An-Najah National University

Faculty of Graduate Studies

Reuse of Treated Wastewater to Produce Legume Grains
(case study alfalfa and vetch)

By

Ahmed Jabri Mohamed Lebdi

Supervisors

Dr. Numan Mizyed

Co- Supervisors

Dr. Hassan Abu Qaoud

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This thesis was defended successfully on 15 / 5 /2014 and approved by:

Defense Committee Members		**Signature**
1-Dr. Numan Mizyed	**(Supervisor)**	
2-Dr. Hassan Abu Qaoud	**(Co-Supervisor)**	
3- Dr. Mahmoud Rahil	**(External Examiner)**	
4- Dr. Heba Al-Fares	**(Internal Examiner)**	

Dedication

This thesis is dedicated to my father, mother, brother, sisters and my friends; for their endless love, support and encouragement

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الإقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Reuse of Treated Wastewater to Produce Legume Grains (case study alfalfa and vetch)

أقر بأن ما اشتملت عليه هذه الرسالة إنما هي انتاج جهدي الخاص، باستثناء ما تم الإشارة إليه حيثما ورد، وأن هذه الرسالة ككل، أو أي جزء منها لم يقدم لنيل أي درجة أو لقب علمي أو بحثي لدى أية مؤسسة تعليمية أو بحثية أخرى.

Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's Name: **اسم الطالب :**

Signature: **التوقيع:**

Date: **التاريخ:**

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Abstract

This study was conducted to evaluate the production of two fodder crops; common vetch (*Vicia sativa* L.), and Alfalfa (*Medicago sativa* L.) irrigated with treated wastewater. The study was implemented during summer 2012. Five water regimes were used in the experiment including: Irrigation with fresh water (control), fresh water supplied by 10 ppm N–P–K fertilizers, treated wastewater, treated wastewater supplied with 10 ppm N–P–K fertilizers, and treated wastewater supplied with 40 ppm N–P–K fertilizers. The crops were planted in 5 liters plastic pots in 4:1 v/v sandy to clay soil. The soil was analyzed before and after planting. The following plant parameters were recorded: Plant high, fresh weight, dry weight, leaves number per plant, fruit number per plant and fruit weight per plant.

The results show that using treated wastewater significantly increased production parameters; the highest production was obtained with treated wastewater supplied with 40 ppm fertilizers (plant height was 81.5 cm for vetch and 112.5 cm for alfalfa). Plant fresh weights for both vetch and alfalfa were higher in treated wastewater treatments than those of fresh water treatments. Regarding the dry weight, irrigation with TWW produced (33.83 g/plant and 44.67 g/plant) compared to 22 g/plant and

24.5 g/plant for irrigation with fresh water for vetch and alfalfa respectively.

The results of soil analysis show an increase in soil content of nitrogen, phosphorus and potassium, as well as an increase in the soil salinity and SAR values in pots irrigated by treated wastewater alone and in treated wastewater plus 10 and 40 ppm N-P-K fertilizer.

Chapter One

Introduction

1.1 Background

The global demand for water is continuously increasing, where the world population has exceeded seven billions and still growing. Not only the continuous population growth is requiring water for domestic purposes, but also the demand for food is increasing, which causes an increasing and a growing water demand for irrigation. At the same time, the quantity of water in the earth is limited where earth contains an estimated 1,351 million cubic km of water. Only 0.003 percent of this is classified as fresh water resources, that is, water that can be a source for domestic, agriculture, and industry (Winpenny et al., 2010).

The competition among different sectors over water user is increasing, and agriculture is the most vulnerable sector since it is the main consumer of water. Moreover, the scarcity of fresh water resources in many areas of the world is pushing towards utilizing new nonconventional water sources such as brackish and treated wastewater.

In Palestine, the situation of water utilization and availability is more complex, where Palestine as a part of the eastern Mediterranean is located in a semiarid region. In many arid and semi-arid countries water is becoming an increasingly scarce resource and planners are forced to consider any source of water which might be used economically and effectively to promote further development (Pescod, 1992).

Moreover the fresh water resources in Palestine are limited in both the availability and accessibility to the Palestinians due to the Israeli occupation practices on ground. With the continuous high population growth, the demand on water is growing fast by all sectors, and the competition among the different water users is clearly apparent, where the per capita share is less than 70 liters per day (The World Bank, 2009). The scarcity of water is combined with the absence of the free access to water resources, where the Palestinian are allowed to use only 15% of the available resources and the rest 85% are used by Israelis (Jayyousi and Srouji, 2009), which complicates the dilemma for the water management in Palestine.

1.2 State of the problem

In Palestine, the water scarcity is growing severely and fast due to many reasons, among them the fact that water resources are limited, and the available water resources are only the ground water resources (The World Bank, 2009; Jayyousi and Srouji, 2009), and the increasing demand for the domestic use, where currently the domestic uses are estimated to be 50 liter per capita per day (The World Bank, 2009). This is combined by a continuous growth in population.

Not only the demand on water is increasing, but the demand on food is increasing at the same time, and the level of food production does not meets the requirements in all sectors. This leads to importing food products from different sources, and at the same time prohibiting the food security. According to FAO estimates, 80 percent of the increase in food demand by the year 2030 will be met from irrigated crops (FAO, 2002).

Agriculture in Palestine as in most developing countries in the world is the main consumer for water, where it is estimated that the total available water quantities are estimated to be 291 MCM per year, among this agriculture is consuming 150 MCM, which is equivalent to 51.5% (The World Bank, 2004). Not only but moreover the irrigated area is only limited to about 8% of the agricultural area in the West Bank and 11% of the Gaza Strip (PCBS, 2007). In other studies, the irrigated area is estimated at about 247,000 dunums out of 708,000 dunums suitable for irrigation (The World Bank, 2009). This means that there is a good opportunity to expand the irrigated area if more irrigation water becomes available for agriculture.

Under the current political climate, it is not expected for the Palestinians to have new fresh water quantities for irrigation, and the only foreseen scenario is to utilize marginal water resources, as brackish water and treated wastewater (Jayyousi and Srouji, 2009).

The treated wastewater is a high important potential source for irrigation in Palestine, where it is estimated that the annual generation of raw wastewater is 106 MCM (50MCM in the West Bank, and 56 MCM in Gaza). If these quantities were treated to an accepted level and utilized in agriculture, the irrigated area could be expanded significantly (Jayyousi and Srouji, 2009).

Taking into account that the area planted with fodders is very small in Palestine forming only 4% of the cultivated area (Alhaj Hussein, 2010; Mansour, 2009), where total cultivated areas of alfalfa and vetch in Palestinian territory are 25,305 and 17,684 dunums respectively. Most of the required fodders for animal agricultural sector are imported (PCBS, 2007), which create a growing difficulties for the farmers and increase the production costs for them.

At the same time, the Palestinian agricultural laws and the technical obligatory regulations for the use of treated wastewater in irrigation prevent the use of treated wastewater to irrigate vegetables. For this, fruit trees and field crops are the only crops which can be irrigated by such source. In addition to this, and due to the high need for increased fodder production, it is more feasible to shift towards increasing the fodders production through irrigation with treated wastewater (Palestinian technical regulation (Annex 1).

This study is examining the differences of production in two fodder crops irrigated with fresh water and treated wastewater as part of the efforts trying to figure out the possibility of utilizing this new source in agriculture. It is aiming to assess the effect of using treated wastewater on the growth and production of two fodders of common vetch and alfalfa and its effect on nutrient content of plant.

1.3 The study objectives

Due to the fact that the Palestinian farmers are facing many problems in feeding their animals, and that fodder production sector is very weak, the study objectives are:

1. To assess the effects of reusing treated wastewater on the growth and production of alfalfa and vetch.

2. To study the effect of reusing treated wastewater on the crud protein content of plant.

3. To study the impact of reusing treated wastewater on chemical soil properties.

Chapter Tow

Literature Review

2.1 Importance of wastewater reuse

In arid and semiarid regions, the growth and development of plants is largely restricted by water availability (El-Sawaf, 2005). The water shortage and scarcity in these regions are pushing towards utilizing new water resources. Thus, reuse of treated wastewater for irrigating agricultural lands is on the rise particularly in rural areas of developing countries (Rattan et al., 2005). Meli (2001), indicated that the reduced availability of water resources in semi-arid Mediterranean regions requires an efficient use of water resources. Treated wastewater may constitute an important resource for irrigation in areas characterized by intensive agriculture (Meli et al., 2002).

The lack of water resources have encouraged researchers to investigate the use of non- conventional water resources including saline water, municipal and industrial waste water. By increasing population, water consumption increases wastewater production as well (Galavi, 2009). Moreover treated wastewater may be considered as a new water resource, which can be added to the general water balance of a region. This new source can substitute conventional water (potable water) used for irrigation or for other purposes that do not require water of drinking quality, while releasing some of the pressure on the conventional water resources. Treated wastewater helps to close a negative water balance in areas where all the conventional water resources are exploited to their maximum capacity (Friedler, 2001). Wastewater reuse in agriculture represents a potentially important alternative for fresh water and save it for drinking and industrial water supplies (Al-Karaki, 2011).

2.2 Wastewater Reuse in Agriculture

Agriculture is the main water consumer around the world, where the agricultural consumption is estimated to be around 70% of total water use; the range differs from 45% in developed countries to about 81% in some developing countries. The reuse of treated wastewater is important in developing countries as they are often located in arid or semi-arid areas, which they are consider home to three-quarters of the world's irrigated area and very dependent on agriculture to feed their populations and increase their income. In addition, agriculture is responsible for up to 80% of export earnings in these countries (The World Bank, 2012).

According to Abu Madi and Al – Sae'd, (2009), the alleviation of the water scarcity implies reallocation of freshwater from agricultural to domestic and industrial uses, where a reduction in agricultural water use by 15% would double the water available to households and industry in the Middle East region. This would reduce irrigated agriculture at the time many countries aim to expand it due to food security reasons. In search for additional water supplies, the regional water experts and aid agencies have recognized treated wastewater as a valuable non-conventional water resource. But at the same time and due to the high need for increasing food production, shifting from rainfed to irrigated agriculture can increase yield production. Winpenny et al. (2010), reported that converting from rainfed to irrigated agriculture can increase yields of most crops by 100 to 400% and can permit the growth of different crops with higher income value. Shifting away from rainfed agriculture often means that water must be available at unnatural times and locations. Compared to the daily drinking water requirement of 2 to 4 liters per person, producing a day's food requirement takes 2000 to 5000 liters of water per head. As a result, agriculture is by far the largest user of water, and its demand is increasing.

For this and in countries of water scarcity, it is a crucial step to reuse treated waste water, since treated wastewater (TWW) is rich of fertilizing elements required for plants in addition to the water content, and has been used for irrigation in many places of the world (FAO,1992; Tavakoli and Tabatabaee, 1997). Water reuse is implemented in many urban areas in the world to cope with this increasing water shortage. Currently, water conservation and the use of treated wastewater are being considered as strategic solutions in arid and semi-arid countries (Al-Jasser, 2011).

The precaution is needed when using this kind of water to avoid harming the agricultural soils and to prevent consumer health risks (Al-Karaki, 2011). This is confirmed by Alberta Environment (2000) where it says not all treated municipal wastewater meets a quality that would enable unrestricted use for irrigation. Treated municipal wastewater has been found to contain salt or sodium at levels that would completely exclude consideration of its use for irrigation due to the harmful effects it would cause to the land and the crops grown.

2.3 Benefits and Risks of Wastewater Reuse in Agriculture

Wastewater may contain many pollutants: salts, metals, metalloids, pathogens, residual drugs, organic compounds, endocrine disruptor compounds, and active residues of personal care products. Any of these components can harm human health and the environment. Farmers can suffer harmful health effects from the contact with wastewater, while consumers are at risk from eating vegetables and cereals irrigated with wastewater. Application of wastewater has to be carefully managed for effective use (Qadir et al., 2007).

To avoid health and environmental risks, wastewater needs to be treated to acceptable levels. When it is submitted to adequate recycling systems, then treated effluents are being reused for different purposes without presenting any risk for human health. In these cases, reuse conditions are met and recycled water is considered an important alternative resource for sustainable development and food production. Other social and economic benefits may result from such schemes such as employment and products for export markets. It is, however, essential that the development of reuse prevents negative effects on environment and public health since wastewater content in mineral and organic trace substances and pathogens represents a risk for human health. Adequate treatment has therefore to be provided for the intended reuse. Wastewater can have positive agronomic results. Moreover, wastewater reuse schemes, when properly planned and managed, can have positive environmental and health impact, besides providing increased agricultural yields. However, reuse of treated wastewater may also have adverse effects on the environment and public health (Kamizoulis et al., 2003).

The treatment of raw wastewater is an environmental requirement, to reduce the hazard coming from its content (Qadir et al., 2007; Kamizoulis et al., 2003; Mekala, 2009). Abu Madi and Al – Sae'd (2009), stated that the untreated wastewater contains disease causing organisms which reside in the tract of human intestine. Nutrients which cause eutrophication problems due to the excessive growth of aquatic plants and algae and toxic compounds.

As wastewater treated to an acceptable level it could be used in different sectors. This implies meeting the requirements of each user. But the cost of treatment increases as the required quality increases. However Agriculture remains the main field for reusing Treated wastewater (Mekala, 2009).

Treated wastewater content of nutrient elements can be used as nutritional elements for plants, as well as fertilizers for the plants and also it will result in water saving. Application of wastewater irrigation increases soil nutrient elements and thus increases soil fertility. The convenient access of plants to high concentration of nutrients will result in increment the growth and biomass of plants. Wastewater application as plant irrigation should be done based on proper management and consistent control, but wastewater needs to be treated to an accepted level (Gholamali et al., 2011).

Babayan et al. (2011), indicated that the use of treated wastewater in irrigation has been reported in many studies, showing positive impacts on crop productivity due to the nutrients and organic matter. A forage crop that has been irrigated with treated wastewater for two years caused increasing of barley biomass production. Also irrigation with treated wastewater in all the growth stages caused the most biological yield of corn to be achieved.

Balkhair et al. (2013), reported positive effects for mixed water (40% treated wastewater, 60% fresh water). This positive effect is coming from the increase in the nutrients of the soil under wastewater irrigation, which improved the physical and nutrient contents of the soil. Hence significantly increased the total chlorophyll and carotene and established good growth and increased biomass and yield of the crop. Yi et al. (2011), found that no significant differences were observed between the control of fresh water irrigation and the treatments of treated wastewater irrigation on the quality of vitamin c, protein and dissolved sugar in short-term irrigation. For micronutrients, there were no significant differences for Na, Mg, K, Ca and Zn contents in cabbage in short-term irrigation.

Lady finger (*Abelmoschus esculentus L.*) was able to meet its nutrient requirements from treated wastewater and established good growth showing no signs of toxicity at any stage of growth. The wastewater also increased the organic matter, N, available P and exchangeable nutrient contents in soil enhancing the growth of plants (Thapliyal, 2011).

In an economic study of treated wastewater in irrigation of field crops in Saudi Arabia, Balkhair et al., (2013) stated that, up to 45% in fertilizers cost for wheat crop and 94% for alfalfa crop were saved compared to irrigation with well water. This is due to the fact that treated wastewater contains the essential elements needed by such crops. They also indicated that the usage of treated sewage water in irrigating of wheat and alfalfa crops increased their yield by 11 and 23%, respectively, and consequently increasing the profit by 14 and 28%, respectively as compared to irrigation with well water.

Moreover, it is reported that the primary-treated wastewater increased the yield of all vegetables crops, the increase have been statistically significant in most cases. On the other hand, the positive responses of using wastewater in irrigation of lettuce crop, especially under the sub-surface irrigation system were observed in Saudi Arabia (Balkhair et al., 2013).

Corn yield and whole plant dry matter of corn increased by irrigation with treated wastewater as compared to irrigation with well water, they attributed this increase to the enhancement of nutrient uptake and improvement of the physical properties of the soil (Babayan et al., 2011).

Another study on sorghum irrigated by treated wastewater showed that plant height, ear length, ear weight and grain yield increased with N and P application and this increased grain yield of sorghum and reduced cell wall and cell wall without hemi cellulose. Harati (2003), during a study of wastewater effects on corn, concluded that macro (N, P and K) and micro elements in the wastewater improve growth and yield of maize.

Harati et al. (2011), analyzed sewage coming from Tehran city and they found that effluent contains 2 to 7% nitrogen and 1 to 5% phosphorus, which is equivalent to 2 to 10% phosphorus fertilizer as P2O5. Both nitrate and ammonia in the sewage water are absorbable by plants and they affect plant growth. While sewages are poor in respect to potassium, small amounts of this element are available in sewages. Therefore, application of chemical fertilizers containing potassium is necessary, especially for corn and potato. Other researchers found that meadows irrigated with wastewater received N and P in amounts equivalent or superior to the recommended dose of fertilizers for meadows. With ray grass an improvement of nitrogen concentration of tissue of plants grown in sewage sludge amended soils (Babayan et al., 2011).

Singh et al. (2012), found that application of sewage water increased the yield of rabi crops compared to irrigation with well water; it also increased total N, P, K and organic carbon content of soil. Also, the test weight of seeds of rabi crops like wheat, gram, palak, methi and berseem was significantly higher in sewage treatment and was in the range of 1.40 in to 16.70 grams whereas in well water irrigation it ranged from 1.23 to 16.23 grams.

TWW can be used for the irrigation of a variety of field crops. It can be applied to trees like olives as well to cereal or forage crops. Khaskhoussy et al. (2013), conducted a research to compare the effects of irrigation with wastewater and pump water on wheat and concluded that wastewater irrigation produced taller plants, heavier seeds and higher grain yields than pump water. On the other hand, the wastewater irrigation treatments increase the availability of phosphorus and microelements as well as N, K, Ca, Mg, Na, Fe, Mn, Zn, Cu, to plants and lead to the increase of cauliflower and red cabbage yields.

Moreover, the use of treated effluent was found to increase the quality of fodders, this was reported by many studies. Al Ajmi et al. (2009), indicated that barely irrigated with various levels of treated sewage effluent may be used for feeding livestock without adverse effects on health or performance. It offers good use of treated sewage effluent to increase farmer's benefits. Proximate chemical analyses indicated that barely fodder may probably be superior in some aspects to commercial Rhodes grass hay used mainly as a source of roughage for livestock in the Gulf region. Taha et al. (2002), found that irrigation with Treated Secondary Effluent resulted in relatively taller sorghum plants; plants looked vigorous and healthy, with less fiber content, high protein values and significantly higher dry yields compared to those irrigated by normal water.

Pereira et al. (2011), found that raw wastewater (RWW) positively influences citrus nutrition by rendering the concentration of macro nutrients, i.e. P, Ca, and K closer to their optimum levels. Moreover, RWW irrigation acidified soil by 0.4–0.7 pH units and increased soil sodicity (SAR) and salinity (EC) about 2-3 times.

Another study reported that there is no limitation about wastewater application for irrigation of woody trees, like pine, spruce and oak and we can irrigate them easily and safely by wastewater. Ability of plants to absorb and accumulate heavy metals from soil and water is different and it depends on plant species and type of elements. Legume and grass plants have less ability to accumulate cadmium in their leaves when compared with leafy vegetables like spinach and lettuce. On the other hand, tomato has high ability to accumulate cadmium when compared with barley, bean, carrot and cabbage (Harati et al., 2011).

Babayan et al. (2011), concluded that macro (N, P and K) and micro elements in the wastewater improve growth and yield of maize, while accumulation of heavy metals such as cadmium and lead in corn was more than the standard limits and critical step for animal feeding. They stated that a weekly application of 25 mm of wastewater was enough to supply 40-80% of the corn N requirements and all P needed.

However, treated wastewaters can still be used for irrigation under controlled conditions which minimize hazard from pathogenic and toxic contaminants to agricultural products, soils, surface, and groundwater. At the same time the possibility of bioaccumulation of hazardous chemicals such as heavy metals which vary from crop to crop in plant parts and soil needs to be looked into (Thapliyal et al., 2011).

In spite of the benefits of using wastewater in crop production, the production is faced by some risks from heavy metal accumulation and microbial pollution. The main risk associated with wastewater irrigation is infection with intestinal helminthes (Balkhair et al., 2013). Moreover, improper management of wastewater irrigation may provide the crops with nutrients beyond their specific requirement and subsequently accumulate them at undesirable high levels in the crop. This would lead to reduction in the yield and its quality. Therefore, management of irrigation with wastewater should consider the nutrient content in relation to the specific crop requirements and the rate of application of wastewater should be adjusted accordingly (Babayan et al., 2011).

In addition, there is a concern about the contamination and bioaccumulation of potentially toxic elements such as Cd, Cu, Fe, Mn, Pb, and Zn from both domestic and industrial sources by vegetables (Thapliyal et al., 2011). Moreover, inhibition of root growth, shoot development and various metabolic processes in plants have been reported because of higher concentrations of heavy metals in soils which further resulted in chlorisis, damage to root tips, reduced water and nutrient uptake and damage to enzyme system (Zeid et al., 2013).

Nutritional elements in wastewater result in higher yields of crops. Transmitted heavy metals to the soil are function of the clay, organic matter, and cation exchange capacity. Hence plants as first cycle of food chain have considerable influence on living organisms, so influent agent of metal pollutants to food chain should be considered more than another food levels. In lands under wastewater irrigation in various countries, with heavy metal concentration in the assembly plant, average cadmium concentration was equivalent to 0.07, chrome 0.16, lead 0.43 and zinc 39.2 milligrams per kilogram in brown rice (Gholamali et al., 2011).

Not only the content of nutrients, mainly as N, P, and K but also the oversupply with nitrogen may result in excessive vegetative growth and reduced fruit set for crops, or delays in maturation. Nitrate (NO3-) is the most mobile form of nitrogen in the soil. Being poorly bond to soil particles, it leaches freely and is the most commonly reported pollutant in drinking water around the world (Yi et al., 2011).

Gholami et al. (2011), found that heavy metal accumulation in plants has multiple direct and indirect effects on plant growth and alters many physiological functions by forming complexes with O, N and S ligands. They interfere with mineral uptake, protein metabolism, membrane functioning, water relations and seed germination.

From an economic viewpoint, wastewater irrigation of crops under proper agronomic and water management practices may provide the following benefits: (1) higher yields, (2) additional water for irrigation, and (3) value of fertilizer saved. Alternatively, if plant food nutrients delivered through wastewater irrigation result in nutrient over supply, yields may negatively be affected (Hussain et al., 2002).

Hussain et al. (2002), evaluated the effect of crop selection on cost and revenue streams and system efficiency by selecting three cropping patterns viz. reed canary grass, alfalfa, corn and forest plantations. Their analysis suggests that, as reed canary grass allows year round use of wastewater, it is a more efficient and economical system. Alfalfa and corn become more cost-effective than reed canary grass if wastewater can be used for longer durations.

2.4 Wastewater Effluent in Palestine

In Palestine, it is estimated that sanitary services are serving only one third of the population in the West Bank, where only (35.5%) have access to a waste water network, while almost two-thirds (63.5%) rely on porous and tight cesspits for waste water disposal. 1% has other (or no) means for waste water disposal (Van der Molen et al., 2011; the World Bank, 2009;

Jayyousi and Srouji, 2009). A much more alarming picture provides by Van der Molen et al. (2011), when states that between 50 and 80 million liters of untreated or partially treated sewage discharged into the environment daily. They indicates that waste water quantities (approximately 106 MCM per year) are almost equally spread between the West Bank (50 MCM) and Gaza (56 MCM). At present, 4 treatment plants have been established and functioning by the Palestinian Authorities, of which 3 in Gaza Strip and one in Al Bireh in the West Bank (Nablus West started functioning during the last quarter of 2013). Treatment capacities are relatively small (35 MCM per year from the ones in Gaza; 2 MCM per year in the West Bank).

About 90% of the sewage produced in the Governorates is discharged untreated in the environment. The number of sites where the collected wastewater is discharged into the environment is around 363 sites. From those sites, untreated wastewater effluent is running directly from the cesspits or terminal sewage network collectors into numerous wadis (PWA, 2006).

Per capita water consumption in the West Bank is low (less than 70 l/c/d) due to the lack of adequate and regular water supply. Therefore, the generated domestic wastewater (separate sewer system) is concentrated and its strength is high (The World Bank, 2009).

In most West Bank localities, light industries are prevailing, which means that heavy metal contamination is not probable. Table 2.1 gives the characteristics of wastewater of some cities and rural areas in the West Bank. Wastewater is of high organic strength, hence, the treatment process might be complicated and therefore costly in order to reach an effluent that is safe to discharge in the wadis or reuse in agriculture (Zimmo et al., 2005). In this study the raw effluent was analyzed and presented

Table 2.1: Characteristics of raw municipal and rural domestic wastewater in the West Bank.

	Municipal Urban Wastewater				**Rural domestic Wastewater**	
Parameter	Ramallah	Nablus	Hebron	Al - Beireh	Grey	Black
BOD_5	525	1185	1008	522	286	282
COD	1390	2115	2886	1044	630	560
Kj – N	79	120	278	73	17	360
NH_4 – N	51	104	113	27	10	-
NO_3 – N	0.6	1.7	0.3	-	1	-
SO_4	132	137	267	-	53	36
PO_4	13.1	7.5	20	44	16	34
Cl^-	350	-	1155	1099	200	-
TSS	1290	-	1188	554	-	-
All data in mg/L ; - = No data were given						

Source Zimmo et al., 2005.

Moreover the chloride concentration was highlighted in Zimmo et al. (2005), where they reported that another important parameter is the chloride concentration in wastewater. Since chloride ions are dissolved in the wastewater, the conventional treatment processes do not remove chlorides. Thus, if treated wastewater is to be used in agriculture, then salt-tolerant crops should be considered.

The commonly used type of treatment for wastewater in Gaza Strip and West Bank is the biological treatment, although the system used varies from one plant to another. The most common systems are formed of aerated lagoons, stabilization ponds, trickling filters and activated sludge. The efficiency of Gaza Strip plants is higher than for the West Bank, as it approaches 70% in Beit Lahia, while it is only 15% in Tulkarm plant. However the Jenin plant is not operating (PCBS, 2000).

Recently new treatment plants are either under construction (in Tubas and Jericho) or have been constructed and expected to start functioning soon (in Nablus and Jenin). These new plants are expected to produce around 30 MCM of treated effluent within the coming 5 years. Taking into account that the area planted with fodders is very small in Palestine forming only 4% of the cultivated area, where most of the required fodders for animal agricultural sector are imported (Alhaj Hussein, 2010; Mansour, 2009), and the Palestinians are importing more than 95% of their animals need of fodders, the expansion of fodders planting become high priority to be irrigated with treated wastewater.

2.5 Treated Wastewater Reuse in Palestine Territories

2.5.1. Gaza Strip

A good demonstration example for the Palestinian practice of treated wastewater reuse in agricultural production was in 2003 through a French program called strategy of agricultural water management in the Middle East. Two areas were chosen for the implementation of this project in the Palestinian Territories: Gaza Strip and Al Bathan Al Farah valley in the West Bank (Mogheir et al., 2005).

Two areas in the Gaza Strip were selected: 1. Beit Lahia area where treated wastewater coming from the Beit Lahia WWTP was used to irrigate alfalfa plants and 2**.** CAMP area (Coastal Aquifer Management Programme) where TWW from the Gaza city WWTP was used to irrigate existing citrus farms of 20 dunums in area (Mogheir et al., 2005).

Mogheir et al. (2005), indicted that an initial attempt of vegetables production had been done in a greenhouse inside the Northern WWTP but it was later abandoned due to the resistance of the consumers. The production of flowers (carnation) was initially considered but the Ministry of Agriculture decided not to use wastewater for this production because of the hypothetic risks on export.

2.5.2. The West Bank

Al-Bireh reuse demonstration project conducted the different aspects of reclaimed water use in irrigation by developing a set of different effluent polishing and irrigation techniques on crops. The primary goals of the project were to build the initial institutional relationships, raise the profile of wastewater reuse and compost use, and to develop the first stage of on the ground experience and capacity in the field of wastewater reuse (Mogheir et al., 2005).

The treatment system in Al Bireh WWTP is extended aeration with mechanical solids handling. The plant was designed to treat 5750 m^3/day with an overall retention time of 20 days (the present total inflow is 3200 m^3/day).

Mogheir et al. (2005), reported that Ornamental crops like roses, flowers, bougainvillea and hedgerows were selected by Al-Bireh reuse demonstration project for site beautification. On an area of 5 dunums, 2 to 4 year old orchard trees were planted, including different varieties of olives, date palms, stone fruits, citrus, cherries, mango, avocado, guava, pomegranate, figs and grapes. On an area of 3 dunums, different trees including nut trees, pistachio, walnut, pecan, macadema, pinenuts, asacia, pines and carob were irrigated by treated wastewater. A parcel of 0.7 dunum was planted with sweet corn. Nitrogen application through the reclaimed wastewater was 7 kg/dunum. A nursery of 600 m^2 for annual cultivation of 80,000 seedlings of indigenous trees and cooked vegetables was installed.

Mogheir et al. (2005), indicated that two different types of effluent were identified for reuse; high effluent quality and very high quality effluent applied on many different types of agricultural crops and trees. Table 2.2 summarizes the adopted regulations, applications and achievements of Al-Bireh WWTP reclaimed water use

Table 2.2: Summary of Al-Bireh WWTP reclaimed water use achievements

Effluent Type	**Regulation**	**Application**	**Achievements**
High quality	BOD/TSS<20/30 mg/l F.C[*]<1,000 MPN/100 ml	Orchard, olives, Ornamentals Grape stocks Processed vegetables Restricted area landscaping	High growth High yield
Very high quality	F.C[*] non-detectable Effluent polishing[**]	Cooked vegetables Nursery (eggplants)	High yield No contamination

[*] F.C: Fecal Coliform [**] Gravel media filtration and chlorination used.

Source: Mogheir et al., (2005).

The test results show that the tertiary treatment generates reclaimed water suitable for unrestricted agriculture reuse application. Crop quality tests showed that eggplants irrigated with reclaimed water were not contaminated with fecal coliform and intestinal viruses. In the nursery, seedling germination rates were high (>90%) and seedlings irrigated with the reclaimed water showed high vegetative growth (Mogheir et al., 2005).

2.6 Local experience of reusing treated wastewater

Abu Nada (2009), conducted a field experiment to study the impacts of treated wastewater irrigation on soil and crop properties in the northern Gaza strip, where wastewater effluent was used for alfalfa irrigation.

Results revealed that Beit Lahia Wastewater Treatment Plant (BLWWTP) effluent is suitable to be used for irrigation as its quality matches the local and international standards for wastewater irrigation except Na, Cl and Pb. Long term wastewater irrigation increased salt, organic matter and plant nutrients in both soil layers but soil pH was not consistently affected. Pb was the dominant heavy metal in wastewater. Although Pb level was in the acceptable range for soil, it was noticed that Pb has higher levels in alfalfa compared with other metals. Alfalfa yield irrigated with wastewater was higher than alfalfa yield irrigated by fresh water in the first year.

Nassar et al. (2009), has investigated the socio-economical aspects of reuse in the Gaza Strip. The study was conducted by using field investigations and questionnaire analysis.

The field investigations is concerned about the potential lands for reuse and models to identify the quality of irrigated water in two agricultural areas in the Gaza Strip. In Biet Hanoun (North Gaza), 68% of farmers agreed to use the treated wastewater for irrigation purposes, in the Southern area, 91% of farmers accepted direct wastewater reuse schemes.

The educational level, standard living, and the environment played a remarkable role in convincing the farmers about the feasibility of using treated wastewater. The study indicated an economical improvement for farmers switching from groundwater to effluent irrigation.

Abu Madi et al. (2008), studied the perceptions of Deir Debwan farmers and the public towards wastewater reuse for agricultural irrigation (treated effluent of Al-Bireh Wastewater Treatment Plant WWTP). The results of that study (Abu Madi et., 2008) showed that the participants had good knowledge about the general water crisis. 93% were aware of the water crisis in Palestine, and 90% were aware of water crisis in their village. Interestingly, 73% agreed that there are negative impacts for using untreated wastewater in irrigation, and 24% knew that there are negative impacts from using treated wastewater. Further, only 40% knew that there are special standards for wastewater reuse and 42% did not know if there should be special standards for wastewater reuse. However, the situation was opposite concerning untreated wastewater with only 6% were willing to use it and 10% were willing to consume products irrigated with it.

Health was the main concern followed by environmental and economic concerns for not accepting the reuse of wastewater.

Idais (2013) conducted a field experiment to investigate the impact of using treated wastewater for irrigation on soil chemical properties and crop productivity in Gaza Strip. A comparison was carried out between the soil properties in two experimental plots; one was irrigated with the effluent from Gaza Wastewater Treatment Plant while the other was irrigated with fresh water and the crop used was sorghum. The results indicated that the level of TDS, Na, Cl, TSS, Zn and Fe were higher in the effluent than the fresh water; it was above the recommended Palestinian standard for dry fodder irrigated by treated wastewater. Also, irrigation with wastewater leads to significant increase in O.M, CEC, K, TP, Ca, Mg, Na, and Cl in soil than irrigation with fresh water. In addition, the increases of Zn, Fe, Mn, and Pb in soil and sorghum plant irrigated with treated wastewater were significant in comparison with the plants irrigated with fresh water. Further, treated wastewater increased the plants height, and grain weight of sorghum.

Isaed et al. (2008), investigated farmers and consumers awareness for treated wastewater use, the acceptance of farmers to use and buy reclaimed wastewater, the acceptance of the public to use and pay for crops watered with reclaimed water, and the factors that affect the attitudes of farmers and consumers in Dura (Hebron, Palestine) Municipality and the surrounding villages.

The basic conclusion emerging is that there is low social acceptance for the usage of treated water but it needs to be supported. The factors effecting farmers decision to use and to pay treated water are age, marital status, education, average monthly income, land ownership, area of land planted and irrigated, and the type of water used for irrigation. Consumers, on the other hand, in their decision to use and to pay treated water are affected by gender, and marital status.

It was found that 60% of consumers were negatively positioned towards consuming fruits irrigated with restricted water, while 39% of the consumers were willing to pay for fruits and vegetable irrigated with treated wastewater. The majority of consumers who accepted to pay voted for willingness to pay almost half the price of fruits and vegetables irrigated with fresh water.

Abu Shaban et al. (2006), studied the determinants of farmers acceptance of treated wastewater in irrigated agriculture. The study was based on data from a random sample from 94 farmers in Biet Hanoun city in the northern Gaza Strip and surrounding areas. Methods comprised family surveys using standardized questionnaire and informal interviews with key persons.

The results showed that farmers' knowledge on potential impacts and side effects of using treated wastewater in agriculture is likely to be the major determinant for the success of the process of change. Improving farmers knowledge may thus be a challenge of equal or even larger importance than finding solutions for compensating owners of private wells for the abandonment of freshwater withdrawal from the Gaza Strip's aquifers.

Othman (2004), studied the use of treated gray water for irrigation of rain-fed olives. The study was concerned on the effect of different water regimes with different quality on the growth and production of "Nabali" olive cultivars. Thirty years old olive "Nabali" trees were irrigated with two types of water (fresh water and wastewater) and three levels of water (20, 25, 30 m3/tree/year). Each level was applied to a tree. Irrigation was applied by drip laterals. Both higher level (25, 30 CM) of water treatment significantly increased olive oil content compared to that obtained in the control. A higher vegetative growth (shoot number and length) was obtained with higher water level (30m3/tree). The results of this study indicated that this kind of treated wastewater is suitable for application to olive orchards.

Afifi & Tubail (1998), conducted a field experiment to study the impact of treated wastewater reuse in agriculture on soil and plants. The study conducted in a greenhouse with three different types of water (100%, 50%, 0 % treated wastewater) and three different crops were used in the study (eggplant, tomato, and pepper).

The results showed a positive effect of using treated wastewater as fertilizer for the main three nutrient elements (N, P and K). Also fecal coliform (FC) and parasite in the eatable parts of different crops, increased with increasing the percentage of treated wastewater. The soil samples analysis before and after the study indicated limited changes in soil chemistry, however, the biological contamination of fecal coliform in top soil level was higher than in deeper soil level and increased with increasing the percentage of treated wastewater.

2.7 Regulations and Standards for Treated Wastewater

2.7.1. Palestinian Standards

In Palestine the national Authority was established in 1994, thus, Palestine did not have any specific wastewater regulations, references were usually made to the WHO recommendations or to the neighbored country's standards (ex. Egypt, Jordan). The first draft of the Palestinian standard principles mainly envisage; a) Sanitary, b) Environmental and c) Agro technical quality requirements. a) Sanitary requirements centered upon the pathogens potentially present in wastewater, namely bacteria and intestinal nematodes (Ascaris and Trichuris species and hookworms). Where it is recommended that less than 1 intestinal nematode per liter and 200 to 1000 fecal coliforms per 100 ml of wastewater depending on the reuse conditions, b) From the environmental viewpoint concentration of various heavy metals (particularly cadmium, copper, zinc), salt, nutrients (N and P) and malodors were taken into consideration, c) Agro-technical requirements include: total salt and several anions (Cl, SO4, HCO3), cations (Ca, Mg, Na) and boron concentrations which determine traditional irrigation water quality standards depending on the plant species, soil physical and chemical properties, climate and irrigation methods (Medware,2005).

Most of the reuse projects in the Gaza Strip and West Bank are using treated wastewater for irrigation according to WHO and FAO guidelines. The WHO guidelines are strict in respect to the requirements to keep the number of eggs (ascaris and hookworms) in effluent below one egg per liter whether the effluent is used for restricted or unrestricted irrigation using surface and sprinkler irrigation. This is not applicable in case of restricted irrigation where exposure of workers and public does not occur (Medware, 2005).

The main features of WHO guidelines for wastewater reuse in agriculture are:

1. Wastewater is considered as a resource to be used safely.

2. The aim of the guidelines is to protect against excess infection in exposed.

populations (consumers, farm workers, populations living near irrigated fields).

3. Fecal coliforms and intestinal nematode eggs are used as pathogen indicators.

4. Measures comprising good reuse management practice are proposed alongside wastewater quality and treatment goals; restrictions on crops to be irrigated with wastewater; selection of irrigation methods providing increased health protection, and observation of good personal hygiene including the use of protective clothing (WHO, 1989).

Table 2.3: Classification of treated wastewater according to the quality.

Category	Reuse Condition	Exposed group	Intestinal nematode (arithmetic mean no. eggs per liter)	Fecal coliforms (geometric mean no. per 00 ml)	Wastewater treatment expected to achieve the required microbiological guideline
A	Irrigation of crops likely to be eaten uncooked. Sports fields, public parked	Worker, consum, public	≤1	≤1000	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, fodder crops, pasture and trees	Workers	≤1	No standard recommended	Retention in stabilization ponds for 8-10 days or equivalent treatment
C	Localized irrigation of crops in category B if exposure to worker and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by irrigation technology, but not less than primary sedimentation

(Source WHO, 1989).

As it is a crucial step to setup the Palestinian standards for the reuse of treated effluent, The Palestinian Standards Institute released the first standards for the reuse of treated effluent in 2003. These standards were prepared in cooperation between the Governmental institutes, the universities and the local experts (Yaqoub, 2004). These standards are focusing on BOD, TSS and FC. The standards classify treated effluent into 4 categories : A – D, where class A is the highest quality (20 – 30 mg/l BOD – TSS , FC< 200/100ml), class B (20 – 30 mg/l BOD – TSS, FC< 1000/ 100ml), class C (40 – 50 mg/l BOD – TSS, FC<1000 /100ml) and class D is the lowest quality (60 – 90 mg/l BOD – TSS , FC< 1000/100m) . In addition to that, these standards set numbers of barriers for each group of crops and at the same time they set the minimum space when using sprinklers in irrigation (Alhaj Hussein, 2013).

However in 2009, the Ministry of Agriculture issued “Obligatory Technical, Regulations: For the Reuse of Treated Wastewater in Irrigation” signed by the minister of Agriculture and PSI has started a working group upon the request of ministry of agriculture to prepare a new technical regulations. This technical regulation was declared in 2012 after approval of the cabinet of ministers. These new regulations are obligatory (annex 1), in these regulations not only BOD and TSS were considered, but many other parameters also, like total Nitrogen, Phosphorus, in addition to other parameters. Table 2.4 shows part of the regulations. In addition and based on these regulations the efforts now are to upgrade the Palestinian standards, where it is under preparation (Alhaj Hussein, 2013).

Table 2.4: The new obligatory technical regulation in Palestine.

Maximum level of parameters in mg/L unless other units are mentioned	Water Quality			
	High quality (A)	**Good quality (B)**	**Medium quality (C)**	**Low quality (D)**
BOD_5	20	20	40	60
TSS	30	30	50	90
FC	200	1000	1000	1000
COD	50	50	100	150
DO	1<	1<	1<	1<
TDS	1200	1500	1500	1500
pH	6-9	6-9	6-9	6-9
Fat, Oil & Grease	5	5	5	5
Phenol	0.002	0.002	0.002	0.002
MPAS	15	15	15	25
$NO_3 – N$	20	20	30	40
$NH_4 – N$	5	5	10	15
Total – N	30	30	45	60
Cl^-	400	400	400	400

Source the technical regulation (MOA) 2012.

2.8 Vetch and Alfalfa

Common vetch (Vicia sativa L.), and Alfalfa (Medicago sativa L.) are both legumes that are widely known and planted around the world, vetch is a common forage legume in rainfed and semiarid systems of the Mediterranean region. In Mediterranean region, mixtures of certain annual legumes with winter cereals are used extensively for forage production (Anil et al., 1998; Qamar et al., 1999; and Paoastylianou, 2004).

Common vetch (Vicia sativa L.) is the most important legume used for fresh and dry fodder production in Turkey. It has an important role in crop rotation before sowing of wheat. Cereals are also important contributors to animal feeding in Turkey, both as grain and forage. Cereals grown in this region are capable of high yields owing to many years of plant breeding and optimization of cultural practices (Tuna and Orak, 2007).

In forage-animal production system, legumes are preferred owing to several advantages over monocultures (Haynes, 1980). In general, legumes are rich in protein while grasses are rich in carbohydrates. Cereals constitute forages relatively low in protein (Robinson, 1969), and animals usually require some form of relatively costly protein concentrate supplementation (Anil et al., 1998). Forage crops constitute the major component of dairy feeds (Mustafa et al., 2000).

Hall and Kephart (1991), found that when environmental conditions limit production of perennial forage crops, annual species can be effectively used.

Vetch was known as an important legume fodder where vetch is the most important annual legume grown in Oregon. The national research council reported a comparison between different fodders in their value for animal feeding (Table 2.5).

Table 2.5: The comparison between vetch, clover, and alfalfa

O. A. C. Experiment station Bulletin 213 Analysis of Willmette valley hays							
	Number of analyses	Water %	Ash %	Crude Protein %	Ether extract %	Crude fiber %	Nitrogen free extract %
Alfalfa	9	7.92	6.91	12.55	1.09	30.90	40.63
Clover, Red	19	8.03	6.08	10.23	1.51	26.55	47.60
Clover, alsike	8	8.21	6.9	9.28	1.26	30.62	43.73
Vetch	35	8.36	6. 10	13.26	0.97	25.80	45.51

Source (NRC, 1989).

In many researches, it was found that vetch is usually planted mixed with other cereals (Tuna, and Orak, 2007). Sattell et al. (1998), reported that it also grows well in mixtures with cereal grains that can provide both cool – weather weed suppression and fall N scavenging. Common vetch has been used successfully as a cover crop in vineyards and orchards. Lauriault and Kirksey, (2004) confirmed that warm-season and cool-season annual grasses are also used as hay, silage, and green chop in dairy rations. These forages, however, do not provide quality equal to that of alfalfa and must be supplemented with protein. They also reported that legumes forage crops as vetch and alfalfa are poor in energy, while cereals crops are poor in protein. On the contrary to this, Anne(2001) found that alfalfa is rich in energy and contain energy enough to feed horses. Alfalfa hay is an excellent source of energy, protein, calcium and some other nutrients for horses. Its concentrations of protein and calcium meet the nutrient needs of horses in high levels of production, such as growth and lactation, but exceed the nutrient requirements of horses in other life stages.

Figure1. Common vetch plants.

Figure 2. Alfalfa plants.

However both crops are well known to be planted here in Palestine and used as fodders (usually dry fodders) for animal feeding. The agricultural statistics show that both crops are planted (PCBS, 2007), but at the same time these statistics are showing that the forage crops planting in Palestine is very limited and the production is very weak, where the animal raising farmers are almost importing all of the fodders they use for feeding their animals.

Delgado et al. (2001), reported that alfalfa had a relatively high water demand because of the long production season and frequent harvesting. In the Ebro Valley and central Spain, where the average precipitation is about 400 mm/year, irrigation was required to obtain high forage yields. The water consumption by alfalfa in the Ebro Valley was about 11,000 m3/ha , and the water supplied by irrigation is between 600 and 1000 mm per season.

2.8.1. Effect of Fertilizer on Alfalfa and Vetch:

2.8.1.1 Growth and Growth Components:

Effect of Nitrogen:

Nitrogen is required by plants in comparatively larger amounts than other elements. Nitrogen deficiency generally results in stunted growth and chlorotic leaves caused by poor assimilate formation that leads to premature flowering and shortening of the growth cycle. The presence of N in excess promotes development of the above ground organs with abundant dark green (high chlorophyll) tissues of soft consistency and relatively poor root growth. This increases the risk of lodging and reduces the plants resistance to harsh climatic conditions and to foliar diseases (Tarang et al., 2013).

Delgado et al. (2001), indicated increase of dry matter yield (18.7%) in whole plant due to N fertilization but no differences were observed in shooting after cutting.

Yolcu (2011), concluded that application of 68-70 kg N ha^{-1} plus 20 ton ha^{-1} solid cattle manure and 51-52 L. ha N plus 10000L/ha liquid cattle manure may be used to obtain high quality forages. While chemical fertilizer applications (CF = 30 kg N h^{-1} + 80-100 kg P_2O_5 ha^{-1}) had significant effect on dry hay yield, leaf weight, stem weight, CP, and mineral contents of vetch plants.

Vasileva (2013), reported that Lucerne is nitrogen–fixing crop and the potential for nitrogen fixation via symbiosis is in average 450 kg h^{-1} $year^{-1}$. Up to 216 kg N h^{-1} might be fixed in Lucerne. Many authors confirmed the need for nitrogen fertilization in this crop. Dry mass yield increased with the increase doses of mineral nitrogen fertilization in the cuts, harvested later.

Effect of Phosphorus:

Singh and Singh (1977), reported that application of phosphorus significantly

affected the dry matter yield except during first cutting. The application of 320 kg and 160 kg P_2O_5 ha^{-1} were during second and fourth cuttings. However, during the third cutting, application of 320 kg P_2O_5 ha^{-1} was significantly superior to treatment with 160 kg P_2O_5 ha^{-1}, in improving the dry matter yield of berseem.

Application of 90 kg P_2O_5 ha^{-1} to lucerne recorded highest plant height and dry matter accumulation as compared to control (Shah et al., 1991), while application of 80 kg P_2O_5 ha^{-1} increased dry matter yield of berseem significantly over control and 40 kg P_2O_5 ha^{-1} during both the years. The mean percent increase in 80 kg P_2O_5 ha^{-1} over control and 40 kg P_2O_5 ha^{-1} was 19.32 and 47.14 in dry matter yield (Rana et al., 1992).

Solanki and Patel (1999), reported that application of 120 kg P_2O_5 ha^{-1} significantly increased the plant height of lucerne over 60 kg P_2O_5 ha^{-1}.

Effect of Potassium:

Grewal and Williams (2003), observed that K application at 60, 80 and 100 kg K ha^{-1} significantly improved the leaf to stem ratio of lucerne. Further, they found that the adequate rate of K to obtain 90 percent of maximum leaf to stem ratio was 42 kg K ha^{-1}.

Berg et al. (2005), reported that potassium fertilizer application did not influence plant population. They also noticed that shoots per plant was not affected by application of nutrient, while shoots m^{-2} generally declined with increased K application.

2.8.1.2 Green Forage Yield

Effect of Nitrogen:

Dineshkumar (2007), reported that application of nitrogen to berseem crop could not influence forage yield. In an acidic soil when lucerne was supplied with 50, 100 and 150 kg N ha^{-1} the crop recorded hay yields of 10.6, 10.7 and 11.46 t ha^{-1}, respectively.

Khalak and Munegowda (1990), reported that application of 20 t of FYM, 75 kg N (or *Rhizobium* inoculation of seeds), 100 kg P_2O_5 and 50 kg K2O ha^{-1} at the time of sowing gave maximum green forage yields.

Tarang et al. (2013), found that the highest grain yield, biological yield, grain weight, number of grains per ear, number of grains per row, and harvest index were obtained by 450 kg/ha nitrogen fertilizer consumption in corn.

Effect of Phosphorus:

Dineshkumar (2007), reported that in lucerne, phosphorus application had consistent positive yield responses. Application of 30 kg P_2O_5 ha-1 and 60 kg P_2O_5 ha^{-1} resulted in an increase in the yield to the extent of 33.93 and

42.37 percent respectively, over unfertilized control. However, the additional yield due to the application of 60 kg P_2O_5 ha^{-1} over 30 kg P_2O_5 ha^{-1} was found to be not significant.

Sürmen et al. (2011), reported that Phosphorus fertilizer increased forage yield and quality of common vetch. While P fertilization increased N and P contents and decreased K content of some vetch species.

The application of phosphorus at the rate of 100 and 200 kg P_2O_5 ha^{-1} increased the yield by 48 and 56 percent respectively, over no phosphorus when lucerne was grown on soil having a low amount of available phosphorus (0.19 mg/100 g soil) and pH 8.2 (Dineshkumar, 2007).

Mahale et al. (2004), revealed that application of 150 kg P_2O_5 ha^{-1} recorded significantly higher green and dry fodder yield over all other levels (0, 50, 100 and 150 kg P_2O_5 ha^{-1}) during all seasons.

Dineshkumar (2007), reported that the optimum level of phosphorus for berseem was 173 kg P_2O_5 ha^{-1}. Application of 150 kg P_2O_5 ha^{-1} gave 19 percent higher yield of green fodder over that at 75 kg P_2O_5 ha^{-1}, while 225 kg P_2O_5 ha^{-1} gave only marginal increase in the yield over 150 kg P_2O_5 ha^{-1}.

The green fodder yield was significantly increased by the application of phosphorus up to 80 kg P_2O_5 ha^{-1} only. The increase in green fodder yield due to 80 kg P_2O_5 ha^{-1} over no phosphorus and 40 kg P_2O_5 ha^{-1} was 42.3 and 20 percent, respectively. This improvement in the yield by the application of 80 kg P_2O_5 ha^{-1} was attributed to improved growth, fresh and dry matter, and better plant population which was achieved by better root development and high microbial activity that led to adequate supply of nutrients (Dineshkumar 2007).

Berg (2005), reported that application of 0, 25, 50 and 100 kg P ha^{-1} to Lucerne as triple superphosphate, which was surface broadcasted and an annual fertilizer application of 50 kg P ha^{-1} in first year followed by 100 kg P ha^{-1} in each subsequent year showed that phosphorus fertilizer application increased lucerne forage production during four years of study with a total accumulated effect of 228 kg dry matter kg^{-1} of P. The highest productivity was recorded in the first two years with the initial rate of 100 kg P ha^{-1}.

A comparison of phosphorus levels indicated that the application of 320 kg P_2O_5 ha-^{1} gave the highest green fodder yield and it was superior over the rest of the phosphorus levels (20, 40, 80 and 160 kg P_2O_5 ha^{-1}), except during second and fourth cuttings where it was on part with 160 kg P_2O_5 ha^{-1}. (Dineshkumar 2007).

On a loamy soil application of 50 kg P_2O_5 ha^{-1} to four *Medicago sativa* cultivars produced average yields of 33.5 t fresh fodder and 7.95 ton dry matter ha^{-1} compared with 30.1 ton fresh matter and 7.12 ton dry matter ha^{-1} without phosphorus. Yields were not further increased with 100 kg P_2O_5 ha^{-1} (Dineshkumar 2007).

Effect of Potassium:

Dineshkumar (2007), reported that the green fodder yield was significantly higher by 11.4 percent (294.8 q ha^{-1}) due to K application (50 kg P_2O_5 ha^{-1}) in *rabi* season compared to control (264.7 q ha^{-1}). This may be due to increased plant height by K nutrition.

Grewal and Williams (2003), reported that total herbage yield of lucerne increased significantly with K application. The adequate rate of K supply producing 90 percent total herbage yield was 100 kg K ha^{-1}.

2.8.1.3 Forage quality

Effect of Nitrogen:

The effect of increasing doses of mineral nitrogen fertilization (40, 80, 120 and 160 mg N kg^{-1} soil) on chemical composition of lucerne (*Medicago sativa* L.) at the stage of budding was studied in pot trial by (Vasileva, 2013). They concluded that with increasing doses of mineral nitrogen fertilization (40, 80, 120 and 160 mg N kg^{-1} soil), crude protein content in dry aboveground mass increased from 13 to 19% under the conditions of optimum moisture (75–80% of Field Capacity) and decreased from 6 to 14% under water deficiency stress(37–40% of Field Capacity).

In a field trial *Medicago sativa* was subjected to the following treatments: no fertilizer, 50 kg N ha^{-1}, 120 kg N ha^{-1} and 20 kg N ha^{-1}+ *Rhizobium* inoculation. Crude protein content was in ranges 17.10, 16.77, 16.36 and

15.99 %, respectively according to treatments (no fertilizer, 50 kg N ha^{-1}, 120 kg N ha^{-1} and 20 kg N ha^{-1}+ *Rhizobium* inoculation (Dineshkumar, 2007).

Alfalfa meadow was supplied with 0 and 50 kg N ha^{-1}. Nitrogen application found to increase the crude protein content and decrease in crude fibre content of alfalfa (Dineshkumar, 2007).

Vasileva (2013), found that protein content in dry root mass of *Medicago sativa* L. under optimum moisture (75–80% of Field Capacity) varied between 133.5 and 151.3 g kg^{-1} DM.

Delgado et al. (2001), noticed that increase of crude protein content (11.3 %) in whole plant was observed due to N fertilization.

Vasileva (2013), reported that supply of Lucerne plants with nitrogen is important and their data indirectly confirm the opinion of other authors, that lucerne used soil and fertilizer nitrogen despite nitrogen fixing ability.

Effect of Phosphorus:

Sürmen et al, (2011) reported that Phosphorus fertilization affects dry matter yield and chemical composition of vetch.

Dineshkumar (2007), reported that the nitrogen percentage in lucerne hay was not affected significantly by phosphorus fertilization. Also he reported that the phosphorus application in general did not affect the crude protein content of the lucerne forage.

Surmen et al. (2011), concluded that the highest DMY of common vetch was obtained from 90 kg P ha^{-1} fertilization doses. Concentration of N and P increased while increasing P fertilization rates.

Dineshkumar (2007), reported that the crude protein content of berseem forage showed highly significant difference as a result of phosphorus fertilization at all the three levels of phosphorus (40, 80, 160 kg P_2O_5 ha^{-1}). Phosphorus fertilizer consistently increased the protein content. The value was maximum at the highest level of phosphorus (160 kg P_2O_5 ha^{-1}) and minimum at the lowest level (40 kg P_2O_5 ha^{-1}) with a difference of 2.7%.

Surmen et al, (2011) concluded that at the end of the 2-year research, 90 kg ha^{-1} phosphorus fertilizer and harvesting at the beginning of flowering stage could be recommended for high herbage quality of common vetch growing at similar soils and environments of Turkey.

The application of 80 kg P_2O_5 ha^{-1} showed higher ash content of cowpea forage, and ash content was reduced when the phosphorus level was either raised to 120 kg P_2O_5 ha^{-1} or reduced to 40 kg P_2O_5 ha^{-1}. But the ash content was significantly increased with phosphorus application to Lucerne. Increased crude protein (CP) yield with increase in P levels, wherein P was applied at 0-120 kg P_2O_5 ha^{-1}. (Dineshkumar, 2007).

Zhu et al. (2011), found that Application of P fertilizer significantly affected the dry matter yield of hairy vetch in the low fertility red soil. When compared with no P treatment, as the P application rate increased from 135 to 315 kg P_2O_5 ha^{-1}, the dry matter yield increased by 39.66 to 56.54%.

Zhu et al. (2011), reported that the maximum fresh yield of hairy vetch was 22992 kg ha^{-1}, at a P application rate of 152.85 kg ha^{-1}. Also Application of P fertilizer significantly affected the total P uptake in hairy vetch but P application can promote P absorption by hairy vetch, while too much of it will inhibit P absorption.

Dineshkumar (2007), reported that application of 0, 7.5 or 15 t FYM ha^{-1} and 10-100 kg P_2O_5 ha^{-1} as single super phosphate to berseem increased N and P contents of fodder with increasing rates of P and FYM application. P and FYM individually or together increased the crude protein, fat and fibre contents of fodder Phosphorus application recorded significantly increased forage yield but did not increase the quality in lucerne as observed by (Wang et al., 1996).

Delgado et al. (2001), reported that initial DM of alfalfa increased with the addition of P, although latter applications did not affect the DM yields. Soil P contents increased with the application of P. In soils with low P contents, a 27% DM yield increase occurred from 54 t/ha to 69 t/ha, with the application of 40 kg/ha of P.

Effect of Potassium:

Shukla et al. (2003), noticed that application of 0, 49.8 and 99.6 kg K ha^{-1} to lucerne under irrigation increased crude protein yield significantly up to 49.8 kg K ha^{-1}, beyond this level there was no significant increase.

Higher responses to K were reported by Delgado et al. (2001), in irrigated eastern Mediterranean conditions. In this area yields were raised from 15.2 t/ha with 0 K to 20.9 t/ha DM with applications of 316 kg/ha of K in a soil with initial K values of about 180 mg/kg of K.

Dineshkumar (2007), reported that application of fertilizer K would increase yield, crude protein and K contents of alfalfa.

Chapter Three

Materials and Methods

3.1 Methodology

Prior to the experiment, three workshops were conducted in Nablus area: Ramein, Ar-Rameh, and Sabastia, for the farmers who will use treated wastewater in irrigation. These workshops included questionnaire seeking to assess their knowledge and willingness to use this water in irrigation. The questionnaire included fifty farmers in the three villages.

The experiment was implemented in July 2012 and harvested in November 2012, close to the treatment plant in Atteil town north of Tulkarum city. The two crops seeds were planted in plastic pots filled by 5 kg of soil with 4:1 v/v sandy to clay soil.

The seeds of the plants were of local varieties coming from the local market (similar to the source available for the farmers), and the crops were planted as seeds directly in the pots at 4cm depth and covered well by soil. Fertilizers were added in concentrations of 10 ppm of 13-13-13 NPK fertilizer in both fresh and treated wastewater tanks and in concentrations of 40 ppm/l NPK as full fertilizer programs in treated wastewater tanks only.

The experiment was carried out in completely randomized block design experiment with five treatments each replicated six times. Each of the plant species was subjected to the following treatments:

T1: (blank; control), irrigation with fresh water, no mineral fertilization

T2: irrigation with fresh water, partial mineral fertilization (10 ppm N-P-K)

T3: irrigation with treated wastewater, no mineral fertilization,

T4: irrigation with treated wastewater, and partial mineral fertilization (10 ppm N-P-K),

T5: irrigation with treated wastewater and complete mineral fertilization (40 ppm N-P-K).

The treated wastewater was obtained from Attil treatment plant. The plant is composed of settling tank followed by anaerobic up flow gravel filter, and then a trickling filter and aerobic filter and finally the clarifier and the storage tank. While the freshwater was obtained from neighboring ground water well which used in irrigating vegetables in fields near the plant. The wastewater effluent conveyed from Attil plant by pipes to the experiment site which was about 250m from the plant.

Irrigation with treated and fresh water started with the planting. The irrigation schedule was selected to be four days irrigation interval schedule. Drip irrigation system was applied in the field.

The crop water requirements were estimated based on the calculation of the reference evapotranspiration (ET_o) from the climatic data using the modified Penman – Montieth formula (Allen et al., 1998). Then the reference evapotranspiration was used to calculate the crop water requirements during the different growth stages using CROPWAT software.

The climatic data were obtained from monthly averages measured in Tulkarm meteorological department for the area, and the long term averages (40 years averages) were used in the calculations. The reference evapotranspiration was calculated from the climatic data of Tulkarm, which were obtained from the Meteorological Department in Tulkarm, these data were monthly data as shown in Table 3.1. The climatic data were processed through FAO – modified Penman Montieth formula to calculate reference evapotranspiration.

Table 3.1: Climatic data and calculated ET.

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Radiation	ETo
	°C	°C	%	km/day	Hours	$MJ/m^2/day$	mm/day
July	23.4	31.5	61	75	9.7	24.3	5.16
August	24.3	31.9	63	73	8.9	22.1	4.81
September	22.9	30.5	61	67	8.3	19.2	4.03
October	20.2	28.8	57	63	7.6	15.5	3.09
November	14.7	23.9	56	76	6.7	12	2.21
December	11.8	19.6	60	68	5.3	9.6	1.55
Average	16.8	25.3	60	76	7.6	17.5	3.34

The table above shows that maximum evapotranspiration occurs in July with an average of 5.16 mm/day (figure3), thus the maximum crop water requirements are in the period May – September. The crop water requirements were calculated by introducing the crop coefficients for no stress case to insure providing the crops with full requirements and to avoid any reduction in growth or production due to water stress.

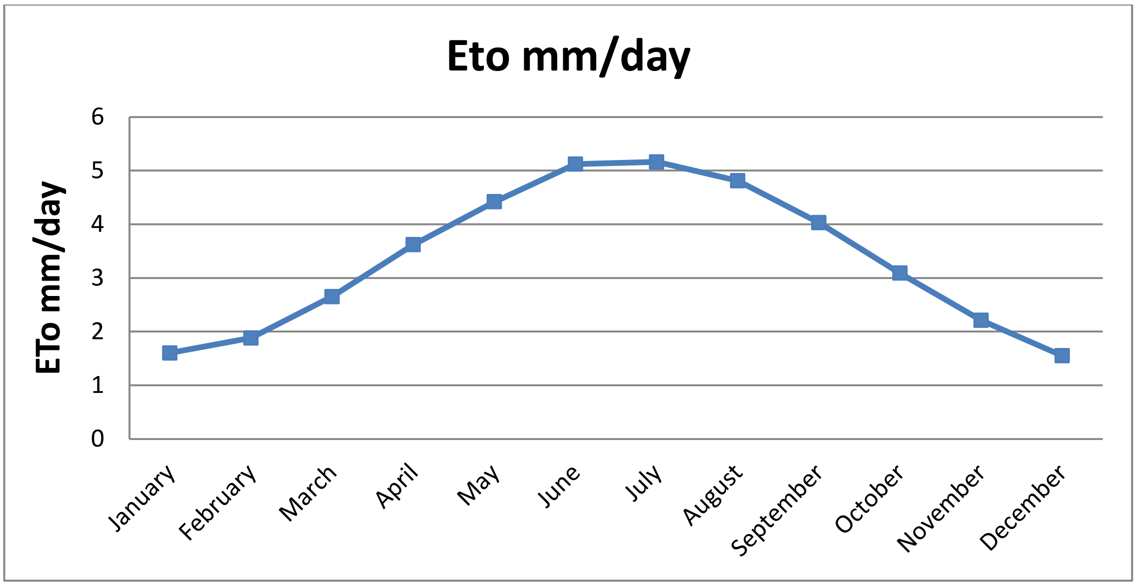

Figure 3. Reference evapotranspiration in Tulkarm area.

The Vetch and alfalfa water requirements are shown in table 3.2. Where the results show that vetch requirements are higher during the growth of the crops, Vetch requirements are 503.8 mm as a total while alfalfa requires 419.7 mm. These requirements were calculated taking the global values of Kc for alfalfa as published in Allen et al (1998).

Table 3.2: Crop water requirements and Kc valuesfor vetch and alfalfa.

		Irrigation requirements		Kc values for alfalfa	Kc values for vetch
		Alfalfa	Vetch		
Month	Decade				
		mm/dec			
Jul	1	20.6	20.6	0.40	0.40
Jul	2	21.5	21.8	0.41	0.42
Jul	3	28.6	31.4	0.55	0.60
Aug	1	30.9	35.7	0.64	0.74
Aug	2	35.2	42.1	0.73	0.87
Aug	3	42	51.5	0.87	1.07
Sep	1	37.5	46.3	0.93	1.14
Sep	2	35.2	43.5	0.87	1.08
Sep	3	32.5	40.1	0.80	1.00
Oct	1	29.7	36.7	0.96	1.20
Oct	2	27	33.4	0.87	1.08
Oct	3	26.9	33.2	0.87	1.07
Nov	1	21.6	27	0.97	1.20
Nov	2	18.8	23.8	0.85	1.07
Nov	3	11.7	16.7	0.52	0.75

These quantities of water are the plant water requirements; it didn't include the leaching fraction or the irrigation system efficiency, this is due to the fact that the experiment is implemented for short period and there is a need to measure the impact on soil and monitoring the salt accumulation in the soil.

As suggested by many studies (Yolcu 2011; Taha 2002; Delgado 2001; Al Ajmi 2009; and others) fertilization rate were ranging from 10 – 80 ppm with N – P – K; however they indicated that 5 kg N per dunum is recommended.

Taking in consideration that fertilizers are added through irrigation (fertigation) and that total water quantity through growing period was 419 for alfalfa and 503 for vetch then the fertilizer concentration is equivalent to 11 ppm for alfalfa and 9 ppm for vetch.

The soil was analyzed before and after the end of the experiment to examine the effect of treated wastewater on the soil. Treated wastewater and fresh water used for irrigation was collected in polythene bottles from the study area. Similarly, soil samples were also collected in paper bags from each pot before and after the end of the experiment. The irrigation water and soil samples were analyzed at the environmental laboratory of An-Najah National University.

The Plant growth was monitored at final growth stage (maturity stage after seed filing period). The selected crops were subjected to the following monitoring parameters: Plant high at maturity stage, fresh and dry weight, leaves number per plant, seeds number and seeds weight per plant.

Chapter Four

Results and Discussion

4.1. Opinion Questionnaire

Three workshops were held in Nablus area for farmers of Ar – Rameh , Ramein, and Sabastia, which are highly potential areas for the reuse. Fifty farmers participated in the workshops that included an opinion questionnaire for the farmers evaluate the public acceptance for the reuse of treated wastewater.

The questionnaire, revealed that 46% of participants have a high school education level, where 36% of them have elementary school level and 18% have collage education level. Fifty four percent of participants' have more than 10 years agricultural experience, 32% with an average of 5-10 years experience in agriculture and 14% have less than 5 years experience in agriculture. Agricultural contribution to household income ranged from 55-63% of total income.

In this questionnaire, it was noticed that the water supply for farming is absent in these villages, more over these villages are lacking the sanitary services and treatment plants.

In the questionnaire 46% of the farmers answered that they are familiar with the technical regulations of treated wastewater reuse, while the rest of the farmers don't know these regulations. At the same time 78% of the farmers agree that it is possible to produce crops irrigated with treated wastewater and be safe for human consumption, while 22% rejected this. However, the 78% confirmed that this is only for some crops and not for all crops. The interesting result is that 74% of the farmers agree to use the treated wastewater in irrigation under some conditions, while 26% of them agree to use it without conditions.

Regarding the question about crops favored by the farmers, it was found that the majority of the farmers (38%) are tending to use TWW to irrigate fodders, 31% suggest using it in irrigation of cotton while 17% select fruit trees to be irrigated by TWW. Only 7% agree to use TWW as supplement irrigation to irrigate olive orchards. At the same time 7% agree to irrigate vegetables if the quality of water is high.

The farmers are showing high awareness for the irrigation, where 86% of them will use drip irrigation and only 14% may use sprinklers. While they expressed high awareness for harvesting technique and post harvest practices, where 76% of them will use mechanical harvesting while 24% tend to use manual harvesting with protective cloves and in case of mechanical harvesting, all farmers are ready to clean up the machine used in harvesting crops irrigated with treated wastewater before it use in harvesting other crops.

Regarding the fears of the farmers for using TWW in irrigation, 41% of the farmers were concerned about the health prospective and 34% of the farmers were concerned for the personal and family safety, while 25% were worrying about the marketing problems.

All of the farmers showed the willingness to pay only the pumping costs but not the water price.

The farmers are showing high tendency for using sludge that resulting from wastewater treatment plants as fertilizers for crops, where 56% of them agree to use it for all crops, 14% show that it could not be used safely and 30% of them agree to use it for some crops like fruit trees, ornamental trees, sorghum, millet, cotton, citrus and almonds.

In the questionnaire, 18% of farmers are familiar with the technical regulations of the reuse of sludge in agriculture, while the rest of the farmers (82%) don't know these regulations. There are many concerns for using sludge as fertilizer regarding the crops type, where 42% care about health problems, 18% show technology fears, 32% were concerned for environmental problems and 8% worry about religious concerns.

All of the farmers showed the willingness to use sludge in their land in a dry form only and tend to pay only the transportation costs to the farm; in addition they are willing to establish a water user association.

These results are showing that the farmers are willing to reuse this type of irrigation water for their crops, and they are aware of the problems combined with the reuse of this type of marginal water. But as mentioned earlier, these villages are suffering from the water shortage, and the farmers need any source of water, hence it might be the reason for them to agree on using treated wastewater water in irrigation.

However this questionnaire is primary and tending to figure the farmers acceptance for the reuse of treated waste water, therefore it is highly important to conduct more intensive research about the potential opportunities of using these types of marginal water and the farmers and social acceptance.

4.2. Chemical Characteristics of Water Used for Irrigation

Analysis of treated wastewater shows clearly that this water is classified as class D treated effluents according to the Palestinian obligatory technical regulations, as shown in table 4.1. Where BOD_5 is 156, TDS is 1200, TN is 85. These values are even far from the tabulated values in the regulations.

Table 4.1: The results of water samples analysis.

Parameter	**TWW**	**Fresh Water**
PH	7.45	7.21
EC (ds/m)	1.65	0.56
BOD5 (mg/l)	156	……..
COD (mg/l)	237	…….
TDS (mg/l)	1200	560
Cl (mg/l)	278	115
TN (mg/l)	85	8
TP (mg/l)	0.6	0.09
TK (mg/l)	41	7
Ca (mg/l)	54.4	14
Mg (mg/l)	100	43
Na (mg/l)	117	57
SAR	2.17	1.69
TFC (CFU/100ml)	20	…….

These Results show that SAR is 2.17 this indicates that SAR has no expected negative impact on the soil in the future; also salinity is expected to cause negative impacts as indicated by (Abu Nada, 2009). Where the other cations existing in the TWW such as Ca^{2+} and Mg^{2+} are going to balance the negative effect of sodium ions.

4.3 Nutrients Content of Water Used in Irrigation

As established in the Materials and methods, the water quantities supplied to the crops were 419 mm and 503 mm for alfalfa and vetch respectively. The nitrogen concentration in treated wastewater was (85 ppm), while phosphorus was (0.6 ppm) and K (41 ppm). The nitrogen, phosphorus and potassium supplied to the crops via fertilizers were in concentrations of 10 ppm partial mineral fertilization program and in concentration of 40 ppm for complete mineral fertilization program. Total N-P-K applied through TWW and fresh water with fertilizers to crops are shown in table 4.2.

Table 4.2: Total N-P-K supplied through irrigation (kg/dunum).

Nutrient concentration	Crop type	Fresh water + 10 ppm fertilizer	TWW	TWW+ 40 ppm fertilizer
N	alfalfa	4.2	35.6	52.3
	vetch	5	42.7	62.8
P	alfalfa	4.2	0.25	17
	vetch	5	0.3	20.4
K	alfalfa	4.2	17	33.7
	vetch	5	20.6	40.7

These results show that the treated wastewater supply the crops with enough nutritional elements quantities, these concentrations are nearly double of what was suggested by Delgado et al. (2001), who concluded that alfalfa fertilized with 150 and 200 kg N/ha increased the total plant DMY and CP percentages by 18.7% and 11.3%, respectively.

4.4 Plant Parameters

4.4.1 Plant Height

1. Vetch

The results of plant height show that treated wastewater with fertilizers 40 ppm has the highest plant height in vetch, where the average plant height was 81.5 cm / plant compared to 42.8 cm/plant for fresh water. In the results there are significant differences at 95 % confidence level (α= 0.05) as shown in table (4.3).

Table 4.3: T – Test of vetch plant height (cm/plant) at (α= 0.05) for vetch

		Vetch
	Treatment	**Mean**
1	TWW + fertilizer 40 ppm N-P-K	81.5 a
2	TWW + fertilizer 10 ppm N-P-k	75.5b
3	TWW	68.5 c
4	fresh water + fertilizer 10 ppm N-P-k	51.167 d
5	Control (fresh water only)	42.83 e

Numbers followed by the same letter (s) are not significantly differing at 0.05 levels according to LSD test.

2. Alfalfa

The results of plant height show that treated wastewater with fertilizers 40 ppm has the highest plant height in alfalfa, where the average plant height was 112.5 cm/plant in alfalfa compared to 59.3 cm/plant in alfalfa irrigated with fresh water as shown in table (4.4). In these results there are significant differences at 95 % confidence level (α= 0.05) as shown in table (4.4).

Table 4.4: T – Test of alfalfa plant height (cm/plant) at (α= 0.05)

		Alfalfa
	Treatment	**Mean**
1	TWW + fertilizer 40 ppm	112.5 a
2	TWW + fertilizer 10 ppm N-P-k	106.17 b
3	TWW	99.33 c
4	fresh water + fertilizer 10 ppm N-P-k	66.17 d
5	Control (fresh water only)	59.33 e

These results agree with the results of (Gholamali Akbari, 2011; Mekala Gayathri Devi, 2009) where treated wastewater contain nutrient element that satisfy the plants needs and enhance the growth parameters.

In addition to this, the plants irrigated with treated wastewater without any fertilizers significantly have larger plant height than those plants irrigated with fresh water supplied with fertilizers in both crops; this means that without any additional mineral fertilizers the production could be increased. This is due to the nutrient content of the treated wastewater that met the plants requirements during the different growth stages as indicated by (Gholamali Akbari, 2011; Babayan et al., 2011).

The result of this study was in agreement with other previous studies (Tuna and Orak, 2007; Tuna and Orak 2002; Basbag et al., 1999). For example Tuna and Orak (2007), conducted an experiment using vetch plants for two years. The results they obtained for plant high were 64.5 cm and 57.8 cm, these results agree with the results of vetch irrigated with fresh water and supplied with fertilizers (51.2 cm). Tuna and Orak (2002), pointed out that plant height of common vetch were obtained 56.54 cm and 23.90cm in the first and second year, respectively. Basbag et al., (1999) found similar results.

4.4.2 Fresh and Dry Weight

1. Vetch

The results of fresh and dry weight of above ground total mass show that irrigation with treated wastewater has positive effect on the fresh weight (tables 4.5 and 4.6). It was found that there are significant differences in the fresh weight production among the different treatments.

Table 4.5: T – test results for fresh weight (g/plant) in vetch at (α= 0.05)

		Vetch
	Treatment	**Mean**
1	TWW + fertilizer 40 ppm N-P-k	82.33 a
2	TWW + fertilizer 10 ppm N-P-k	77.167 b
3	TWW	71.50 c
4	fresh water + fertilizer 10 ppm N-P-k	60.83 d
5	Control (fresh water only)	53.83 e

Table 4.6: T – Test results for dry weight (g/plant) in vetch at (α= 0.05)

		Vetch
	Treatment	**Mean**
1	TWW + fertilizer 40 ppm N-P-k	43.50 a
2	TWW + fertilizer 10 ppm N-P-k	40.50 b
3	TWW	33.83 c
4	fresh water + fertilizer 10 ppm N-P-k	24.83 d
5	Control (fresh water only)	22.00 e

2. Alfalfa

The results of fresh and dry weight showed that treated wastewater have higher weight production with significant differences at 95% confidence level (α= 0.05) as shown in tables (4.7 and 4.8).

Table 4.7: T – Test results of fresh weight (g/plant) in alfalfa at (α= 0.05)

		alfalfa
	Treatment	**Mean**
1	TWW + fertilizer 40 ppm N-P-k	112.17 a
2	TWW + fertilizer 10 ppm N-P-k	105.0 b
3	TWW	87.167 c
4	fresh water + fertilizer 10 ppm N-P-k	72.00 d
5	Control (fresh water only)	62.83 e

Table 4.8: T – Test results of dry weight (g/plant) in alfalfa at (α= 0.05)

		alfalfa
	Treatment	**Mean**
1	TWW + fertilizer 40 ppm N-P-k	53.50 a
2	TWW + fertilizer 10 ppm N-P-k	50.00 b
3	TWW	44.67 c
4	fresh water + fertilizer 10 ppm N-P-k	30.50 d
5	Control (fresh water only)	24.50 e

The results show significant differences among the treatments according to the type of irrigation, the highest average fresh weight in vetch was obtained from plants irrigated with TWW and supplied with (40 ppm) fertilizers (82.3 g/plant) compared to (53.8 g/plant) with fresh water alone and (60.83 g/plant) for plants irrigated with fresh water and supplied with 10 ppm fertilizer. The vetch plants irrigated with treated wastewater without any additional fertilizers (71.5 g/ plant) were lower in fresh weight than those irrigated with treated wastewater and supplied with 40 ppm fertilizer (77.12g/ plant) but in the same time were higher than those for fresh water and freshwater with 10 ppm fertilizer (60.8 g/plant).

Converting the results into weight per unit area and taking the normal seed weight of vetch, Taser et al (2005) reported that one hundred seed weights of Hungarian and common vetch seed were 4.33 and 5.88 g, respectively. (8.4 g/ 100 seed) was obtained in our results, and taking the normal plant density of 12 kg/ dunum (120kg ha^{-1} for the vetch) (Soysal, 1993). This gives (142,857 plant per dunum or 142,857,142 plant per hectare). The results of dry weight then become as shown in table 4.9.

Table 4.9: The fresh and dry weight of vetch

Treatment	Vetch			
	Fresh weight		Dry weight	
	g/plant	Kg/dunum	g/plant	Kg/dunum
Control	53.83	7689	22	3142
Fresh water + 10 ppm N-P-k fertilizer	60.83	8689	24.83	3547
TWW	71.5	10214	33.833	4833
TWW + 10 ppm fertilizers	77.17	11024	40.5	5785
TWW + 40 ppm fertilizers	82.33	11761	43.5	6214

For alfalfa the weight of 1000 seeds was 2.29 g (Majid Rashidi et al., 2009) where they obtained a highest yield at 2.5 kg/ha planting rate, in our results seed weight was 2 g/1000 seeds which means 125000 plants/dunum, the results are shown in table (4.10).

Table 4.10: Fresh and dry weight of alfalfa.

Treatment	Alfalfa			
	Fresh weight		Dry weight	
	g/plant	Kg/dunum	g/plant	Kg/dunum
Control	62.83	7853	24.5	3062
Fresh water + 10 ppm N-P-k fertilizer	72	9000	30.5	3812
TWW	87.17	10896	44.67	5583
TWW + 10 ppm fertilizer	105	13125	50	6250
TWW + 40 ppm fertilizer	112.17	14021	53.5	6687

These results agree with (Balkhair et al., 2013), Tuna and Orak (2007) reported similar results for vetch fresh yield.

4.4.3 Crude Protein Content

1. Vetch

The results of crude protein content (CP) are shown in table (4.11).

Table 4.11: Crude protein content in dry aerial parts of vetch.

Treatments	TWW+40 ppm fertilizer	TWW+10 ppm fertilizer	TWW	fresh water +10 ppm fertilizer	Control (fresh water only)
CP (%)	17.75	18.16	17.67	17	16.8

The results show that the highest content 18.16% of crude protein is found in dried aerial parts of vetch plants irrigated with treated wastewater and supplied with 10 ppm N-P-K.

2. Alfalfa

Table 4.12 shows the crude protein content in alfalfa, where the results show clearly that irrigation with treated wastewater enhanced the plants content of crude protein.

Table 4.12: Crude protein content in dry aerial parts of alfalfa .

Treatments	TWW+40 ppm fertilizer	TWW+10 ppm fertilizer	TWW	fresh water + 10 ppm fertilizer	Control (fresh water only)
CP (%)	18.32	18.56	18.24	17.27	16.95

The results show that the highest crude protein content was in dried aerial parts of plants irrigated with treated wastewater and supplied with 10 ppm N-P-K with an average 18.56% and 18.16% in alfalfa and vetch respectively, while the plants irrigated with fresh water alone have the lowest crude protein content with an average 16.95% and 16.8% in alfalfa and vetch respectively. These values are close to recommended crude protein concentration in aerial parts of alfalfa and vetch as indicated by National Research Council (NRC) which was 19.4% in alfalfa and 18.3% in vetch as indicated by NRC (NRC, 1989)

The results of crude protein content as shown in tables (4.11 and 4.12) are in agreement with other previous studies, where the increase in crude protein content of dried aerial parts are resulting from the nutrient content in the TWW which was enough to satisfy plant nutrient requirement and enhance their growth and their nitrogen content, while the amount of added fertilizers in the fresh water was not enough to satisfy the plants nitrogen requirements. These results agree with (Thapliyal, 2011; Balkhair et al., 2013) while the crude protein is higher in alfalfa.

4.4.4 Number of Leaves

1. Vetch

The results of leaves number show that there are significant differences at (α = 0.05) as presented in table 4.13. The highest number of leaves per plant is found for those plants irrigated with treated wastewater and supplied with 40 ppm fertilizer (52.84 leaves per plant) compared to (26 leaves per plant) for fresh water.

Table 4.13: T – Test analysis for No. of leaves per plant in vetch (α = 0.05).

	vetch
Treatment	**Mean**
TWW + fertilizer 40 ppm N-P-k	52.83 a
TWW + fertilizer 10 ppm N-P-k	48.67 b
TWW	41.33 c
fresh water + fertilizer 10 ppm N-P-k	30.17 d
Control (fresh water only)	26.00 e

2. Alfalfa

The results of number of leaves in alfalfa are showing the same trend as in vetch (table 4.14). The results have significant differences at 95% confidence level (α = 0.05). The plants irrigated with TWW have 72.66 leaves per plant compared to 54.167 leaves per plant for plants irrigated with fresh water and 10 ppm fertilizer. Balkhair et al (2013) explained this by referring it to the increase in the nutrients of the soil under wastewater irrigation, which improved the physical and nutrient contents of the soil, hence significantly increased the total chlorophyll and carotene and established good growth and increased biomass and yield of the crop.

Table 4.14: T – Test results for No. of leaves per plant at (α= 0.05) in alfalfa.

	Alfalfa
Treatment	**Mean**
TWW + fertilizer 40 ppm N-P-k	84.50 a
TWW + fertilizer 10 ppm N-P-k	79.00 b
TWW	72.67 c
fresh water + fertilizer 10 ppm N-P-k	54.17 d
Control (fresh water only)	33.00 e

4.4.5 Seed Number and Weight:

1. Vetch

The results of seed number and weight are showing significant differences with a highest fruit number per plant in vetch plants irrigated with TWW and supplied with 40 ppm (N,P,K) (126.67 fruits per plant) while the lowest was for the fresh water alone (86.5 fruits per plant) (table 4.15).

Table 4.15: The Number of fruits and the seed weight for vetch.

Treatments	Fruit No. per plant	Fruit weight per 100 seed
TWW + fertilizer 40 ppm N-P-k	126.7	16.2
TWW + fertilizer 10 ppm N-P-k	122.8	16.5
TWW	117	14.1
Fresh water + fertilizer 10 ppm N-P-k	98.3	10.6
Control	86.5	8.4

Table 4.16: T – Test for fruit number per plant in vetch and alfalfa at (α= 0.05).

	vetch	Alfalfa
Treatment	**Mean**	**Mean**
TWW + fertilizer 40 ppm N-P-k	126.67 a	1810.67 a
TWW + fertilizer 10 ppm N-P-k	122.83 b	1703.33 b
TWW	117.00 c	1580.83 c
Fresh water + fertilizer 10 ppm N-P-k	98.33 d	909.67 d
Control (fresh water only)	86.500 e	720.83 e

The results show significant differences among the treatments where the highest fruit number in both crops were for the plants irrigated with treated wastewater and 40 ppm fertilizers (126 fruits/ plant in vetch and 1810.67 in alfalfa)

2. Alfalfa

The results of seeds production are presented in table 4.17, the plants irrigated with fresh water have the minimum seed production in terms of number and seed weight, while those plants irrigated with treated wastewater and 40 ppm N – P – K have the highest production (1810.67 fruits/ plant) and 4.4 g / 1000 seeds.

Table 4.17: The Number of fruits and the seed weight for alfalfa

Treatments	Fruit No. per plant	Fruit weight per 1000 seed
TWW + fertilizer 40 ppm N-P-k	1810	4.4
TWW + fertilizer 10 ppm N-P-k	1703	4.4
TWW	1580	3.8
Fresh water + fertilizer 10 ppm N-P-k	909	2.6
Control	720	2

The results of analysis show that there are significant differences in the production of seeds at (α= 0.05).

Table 4.18: T – Test for fruit number per plant for crop in alfalfa at (α= 0.05).

	alfalfa
Treatment	**Mean**
TWW + fertilizer 40 ppm N-P-k	1810.67 a
TWW + fertilizer 10 ppm N-P-k	1703.33 b
TWW	1580.83 c
fresh water fertilizer 10 ppm N-P-k	909.67 d
Control (fresh water only)	720.83 e

These results in agreement with the other parameters, where we found significant differences in fruit number per plant according to the irrigation water.

In the same time the fruit weight have interesting results for vetch and alfalfa (table 4.15 and 4.17), where the analysis shows that there are no significant differences in the fruit production between the plants irrigated with treated wastewater alone and treated wastewater supplied with fertilizers (10 + 40 ppm N-P-k) compare to the other treatments.

Table 4.19: Results of T–test analysis for fruit weight per plant in vetch crop.

	Vetch	alfalfa
Treatment	**Mean**	**Mean**
Tww + fertilizer 40 ppm N-P-k	16.03 a	4.43 a
Tww + fertilizer 10 ppm N-P-k	16.43 a	4.43 a
Tww	14.07 b	3.78 b
fresh water + fertilizer 10 ppm N-P-k	10.52 c	2.60 c
Control (fresh water only)	8.27 d	2.15 d

Moreover the plants irrigated with Treated wastewater and supplied with 10 ppm mineral fertilizer have fruit production higher than those irrigated with

treated wastewater and supplied with 40 ppm mineral fertilizers in vetch as shown in table 4.19. This indicates that there is no need to increase the fertilization in both crops.

4.5 Soil and Water Results

The results of soil analysis are confirming the explanation given for the plants parameters, where the soil content of nitrogen has increased from 57 ppm before planting to reach 343 ppm in pots irrigated by TWW and fertilizers (Table 4.20). The results for soil nitrogen content analysis increased sharply by utilizing treated effluent in irrigation (figure 4).

This increase in soil nitrogen content is not coming from the fertilizer rather than coming from the nitrogen content in the treated effluent, since the increase in nitrogen content was slight when adding the fertilizers (it increased from 76 ppm when using fresh water to reach 89 ppm when adding fertilizer with 40 ppm concentration, and again in the treated effluent without fertilizer it was 326 ppm, while when adding fertilizer was 334 ppm, but clearly it jumped by irrigating with treated effluent. This is due to the nitrogen content of the treated effluent (85 mg/l) which enhanced the nitrogen content of the soil, and as a result obtained the plants nitrogen requirements.

Table 4.20 The soil analysis results for the different treatments

Parameter	Initial (before planting)	TWW + 40 ppm NPK	TWW + 10 ppm NPK	TWW	Fresh water + 10 ppm NPK	Control
pH	7.57	7.38	7.36	7.35	7.47	7.46
EC (ds/m)	0.45	2.32	2.2	1.9	1.2	0.8
Ca (ppm)	134	98	96	94	74	73
Mg (ppm)	50	72	71	69	57	55
Na (ppm)	30	124	123	120	92	81
SAR	0.56	2.31	2.3	2.28	1.94	1.73
k (ppm)	4	21	18	15	9	6
CEC (meq/100 g)	12.27	16.82	16.52	16.01	12.67	11.9
P (ppm)	0.5	4.5	4.1	3.8	1.4	0.85
TN (ppm)	57	343	334	326	89	76
chloride (ppm)	140	529	531	525	400	394

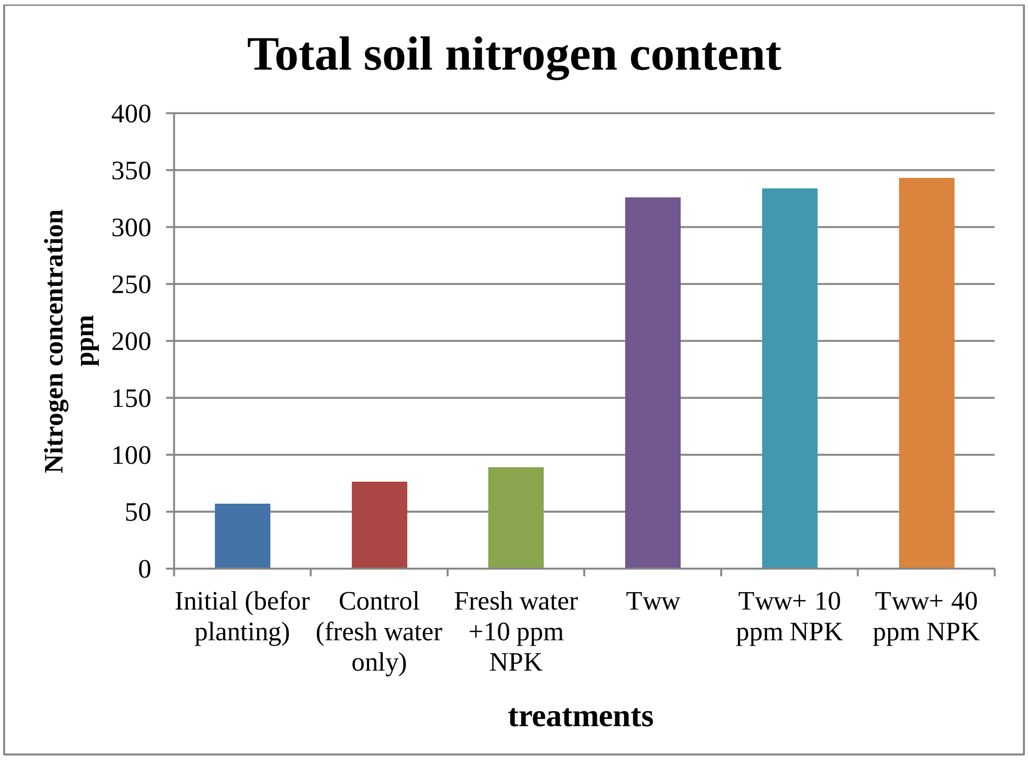

Figure 4. Total soil nitrogen content.

The soil salinity (figure 5) increased when the treated wastewater was used for irrigation from 0.45 dS/m to reach 2.32 dS/m, this is expected since the water contains salts and no leaching was conducted through the experiment, more over this is confirmed by the results of water analysis as shown in table (4.20) which shows that salts load are increasing from 0.56 dS/m in fresh water to 1.65 dS/m in treated effluent, and the TDS is increasing from 560 in fresh water to 1200 in treated wastewater effluent.

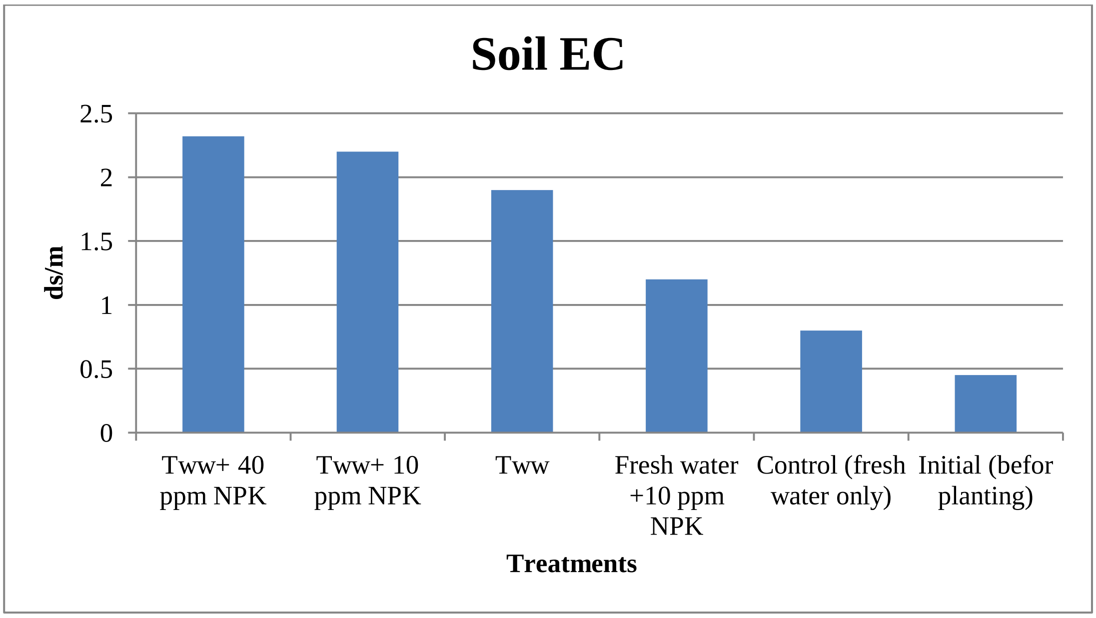

Figure 5. Soil EC results.

Combining these results of salinity with the results of SAR, we find that SAR increased from 0.56 before planting to 2.31 in soils irrigated with treated wastewater and supplied with 40 ppm fertilizer. This is expected since when we start to irrigate we add Na^+ with water. Knowing that the source of TWW is from domestic source, it is expected that SAR values will increase, since the water content of Na^+ is high. Figure 6 shows that the jump starts when we irrigate with TWW which is the major source of Na^+ (table salts and detergents).

In the area of the experiment, the average annual rain fall exceeds 500 mm, thus it is enough to make the leaching of the excess salts that have been accumulated through the irrigation period of the experiment from the root zone, therefore no negative impact is expected on the soil in the short term, but it is required to test this impact for the long term irrigation.

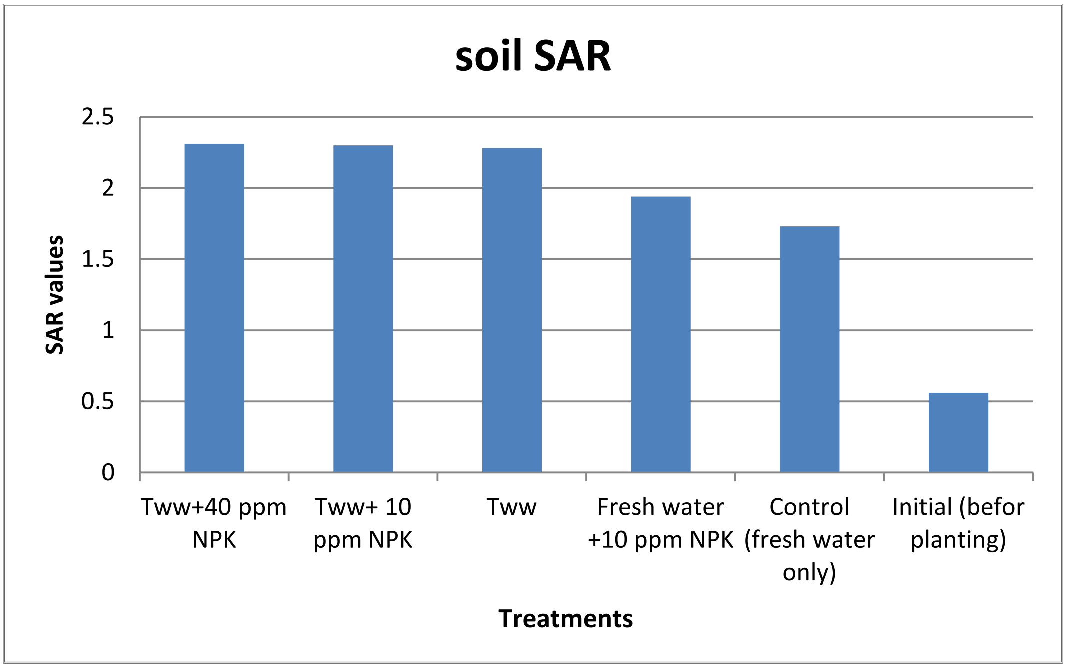

Figure 6. SAR values in the soil.

But in the same time these values of SAR are unlikely to cause any negative impact on the soil, since it is combined by an increase with salinity (Abu nada, 2009).

The results of soil pH is decreasing slightly, this is normal when using TWW which tend to reduce the soil pH as indicated by Kiziloglu et al. (2007), who reported that irrigating with TWW tend to decrease the soil pH as generally pH values in soil irrigated with wastewater are always less than that for non wastewater irrigation due to high organic matter content. This agrees with the results obtained from the soil analysis.

Regarding the soil CEC, it is noticed that there is a reduction in CEC values when irrigation with fresh water alone and then it started to increase, this reduction might be due to the fact that the fresh water content of salts is very low, thus as irrigation starts there will be leaching for some cations from the soil and the CEC will decrease, while as we added treated wastewater the soil content of organic matter will increase and since the organic matter has a high CEC then it is normal to have higher values of CEC. This agrees with the results of (Abu nada, 2009).

The results show an increase in soil content of phosphorus and potassium. Phosphorus has increase from 0.5 ppm to 4.5 ppm as shown in figure (7)

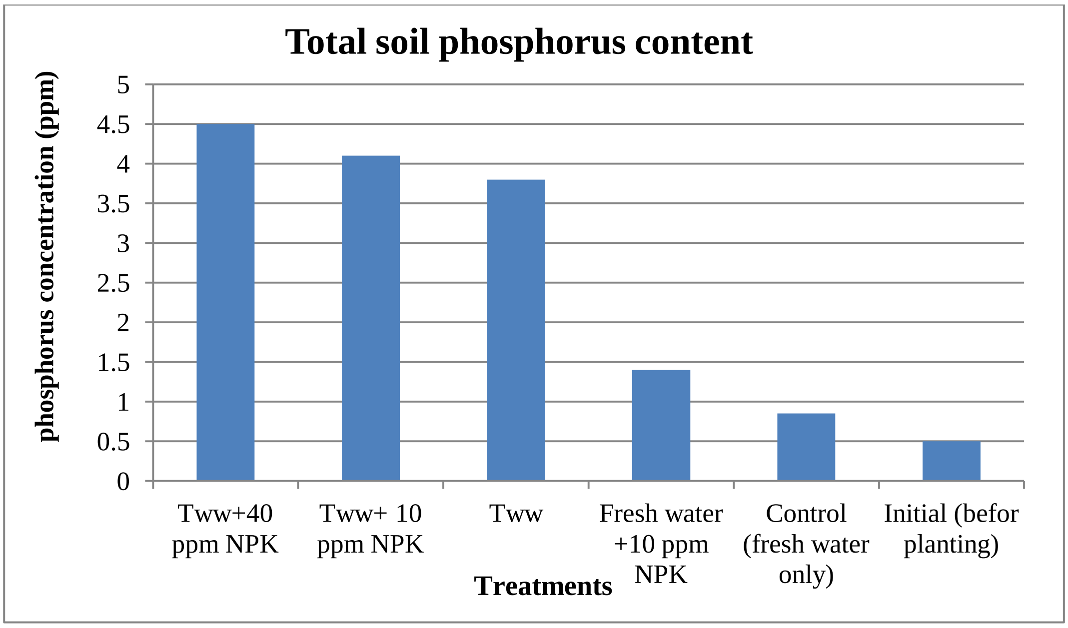

Figure 7. Total Phosphorus content in the soil.

The results agree with Abu nada (2009), who reported that phosphorus can be found in low amount in wastewater this makes the use of wastewater beneficial and has positive impact even if the P concentration is too high and wastewater used for long time. Wastewater treatment plants need extensive treatment to remove P, thus the use of wastewater in agriculture can save these costs and minimize the environmental impacts.

Results of Potassium show an increase from 4 to 21 ppm, this is due to the fact that Potassium either is present in soil with high concentration but it is generally bounded to other elements. So it needs to be added to soil as a fertilizer. Generally185kg of K /hectare for field crops are required so wastewater contains low potassium level does not cover the crop demand. Usually no significant negative impacts associated with potassium (Abu nada, 2009).

On the other hand the soil chloride content has increased from 140 ppm to reach 529 when soil is irrigated with TWW and supplied with fertilizers. The increase in all treatments indicating that TWW content of chlorides can reach high levels causing toxicity to the plants (over 400 ppm), this agrees with (Abu nada, 2009), so there is need to leach out salts and chlorides from the soil by adding additional water in irrigation or from precipitation as indicated by Ayers and Westcot (1985).

Chapter Five

Conclusions and Recommendations

5.1. Conclusions

The reuse of treated wastewater is highly possible in the Palestinian area, where there is high acceptance for the reuse of treated wastewater in irrigation due to water shortages.

Farmers interviewed in this study, showed an acceptance and wellings to use treated wastewater in irrigating fodders. The irrigation of fodders with treated wastewater could increase the production by at least 40%.

The experiment conducted in this study showed that treated effluent has important nutritional values where crude protein content in dried aerial parts reached 18.16% and 18.56% in vetch and alfalfa respectively.

There is a slightly negative impact on the soil, where soil salinity has increased from 0.45 ds/m before planting to reach 2.32 ds/m in soils irrigated with treated wastewater plus 40 ppm N-P-K .

Also soil SAR value increased as treated wastewater utilized in irrigation from 0.65 before planting to 2.31 in soils irrigated with treated wastewater plus 40 ppm N-P-K.

However, the effects of SAR and salinity on soil could be solved by leaching out excess salts through adding additional amounts of irrigation water or naturally by precipitation where average annual rain fall exceeds 500 mm in Nablus and Tulkarm areas where the experiment and the survey were conducted.

Salinity and SAR do not expect to cause negative impacts on soil in short term irrigation but it is required to monitor their impacts for long term irrigation. The research extended for one season only and thus leaching issue was not addressed as leaching and salinity effects take time to show.

Soil nitrogen, phosphorus and potassium content increased in soils irrigated by treated wastewater alone and treated wastewater plus 10 and 40 ppm N-P-K.

The experiment showed that the high nitrogen and phosphorus contents of treated wastewater have positive impacts on the yield and quality of alfalfa and vetch. Therefore, based on this study, fodders crops could be irrigated with treated wastewater without the need for nitrogen and phosphorous removal at the treatment plants.

5.2. Recommendations

Further searches on the socio-economical aspects need to be implemented in regard of reusing treated wastewater.

It is highly important to conduct scientific researches on different fodder crops irrigated with treated wastewater under the local conditions and utilizing different irrigation management practices.

More researches on the long term impacts of treated wastewater on the soil are needed and further investigations on optimal management policies to reduce these impacts are also needed.

It is highly recommended to repeat this study for longer period and in different time during the year.

Treated wastewater is a high potential source for irrigation water and it is important to start the reuse of treated wastewater in small scale pilot areas to demonstrate the results to the local community.

There is a need to concentrate on the public awareness on the importance of using the treated wastewater

There are many concerns among farmers regarding the use of treated waste water, and they need training and capacity building to insure the good management of this kind of water.

It is highly recommended to start a pilot reuse project at Nablus West wastewater treatment plants to encourage farmers to utilize treated wastewater there. Since, the treatment plant there does not include nitrogen and phosphorous removal, it will be recommended to reuse that treated wastewater in planting fodders. When phosphorus and nitrogen removal technologies are added, fruit crops could be irrigated with treated wastewater there.

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Appendix (1): The Palestinian Obligatory technical regulations

التعليمات الفنية الإلزامية 34-2012

المياه المعالجة للري الزراعي

(2012/1/23)

مقدمة

تهدف هذه التعليمات الفنية الإلزامية إلى ما يلي:

(1) وضع أسس لاستخدام المياه المعالجة للري الزراعي بشكل لا يضر بصحة الإنسان والحيوان وبالمزروعات.

(2) ضمان أن لا تشكل المياه المعالجة للري الزراعي ضررا على العناصر البيئية من تربة ومياه وهواء.

مادة (1)

المجال

تسري أحكام هذه التعليمات على المياه المعالجة الخارجة من محطات المعالجة بهدف استخدامها للري الزراعي.

مادة (2)

تعريفات

لغايات تطبيق أحكام هذه التعليمات يكون للكلمات والعبارات التالية المعاني المخصصة لها أدناه، ما لم تدل القرينة على خلاف ذلك:

2-1 الجهة المختصة: الجهة أو الجهات التي يحددها مجلس الوزراء لتنفيذ أحكام هذه التعليمات بموجب المادة (23) من قانون مؤسسة المواصفات والمقاييس والقوانين السارية الأخرى ذات الصلة.

2-2 المستخدم: شخص أو مقاول أو منشأة حكومية أو اهلية أو خاصة تستخدم أو تستفيد من المياه المعالجة للري الزراعي.

2-3 المياه العادمة: هي المياه الملوثة بمواد فيزيائية أو كيميائية أو بيولوجية أو إشعاعية ونتجت أو تخلفت عن استخدام المياه للأغراض المنزلية أو الصناعية أو التجارية أو الزراعية بحيث أصبحت تشكل خطورة عند إعادة استخدامها أو صرفها بشكل مخالف لأحكام القوانين السارية ذات الصلة.

التعليمات الفنية الإلزامية 34-2012

المياه المعالجة للري الزراعي

(2012/1/23)

مقدمة

تهدف هذه التعليمات الفنية الإلزامية إلى ما يلي:

(1) وضع أسس لاستخدام المياه المعالجة للري الزراعي بشكل لا يضر بصحة الإنسان والحيوان وبالمزروعات.

(2) ضمان أن لا تشكل المياه المعالجة للري الزراعي ضررا على العناصر البيئية من تربة ومياه وهواء.

مادة (1)

المجال

تسري أحكام هذه التعليمات على المياه المعالجة الخارجة من محطات المعالجة بهدف استخدامها للري الزراعي.

مادة (2)

تعريفات

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يجب على الجهة المختصة مراقبة جودة المياه المعالجة للري الزراعي من خلال تطبيق نظام المراقبة المذكور في المواصفة الفلسطينية رقم 742.

مادة (8)

يحظر استخدام المياه المعالجة للري الزراعي في:

(أ) سقاية المواشي والدواجن.

(ب) ري جميع أنواع الخضار.

(ت) تغذية المياه الجوفية عن طريق الحقن المباشر.

(ث) الاستزراع السمكي.

مادة (9)

لا يجوز للمستخدم التصرف في المياه المعالجة للري الزراعي في استخدامات غير تلك التي حددتها الجهة المختصة بالري الزراعي.

مادة (10)

عند وجود تعارض مع وثائق رسمية صادرة عن جهات أخرى، يجب تعديل تلك الوثائق بما ينسجم مع هذه التعليمات.

مادة (11)

تسري هذه التعليمات اعتباراً من تاريخ المصادقة عليها والإعلان عنها.

مادة (12)

في حال ظهور أي خلاف في تفسير أحد نصوص هذه التعليمات، فإنه يجب اعتماد التفسير الصادر عن لجنة التعليمات الفنية الإلزامية.

مادة (13)

على الجهة المختصة أن تضع خطة لتطبيق جميع احكام هذه التعليمات بحيث تتضمن مراحل التطبيق والموارد المطلوبة لتنفيذها على أن لا تتجاوز مدة هذه الخطة عن ثلاث سنوات من سريان هذه التعليمات.

ملحق (1)
تصنيف المياه المعالجة حسب جودتها

الحدود القصوى للخصائص الكيميائية والبيولوجية (ملغم/لتر) ما لم يذكر غير ذلك	جودة المياه المعالجة			
	جودة عالية (A)	جودة جيدة (B)	جودة متوسطة (C)	جودة متدنية (D)
الأوكسجين الممتص حيوياً BOD_5	20	20	40	60
المواد العالقة الكلية TSS	30	30	50	90
بكتيريا قولونية برازية FC (مستعمرة/100مل)	200	1000	1000	1000
الأوكسجين الممتص كيميائياً COD	50	50	100	150
الأكسجين المذاب DO	1<	1<	1<	1<
المواد الذائبة الكلية TDS	1200	1500	1500	1500
الرقم الهيدروجيني pH	9-6	9-6	9-6	9-6
الدهون والزيوت والشحوم Fat, Oil & Grease	5	5	5	5
الفينول Phenol	0.002	0.002	0.002	0.002
المنظفات الصناعية MBAS	15	15	15	25
النترات- نيتروجين NO_3-N	20	20	30	40
الأمونيوم- نيتروجين NH_4-N	5	5	10	15
النيتروجين الكلي Total-N	30	30	45	60
الكلوريد Cl	400	400	400	400
الكبريتات SO_4	300	300	300	300
الصوديوم Na	200	200	200	200
المغنيسيوم Mg	60	60	60	60
الكالسيوم Ca	300	300	300	300
نسبة ادمصاص الصوديوم SAR	5.83	5.83	5.83	5.83
الفوسفات – فسفور PO_4-P	30	30	30	30
الألمنيوم Al	5	5	5	5
الزرنيخ As	0.1	0.1	0.1	0.1
النحاس Cu	0.2	0.2	0.2	0.2

الحدود القصوى للخصائص الكيميائية والبيولوجية (ملغم/لتر) ما لم يذكر غير ذلك	جودة المياه المعالجة			
	جودة عالية (A)	جودة جيدة (B)	جودة متوسطة (C)	جودة متدنية (D)
الحديد Fe	5	5	5	5
المنغنيز Mn	0.2	0.2	0.2	0.2
النيكل Ni	0.2	0.2	0.2	0.2
الرصاص Pb	0.2	0.2	0.2	0.2
السيلينيوم Se	0.02	0.02	0.02	0.02
الكادميوم Cd	0.01	0.01	0.01	0.01
الزنك Zn	2	2	2	2
السيانيد CN	0.05	0.05	0.05	0.05
الكروم Cr	0.1	0.1	0.1	0.1
الزئبق Hg	0.001	0.001	0.001	0.001
كوبالت Co	0.05	0.05	0.05	0.05
البورون B	0.7	0.7	0.7	0.7
بكتيريا *E. coli* (مستعمرة/100مل)	100	1000	1000	1000
بيوض الديدان المعوية (Eggs/L) Nematodes	1≥	1≥	1≥	1≥

Appendix (2)

استبيان:

لقد تم عمل هذا الاستبيان لتقييم مدى القبول العام لدى المزارعين لاعادة استخدام المياه العادمة المعالجة من محطة نابلس الغربية في منطقة الدراسة ولمعرفة المجالات المحتملة لغاية اعادة استخدامها في الزراعة.

1. معلومات عامة

1.1 اسم الموقع/المنطقة:

2. معلومات عن المزارع:

2.1 المستوى التعليمي: ....

أ. أمي　　　　ب. مدرسة ابتدائية　　　　ج. مدرسة ثانوية　　　　د. كلية/جامعة

2.2 الخبرة بالزراعية:

أ. أكثر من 10 سنوات　　　ب. متوسط من 5−10 سنوات　　　ج. أقل من 5 سنوات

2.3 عدد أفراد الأسرة : .... أفراد

2.4 عدد أفراد الأسرة الذين يعملون في الزراعة: ....افراد.

2.5 عدد أفؤاد الأسرة الذين يعملون في وظائف أخرى:..............افراد

2.6 النسبة المئوية للزراعة في الدخل العائلي: ....%

2.7 توفر المياه للري:　　　　نعم　　　　لا

2.8 ثمن المياه للري .... شيقل لكل متر مكعب.

3. موقف المزارع بشأن إعادة استخدام المياه المعالجة

3.1 هل تعرف المعايير الفلسطينية بشأن معالجة المياه العادمة وإعادة استخدامها؟

أ. نعم　　　　ب. لا

3.2 هل من الممكن إنتاج محاصيل زراعية عندما تروى بالمياه العادمة المعالجة والمنتج سيكون امن للاستهلاك البشري؟

أ. نعم (بالنسبة لجميع المحاصيل)　　ب. نعم (بالنسبة لكثير من المحاصيل)　　ج. لا

3.3 هل أنت على استعداد لاستخدام المياه العادمة المعالجة:

أ. نعم ب. لا ج. نعم بشرط

3.4 أنواع المحاصيل التي سوف تقبل ريها بالمياه العادمة:

أ.القطن ب.العلف ج.أشجار الفاكهة د.ري إضافي للزيتون

و.الخضروات إذا كانت جودة المياه جيدة

3.5 مخاوف بشأن إعادة استخدام المياه العادمة المعالجة:

أ.السلامة الشخصية والعائلية أثناء الري

ب.المخاطر الصحية المرتبطة المحاصيل المروية

ج.مشاكل السوق

3.6 طريق الحصاد المتبعة؟

1. الحصاد اليدوي بدون قفاز واقي
2. الحصاد اليدوي مع قفاز يد واقي
3. الحصاد الآلي
4. أخرى

3.7 في حالة الري بالمياه المعالجة هل أنت مستعد لتنظيف آليات الحصاد المستخدمة لجمع المحاصيل المروية بالمياه المعالجة قبل أن يتم إعادة استخدامها في جمع محاصيل أخرى؟

أ. نعم ب. لا

3.8 إذا تم استخدام المياه المعالجة في ري المحاصيل الزراعية، ما هي الطريقة الأنسب لري مثل تلك المحاصيل؟

1. الري بالتنقيط،
2. الري بالرشاشات
3. الري بالقنوات

3.9 استعدادك لدفع ثمن المياه العادمة المعالجة:

أ. لا شيء ب. مستعد لدفع تكاليف الضخ إلى المزرعة

ج. .... شيقل لكل متر مكعب

4 استخدام الحمأة (الراسب الطيني\الوحلي) الناتج من محطات معالجة مياه الصرف:

4.1 هل أنت على علم بأن الحمأة يمكن استخدامها كسماد للمحاصيل؟

أ. نعم (بالنسبة لجميع المحاصيل) ب. نعم(بالنسبة لبعض المحاصيل)

ج. لا،فانه لا يمكن استخدامها بأمان

4.2 هل تعرف المعايير المحلية بشأن استخدام الحمأة في الزراعة:

أ.نعم ب.لا

4.3 المخاوف بشأن استخدام الحمأة في الزراعة :

أ.مخاوف صحية ب.مخاوف تقنية ج.مخاوف بيئية د.مخاوف دينية

4.4 شكل الحمأة التي ستقبل استخدامها:

أ. رطب ب. جاف ج. يتوقف ذلك على نوع المحصول د. لاشيء

4.5 على استعداد لدفع ثمن:

أ. لا شيء ب. تكلفة النقل من منطقة التخفيف إلى المزرعة

ج. .... شيقل لكل متر مكعب

5 هل ترغب في ان يتم انشاء جمعية خاصة لمصلحة المياه المعالجة وما هي المهام التي برايك قد تنجزها الجمعية للمزارع: نعم لا

1.متابعة تمديد الشبكات الخاصة بالمياه المعالجة لايصالها للحقل

2.تحصيل ثمن المياه المعالجة من المزارعين

3.متابعة الامور الفنية للشبكة

4.عمل نشرات ارشادية خاصة بمجالات استخدام المياه المعاجة والطرق السليمة لاستعمالها

5.تمثيل المزارعين في المنطقة حيث تكون الجمعية صلة الوصل بين المزارع والجهات الرسمية الاخرى

6.جميع ما ذكر بالاضافة الى المهام الاخرى التي تكون في مصلحة المزارع

جامعة النجاح الوطنية

كلية الدراسات العليا

اعادة استخدام المياه المعالجة لانتاج البقوليات / دراسة حالة – البرسيم الحجازي والبيقا

اعداد

احمد جبري محمد لبدي

اشراف

د. نعمان مزيد

د. حسان ابو قاعود

قدمت هذه الاطروحة استكمالاً لمتطلبات الحصول على درجة الماجستير في الانتاج النباتي بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس– فلسطين.

2014

اعادة استخدام المياه المعالجة لانتاج البقوليات / دراسة حالة – البرسيم الحجازي والبيقا

اعداد

احمد جبري محمد لبدي

اشراف

د. نعمان مزيد

د. حسان ابو قاعود

الملخص

تم تنفيذ هذه الدراسة بهدف تقييم الانتاج لصنفين من المحاصيل العلفية البقولية (البيقيا الشائعة، والبرسيم الحجازي) التي تروى بالمياه العادمة المعالجة. وتم تنفيذ الدراسة خلال صيف 2012، حيث استخدمت خمسة معاملات من مياه الري و تتضمن الري بالمياه العذبة، الري بالمياه العذبة التي أضيف لها 10 جزء بالمليون سماد (نيتروجين – فسفور– بوتاس)، الري بالمياه المعالجة، الري بالمياه المعالجة المضاف لها 10 جزء بالمليون سماد (نيتروجين – فسفور– بوتاس)، والري بالمياه المعالجة المضاف لها 40 جزء بالمليون سماد (نيتروجين – فسفور– بوتاس).

تمت الزراعة في حاويات بلاستيكية بسعة 5 لتر لكل حاوية تحتوي على 1:4 تربة رملية: تربة طينية. وتم تحليل عينات التربة قبل الزراعة و بعد الزراعة، كما تم تسجيل المؤشرات التالية للنبات: طول النبات، الوزن الأخضر، الوزن الجاف، عدد الأوراق / نبات، عدد الثمار/ نبات، ووزن الثمار/ نبات.

وتشير النتائج الى أن استخدام المياه المعالجة يزيد من الانتاج بشكل محسوس ومؤثر احصائيا بالنسبة لجميع المؤشرات. تم الحصول على أعلى انتاج لارتفاع النبات من استخدام المياه المعالجة المزودة ب 40 جزء بالمليون (81.5 سم / نبات البيقيا، و112.5 سم / نبات في البرسيم)

أظهرت النتائج أن استخدام مياه الصرف الصحي المعالجة بدون اضافة سماد مقارنة بالمياه العذبة وحده مقارنة مع المياه العذبة: الأوزان الطازجة (62.8 جم / نبات) 82.33 جم / نبات

(132 و87.17 جم / نبات) البيقية والبرسيم على التوالي، وبالنسبة للوزن الجاف، تم الحصول على (33.83 جم / نبات و44.67 جم / نبات) البيقية و البرسيم على التوالي. مقارنة ب 22 جم / نبات و24.5 جم / نبات للري بواسطة المياه العذبة.

كما أظهرت نتائج تحليل التربة زيادة في محتوى التربة من النيتروجين والفوسفور والبوتاسيوم، وكذلك زيادة في الملوحة وقيم ادمصاص الصوديوم في التربة التي تم سقايتها بالمياه العادمية والمياه العادمة مضافا لها القيم السمادية 10+ 40 جزء بالمليون من النيتروجين والفسفور والبوتاس.