An-Najah National University
Faculty of Graduate studies

The Use of Treated Gray Water for Irrigation of Rainfed Olives

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Submitted in Partial Fulfilment for the Requirements for the Degree of Master in Environmental Sciences, Faculty of Graduate Studies at An-Najah National University, Nablus, Palestine

2004

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Dedication

To My Beloved Family
with Respect and Love

Acknowledgment

My sincere gratitude and appreciation to my supervisor Dr. Hassan Abu Qaoud for high experienced advice for achieving this thesis. I am greatly appreciative to Dr. Numan Mizyed for his ideas and suggestions before conducting the work. Sincere gratitude are extended to the staff of the Palestinian Agriculture Relief Committee PARC, for their support and help, especially to Dr. Ismail Daiq, Mr. Judeh Abdullah and Dr. Abdellateef Mohammad. Special thank is also extended to Mr. Fares Aljabi from MOA for his continuous help and advice.

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Abstract

The effect of different water regimes with different quality on the growth and production of “Nabali” olive cultivars was studied. Three levels of fresh water (20, 25 and 30 CM) and three levels of treated gray waste water (20, 25, and 30 CM) were used. A control treatment without irrigation was also included. Thirty year old olive cv “Nabali” trees were irrigated from April to July with the different water treatments, each level was applied for a tree. Irrigation water was applied by drip laterals. The experiment was conducted as Beit Doko village close to Jerusalem. Gray waste water was treated through a gravel and filter plant. Both types of water significantly increased olive yield compared to that obtained in the control. A higher vegetative growth (shoot number and length) was obtained with higher water level (30 CM / tree) treated water. Higher olive fruit production was obtained with both olive 30 CM / tree of fresh and treated water. Non irrigated trees exhibited the lowest production and shoot growth.

Both higher levels (25 and 30 CM) of water treatment gave significantly higher oil percent, product or oil acidity and refractive index were not highly influenced by water treatments. These results influenced by the water treatments. These results indicated that this kind of treated wastewater is suitable for application to olive orchards.

Chapter I

Introduction

1.1 Literature background

Many parts of the world are threatened by water scarcity. By the year 2025, it is projected that one fourth of the words' nearly six billion people will suffer from water shortage (Al-Khayari, *et al.*, 1999). In the Middle East the threat of water scarcity is particularly important as it is an arid region with limited fresh water sources. The large increase in the population of the world and the improved living standards require more water (Al-Khayari, 1999).

Agricultural is a main water consuming sector and is highly affected by shortages of water. The major share of water in Palestine is being used in agriculture. The role of agriculture is particularly important in the economy of Palestine due to its high contribution to the GDP and the high percentage of people working in agriculture. Irrigated agriculture contributes more than 37% of total agricultural production compared to only 24% from rainfed agriculture. Agriculture has a major role in national trade, as agricultural products constitute 23% of the national commodities export (PWA, PECDAR, 2001).

At present, the total irrigated land area in Palestine is 240,000 dunums with the irrigated area in West Bank being estimated at 125,000 dunums with a total water supply for irrigated agriculture estimated to be about 89 MCM/year. The irrigated area in the Gaza Strip is estimated to be about 114,000 dunums, consuming about 83 MCM/year (PWA, PECDAR, 2001).

It is predicted that the growth in population will increase from 3,321,000 in the year 2000 to about 3,884,000 and 4,437, 000 by the year 2005 and 2010, respectively. In view of the geopolitical situation of Palestine, it is recommended to increase the irrigated area since it was restricted due to the occupation. Consequently, this growth in the irrigated land area should be based on available local water resources to increase national production to feed the nation. It is worth noting that the source of water for irrigation in the West Bank is mainly from groundwater in the form of wells and springs, and only from wells in the Gaza strip (PWA, PECDAR, 2001).

1.2 The current irrigation water supply

The current irrigation water supply is about 172 MCM/year, about 89 MCM of which are utilized in the West Bank coming from springs and wells. It is important to note that water supplies for irrigation are either shallow, small old wells or natural springs. Natural springs face the severe problem of discharge variability, and thus these spring sources are not reliable water sources. The spring discharge is low in dry years and high in wet years. Due to lack of storage structures, large volumes are lost in wet months and wet years.

For the Gaza Strip, only 200,000 dunums are suitable for cultivation. The rest of the land area is sand dunes and areas not suitable for cultivation. The irrigated area is currently estimated at 114,000 dunums; however, this area is subject to reduction due to urbanization resulting from the high population growth (PAW, PECDAR, 2001).

Table 1.1 Estimated total water supply for irrigation in the West Bank and Gaza.

Districts	Wells (MCM)	Brackish	Springs (MCM)	Total (MCM)
West Bank	40.3	0	49	89.3
Gaza Strip	40	43	0	83
Total	80.3	43	49	172.3

(PAW, PECDAR, 2001)

For the purpose of estimating irrigation water demand, the needed irrigated land area of 0.14 dunums per capita can be used (which is around the Jordanian per capita share since Jordan is similar in water resources scarcity and conditions to Palestine). Based on this and on population projections, the total land requirement for agriculture will be 465,000, 544,000, and 621,000, dunums in the years 2000, 2005 and 2010 respectively. Accordingly, agricultural water demand by the year 2000 was around 279 MCM/year. The current water supply to the agricultural sector is estimated at 172 MCM/year resulting in an immediate current deficit of 107 MCM/year, if no additional water resources are made available.

In the years 2005 and 2010, annual agricultural water demands were estimated at 326 and 373 MCM/year, respectively. The current water supply estimated at 172 MCM/year thus results in a deficit of 154 and 201 MCM/year in the years 2005 and 2010 respectively, if no additional water resources are made available.

The present Palestinian per capita irrigation water share of 52 M^3/ Capita is the lowest among the region and that the future Palestinian per capita agricultural water demand of 84m^3/ capita would be the lowest in the region for all horizons when compared too the Jordanian and Israeli demands. The expected expansion in the irrigated land area will be only in the West Bank and mainly in the Jordan Valley where land is more available since the Gaza Strip faces a severe problem of water quality deterioration and urban pressure (PWA, 2001; PECDAR, 2001).

The future of water balance in the area will depend upon the portion of effluent reused in irrigation and to recharge the aquifer. Safe treated wastewater is required. Treated wastewater is a valuable resource in a water scarce region. Having been collected it should be treated to acceptable standards for re-use or recharge to the aquifer. Wastewater treatment plants are planned, or under construction, for each of the major urban areas, which would provide secondary treatment. The effluent from these plants, while much fresher and lower in pathogens than the influent, would still contain high levels of pathogens and present a health risk when used for unrestricted agriculture. The challenge is to make use of this water for agriculture, while minimizing the health risk.

Communities who do not have a piped water supply, or who suffer from intermittent water supplies especially in summer, commonly use cisterns. Several detrimental practices are widespread and include: the addition of petrol to prevent breeding of insects, the failure to disinfect this water though chlorine tablets which are freely available, construction of cesspits near their cisterns, with cross pollution livestock is allowed to contaminate the water (PAW, PECDAR, 2001).

Irrigation with reclaimed water is growing so fast all over the world. Reclaimed water serves as an extra source of water available for that rural sector for irrigation, this source is especially important in regions with limited water resource, where the increasing water demand growth by the urban sector. The supply of treated wastewater is quantitatively reliable for the farmers, since it depends neither on precipitation nor on the water balance of the whole region (Juanic, 2002). Irrigation adds significant polishing treatment to the effluents via break down of xenobiotic compounds in the soil, evaporation of volatile compounds, pathogens die-off biological degrade of remaining organic matter, and other processes. Disposal of the treated effluents via irrigation may be the cheapest disposal alternative (for both construction and operational costs) when compared with disposal via discharge to rivers or lakes. Disposal of the treated effluents via irrigation may also be the alternative with minimal impact on the environment (Junic, 2002).

Land and water resources are the primary resources for agricultural development in the West Bank. The West Bank comprises about six million dunums (31.7%) of which are cultivated while in Gaza 47.8% of the strip's 365,000 dunums are cultivated. In the West Bank 104,000 dunums are irrigated - 5.5% of cultivated land - and in Gaza 108, 5 dunums – 49.3% of cultivated land (Abedullah, 1998).

The estimated annual ground water recharge in the West Bank is 600 MCM of which the Palestinians are only permitted to use 115 MCM while in Gaza strip the renewable supply is about 80 MCM while 120-140 MCM are actually being abstracted leading to salinity problems for Gaza agriculture (Abedullah, 1998).

In terms of annual rainfall, 60% of the country may be defined as arid or semi arid rain falls only between November and April, with uneven distribution yearly precipitation, ranging from 28 inches (70cm) in the north to less than two inches (5cm) in the south. Annual renewable water resources amount to some 1-6 billion C.M.; about 75% at which is used for agriculture. Of the latter, two thirds is potable-a share which is likely to decrease substantially in the coming years as more sewage treatment plants come on line (Israeli Ministry of Foreign Affairs, 1998). Data presented in Tables 1.2, 1.3 and figure 1 show the monthly recorded rain fall in the area during the study period and the initial soil infiltration rate.

Table 1.2 Rain fall in mm during the year 2000-2001.

Month	03..2000	10. 2000	11. 2000	12. 2000	-------	------	01.2001
Rain/mm	15	19	2.3	152.2	--------	------	101.7
Month	02. 2001	03. 2001	04.2001	05 2001	10. 2001	11. 2001	12. 2001
Rain/mm	131.8	15	2	74	5.2	88.8	144.3

Table 1.3 Soil infiltration rate before treatment.

Time / min.	**Depth /cm**	**Δ F**	**Δ D**	**ΔD/Δt Infiltration cm/min**
0	0	1	-	-
1	2	1	2	2
2	3	1	1	1
15	17.5	1	1	1
30	34.5	15	14	0.93
45	47.5	15	13	0.87
60	59.5	15	12	0.80
90	82	30	23	0.77
120	104	30	22	0.73
180	147	60	43	0.72

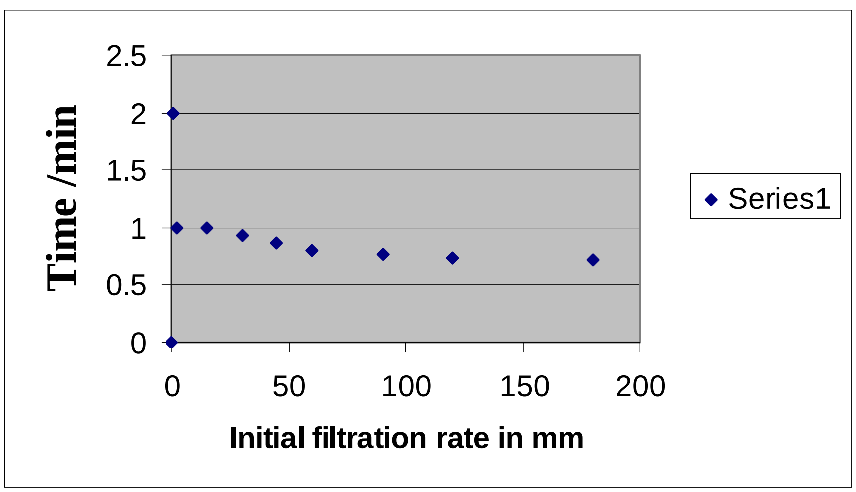

Figure 1. Soil infiltration rate before treatment

The olive tree has a distinguished importance in the economical and social life of the Palestinian people. This sector is one of the main resources of the agricultural income. In some years the contribution of olive reaches to 12% of the agricultural income. The export of olive oil and olives took the first class of the Palestinian exports for several years and it played an important role in the Palestinian trade scale (Al-Jabi, 2003).

The olive trees grown in Palestine are traditionally non-irrigated. The majorities of the olive orchards are old (60 to few hundred years and in some sites over one thousand years) and consists mainly of the 'Souri' cultivars. More recently many of the 'Nabali' cultivars have been planted, these cultivars are well known for their high quality, good taste, and high oil content. The fruit size of these cultivars reaches 1.5 - 2.5 gr. with oil content of 25 - 35%. Each tree occupies an average of 100sqm. and produces a commercial crop for 10-12 years after planting. The average long-term yield of these cultivars is around 15-25kg/year per tree. The production of the Souri fluctuates on a strict pattern, each tree producing a good yield only every other year. Experts and farmers attribute this phenomenon to the destructive means used in harvesting and to non-irrigation. During the years of the good years of olive yield, the olives are often small and shriveled during July- August and this was attributed to water stress (Abed Al-Hadi *et al.*, 1990).

Although olive trees can grow and survive under low water availability conditions, adequate water supply was found to be essential for satisfactory yield. The scarcity of water in our region as well as the topography of olive orchards makes irrigation of olive trees very difficult.

Therefore, the main objective of this work is to use treated gray wastewater in irrigating mature olive trees.

1.3 Methods of waste water treatment

Wastewater in the West Bank -Palestine is mostly disposed of in cesspits where it infiltrates into the surrounding soil. A few cases use settling tanks letting the solids to settle before the wastewater infiltrates into the soil to minimize soil clogging. On site disposal systems, are generally used, as only 20% of the populations in the West Bank are connected to sewer systems, where all rural communities and the outskirts of the cities rely on cesspits as on-site disposal systems.

Cesspits include settling of wastewater; anaerobic digestion of sludge percolation of liquid into the ground, but the functioning of these systems usually fails after some time. The content has to be removed frequently from the filled cesspits and is currently disposed into open areas, wads or existing treatment plants. The infiltration of settled wastewater into the surrounding soil and the present practice of sludge disposal affect the quality of water resources mainly the ground water (Burnat, 2003).

There are many methods of treatment such as aerated lagoons, aerobic digestion, anaerobic digestion, rotating biological contractors, and stabilization ponds were also developed and used. Since the 1960's the era of reclamation, recycling, and reuse started. By the year 1984, potable water reuse plants were in operation (Kalbounh, 1997).

Studies on septic tank- gravel filter in the West Bank are very limited, septic tanks were reported to provide for particle treatment of wastewater and the effluents might not satisfactory meet the standards and environmental pollution control requirements, since the reduction of BOD5 concentration in the septic tank is of the order 25-50 percent depending on the retention time (Burnat, 2003).

1.4 Irrigation of olives

Olive tree is remarkably resistant to drought. This has been emphasized by many authors 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% of Etc. 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, 2000).

Increased vegetative growth, better budding flowering, 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 growth by 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 -0.02 to –0.06 MPa were compared with non-irrigated trees in Crete. Soil moisture reached wilting point at the end of July in the non- irrigated treatment, and on the end of September and august in the irrigated treatments (Michelakis, *et al.*, 1946).

A riled 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 SAP and EC (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 decrease in leaf growth, function 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 not 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).

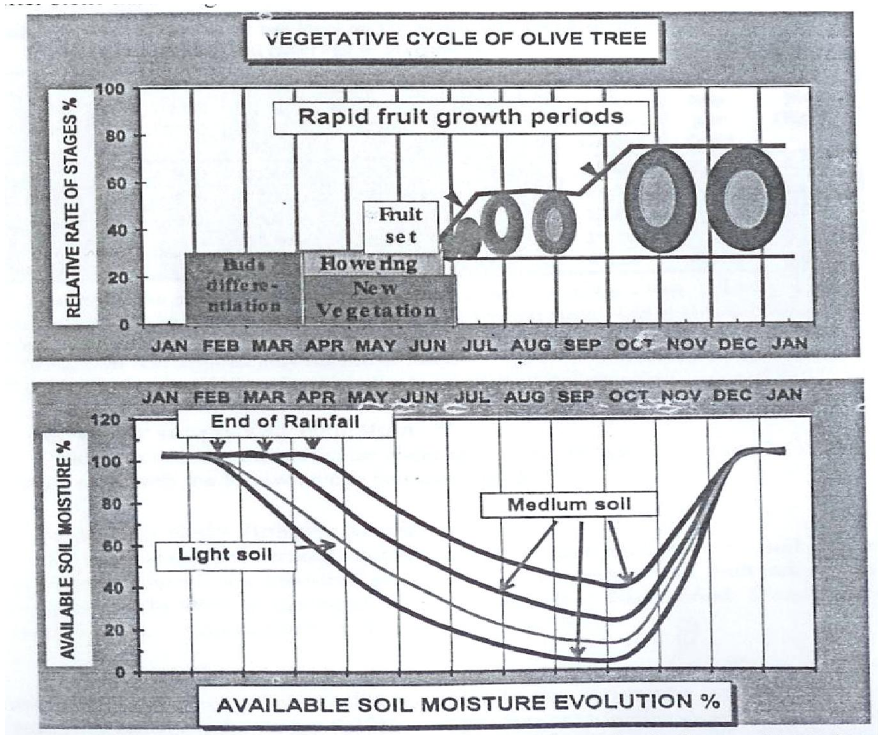

Figure 2. Schematic representation of the vegetative cycle of olive tree in relation to the available soil moisture. (Adopted from Michelakis, 1998)

Therefore, it can be inferred that, to insure appropriate fruit size adequate soil water availability is indispensable 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).

Chapter II

Material and methods

2.1 Beit Doko gray wastewater treatment plant

Field work was performed in this village in the West Bank during a period of 24 months starting from April 2000 to July 2002. Works included construction of septic tank with a gravel filter treatment system, monitoring the operation of the system and collecting and analyzing fresh and treated wastewater samples in order to find the characteristics of fresh gray wastewater and to assess the performance of the treatment system. About twenty houses are connected to the treatment plant.

Beit Doko village is a typical example of a rural community which is expected to be sewered for many years to come. The population number, the comparatively low density of population and the topographical characteristics of the village which includes three separate topographical catchments areas require at least three sewerage pumping stations for a centralized wastewater treatment and disposal.

The treatment plant under consideration consists of anaerobic pond, gravel filter, sand filter and a polishing pond. It started operation under anaerobic conditions in September 2000. It is connected to around 21 houses with about 180 inhabitants (Fig 2.1).

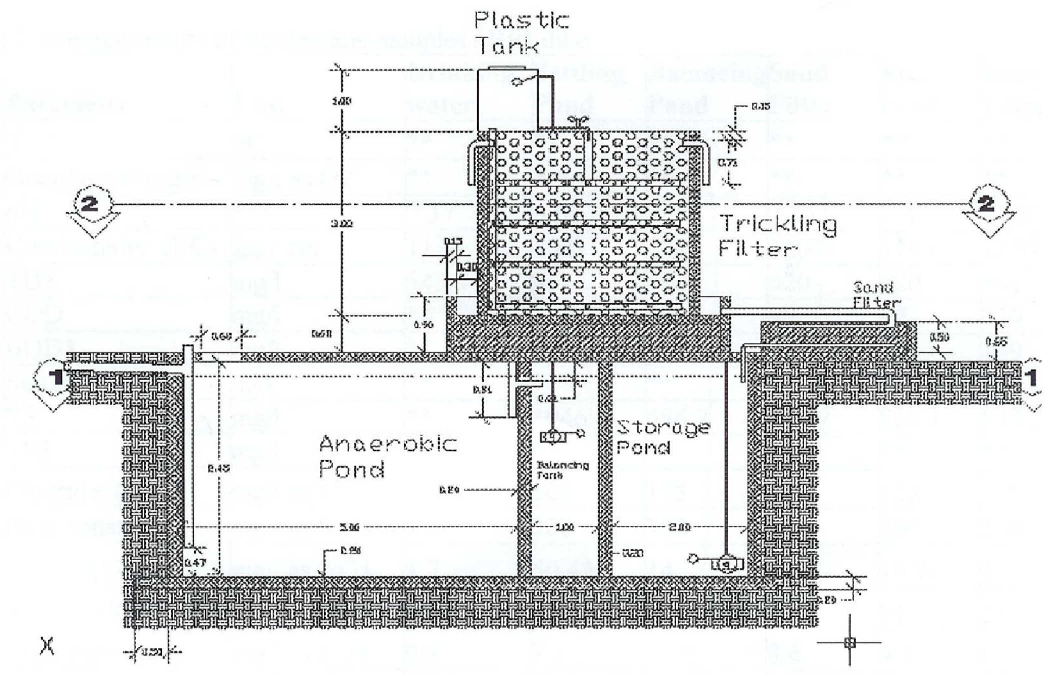

Figure 3. Schemtic diagram of the water treatment plant

2.2 Treatment plant description

Plant site:

The site is located south of (Beit-Doko) village with an area of 150 m^2. This site is sufficient for the construction of the treatment plant facilities with a capacity up to 15m^3 \d. The treatment plant would serve a sewered population of approximately 300 persons at a per capita sewage flow of 50 l/c/d. The topography of the site has natural slope, it was adapted for the treatment units.

Components:

Screen: Wastewater from the sewer is flowing by gravity into the treatment plant through bar screens that is manually freshened.

1. Anaerobic pond: Flow passing through the manual screen enters the anaerobic pond, where the solids settle sown, the grease and foam flows up on the surface. The wastewater takes routes that make its retention time in this pond to be at least two days. The settled solids were designed to be removed every two years (it was noticed that the level of accumulated solids is low). The water from this pond flows to a balancing pond where a submerged pump is installed.

2. Gravel filter: In the gravel filter, pretreated wastewater is pumped from the balancing pond after the anaerobic pond to a tank where it is controlled over the bottom of the filter bed media, acting as up flow anaerobic filter. The water from the gravel filter drops from the top of the filter touching the ambient air, going through a collecting basin to the sand filter.

3. Sand filter: it is an intermittent fine sand filter; it receives water from the gravel filter basin removing the suspended solids like sloughed bacteria. The sand filter surface area is two square meters and its depth is 0.6 meter, it is divided into four compartments.

4. Polishing and storage pond: The water flows into a polishing pond of three days storage capacity and a depth of 1.5 meters; the pond surface is subjected to ambient air. The purpose of this pond is killing the living bacteria by sunrays and acts as three days storage tank for recirculation and irrigation. A re-circulation submerged pump is installed on the polishing pond, its purpose is to keep certain level of water in the balancing pond in order to provide a minimum organic load for the bacteria in the gravel filter when the sewer system goes dry at night. Another pump for irrigation is installed on this polishing pond. All pumps are controlled by electrical floats.

2.3 Methods of water sampling and analysis

Sampling, storage and analysis of samples taken from the treatment systems followed the procedures mentioned in the standard methods for the Examination of water and wastewater, 19th edition summarizes the major analyses carried out. The samples were stored and tested by the Palestinian water authority laboratory.

Table 2.1 Methods of analysis for wastewater.

Item	Method
Chemical oxygen demand (COD)	Closed reflux, calorimetric method
Biochemical oxygen demand (BOD)	Standard method
Ammonia (NH_3)	Direct nesslerization method
Kjeldahl Nitrogen (NKJ)	Macro-Kjeldahl method
Phosphate (P)	Ascorbic acid spectrophotometer metho
Chloride (CL)	Ergonometric titration method
Sulfate (SO_4)	Turbidimetric method
Nitrate (NO_3)	Photometric method

Samples were tested in triplicate after at most two hours from sampling

2.4 Irrigation experiment

Twenty-one Nabali pure trees, 30 year old olive trees, were used in the experiment. The trees were selected of similar size. Seven different water regimes were used to irrigate the trees.

Each treatment was applied for 3 olive trees, the treatments were:

Control (without irrigation)

Irrigation with fresh water (20m^3/tree/year)

Irrigation with fresh water (25m^3/tree/year)

Irrigation with fresh water (30m^3/tree/year)

Irrigation with wastewater (20m^3/tree/year)

Irrigation with wastewater (25m^3/tree/year)

Irrigation with wastewater (30m^3/tree/year)

Each tree was considered as a block. Therefore, the experiment was arranged in a randomized complete block design. Irrigation was started in April until July. Water was applied through drip irrigation; the amount of water was added weekly during the irrigation period, the amount was divided equally over the a period of sixteen weeks.

2.5 Measurements

1. Soil samples: were taken before the initiation of the experiment from three depths, 0-30cm, 30-60cm, 60-90cm. Each sample consists of 6 compost samples that were taken (pH, EC, soil moisture, organic mater calcium, potassium and sodium) from different locations in the field.

The following measurements were determined in the laboratory.

2. Vegetative growth: the assessment of vegetative growth of olive trees was determined by selecting three scaffold of each tree. The no. of new shoots on each scaffold was counted and the average length of the new growing shoots was measured for each tree.

3. Olive production: the total production of each tree was measured after harvesting which was conducted during 20-27 of October 2001. The total yield was calculated per tree. The fruits were then stored in refrigerator at 5-7°C before pressing using special blender and the oil was extracted and calculated as a percent and quantity.

4. Oil Quality Measurements: oil was subjected to different analysis to determine the acidity using titration method, and the reflective index was measured using a spectrophotometer.

2.6 Statistical analysis

One way ANOVA was conducted for the data followed by a mean separation using the Duncan's multiple range test (DMRT), at α = 0.05 level.

Chapter III

Results and Discussion

3.1 Gray wastewater characteristics

The results of the analysis for gray wastewater from the houses in Beit-Doko are summarized in table 3.1.

Table 3.1 Characteristics of gray wastewater before treatments.

Item	Unit	Value
BOD	mg/l	590
COD	mg/l	1270
pH		6.6
EC	µs/cm	1585
TDS	ppm	935
SS	mg/l	11.4
TS	mg/l	1780
TSS	mg/l	1396
CL-	mg/l	255
HCO^{3-}	mg/l	230
NH^{4-}	mg/l	3.8
NO_3^-	mg/l	38
SO_4^{--}	mg/l	74
PO_4^{-3}	mg/l	4.4
Ca^{++}	mg/l	75
Mg^{++}	mg/l	35
Na^+	mg/l	126
K^+	mg/l	16
TC	Cfu/100ml	3100
FC	Number/100ml	60

It is clear that the basic items of gray wastewater has high values of BOD=590, and COD=1270.

Table 3.2 Comparison of water quality of both fresh and treated gray wastewater.

Parameter	Unit	Drinking water	Treated gray water
Temprature	^0C	**	**
Dissolved Oxygen	mg\l as O_2	**	**
pH	***	7.37	7.61
Conductivity (EC)	Ms\cm	1118	1190
TDS	mg\l	543.3	620
COD	mg\l	**	97
BOD5	mg\l	**	32
Settable Solids	ml\l	**	**
TS	mg\l	**	866.4
TSS	mg\l	**	**
Chloride (Cl^-)	mg\l as Cl^-	173	152
Bicarbonate	mg\l as $CaCO_3$	230	297
Nitrate (NO_3-)	mg\l as NO_3	1.7	10.76
Sulfate (SO_4^{-2})	mg\l as SO_4	11	21
Phosphate (PO_4^{--})	mg\l as PO_4	0.2	4.4
Calcium (Ca^+)	mg\l as Ca^+	69	42.5
Magnesium (Mg^+)	mg\l as Mg^+	32	8
Sodium (Na^+)	mg\ l as Na^+	90	153.3
Potassium (K^+)	mg\l as K^+	3.6	25.31
Total Coli forms	CFU\100 ml	**	2500
Fecal Coli forms	CFU\100 ml	**	**

From table 3.2 it is clear that POD & COD after treatment are lower than BOD & COD before treatment.

The value of COD after treatment indicates that this kind of wastewater is suitable for unrestrected irrigation. After checking the quality of the data, the sum of both the cations and anions are approximately equal, however the sum of cations is about ten times the value of the EC. This suggests that the data are reasonably accurate.

Concerning salinity, the EC of the worker was 1.190 dS/m. According to the FAO guidelines this water could be used for crops moderately tolerant to salinity similar to olives. Since sodium concentration was 153 mg/l and the chloride concentration was 152 mg/l, this water can be used to irrigate olive without any complication of sodium and chloride toxicity.

Table 3.3 Guidelines for reuse in agriculture.

Crop	**BOD5 (mg/l)**	**Fecal coli form (CFU/100ml)**	**Suspended solid (mg/l)**
Food Crops	30	75	35
Forages	40	100	45
Gardening	40	800	45

Adopted from FAO, 2001

The number of BOD5 in table 2.9 after treatment is similar to BOD5 of crops for human consumption.

3.2 Soil analysis

Table 3.4 Analysis of the soil samples.

	Depth/cm		
Measurements	0-30	31-60	61-90
pH	7.65	7.71	7.69
EC	0.52µms/cm	0.51ms/cm	0.55ms/cm
Organic Matter	3.02	2.13	4.92%
Calcium	884	884	880 ppm
Potassium	76	72.0	24 ppm
Sodium	1497	1229.8	2968 ppm

From table 3.4 it is clear that the soil is deep, non-saline and non sodic. The soil is fertile, organic matter content more than 2%, both K^{+} and Ca^{++} contents are high.

3.3 Effect of different water regimes on vegetative growth of Nabali olive trees

The effects of irrigating olive trees with different levels of both fresh and treated gray water are shown in figures 4 through 10 (numbers on the top of each column in figures 4-10, followed by the same letter(s) are not significantly differ at probability level ***P*** = 0.05). Higher shoot numbers were obtained with olive trees supplemented with water.

The highest shoot numbers (150) of branches were obtained when treated water was used at a rate of 30 CM/ season. This number significantly differ from other treatments, however, lower shoot number was obtained with from trees without any irrigation (72.9) branch. Both groups of trees supplied with 25 CM of either fresh or treated water gave significantly similar results. Concerning the average shoot length, the result showed significantly higher shoot length of new growing shoots under 30 CM/ tree irrigation regime (23.77cm) followed by both 25 CM treated water and 30 CM fresh water, however there was no significant difference among other water treatments.

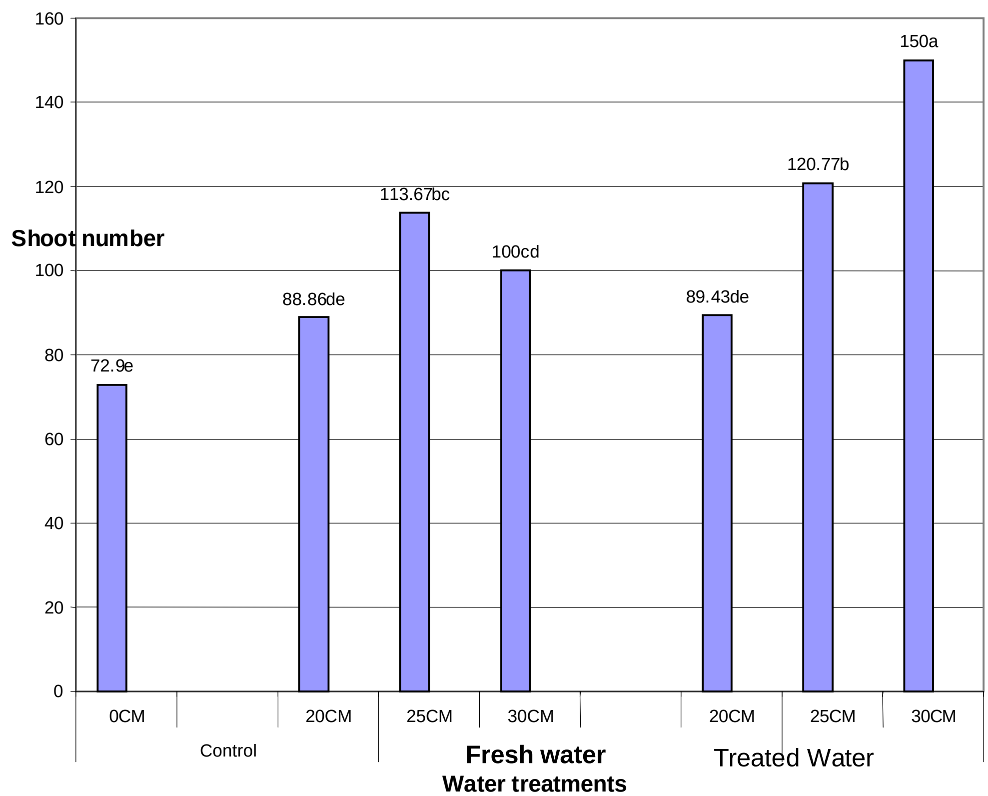

Figure 4. Average number of new shoots of olive trees under different water treatments

The results of vegetative growth strongly indicated the important effect of supplementary irrigation in olive trees. The number of new shoots was highly influenced by the water application. The vegetative growth of the current year is the base for the next year flowering and copping (Michelakis, 1998). Therefore, a high and more stable annual yield is indispensable to insure a certain vegetative growth in all year. Two phases of vegetative growth has been detected in olive; an intensive phase in the spring to early summer and a less active phase in the autumn. The increased vegetative growth was obtained from olive trees provided with adequate water during the spring to early summer. Our results are in agreement with this statement.

Previous reports by Samish and Spiegel (1961) claimed that the tendency of alternate bearing was reduced by spring 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, reduce the tendency of alternate bearing. Nitrogen is another important factor that encourages vegetative growth. The higher nitrate content of treated wastewater 10.76 (Table 4) could explain the superiority of vegetative growth of the olive trees irrigated with this water compared to those received fresh water irrigation.

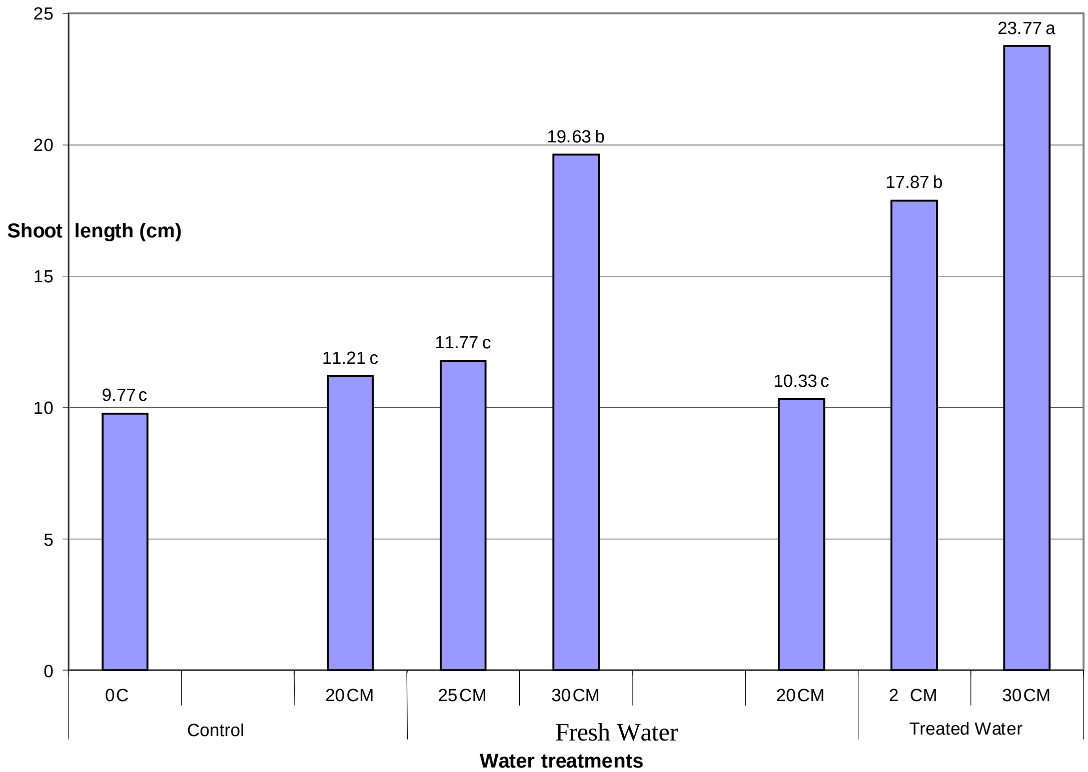

Figure 5. Average shoot length of new growing shoots of olive trees under different water treatments

3.4 Effect of different water regimes on production of 'Nabali' olive trees

The effect of supplementary irrigation of olive trees with two types of water on olive fruit production is shown in Fig 6. Olive production (Kg fruit/ tree) were significantly influenced by the supplementary irrigation. The high yield (kg/ tree) was obtained under both 30 CM of treated and fresh water (27.52 and 23.2 respectively). The lowest production was obtained with olive trees irrigated with 0, 20 CM fresh water and 20 CM treated water. However, both groups of olive trees supplied with 25CM treated water were without significant differences.

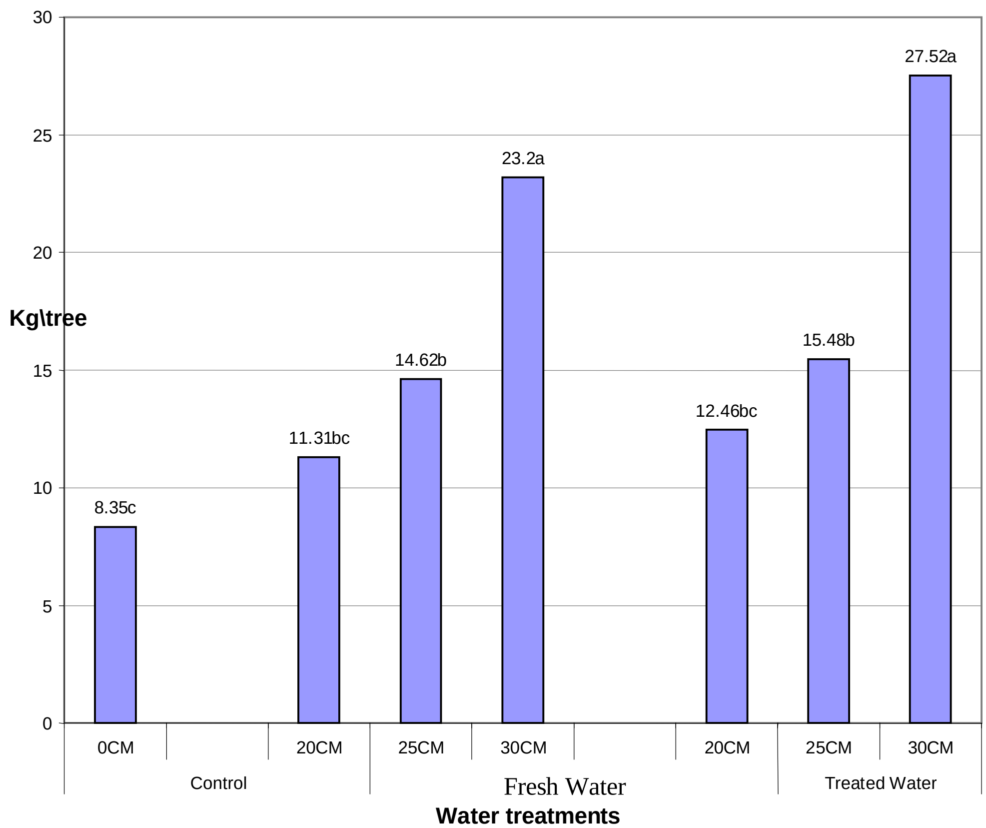

Figure 6. Olive production under different water treatn

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).

The increase in production with water use was explained by Michelakil (1998) as a result of higher numbers of fruits rather than to the increase in fruit size, in our study we did not measure the size of the fruits. Increased fruit size could he attributed to the moisture availability after the pit hardening. Both phenomena could have happened and proposed to explain the higher yield with supplementary irrigation.

3.5 Effects of difference water regime treatments on oil percent production and quality of 'Nabali' olive trees

The effect of supplementary irrigation with both fresh and treated gray wastewater on oil percent production, acidity and reflective index are show in (Figs 7, 8, 9 and 10). The oil percent was ranged from 23.44% in the control to 30.44% with the higher level obtained under 25 and 30 CM of both treated and fresh water. Higher oil production 8.38 under 30 Cm of irrigation with treated water, however, this value was not significantly differ from the same level of irrigation with fresh water, the lowest amount of oil (1.9kg/tree) was obtained from the control treatments. Olive oil content is a vital character, however, the moisture content play an important role in oil production. Our results indicated clearly the significant effect of higher water applications. Our results are in agreement with the previous work of Michelakis (1990) who found that water use levels of 0.3 Ep to 0.6 Ep for all season and 1.0 Ep till May applied to cv 'Kornoeiki' increased significantly fruit and oil yield compared to non irrigated trees. Oil yield is a result of the total number of fruit per tree and the oil contained in each fruit. It is known that the fruits per tree for a given variety vary greatly according to the climatic condition and cultivation from 6-100%, while the oil quantity per fruit varies from 5-10%. Therefore, for a high oil yield it is important to assure a satisfactory number of fruits per tree and a second line a high oil quantity per fruit (Michelatis, 1998).

An adequate water supply only during spring can insure a satisfactory fruit number. In our experiment, the application of water started in April, thus water could have increased the fruit number and therefore oil production on the other hand, and variation in oil percent obtained may be due to the natural variation range. Data presented in Figure 7 shows oil yield in different treatments.

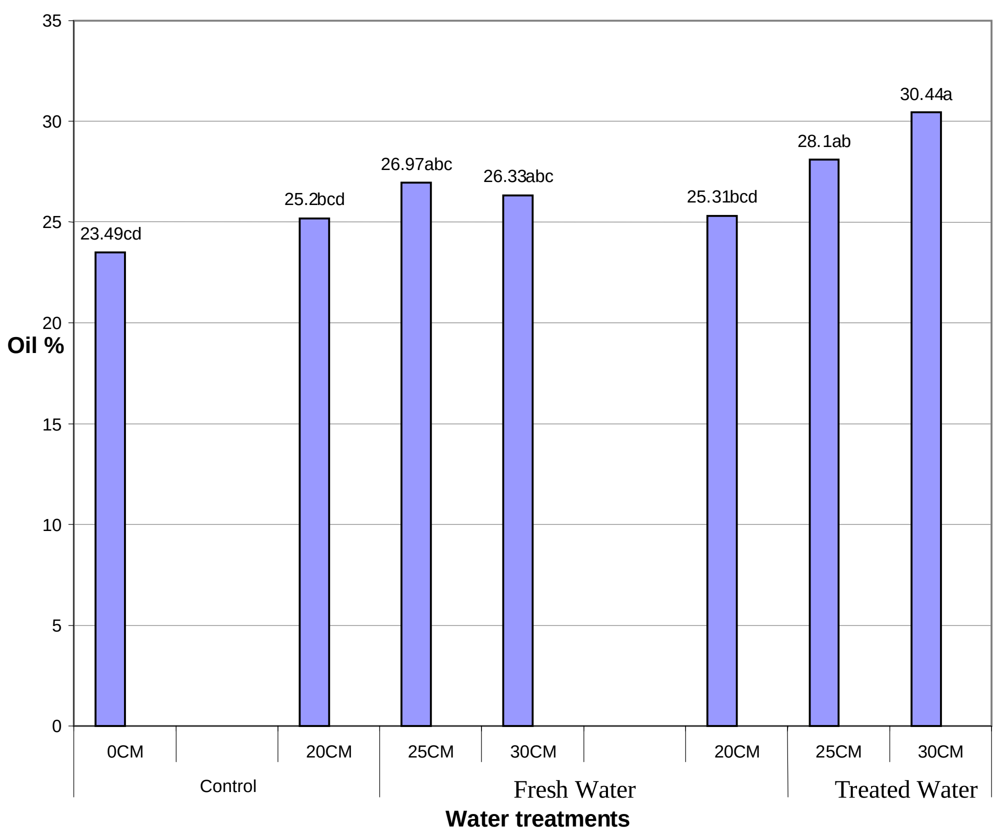

Figure 7. Olive oil percent under different water treatments

The effect of irrigating olive trees with different levels of both fresh and treated gray water on oil acidity and reflective index is shown in (Figs. 8, 9).

From Fig. 8, it is clear that higher acidity was obtained when olive trees were irrigated with 20 and 30 CM of fresh water. The level was significantly higher than other treatment, however, with 25 CM fresh water the acidity level was not significantly differs from that level under 30 CM fresh water application. Acidity under the treated wastewater used was similar to the non-irrigated treatment. Regarding the reflective index, no significant difference was detected in oil from trees subjected to the different water treatments (Fig. 8). This result is inconsistent with the finding of d'Adria 2000 who reported that the acidic composition did not show any considerable variations in relation to the irrigation level of several olive cultivars.

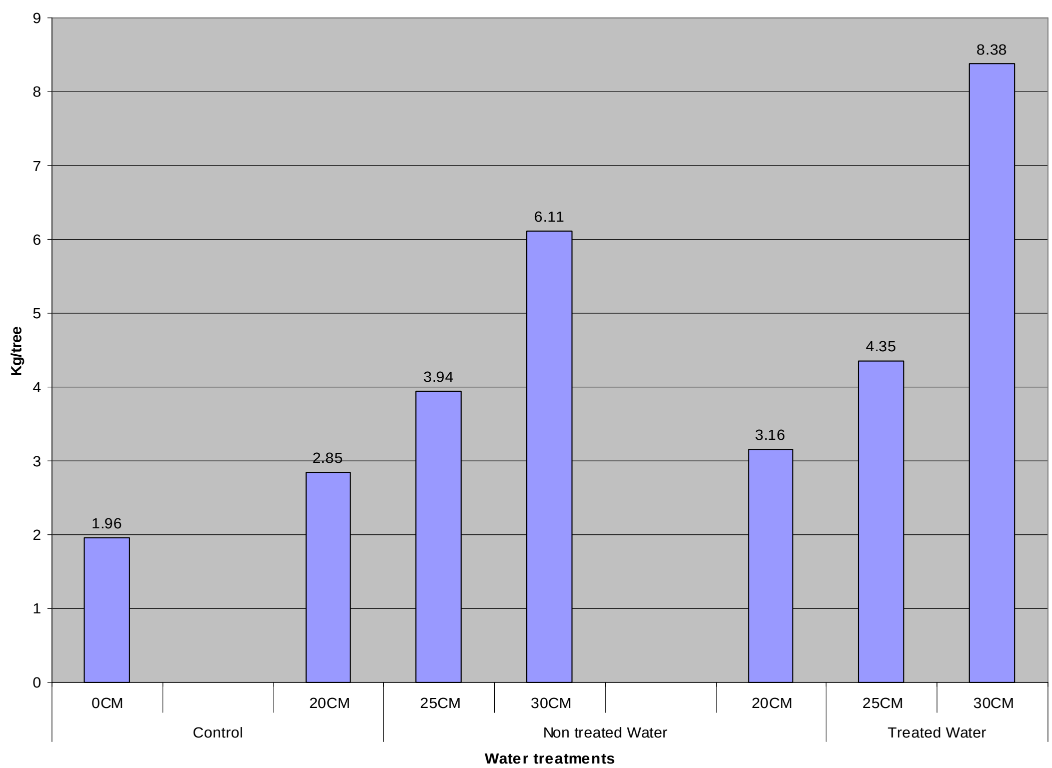

Figure 8. Oil production in kg/tree using different treatments.

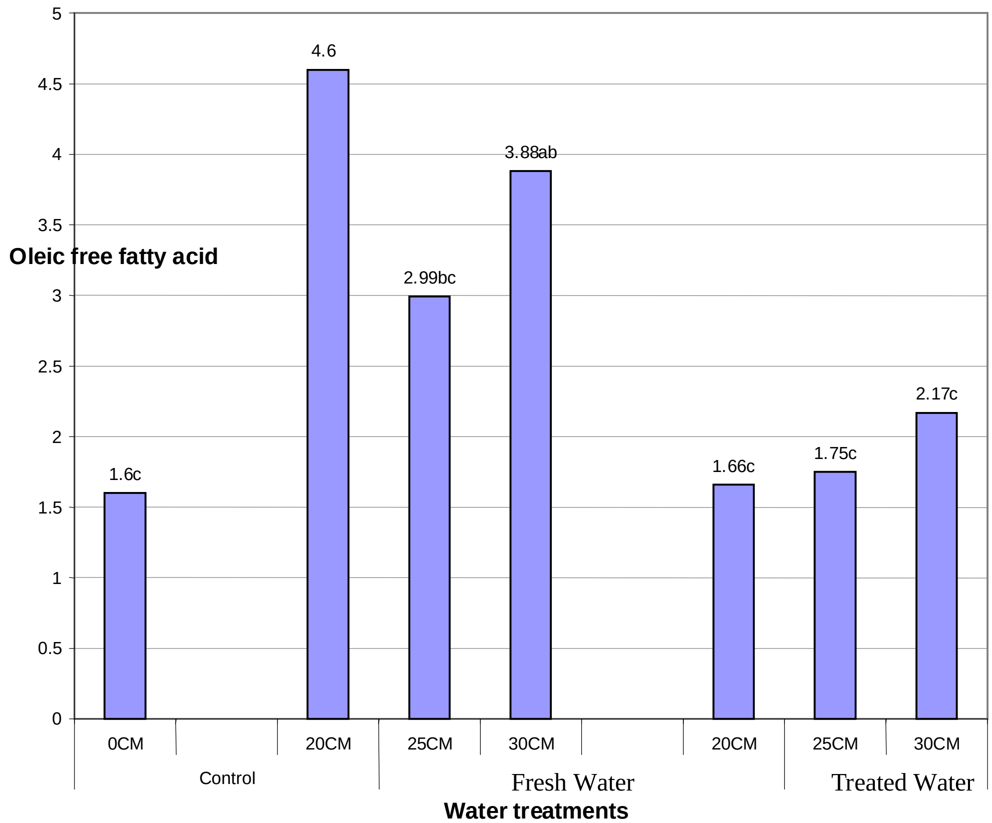

Figure 9. Acidity of olive oil under different water treatments

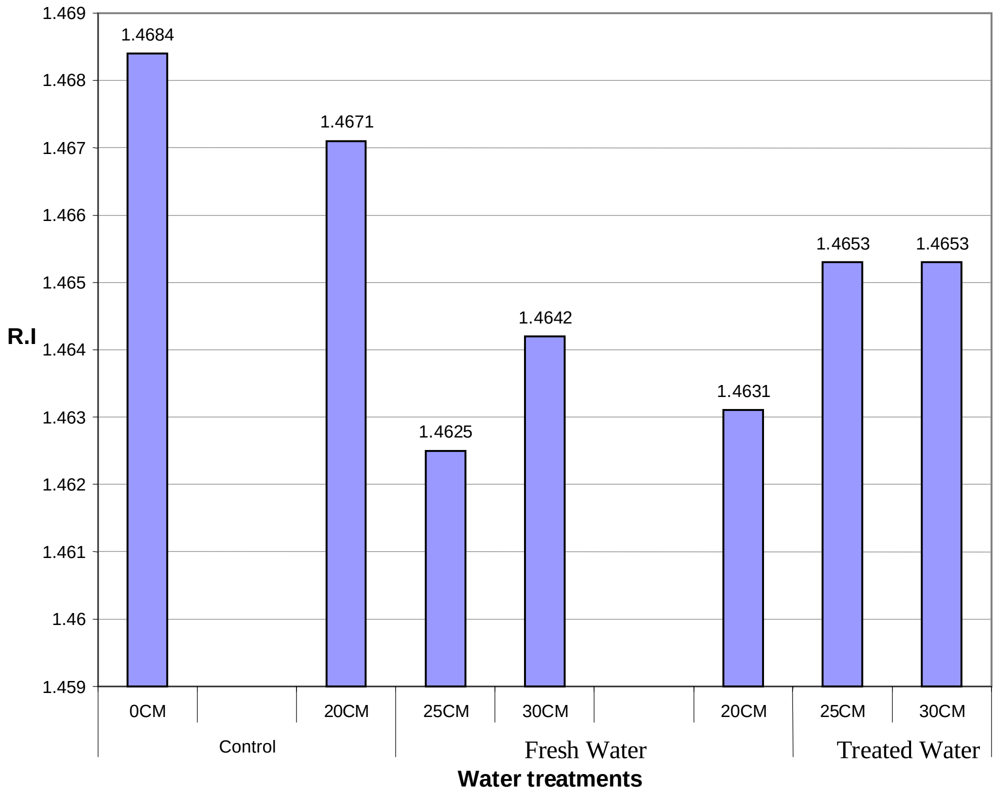

Figure 10. Reflective index of olive oil under different water treatment

Summary and conclusion

1. Gray wastewater was efficiently treated with anaerobic pond, gravel filter, sand filter and polishing pond.
2. Both fresh and treated gray water were efficient in irrigating olive trees under rain-fed condition.
3. Higher vegetative growth of both shoot number and length was obtained with high level of water used (30 CM/ tree).
4. Higher fruit production was obtained with the use of 30 CM /tree fresh and treated water.
5. Higher water level 25-30 CM/tree significantly improved oil production.
6. Oil quality parameters (acidity and reflective index) were not highly influenced by the application of water treatments.

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قدمت هذه الأطروحة استكمالا لمتطلبات درجة الماجستير في العلوم البيئية بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس، فلسطين.

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الملخص

تم دراسة تأثير مستويات مختلفة من المياه النقية والمياه الرمادية المعالجة على نمو إنتاج أشجار الزيتون النبالي والمزروع تحت الظروف المطرية ثم استخدام ثلاث مستويات من المياه النقية (20، 25، 30م^{3}/ شجرة) وكذلك نفس المستويات من المياه الرمادية المعالجة. أستخدم أيضا في التجربة أشجار بدون ري كشاهد. تم استخدام أشجار زيتون بعمر 30 سنة تم إضافة مياه الري عن طريق شبكة ري بالتنقيط، أجريت التجربة في قرية بيت دقو محافظة القدس، تم معالجة المياه الرمادية بواسطة مصفاة رمل و مصفاة حصى.

استمرت عملية الري من شهر نيسان وحتى شهر تموز وذلك أسبوعيا أظهرت النتائج أن استخدام المياه من النوعين في ري أشجار الزيتون أدت إلى زيادة معنوية ملحوظة في الإنتاج والنمو مقارنة مع الأشجار التي لم تروى. حصل أعلى نمو خضري (عدد الأغصان ومعدل طول الغصن) عند أعلى مستوى من المياه الرمادية المعالجة (30م^{3}/شجرة) كما حصل أعلى إنتاج من ثمار الزيتون عند استخدام (30م^{3} مياه) من المياه النقية والمعالجة. بخصوص نسبة الزيت، أعطت المعاملات 25 و30م^{3} من المياه من النوعين أعلى نسبة للزيت والمعاملة 30م^{3} من المياه المعالجة والقيمة اعلى كمية زيت للشجرة الواحدة. لم تتأثر نسبة الحموضة وكذلك معاملة الانكسار بصورة كبيرة في المعاملات المختلفة. أثبتت نتائج التجربة إمكانية استخدام هذا النوع من المياه الرمادية المعالجة لري أشجار الزيتون تحت ظروف التجربة.