية. كما أظهرت نتائج الري مع زيادة الثمار باستخدام مياه الصرف الصحي المعالجة المحتوى المائي، في حين أن نسبة الزيت في الثمار لم تتغير بشكل ملحوظ بين العلاجات 2. ومع ذلك، كانت الأحماض الدهنية الحرة (FFA) في الزيتأكبرالأشجار المروية في حين تم العثور على تركيز حيلة فينولات لتكون أقل من ذلك بكثير الأشجار المروية مقارنة مع تلك غير المروية.

وعلاوة على ذلك، فإن ري أشجار الزيتون بمياه الصرف الصحي المعالجة قد أثرت أيضا على المحتوى الأوراق من المعادن. حيث تم العثور على تركيزات البوتاسيوم، الصوديوم، N، الكالسيوم والكلور في أوراق الأشجار المروية أعلى بكثير أن الأشجار غير المروية، في حين أن تركيزات P والمغنيسيوم كانت أقل بشكل ملحوظ في أوراق الأشجار المروية.

وأظهرت هذه الدراسة أن تحليلات التربة أظهرت النتائج في الربيع أن تركيز معظم المعادن كان أقل نسبيا عما كان عليه في الخريف، فضلا عن قيمة التوصيل الكهربائي، وذلك أساسا بسبب الرشح المعدنية التربة خلال فصل الخريف، في حين أن لا تغير ملموس في تسجيل حموضة التربة، وعلاوة على ذلك، كان تركيز معظم المعادن التربة أعلى بكثير في مؤامرات المروية باستثناء المغنيسيوم حيث أظهرت البيانات نفس التركيزات في كل من العلاجات في كل من التربة أعماق حيث كان محتوى المادة العضوية أعلى أيضا في علاجات المروية في كل من طبقات التربة .

أما خصائص زيت الزيتون, أظهرت الدراسة أن الزيت المستخرج من ثمار الأشجار المروية يحتوي على نسبة FFA أعلى من الثمار التي تحصد من الأشجار غير المروية، وكانت قيمة البيروكسيد هو متماثلة في كل معاملة وأنه أقل من قيمة الحد الأقصى للIOOC ، في حين تم العثور على المحتوى بولي فينول في الزيت من الأشجار غير المروية لتكون مرتفعة جدا مقارنة مع الزيت من الأشجار المروية.

وقدمت النتائج مؤشر ايجابي لامكانية استخدام هذا النوع من المياه المعالجة للري أشجار الزيتون في ظل ظروف التجربة

عمادة الدراسات العليا

جامعة القدس

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