MEDREC SERIES OF R&D REPOTS
MEDREC PROJECT: 12-AS-015

Impact of Irrigation with Desalinated Water on the Productivity and Fruit Quality of Tomato Crop at Marj Na'aja Village

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ACKNOWLEDGMENT

Alhamdulillah at the beginning

First of all I extend my sincere thanks to my supervisor, Dr. Nidal Mahmoud, for his patience and kindness, as well as his academic experience, which have been invaluable to me.

I'd like to acknowledge the Palestinian Water Authority for the financial support through the MEDREC SCHOLARSHIP and to Birzeit University for the financial support and technical advice.

The encouragement, contribution and support of my family;

My Husband who supports me, you are always, my pillar, my joy and my guiding light.

My lovely Kids, I extend my thanks and express my gratitude for your support.

I am extremely grateful to Imad Ghanma my colleague at work, and in the university for his help and support.

My Mother and Father you are the apple of my eyes, your support has great deal in raising my spirit and gave me hope when I was down.

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Abstract

Agricultural wells salinization is a major problem facing the agricultural sector in Palestine Over the past 3 decades, agricultural wells salinity has raised from 570 ppm in 1967 to reach 4500 ppm in 2012 and in some places (wells near the Dead Sea) it reaches more than 19000 ppm. The water salinity in the Jericho district is still under control but due to the excessive agriculture, over pumpage, excessive use of fertilizers and pesticides the problem will become more severe unless some strike management had been done.

In 2012, the Ministry of Agriculture has installed a small desalination unit with a total capacity of 60 m^3/hr and electrical conductivity of 200 ppm to be used for agricultural purposes to irrigate the cultivated lands at Marj Na'aja village which is located 40 km north to Jericho city.

The main objective of the study is to assess the impact of using desalinated, blended, and raw brackish water on the heavy saline soil fertility, the tomato crop productivity, and tomato fruit quality.

Research hypothesis was that irrigating Heavy saline soil with desalinated water might affect the soil fertility and this will have a negative impact on the tomato plant productivity and fruit quality, and this effect could be accommodated by blended with raw saline water with a certain ratio.

The research was conducted during the winter season of 2013/2014, were the seedlings were planted in October in a greenhouse that is located at Marj Na'aja village, four categories of water treatment were used in the research were T1 is the desalinated water with EC=200 ppm and two blended water treatments T2 with EC=750 ppm and T3 with EC=1600 ppm and the last treatment T4 the raw saline water with EC= 4500 ppm.

The main results that were found in this research were:

The heavy saline soil fertility decreased dramatically when irrigated with desalinated water with 200 TDS ppm for all macronutrients as the N deceases from 24.5 ppm (high) to 10 ppm (medium), P decrease from 31.25 ppm to 17, K decease from 111 ppm to 65 ppm, and Ca decease from 485 ppm to 108, while the raw saline water give the highest soil fertility as the concentration of the macro nutrients was slightly decreased at the end of cultivation season.

The tomato plat yield with blended water with TDS 750 ppm (20 kg per plant) followed by blended water with TDS 1600 ppm (18.8 kg/plant), then using raw saline water with TDS 4500 ppm (13 kg/plant), and the lowest value using desalinated water with 200 TDS ppm (12 kg/plant), the research results about the production are aligned with the production quantities documented by MOA (PCBS 2007-2010), according to their reports, the average productivity for the tomato seedling under same conditions in terms of the availability irrigation water and nutrients is 25-28 kg per seedlings.

Regarding the fruit quality significant variations in tomato fruit quality parameters were obtained (TSS) were lowest at TDS 200 ppm and highest when plants were irrigated with raw saline water of TDS 4500 ppm then with blended water with TDS 750, and 1600 ppm respectively. Therefore, irrigating heavy saline soil with desalinated water of different salinity has detrimental effects on the soil fertility, tomato plant productivity and fruit quality. Therefore, negative aspects had been alleviated by irrigating with blended water, which has positive effects on soil fertility and tomato plant productivity and fruit quality.

Abbreviations:

Acronym	**Definition**
LAI	Leaf Area Index
EC	Electrical Conductivity
TSS	Total Soluble Solids
PPM	Part Per Million
MoA	Ministry of Agriculture
TDS	Total Dissolved Solids
N	Nitrogen
P	Phosphorus
K	Potassium
Ca	Calcium
ESP	Exchangeable Sodium Percentage
SAR	Sodium Absorption Ratio
MCM/y	Million Cubic Meter per Year

Chapter One: Introduction

1.1 Background

Limited water resources (recharge of the aquifers ranges 565-822 MCM/y based on the amount of the rainfall only 45% are used for agriculture) restricted the irrigated lands (in the West Bank about 870,000 dunum) (MoA, 2012), scattered in different areas and especially in the Jordan Valley (JV). Water salinization considered as one of the major constraints facing arable lands and cultivation development in the West Bank (WB), mainly in Jordan valley as the wells water quality is deteriorated with time due to in proper water management, excessive use of fertilizers and the sea water intrusion due to over pumpage (PWA, 2012).
Studies showed that irrigating with high level of brackish water can lead to decrease in crop productivity and quality compared to irrigating with fresh water, while irrigating with desalinated water, might also lead to decrease in crop productivity and quality due to the leaching of nutrient present in the soil and also due to water low content of essential nutrient's as N, P, K in the irrigation water (Malasha *et al.*, 2008). In general, saline water conditions reduce the productivity of considerable crops in the West Bank, while the saline water enhance and improved the quality of some crops especially the tomato crop, these results might amply on the desalinated water, but we should take in consideration that the irrigated soil is a sodic soil, and some studies showed that irrigating sodic soil or saline soil with high content of sodium, with fresh water, had led to increase exchangeable sodium percentage (ESP) in the soil profile; and consequently there were some changes on the primary physical processes associated with high sodium (Al- Omran, 2008), this might affect the ability of the crop to uptake the water and the available nutrients in the soil solution. Therefore, there is a need for continued research and studies on problems of irrigating with desalinated water and the many complicated inter-relations to crop production and quality grown with this water quality.
Several researchers have studied the effect of irrigation with different salinity level on the plant leaves macronutrient content. They concluded that the increase in water salinity significantly reduces the concentration of N, P, K, and Ca in plant leaves (Hu *et al.* (1997); Afshari *et al*. (2011); Malasha *et al.* (2008)).
Mixing saline with non-saline water less than 3 dS/m increases the concentration of N, P, K, and Ca in plant leaves in comparison with using brackish water (Malasha *et al.* (2008)).

1.2 Research Hypothesis

Irrigating heavy saline soil with desalinated water might have affect the on the soil fertility and this will have consequences on plant productivity and quality that could be accommodated by blending with raw saline water with a certain ratio.

1.3 Research Objectives:

The overall objective of this research is to assess the impact of using desalinated, blended, raw brackish water, on the heavy saline soil fertility, and the consequences on qualitative and quantitative productivity of tomato crop.

The specific objectives of this research are to assess the effect of using irrigation water of different salinity levels on:

- The effect on heavy saline soil fertility and nutrients availability (N, P, K, Ca) for the tomato plant;
- The effect on nutrients availability and concentrations (N, P, K, Ca) in the tomato leaves;
- Productivity of tomato plants;
- Tomato fruit quality with special attention to the most common marketable fruit quality indicators (fruit pH, TSS, and EC).

Chapter Two: Literature Review

2.1 Effect of Using Irrigation Water with Different Salinity Levels on Productivity and Quality of Tomato Plant

In arid and semi arid zones, where the agriculture land is available mainly the irrigation water is saline; desalination is becoming an attractive method for increasing yields and reducing negative environmental consequences. Technological advances have made desalination an economically feasible solution for high-return agriculture, especially in arid and semi arid regions where water cost may be excessive due to distance from, or depth to, the water supply. In 2006 an expert report by the United Nations Food and Agriculture Organization (Martinez *et al.*, 2006) concluded that while the costs of desalination are still prohibitively high for full use by most irrigated agriculture, its use with high-value cash crops, such as greenhouse vegetables and flowers, has become economically feasible at the present prices. In fact, desalinization of wastewater effluent or brackish groundwater often found in arid and semi arid regions typically costs half or less than desalination of seawater (Zhou *et al.*, 2005). Such desalinated brackish water is being used more and more by farmers for irrigation at small and large scales (Martinez *et al*., 2006). Replacing saline irrigation water with desalinated water is anticipated to increase yields due to reduced salinity stress and to allow drastic decreases in the amount of water currently used for leaching salts out of the root zone. For these reasons, desalination has, in fact, become a real option for planners, decision-makers, and growers in areas like Negev Highlands and Arava Valley. Nevertheless, the initial experience with desalinated water has not been completely positive (Yermiyahu *et al.*, 2007a, b).

Response of vegetables to the presence of increased amounts of salts is primarily stunted

growth (Romero-Aranda *et al*., 2001). The ultimate impact of excess salts is of course very dependent on the other environmental factors such as humidity, temperature, light and air pollution (Shannon et al., 1994).

Most of the studies had concentrated on effect saline water on the tomato crop productivity and its quality and few studies had concentrated on the effects of the desalinated water on the tomato crop productivity and its quality or take in consideration the farmers actual practices to deal with both the saline or desalinated water.

2.1.1 Effect of using irrigation water with different salinity levels on tomato crop productivity

Plant growth and development are mostly affected by the environmental conditions. Water plays the main role in the vital processes occurred in the plants, as the water is needed to transport the essential elements from the roots to plant shoots. So the irrigation water quality is important to enable the plant to absorb and transport the needed plant macro and micro nutrients.

2.1.1.1 Effect of brackish water on tomato crop productivity

Plants could be exposed to different types of biotic stress. Water salinity is one of the most common stresses, were as the salinity of irrigation water increase, it will probably affect the soil, water, and plant relationship. Many studies have documented that irrigation with saline or brackish water requires sensitive and management practices to control the effect on the crops productivity.

The effect of the water salinity on sensitive tomato hybrid (*Lycopersicon esculentum L*.) was studied by several researchers, were in one experiment, tomato plant cultivated and irrigated with saline solution with different EC strength namely (3000, 4000 and 5000 ppm), and in other experiments tomato plant was irrigated by different concentration ranges of saline water (saline water of 4.5 dS/m to non-saline water of 0.55 dS/m). Results indicate that, increasing the level of water salinity significantly reduced and has negative effects on tomato plant growth parameters such as plant height, leaf area, plant fresh and dry weight, number of flowers, fruits number, fruit size and weight, and plant yield (Tantawy *et al,* 2009; Malasha *et al.,* 2008; Kahlaoui *et al,*. 2011; Al-Omran *et al.,* 2010; Romero-Aranda *et al,*. 2002; Boamah *et al.*, 2011).

Also, the response of bell pepper (cv. Taranto) plant to quality of irrigation water was tested under two main water salinity treatments namely; non-saline water (EC=0.6 dS/m) and saline water (EC=3.8 dS/m). As expected and similar to the response of tomato plant to saline water, irrigation of pepper plant by saline water led to a drop in fresh fruit yield from 1450.5 (none-saline water) to 1038.8 g/plant (saline water) (Patil *et al.*, 2011).

It is often difficult to determine the relative influence of osmotic effect and the effect of the toxicity of specific ions on vegetable yield. In any case, yield losses due to osmotic stress can be very significant even before symptoms of toxicity on leaves become noticeable. Under the influence of salt stress growth of many species of vegetables is reduced, such as tomato (Romero-Aranda *et al*., 2001, Maggio *et al*., 2004), pepper (De Pascale *et al*., 2003b), celery (De Pascale *et al*., 2003a) and peas (Maksimovic *et al.*, 2008, Maksimovic *et al* ., 2010). There are significant differences in salt tolerance between plant species and genotypes and similar goes for the ability to tolerate water deficiency (Munns, 2002; Lukovic *et al*., 2009).

The main cause of reduced plant growth in the presence of salt can be impairment of water regime. Increasing the salt concentration in the soil increases the osmotic pressure of the soil solution and plants cannot uptake the water as easily as in the case of relatively non-saline soils. Therefore, as the concentration of salt i.e. soil EC increases, water becomes less accessible to plants, even if the soil contains significant amounts of water and looks wet.

Leaf area index is a plant growth factor that was directly affected by different irrigation water salinity, in which it decreases as water salinity increase, thus it acts as an indirect factor that affect plant productivity. Many researchers concluded that, as leaf area index increase plant productivity increase (Heuvelink *et al.*, 2005; Heuvelink, 1999).

2.1.1.2 Effect of desalinated water on tomato crop productivity

Usually when the water salinity level less than TDS 400 ppm it is expected that the plant doesn't suffer from any problems, and no special management practices are required to improve the plant crop productivity or fruit quality, (Ghermandi *et al.*, 2009; Ben-Gal *et al*., 2009). They documented that the desalinated water up to TDS 350 ppm increases the yield biomass and increase the crop productivity by almost 50% under the condition of adding fertilizers up to the plants needs. Contradictly other researchers have shared different results that showed irrigation with desalinated water up to TDS 200 ppm might also have hamper effects on plant crop productivity. Ben-Gal *et al*. (2009) have reported that irrigating with fully desalinated water (200 ppm) maintained yields less than 90% compared to irrigation with blended water up to 640 ppm, the same results were documented by (Malki *et al.*, 2007) who studied the use of desalinated water on the germination of wheat seed, the results showed that the wheat seed germination decreased as the seeds are irrigated with desalinated water, moreover the best results were obtained with the blended water having a conductivity of 640 ppm.

2.1.2 Effect of using irrigation water with different salinity levels on tomato fruit quality

Fruit quality is an important issue which affects on the fruit marketing process and its economic value, the major fruit quality indicators that are widely used to describe the tomato fruits are the TSS% to measure the fruit firmness and concentration of the soluble solids in the fruit, where as the TSS% the fruit is more marketable for juice and tomato paste manufacture. The Fruits Ec and Fruit pH are used an indicator for the fruit taste quality where as they increased the fruit taste is better and more marketable.

Many Studies have concentrated on the effect of the brackish, saline water, and desalinated water. The majority have concentrated on the effect of brackish water on fruit, the researchers concluded that the fruit quality in term of TSS, EC, and pH were significantly increase as water salinity increase (Malasha *et al.,* 2008; Tantawy *et al.,* 2009; Al-Yahyai *et al.,* 2010). Al-Yahyai *et al.* (2010) found that, fruit quality in term of TSS, EC, and pH were non significantly affected by water salinity in the range of 3-6 dS/m.

2.2 Effect of Using Irrigation Water with Different Salinity Levels on Heavy Saline Soil and Plant Leaves Macronutrients Content

In the preface to the 'Special Issue: Plants and salinity', Tim Flowers (2006) emphasized that "Soil salinity has been a threat to agriculture in some parts of the world for over 3000 years; in recent times, the threat has grown". As the world population continues to increase, more food needs to be grown to feed the people. Moreover, the salinity problem has been aggravated by the requirement of irrigation for crop production in arid and semiarid environments. It is estimated that at least 20% of all irrigated lands are salt-affected (Pitman *et al*., 2002). About 17% of the cultivated land is under irrigation; yet, irrigated agriculture contributes more than 30% of the total agricultural production (Hillel, 2000). The total global area of salt-affected soils has recently been estimated to be approximately 830 million hectares (Martinez-Beltran *et al.*, 2005).

Soil salinity affects plants in different ways such as osmotic effects, specific-ion toxicity and/or nutritional disorders (Läuchli *et al*., 1990). The extent by which one mechanism affects the plant over the others depends upon many factors including the species, genotype, plant age, ionic strength and composition of the salinizing solution, and the organ in question.

The impact of using desalinated water in irrigation is going to be mainly on the soil. Several authors reported that the impact is coming from both salinity of brackish water and very low Ec water like desalinated water (Carrow *et al.*, 2008). However, irrigation-induced sodicity in soils exhibits structural problems created by certain physical processes (slaking, swelling, and dispersion of clays) and specific conditions (surface crusting and hard setting) (Shainberg *et al.*, 1984; Sumner, 1993; Qadir *et al*., 2002). Such problems affect water and air movement, plant-available water holding capacity, root penetration, seedling emergence, runoff, erosion, and tillage and sowing operations (Murtaza *et al.*, 2005). In addition, imbalances and induced deficiencies in plant available nutrients in salt-affected soils may affect plant growth adversely. The adverse effects of salinity on crop growth stem from two aspects: increasing the osmotic pressure and thereby making the water in the soil less available for the plants and specific effects of some elements or ions present in excess concentrations".

Soil salinity may inhibit plant growth for two reasons. First, the presence of salt in the soil solution reduces the ability of the plant to take up water, and this leads to reductions in the growth rate. This is referred to as the osmotic or water-deficit effect of salinity. Second, if excessive amounts of salt enter the plant in the transpiration stream there will be injury to cells in the transpiring leaves and this may cause further reductions in growth. This is called the salt-specific or ion-excess effect of salinity (Greenway et al., 1980).

The accumulation of salts in the leaves cause premature aging, reduces the supply of plant parts with nutrients and products of carbon assimilation of the fastest-growing plant parts and thus impair the growth of the entire plant. In the more sensitive genotypes salts accumulate more rapidly and because cells are not able to isolate the salt ions in vacuoles to the same extent as more tolerant genotypes, the leaves of more sensitive genotypes usually die faster (Munns, 2002; Neumann 1997) suggests that growth inhibition due to excessive salt concentration in the leaves reduces the volume of new leaf tissue in which excess salts can accumulate and therefore, in combination with the continuous accumulation of salts, it can lead to an increase in salt concentration in the tissue.

Hopkins *et al*. (2007) reported that when using irrigation water with salinity concentration below 130 ppm may cause problems for soil and plant. Very low EC water like desalinated water dilutes and/or leaches calcium and makes soil aggregates very weak and causing water infiltration problems and to overcome these problems water is treated by adding excess calcium into the water to reduce SAR and to increase water EC.

Diaz *et al.* (2013), studied the effects of the desalinated sea water and desalinated treated wastewater on the non-saline clay and heavy soil chemical properties, the study main results were that the non-saline soil EC, N, P, K, and Ca increased in the soil profile, while the soil pH decrease. While Ben Gal *et al*. (2009) has reported that the by the end of agricultural season irrigation with desalinated water (TDS 250 ppm) has decreased the soil Ec, then the blended water (TDS 800 ppm), the highest Ec was recorded for the brackish water (TDS 2000 ppm).

Several researchers have studied the effect of irrigation with different salinity level on the plant leaves macronutrient content. They concluded that the increase in water salinity significantly reduces the concentration of N, P, K, and Ca in plant leaves (Hu *et al.,* 1997; Afshari *et al*., 2011; Malasha *et al.,* 2008).

Mixing saline with non-saline water less than 3 dS/m increases the concentration of N, P, K, and Ca in plant leaves in comparison with using brackish water (Malasha *et al.,* 2008).

Chapter 3: Materials and Methods

3.1 Study Location

The research was conducted in Marj Na’aja village located to the Northern part of the Jordan Valley (32° 10′ 56.74 N, 35° 10′ 28.33 E) and about 40 km north to Jericho, and lays 270 m below sea level. The climate of the region is hot and dry in summer and warm to moderately cool in winter, based on Dier A’alla weather station (32° 13′ 00.0 N, 35° 37′ 00.0 E). Temperature ranges from 11.5 °C in the coldest moths mainly January and reaches up to 40.2 °C in July which is the hottest month in the area while, relative humidity ranges from 43% in the dry months and reach about 53% in the wet moths, total rain fall is about 281 mm / year and the rainfall season start mainly in October and extent to April and the maximum rain fall in Jan. /Feb. with 50 mm /month (www.met.jometro.gov.jo).

3.2 Greenhouse Experiment

To assess the impact of using irrigation water of different salinity levels on the soil fertility and thus will affect the qualitative and quantitative productivity of tomato crop. The experiment was conducted in field of the farmer who benefit from the desalination unit. Tomato plant, which is commonly used by farmers, and classified as moderately salt tolerant (Maas 1986) with long growth and productivity period which would gave a more clear picture about the effect of the different irrigation water of different salinity levels on the soil fertility, and could act as a model crop for saline land recovery and use of poor-quality water.

The tomato crop was planted in the green house in mid-October 2013; the soil type is clay loam with Ec 7.4 dS/m which is classified as heavy saline soil. Crop was irrigated with four types of Desalinated water. These types were raw saline water with TDS 4500 ppm (T4), desalinated water with TDS 200 ppm (T1), blended water with TDS 750 ppm (T2), and blended water with TDS 1600 ppm (T3).The randomized plot design was used, four irrigation water of different salinity treatments, each irrigation water of different salinity treatment has three replicates, each replicate consisting 7 m raw. Planting spacing was 0.8 m within rows and 0.8 m between rows (Figure 1 Field Experiment Design and Layout).

As in the greenhouse tomato commercial production, high wire system was used, tomato plants was allowed to grow vertically up to a 3.5-4.0 m high horizontal wire. A common practice of removal of full-grown leaves from below and from just above the harvest-ripe truss was done. The main reasons for leaf removal are prevention of diseases; especially as in the high wire system older leaves would touch the ground surface when not removed, obtaining faster fruit ripening and easier harvest as trusses are no longer hidden by leaves. No fertilizer were used except for iron chalets to minimize the Chlorosis effects, as the farmers don’t use the fertilizers because of the salinity of the soil and instead they use the compost (organic fertilizer) as source of nutrients and also to act as soil amendment.

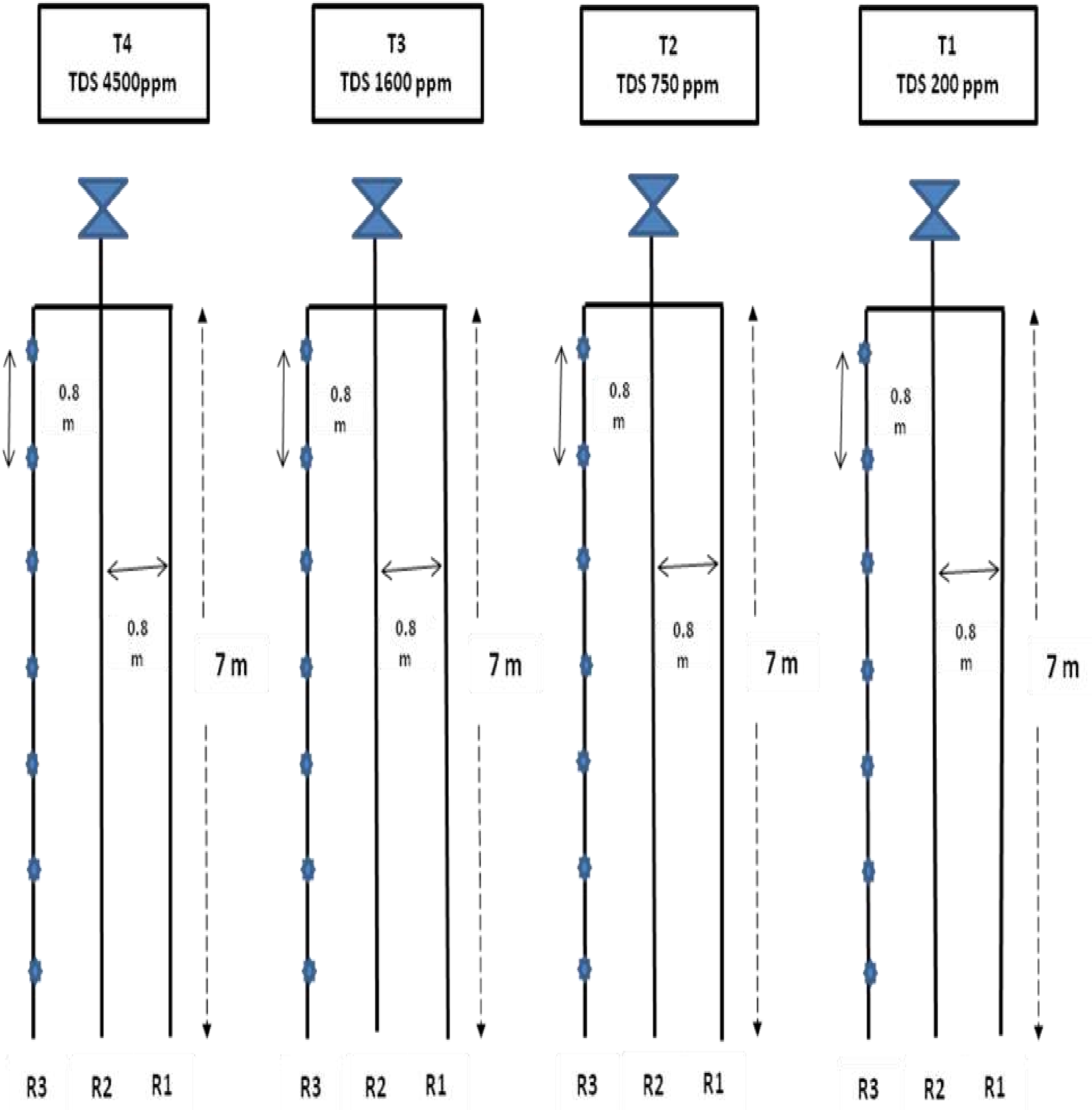

Figure 1: Field experiment design and layout for tomato crop irrigated with 4irrigation water of different salinity treatments

3.3 Irrigation Water Analysis

For each irrigation water treatment of different TDS, the chemical analysis was conducted to study the chemical properties parameters as shown in the Table 3.1.

Table 3.1: Quality of irrigation water of different salinity (T1), blended water (T2 and T3) and raw saline water (T4)

Chemical Parameter	Unit	Desalinated water with TDS 200 ppm (T1)	Blended water with TDS 750 ppm (T2)	Blended water with TDS 1600ppm (T3)	Raw saline water with TDS 4500 ppm (T4)
pH	--	7.2	7.2	7.4	7.5
EC	dS\m	0.3	1.2	2.6	7.2
P	ppm	1.0	2.7	3.3	4.2
K	ppm	24.1	129.3	149.7	337.3
Ca	ppm	4.4	47.2	65.7	125.1
Total N	ppm	12.3	16.3	19.5	28.5

3.4 Soil Analysis

To study the impact of the irrigation water of different salinity treatments on soil in the root zoon until the depth 40 cm, one soil composite sample was taken from each water treatment before and afterconducting the field experiment, and N, P, K, Ca, EC, and pH analysis has been done before and after conducting the field experiment All the Analysis were done based on ICARDA Manual (Ryan *et al.*, 2013) were the Total Nitrogen was analyzed using Kjeldahl method , the Phosphorus was Analyzed using the spectophometry method, Potassium was Analyzed using the flame photometry method , the Calcium was Analyzed using the titration method, the EC was Analyzed using the conductivity bridge method, and the pH was Analyzed using the electronic pH meter method.

3.5 Plant Morphology

To assess the impact of the treatments on the vegetative and reproductive growth, so after 40 days of planting the plants were inspected visually until the end of agricultural season (210 days). The number of flowers and fruits, plant height, leaf color (chlorosis), leaf and fruit malformation, fruit weight, fruit color, were inspected every 10 days, leaf area index was measured 5 times After 80, 110, 140, 170 and 200 days of planting. The leaf area was measured by using graph paper and the areas for three plants per each replicate were defined and divided on the total area of the ground covered by the plant. Accordingly, LAI was calculated (see eq. 1). The stems‘diameters were measured regularly every 10 days using a caliber.

3.6 Plant Leaves Analysis

After 90, 140 and 190 days of planting, 20 leaves were taken randomly from each plant, with ten leaves from the upper part of the plant and the other ten leaves from the lower the leaves the leaves had been analyzed for Total Nitrogen, Phosphorus, Potassium, and Calcium.

3.7 Fruit Quality

The fruits were analyzed for pH, TSS, and EC. Equivalent 24 composite samples were taken to test the fruit quality, by selecting two fruits from 2 different plants within each 4 treatments for the 3replicates.

Chapter 4: Results and Discussions

4.1 Introduction

The results of this research were documented based on quantitative and qualitative measurements and standard, and the results were interoperated in reference to: the actual field measurements and analysis, scientific standard, and previous literature cited, the plant growth period that expand over 180 days (30 days after planting) was divided into three growth stages development, mid, and late stage with 60 days for each stage.

4.2 Irrigation Water Quality

Data presented in Table (3.1) illustrate the water quality of the four different applied treatments namely, desalinated water with TDS 200 ppm (T1), blended water with TDS 750 ppm (T2), blended water with TDS1600 ppm (T3), and raw saline water with TDS 4500 ppm (T4). As shown in Table (3), water pH for the desalinated water of TDS 200 ppm and blended water with TDS 750 ppm were 7.2 for each, while for blended water with TDS 1600 ppm and raw saline with TDS 4500 were 7.4 and 7.5 respectively. Irrigation water EC (dS/m) was dramatically decreased from 7.2 (raw saline water TDS 4500 ppm) to 0.3 (Desalinated water with TDS 200 ppm). Irrigation water P, K, Ca, and total N were significantly decreased, the highest values was for raw saline water with TDS 4500 ppm, and the lower values was for desalinated water with TDS 200 ppm.

4.3 Effect of Irrigation Water of Different Salinity Levels on Plant Growth

4.3.1 Plant height, stem diameter, and chlorosis

Data presented in Table (4.1) illustrate the effect of water salinity on the vegetative plant growth at different growth stages i.e. plant height, stem diameter, and chlorosis. Decreasing the level of water salinity from TDS 4500 ppm to TDS 1600 ppm and from TDS 4500 ppm toTDS 750 significantly increased the plant height at different plant growth stages, blended water with TDS 1600 ppm and TDS 750 ppm gave the higher plant heights. Raw saline water with TDS 4500 ppm gave the lowest plant height. On the other hand stem diameter and chlorosis level non significantly affected due to water salinity at different plant growth stages, but the highest stem diameter were observed at both water level salinity TDS 750 and 1600 ppm, and the worst case plant chlorosis level was observed at TDS 200 ppm. The blended water of TDS 750 and 1600 ppm contain a tremendous amount of different plant macro and some micro nutrients (Table 3.1) this may act as a positive factor to supply the plant with its nutrients requirements, the raw saline water with TDS 4500 ppm have an adverse impact on the plant parameters, i.e. plant height, stem diameter and chlorosis, even of its high content of nutrients, due to the water high salinity of the soil solution that increase the osmotic pressure and the plant need more energy to uptake the nutrients, the same adverse effect was diagnosed for the desalinated water with TDS 200 ppm, this is due to its low content of nutrient and irrigating with this water may leaching part of the soil nutrient out of the root zoon.

The highest water salinity level (Raw saline water with TDS 4500 ppm) reduced plant height relative to those of non-saline water and blended water, (Romero-

Arand *et al*., 2002; Kahlaoui *et al*., 2011; and Malki *et al*., 2007), which confirm research findings. They found that plant height, stem diameter, and chlorosis decreases as water salinity increase.

Table 4.1: Effect of Irrigation Water of Different Salinity Levels on Tomato Plant Growth at Different Plant Growth Stages

Treatments	Plant Height (m)			Stem Diameter (mm)			Chlorosis (1-5)**		
	Development Stage	Mid Stage	Late stage	Development Stage	Mid Stage	Late stage	Development Stage	Mid Stage	Late stage
Desalinated water with TDS 200 ppm (T1)	1.61* b	1.83 c	2.27 c	6.67 ab	7.65 a	8.02 a	1.39 b	2.08 b	1.00 a
Blended water with TDS 750 ppm (T2)	1.75 a++	2.19 b	2.66 b	7.60 a	8.88 a	9.41 a	1.17 a	1.58 a	1.00 a
Blended water with TDS 1600 ppm (T3)	1.80 a	2.34 a	2.97 a	7.12 +++ab	8.97 a	9.39 a	1.17 a	1.58 a	1.00 a
Raw saline water with TDS 4500 ppm (T4)	1.38 c	1.68 d	2.19 c	5.07 b	7.31 a	7.75 a	1.00 a	1.50 a	1.00 a

*Values followed by the same alphabetical letter in each column do not differ significantly from each other using LSD
** Chlorosis: 1 = green, 5 = complete yellow.
++ Letters represent statistical groups (a= the highest value, C= is the lowest) ($p<0.05$)
+++ There is no significant difference

4.3.2 Fruit color, Leaves and fruits malformation

The results presented in Table (4.2) illustrate the effect of water salinity on the vegetative plant growth at different growth stages, i.e. fruits color, leave and, fruits malformation. As shown in Table (4.2) leaves malformation and fruits malformation were not affected by increasing the level of water salinity over the different plant growth stages. None of the leaves malformation neither the fruits malformations were diagnosed. Fruits color at development stage for all treatments still have the least marketable color compared with other two plant growth stages, this is due to that the plant is still in growth stage and the plant need more time for ripening. Favorite marketable color red in mid stage was significantly reached using the blended water with 1600 ppm, then blended water with 750 ppm, while using desalinated water with 200 ppm and raw saline water with 4500 ppm gave low marketable fruits color. Favorite marketable color red in late stage was significantly reached using the blended water with 1600 ppm; the same results were documented for the other three treatments. In general, at last plant growth stage using the four different irrigation water of different salinity treatments the fruit color reached favorite marketable fruits. Chlorosis, fruits and leaves malformation, and fruit color, were measured as per the scale of measuring mentioned in (Annex 5). Kahlaoui *et al*. (2011) found that, saline water significantly affect on plant morphology. These results are differing from the results found in this research where no significant differences were reported. This could be because we planted on a soil were the concentration of the macronutrients were medium (see annex 3), and so the plants didn't suffer from extreme shortage of the nutrients through the whole growth period.

Table 4.2: Effect of Irrigation Water of Different Salinity Levels on Tomato Plant Growth at Different Plant Growth Stages

Treatments	Leaves Malformation(1-5)***			Fruits Malformation (1-5)****			Fruits Color (1-4)*****		
	Development Stage	Mid Stage	Late stage	Development Stage	Mid Stage	Late stage	Development Stage	Mid Stage	Late stage
Desalinated water with TDS 200 ppm (T1)	1.00* a++	2.00 a	1.33 a	0.83 a	0.83 a	1.61 a	1.00 a	2.30 c	3.86 b
Blended water with TDS 750 ppm (T2)	1.00 a	2.00 A	1.17 a	0.94 a	0.94 a	1.64 a	1.00 a	2.67 b	3.89 b
Blended water with TDS 1600 ppm (T3)	1.06 a	2.00 A	1.08 a	1.00 a	1.00 a	1.94 a	1.50 a	3.50 a	4.00 a
Raw saline water with TDS 4500 ppm (T4)	1.11 a	2.00 a	1.00 a	1.11 a	1.11 a	2.06 a	1.00 a	2.47 +++cb	3.86 b

* Values followed by the same alphabetical letter in each column do not differ significantly from each other using LSD
*** Leaves malformation: 1= No malformation, 5= Total malformation
**** Fruits malformation: 1= No malformation, 5= Total malformation
***** Fruit Color: 1= lest marketable color green, 4 = favorite marketable color red
++ Letters represent statistical groups (a= the highest value, C= is the lowest) ($p<0.05$)
+++ There is no significant difference

4.3.3 Number of flowers per plant

Data presented in Table (4.3) illustrate the effect of water salinity on the vegetative plant growth at different growth stages i.e. number of flowers per plant.

Results show in Table (4.3) no significant differences in the number of flowers per plant at development stage for four irrigation water of different salinity treatments. All results show similar number which is 12 flowers per plant. At mid stage, no significant differences in the number of flowers/plant for raw saline water with TDS 4500 ppm, blended water with TDS 1600 ppm, and blended water with TDS 750 ppm. While there is significant difference in the number of flowers per plant between raw saline water with TDS 4500 ppm and desalinated with TDS 200 ppm, the highest value of about ten flowers per plan was reached using raw saline water with TDS 4500, and the lowest value of about six flowers per plant was reached using desalinated water with TDS 200 ppm. Late stage shows that there is a significant difference in the number of flowers per plant, around 12.5 flowers per plant, between raw saline water with TDS 4500 ppm and the other three treatments of average around eight flowers per plant. Similarly, Boamah *et al*. (2011) found that the number of tomato flowers per plant increased as water salinity levels increased.

4.3.4 Number of fruits per plant

Based on the results shown in Table (4.3), there were no significant differences in the number of fruits per plant at development stage for all irrigation water treatments, except desalinated water with TDS 200 ppm and blended water with TDS 750 ppm. At mid stage, there were no significant differences in the number of fruits per plant for four water treatments. Late stage shows that there were a significant difference in the number of fruits per plant between raw saline water with TDS 4500 ppm and the other three treatments. Kahlaoui et al. (2011) found that water salinity significantly affect number of fruits per plant were as water salinity increase number of fruits per plant, this result is compatible with the research result at the late plant growth stage.

4.3.5 Fruit weight

The results presented in Table (4.3) show that tomato fruit weight of the four treatments were significantly different as compared with each others. the trend show that the fruit weight is the highest using blended water with TDS 750 ppm (130 gm), then using blended water with TDS 1600 ppm (120 gm), then using desalinated with TDS 200 ppm (90 gm), and the lowest fruit weight (80 gm) using raw saline water with TDS 4500 ppm, this result was similar to the result found by Ben-Gal *et al.* (2009) and Patil *et al*. (2011). Both researchers stated that, saline water significantly decrease the fresh tomato fruit weight.

4.3.6 Leaf area index (LAI)

Leaf area index significantly differs between the 4 irrigation water treatments, and for all plant growth stage as shown in Table (4.3), the trend show that the leaf area index is the highest using blended water with TDS 1600 ppm (2.55 m^2/m^2) followed by blended water with TDS 750 ppm (2.3 m^2/m^2), then using desalinated water with TDS 200 ppm (1.6m^2/m^2), and the lowest leaf area index (1.3m^2/m^2) using raw saline water with TDS 4500 ppm, the LAI indicate that it has an effect the on the tomato yield productivity as the LAI increased the plant productivity increase, this result is compatible with the result found by Heuvelink *et al*. (2005) and Heuvelink (1999), they stated as the LAI have a direct effect on the yield production, were as the LAI increased the yield increased.

4.3.7 *Average production per plant*

There is no significant difference in average production per plant (kg) between using irrigation water with salinity of TDS 750 ppm and 1600 ppm as shown in Table (4.3), but there is a significant difference between these two aforementioned treatments and the desalinated water with TDS 200 ppm and raw saline water with TDS 4500 ppm.

The trend show that the highest production per plant using blended water with TDS 750 ppm (20 kg) followed by blended water with TDS 1600 ppm (18.8 kg), then using raw saline water with TDS 4500 ppm (13 kg), and the lowest value using desalinated water with TDS 200 ppm (12 kg). The research results about the production are aligned with the production quantities documented by MOA (PCBS 2007-2010), according to their reports, the average productivity for the tomato seedling under same conditions in terms of the availability irrigation water and nutrients is 25-28 kg per seedlings.

All plant parameters illustrated in Tables (4.1), (4.2), and (4.3) show that as water salinity increase up to 1600 ppm (2.5 dS/m) the plant parameter is positively affected, this means that the salinity of irrigation water up 1600 ppm could not reduce tomato yield significantly. However, irrigating tomato with saline water at TDS 4500 ppm reduced its yield significantly. It worth mentioning that, reducing irrigation water salinity from TDS 4500 ppm to TDS 1600 ppm increase tomato production by 40%, and reducing irrigation water salinity from TDS 4500 ppm to TDS 750 ppm increase tomato production by 52%. The research results were matched with the results found by Malki *et al*. (2007) and Al-Omran *et al.* (2010), they found that, blended water at 1 dS per meter gave the highest plant productivity. Contradictly Ghermandi *et al*. (2009) found that irrigation with desalinated water increases the crop yield.

Table 4.3: Effect of Irrigation Water of Different Salinity Levels on Tomato Plant Growth at Different Plant Growth Stages

Treatments	Number of flowers per plant			Number of fruits per plant			Fruit Weight (gm)			Leaf Area Index			Average Production per plant (kg)
	Development Stage	Mid Stage	Late stage	Development Stage	Mid Stage	Late stage	Development Stage	Mid Stage	Late stage	Development Stage	Mid Stage	Late stage	
Desalinated water with 200 ppm (T1)	11.56[*] a[++]	6.13 b	7.92 B	7.50 b	12.30 a	6.11 c	98.22 c	90.87 c	90.17 b	1.68 c	1.52 b	1.55 c	12.16 b
Blended water with 750 ppm (T2)	13.47 A	7.93 ab	8.50 B	10.14 a	12.87 a	7.06 [+++]bc	137.06 a	131.97 a	120.14 a	2.33 b	2.23 a	2.34 b	20.03 a
Blended water with 1600 ppm (T3)	12.08 A	8.27 ab	8.44 B	9.44 ab	13.40 a	7.56 b	123.56 b	120.47 b	112.06 a	2.62 a	2.44 a	2.59 a	18.76 a
Raw saline water with TDS 4500 ppm (T4)	11.72 A	9.83 a	12.58 A	8.11 ab	14.03 a	8.89 a	75.39 d	80.80 d	86.92 b	1.37 d	1.19 c	1.36 c	13.16 b

*Values followed by the same alphabetical letter in each column do not differ significantly from each other using LSD

[++] Letters represent statistical groups (a= the highest value, d= is the lowest) ($p<0.05$)

[+++] There is no significant difference

4.4 Effect of Irrigation Water of Different Salinity Levels on Fruit Quality

Significant variations in tomato fruit quality parameters were obtained when greenhouse-grown tomatos were irrigated with different desalinated water treatments (Table 4.4). Total soluble solids (TSS) were lowest at TDS 200 ppm and highest when plants were irrigated using 750, 1600, and 4500 ppm. The highest TSS value of about 6.4 and 6.2% were documented using Desalinated blended water of TDS 1600 ppm and raw saline water of TDS 4500 ppm respectively.

The fruit pH value (4.3) was highest under blended water with TDS 750 and 1600 ppm compared to the other treatments.Fruit EC were almost the lowest at TDS 750, 1600, and 4500 ppm, (Al-Yahyai *et al.* (2010); Tantawy et al. (2009); and kahlaoui et al. (2011)), which confirms research findings. They reported that fruit TSS and EC were positively affected as the irrigation water salinity increases, while fruit pH was negatively affected.

Table 4.4: Effect of Irrigation Water of Different Salinity Levels on Tomato Fruit Quality at Different Plant Growth Stages

	Fruit TSS %			Fruit pH			Fruit EC dS/m		
Treatments	Development Stage	Mid Stage	Late Stage	Development Stage	Mid Stage	Late Stage	Development Stage	Mid Stage	Late Stage
Desalinated water with TDS 200 ppm (T1)	4.9* a++	5.2 C	4.8 d	4.2 b	4.2 a	4.1 c	6.2 A	5.1 d	4.8 a
Blinding water with TDS 750 ppm (T2)	4.2 b	6.1 A	5.4 c	4.1 c	4.2 a	4.3 a	5.5 C	7.1 b	4.5 b
Blended water with TDS 1600 ppm (T3)	4.0 c	5.4 B	6.4 a	4.3 a	4.1 b	4.2 b	5.8 B	5.3 c	4.9 a
Raw saline water with TDS 4500 ppm (T4)	4.2 b	6.2 A	6.0 b	4.0 d	4.0 b	4.1 c	5.5 C	7.7 a	4.5 b

*Values followed by the same alphabetical letter in each column do not differ significantly from each other using LSD

++ Letters represent statistical groups (a= the highest value, d= is the lowest) ($p<0.05$)

4.5 Effect of Irrigation Water of Different Salinity Levels on Heavy Saline Soil and Plant Macronutrients (N, P, K, and Ca) Content

4.5.1 Effect of irrigation water of different salinity levels on heavy saline soil fertility

To study the effect of different irrigation water of different salinity treatments on soil fertility the soil macronutrient contents, (total N, P, K, Ca,)and also the effect on the soil EC, and pH these parameters were analyzed at the end of planting season and for each irrigation water of different salinity level.

The results presented in Table (4.5) show that, the soil macronutrients (total N, P, K, Ca, soil EC, and pH) values were 24.5 ppm, 31.25 ppm, 111 ppm, 485 ppm, 7.4, and 8.3 respectively. Before planting, total N soil content was high, P soil content was high, K soil content was low, Ca soil content was low, soil EC was high, and pH was moderately alkaline. The results were classification based on soil test interpretation guide by Marx *et al.* (1996)

4.5.1.1 Effect on total Nitrogen

The results presented in Table (4.5) show that, soil total N value was decreased from 24.5 ppm (high) to medium for the four irrigation water of different salinity treatments, the lowest total soil N content value of 10 ppm was for desalinated water with TDS 200 ppm and the highest total soil N content value of 18 ppm for the raw saline water with TDS 4500 ppm. In general, at the top soil (40 cm depth) the total N soil content increases as a result of increasing irrigation water salinity, and this is related to the increase concentration of the N as the water salinity increase as it increase from 12.3 ppm in the desalinated water and reach up to 28.5 ppm to the raw saline water (Table 3.1), and also the fact that the irrigation with desalinated cause more nutrient leaching to lower soil layers.

4.5.1.2 Effect on Phosphorus

Soil P was decreased from 31.25 ppm (high) to 22 ppm (relatively high) for blended water with TDS 750 ppm, and from 31.25 ppm to 24 ppm (relatively high) for blended water with TDS 1600 ppm, and from 31.25 ppm to 27 ppm (relatively high) for raw saline water with TDS 4500 ppm. Furthermore soil P was decreased from 31.25 ppm to 17 ppm (medium) for desalinated water with TDS 200 ppm. In general, at the top soil (40 cm depth) the P soil content increases as a result of increasing irrigation water salinity as it increase from 1.0 ppm for the desalinated water to 4.2 ppm for the raw saline water (Table 3.1), the desalinated water cause more nutrient leaching to lower soil layers the salinity.

4.5.1.3 Effect on Potassium

Soil K value was decreased from 111 ppm (low) to 17 ppm, 22 ppm, 24 ppm, and 27 ppm for desalinated water with TDS 200 ppm, blended water with TDS 750 ppm, blended water with TDS 1600 ppm and raw saline water with TDS 4500 ppm respectively. In general, at the top soil (40 cm depth) the K soil content was still low and increases as a result of increasing irrigation water salinity, and this is due to the increase of K concentration in the water with increasing the salinity as it increase from 24.1 ppm for the desalinated water to 337.3 ppm for the raw saline water (Table 3.1), and also the fact that the desalinated cause more nutrient leaching to lower soil layers.

4.5.1.4 Effect on calcium

Soil Ca value was decreased from 485 ppm (low) to 65 ppm, 78 ppm, 89.5 ppm, and 95.5 ppm for the desalinated water with TDS 200 ppm, blended water with TDS 750 ppm, blended water with TDS 1600 ppm and raw saline water with TDS 4500 ppm respectively. In general, at the top soil (40 cm depth) the K soil content was still low and increases as a result of increasing irrigation water salinityand this is due to the increase of Ca concentration in the water with increasing the salinity as it increase from 4.4 ppm for the desalinated water to 125.1 ppm for the raw saline water (Table 3.1), and also the fact that the desalinated water cause more nutrient leaching to lower soil layers. Under these conditions, the water acted as a source of nutrients that the plants need, and also enriched the soil with nutrients after irrigation.

4.5.1.5 Effect on EC

Soil EC value was decreased from 7.4 dS/m (high) to 1.87 dS/m, 3.11 dS/m, 4.13 dS/m, and 4.47 dS/m for desalinated water with TDS 200 ppm, blended water with TDS 750 ppm, blended water with TDS 1600 ppm and raw saline water with TDS 4500 ppm respectively. In general, at the top soil (40 cm depth) the soil EC was still high but decreases dramatically after planting season, and increases as a result of increasing irrigation water salinity. The soil EC was significantly influenced by the quality of water. Obviously, use of saline water resulted in a significantly higher soil EC as compared to pure or non-saline water. That increase was obviously due to a buildup of salt salinity in the root zone due to continuous supply of saline water.

Soil salinity refers to the presence of excess salts in soil water, which often results from irrigated agriculture. After the plants take up the water, the dissolved salts from irrigated water start to accumulate in the soil. Excess salts generally affect plant growth by increasing osmotic tension in the soil, making it more difficult for the plants to take up water. Excessive uptake of salts from the soil by plants also may have a direct toxic effect on the plants.

4.5.1.6 Effect on pH

As shown in Table 4.5 the Soil pH value was decreased from 8.3 (moderately alkaline) to 8.15, 8.07, 8.05, and 8.01 for desalinated water with TDS 200 ppm, blended water with TDS 750 ppm, blended water with TDS 1600 ppm, and raw saline water with TDS 4500 ppm respectively. In general, at the top soil (40 cm depth) the soil pH was still high (moderately alkaline) but decreases after planting season, and slightly decreases as a result of increasing irrigation water salinity. This may be due to the release of H^+ ions from the exchanger complex by the influence of other soluble cations that are presented and applied by saline waters (Mahrous *et al.,* 1983).

Soil pH is a measure of the soil's acidity or alkalinity, and it affects the plant indirectly by influencing the availability of nutrients and the activity of microorganisms. Nutrients are most available at pH levels between 6.5 and 7.5. Nutrients in the soil may be chemically tied up or bound to soil particles and unavailable to plants if the pH is outside this range. Individual plants have pH preferences and grow best if planted in soils that satisfy their pH requirements.

Table 4.5: Soil Macronutrients, EC and pH Before Irrigation (blank) and at the End of the Tomato Planting Season

Treatment	**Parameter$^+$**					
	N	**P**	**K**	**Ca**	**EC**	**pH**
Before irrigation (blank):	24.5	31.25	111	485	7.4	8.3
At the end of the planting season:						
Desalinated water with TDS 200 ppm (T1)	10	17	65	108	1.87	8.15
Blended water with TDS 750 ppm (T2)	13	22	78	264	3.11	8.07
Blended water with TDS 1600 ppm (T3)	15	24	89.5	393	4.13	8.05
Raw saline water with TDS 4500 ppm (T4)	18	27	95.5	395	4.47	8.01

$^+$: all parameters are in ppm, except EC (dS/m), and pH (-)

Diaz *et al*. (2013) investigated the effect of irrigating heavy non saline soil with desalinated sea water. Their results contradict with the results found in this research that they found that the soil fertility (N, P, K) increase when irrigated with desalinated water, also the soil EC, while we found that the fertility decrease. This might related to the fact that the concentration of the macronutrients (N, P, K, and Ca) in the desalinated sea water is much higher than that of the brackish water.

4.5.2 Effect of Irrigation Water of Different Salinity Levels on Plant Leaves Macronutrients Contents

Tomato plant leaves nutrients content at different plant growth stages for the four irrigation water of different salinity treatments were summarized in Figures 2, 3, 4, and 5.

4.5.2.1 Effect on Total Nitrogen

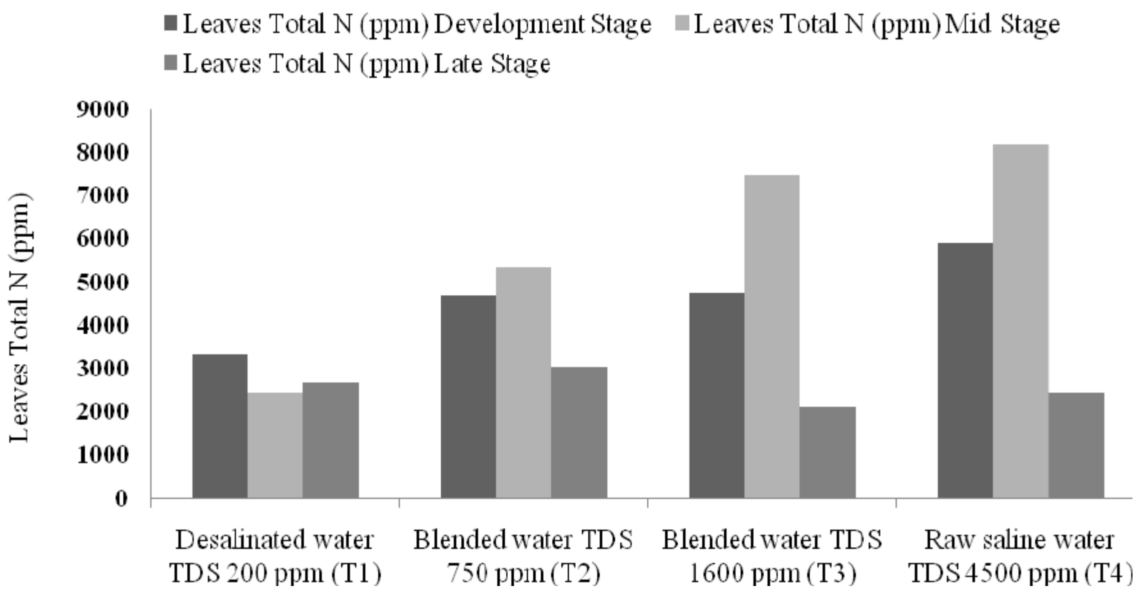

Figure 2A: Total N in tomato plant leaves at different

The results presented in Figure 3A, show that N concentration in plant leaves decreased significantly when the salinity of water decreased at development and mid plant growth stage. While at the late plant growth stage, the highest N concentration in the plant leaves was found when the plants were irrigated by blended water treatment with 750 ppm (T2). While at T3 1600 ppm and T4 4500 ppm the Total N was the lowest concentration values (annex4), this is mainly related to the fact that as the water salinity increased the plant became under more pressure lead to increase in the somatic pressure of the soil solution and plant became under stress that reduce the plant root ability from absorbing more N.

Many greenhouse studies show that under salt stress conditions the N up take by plant is highly affected, and the salinity stress cause low N accumulation in plant parts (Alam *et al*., 1989). While recent studies show that the N concentration differs with the plant organs and the growth stage and it mainly concentrated in leaves (TİRYAKİOĞLU *et al*., 2014).

The results within the same treatments T2, T3 and T4 showed that the actual trend for the N uptake by the plant, were the N concentration in the leaves increased in the development and mid stages as the plant need more N for its growth and these needs became less at the late growth stage and so the N concentration in the leaves decrease, but at T1 the N up take trend differs as the N uptake decrease in the mid and Late stage and this is related to the N leaching from the soil as N is easily leachable from the soil profile.

To support the results found, a linear regression analysis between the Total N concentration in the tomato plant leaves and the water salinity levels were conducted.

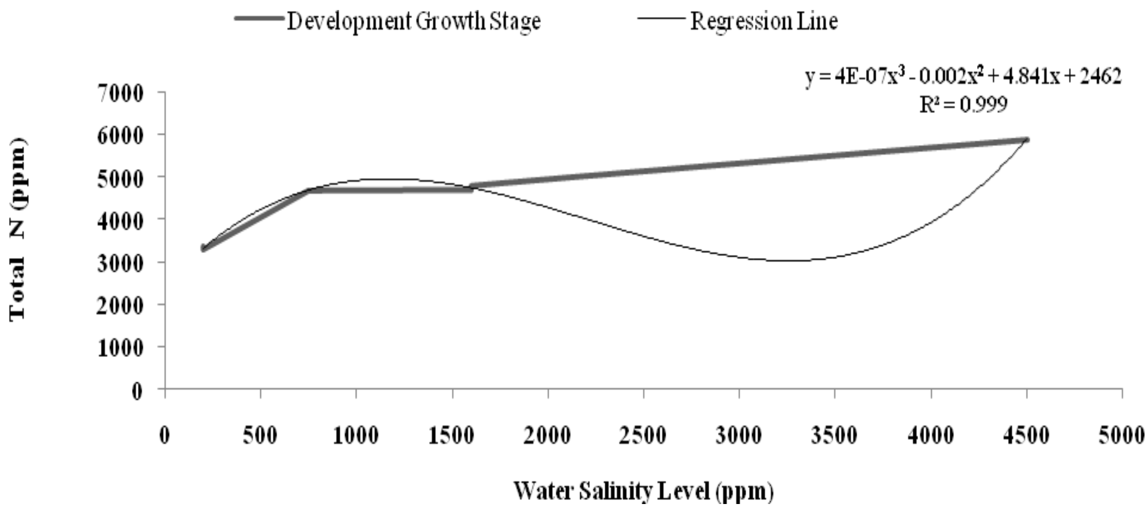

Figure 2B1: Line regression between N content in tomato plant leaves and different water salinitv levels

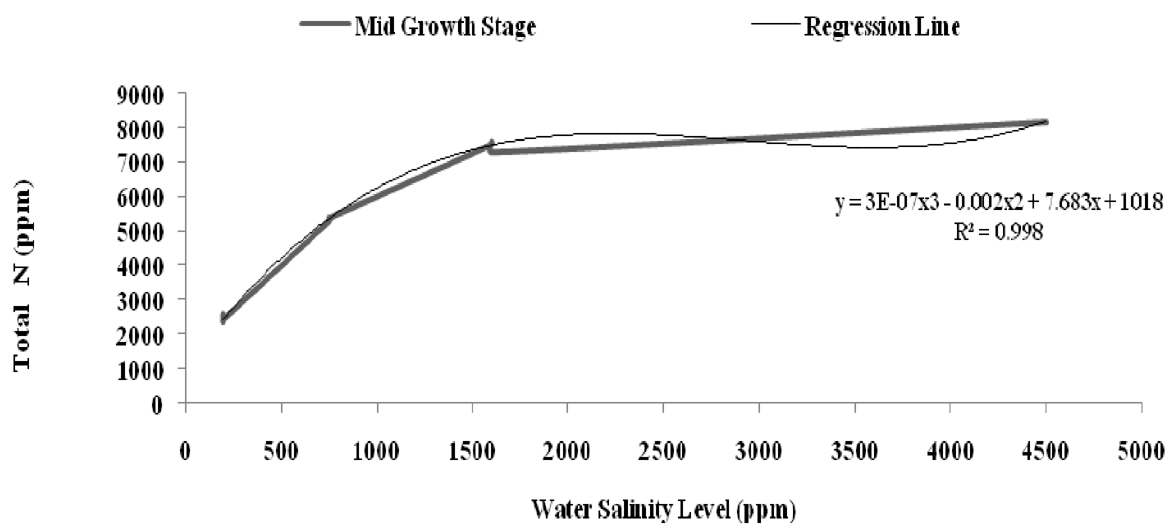

Figure 2B2: Line regression between N content in tomato plant leaves and different water salinity levels

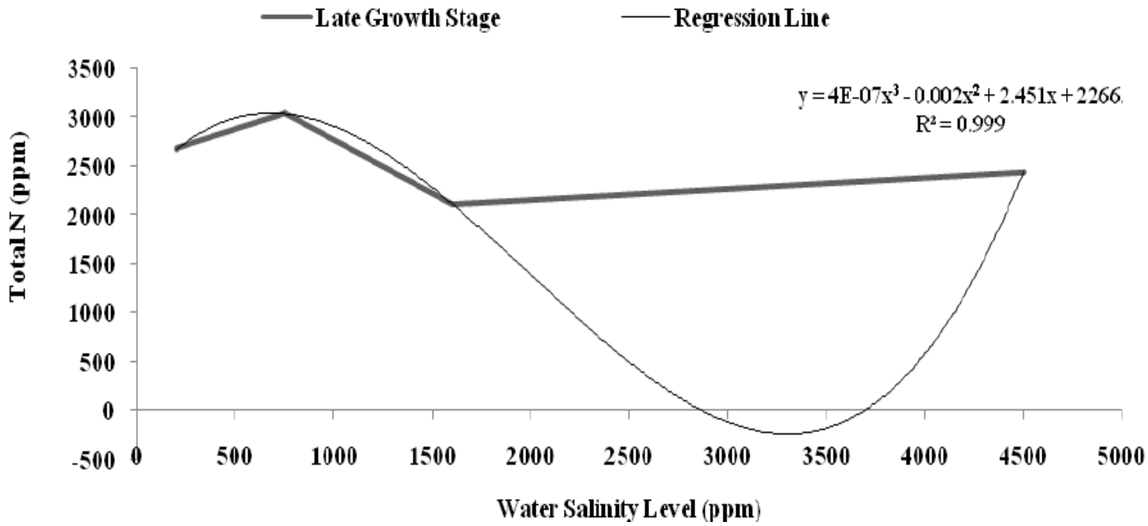

Figure 2B3: Line regression between N content in tomato plant leaves and different water salinity levels

As shown in figures 3B1, 3B2, and 3B3, the coefficient of determination (R^2 show clearly that there is a strong relation between the water salinity and the Total N concentration in the plant leaves in the three growth stages namely; development, mid, and late growth stage. The coefficient of determination equal 0.999 for the three aforementioned growth stages.

4.5.2.2 Effect on Phosphorus

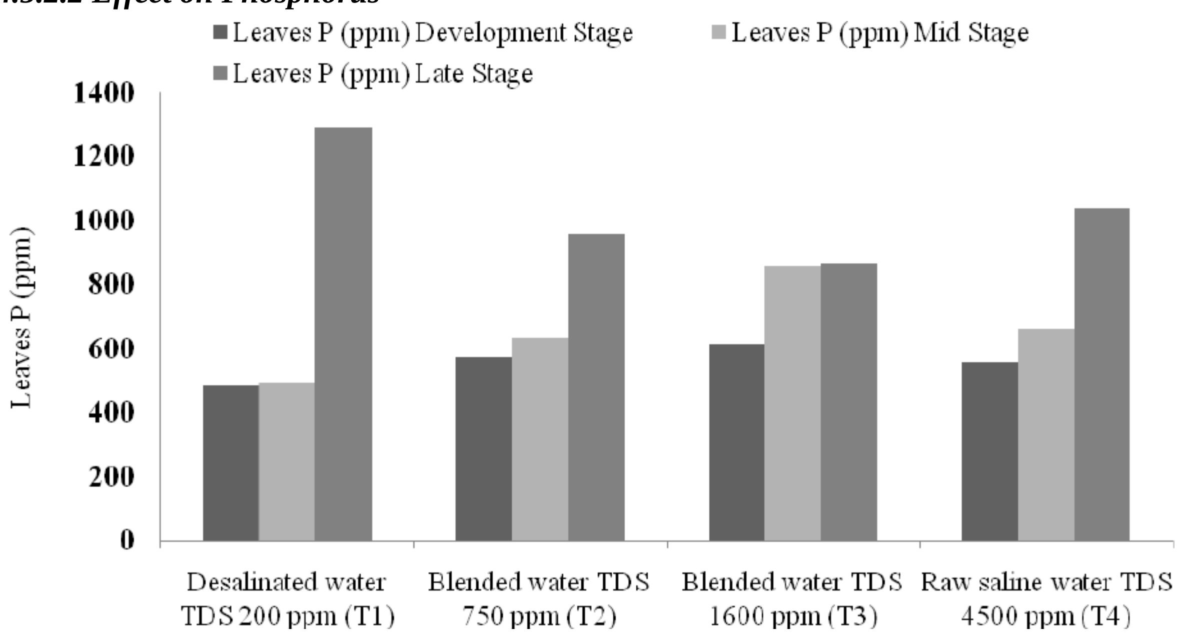

Figure 3A: P in tomato plant leaves at different plant growth stages

As shown in Figure 4A, at T1, T2, T3 ,and T4 the trend of P concentration in the tomato plant leaves at development and mid plant growth stage shows that the P concentration in the plant leaves was decreased significantly (annex 4) when the salinity of water decreased. While at the late plant growth stage the P concentration in the plant leaves was increased significantly when the salinity of water decreased. P has an important and significant role in the energy metabolism of cells, and involved in a number of anabolic and catabolic pathways, some greenhouse studies show that salinity may increase the P requirement of certain plants. Awad *et al*. (1990) found that when salinity increased, the P content in the tomato leaf increased.

Within the same treatments it was recorded that all treatments show the actual trend for the P uptake in the plant as it increased with the plant growth as the plant need more P for its growth, but we should keep in mind that the P uptake is variable and depends on the plant and experimental conditions, were some studied have indicates that the influence of salinity on P accumulation in crop plants is variable and depends on the plant and experimental conditions, sometimes the increase in water salinity decreased the P concentration in plant tissues, due to the competitive occur between P and some other ions like Cl which might affect the P uptake in tomato shoots. Also the reduction in plant P concentration increase in water salinity may result from the reduced activity of P in the soil solution due to the high ionic strength of the soil solution (Sharpley *et al.,* 1992).

To support the results found, a linear regression analysis between the P concentration in the tomato plant leaves and the water salinity levels were conducted.

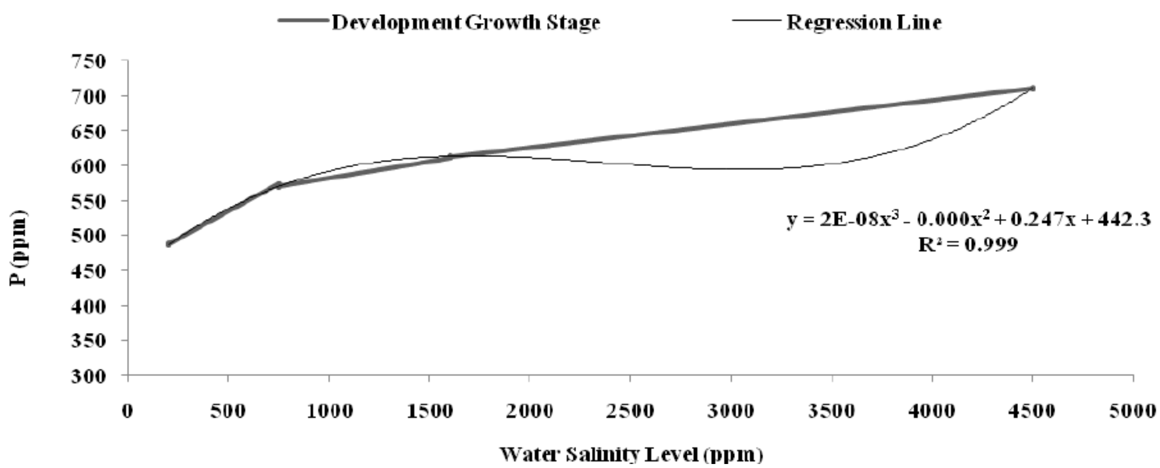

Figure 3B1: Line regression between P content in tomato plant leaves and different water salinity levels

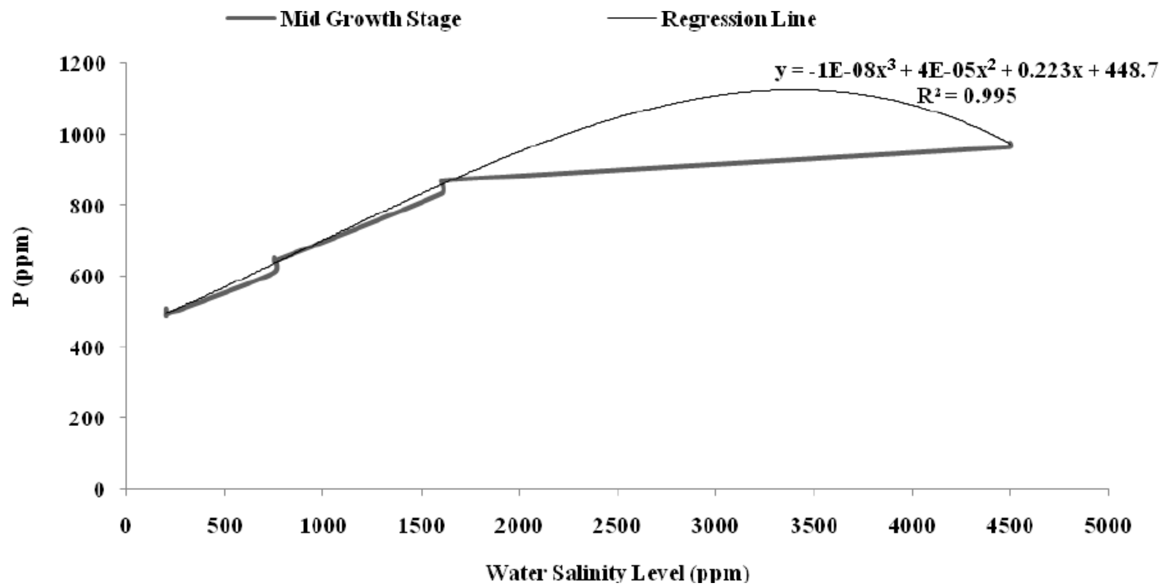

Figure 4B2: Line regression between P content in tomato plant leaves and different water salinity levels

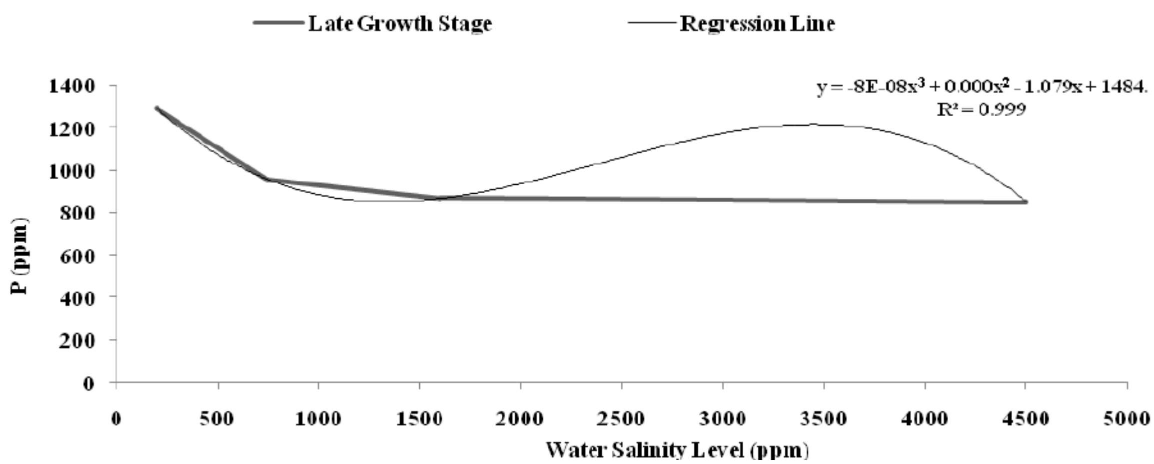

Figure 4B3: Line regression between P content in tomato plant leaves and different water salinity levels

As shown that there is a strong relation between the water salinity and the P concentration in the plant leaves in the three growth stages namely; development, mid, and late growth stage. The coefficient of determination equal 0.99 for the three aforementioned growth stages. Scientifically, P accumulation in plant leaves is also affected by the competitive forces that occur between P and some other ions like Cl which might also affect the P uptake in tomato shoots.

4.5.2.3 Effect on Potassium

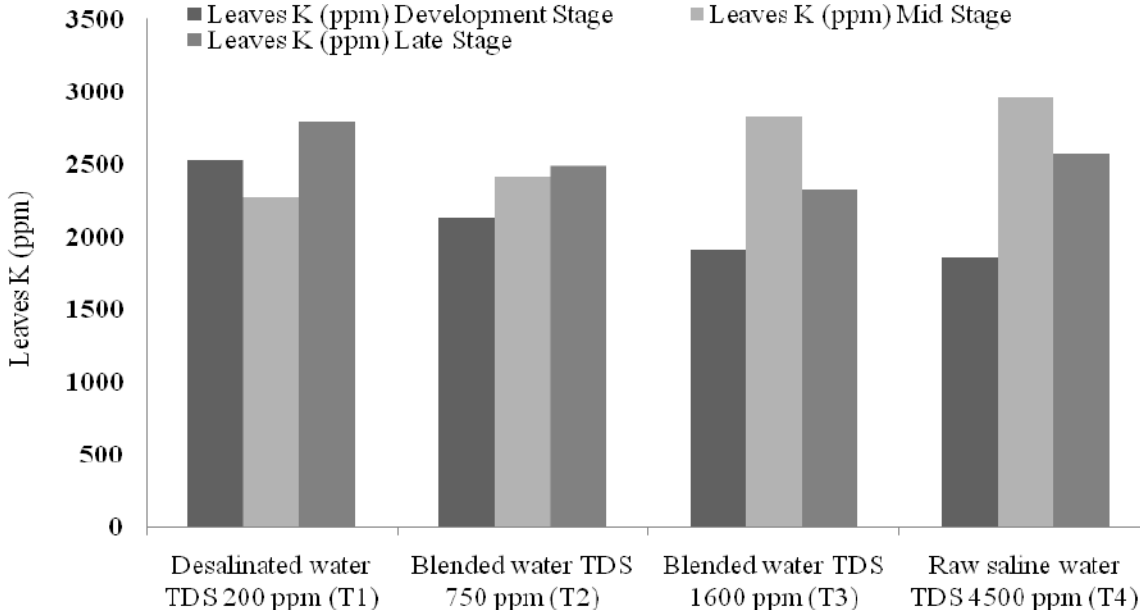

Figure 4A: K in tomato plant leaves at different plant growth stages

Figure 5A show that, at all the water treatments the trend of K concentration in the tomato plant leaves at development and late plant growth stage was that the K concentration in the plant leaves was increased significantly when the salinity of water decreased. While at the mid plant growth stage the K concentration in the plant leaves was increased significantly (annex 4) when the salinity of water increased. K is considered as an essential cytoplasmic element, because of its involvement in osmotic regulation in the plant organs as shoots, roots and leaves, K is frequently considered important under irrigation with saline water. K has a role in the osmotic adjustment under saline conditions, K also plays an important role in turgor-mediated responses such as stomatal and leaf movement. The greenhouse studies have shown that the K uptake be plant decrease as water salinity increase due to competitive process between K^+ and the Na^+ that increase as the water salinity increase (Boursier *et al.,* 1990).

Within the same treatments we find that T3 and T4 show the actual trend for the K uptake in the plant as it increased with the plant growth as the plant need more K for its growth and these needs became less at the late growth stage and so the plant needs of K decrease and the K concentration in the leaves decrease, but at T1and T2 the K up take increased with the growth stages, and this could be because of the competitive process between K and the Na that increase as the water salinity increase.

To support the results found, a linear regression analysis between the K concentration in the tomato plant leaves and the water salinity levels were conducted.

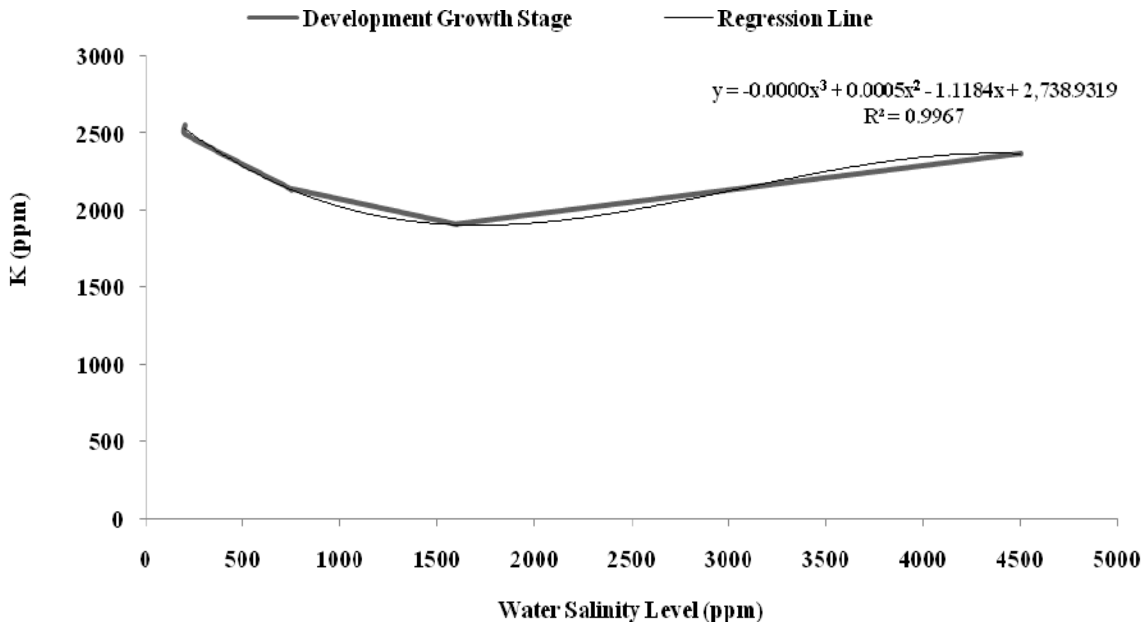

Figure 4B1: Line regression between K content in tomato plant leaves and different water salinity levels

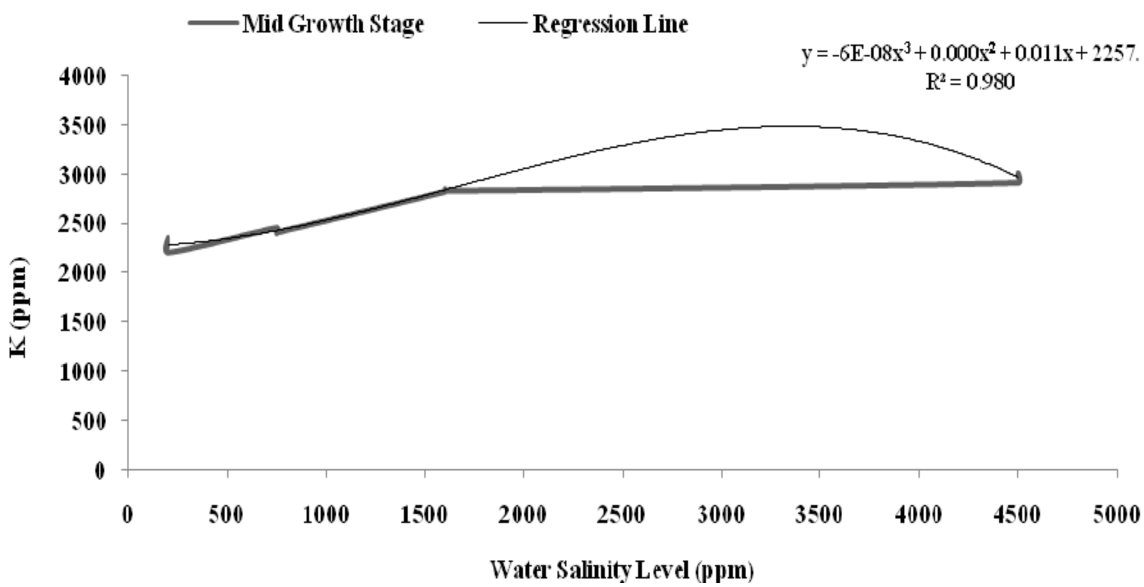

Figure 4B2: Line regression between K content in tomato plant leaves and different water salinity levels

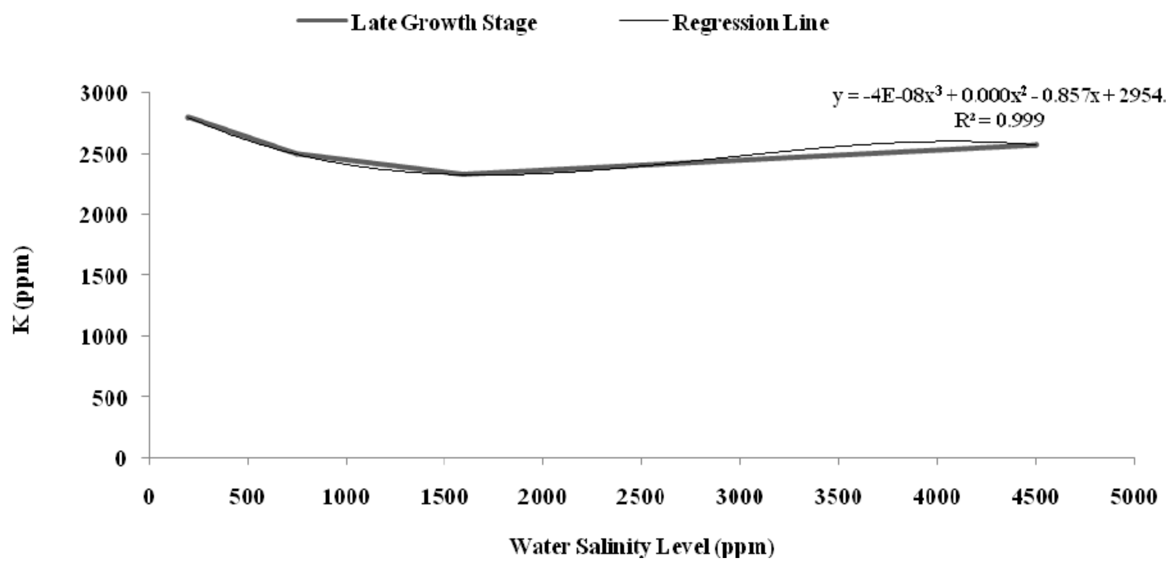

Figure 4B3: Line regression between K content in tomato plant leaves and different water salinity levels

As shown in figures 5B1, 5B2, and 5B3, the coefficient of determination (R^2) show clearly that there is a strong relation between the water salinity and the K concentration in the plant leaves in the three growth stages namely; development, mid, and late growth stage. The coefficient of determination equal 0.99 for the three aforementioned growth stages.

Scientifically, the K uptake by plant is directly related to the plant needs for K, where the K is considered as an essential cytoplasm element, and involves in the osmotic regulation in the plant organs such as shoots, roots and leaves. Furthermore, K plays an important role in turgor-mediated responses such as stomatal and leaf movement.

4.5.2.4 Effect on Calcium

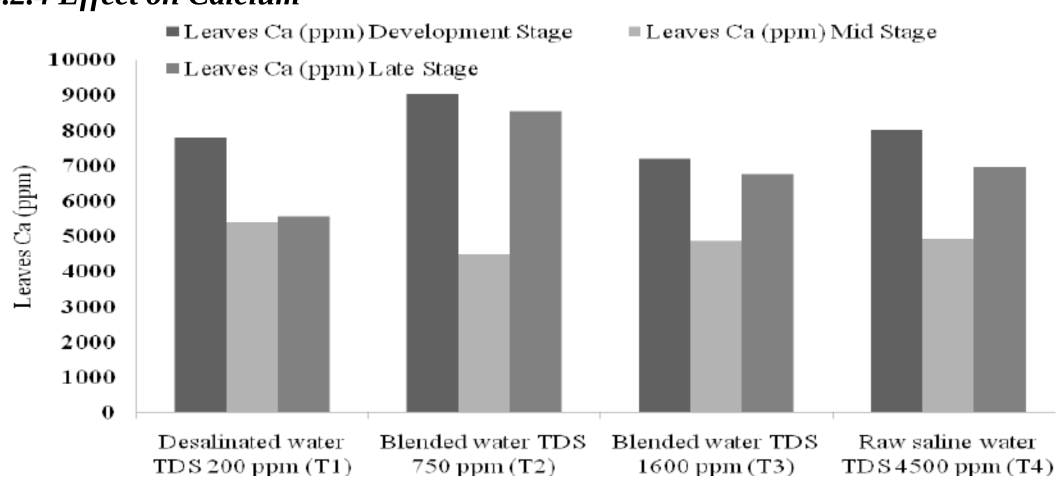

Figure 5A: Ca in tomato plant leaves at different plant growth stages

As shown in Figure 6A, the trend of Ca concentration in the tomato plant leaves at development and late plant growth stage, the highly significant Ca concentration (annex 4) in the plant leaves was found when the plant irrigated by blended water with TDS 750 ppm (T2), while at mid plant growth the Ca concentration in the plant leaves was decreased significantly in all water treatment without any consideration of the water salinity.
As water salinity increases, the requirement of plants for Ca increases as it plays a vital nutritional and physiological role in plant metabolism. Ca, which like K is also an essential mineral nutrient, helps in maintaining the cell membrane integrity. The uptake of Ca from the soil solution is affected by many elements as ion interactions, precipitation, and increases in ionic strength that reduce the activity of Ca and all these factors could increase or decrease the Ca uptake under saline conditions (Lahaye *et al.*, 1971).
To support the results found, a linear regression analysis between the K concentration in the tomato plant leaves and the water salinity levels were conducted.

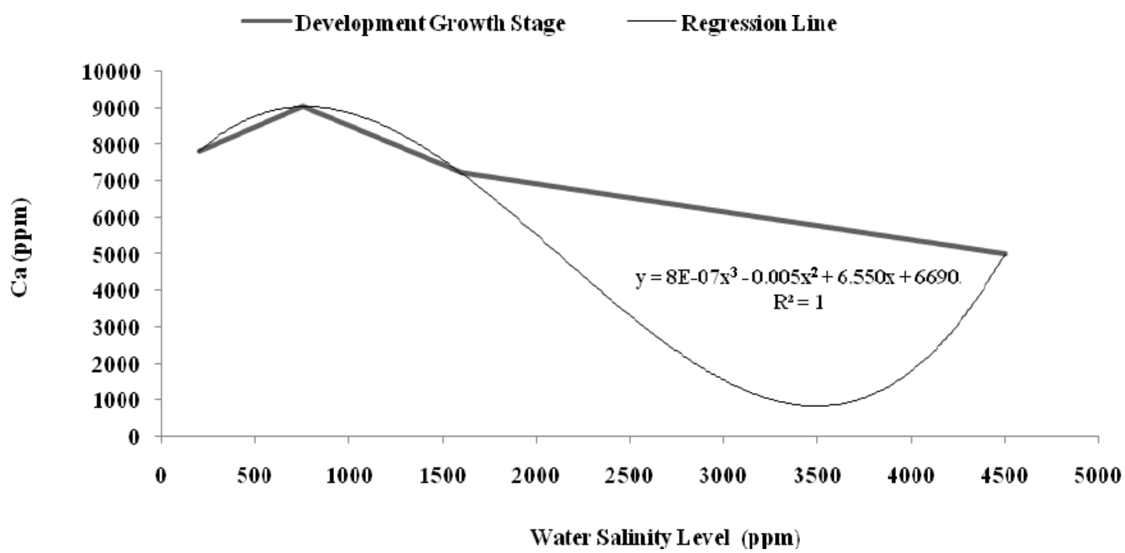

Figure 5B1: Line regression between Ca content in tomato plant leaves and different water salinity levels

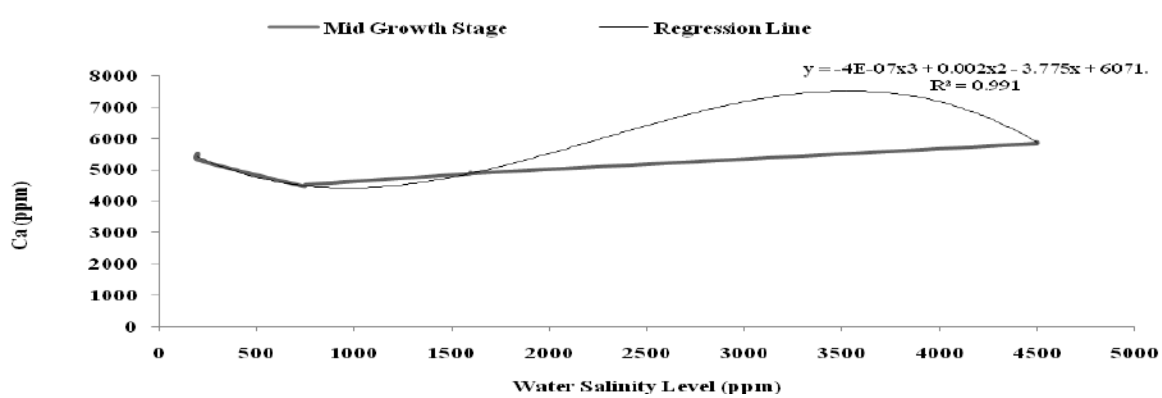

Figure 5B2: Line regression between Ca content in tomato plant leaves and different water salinity levels

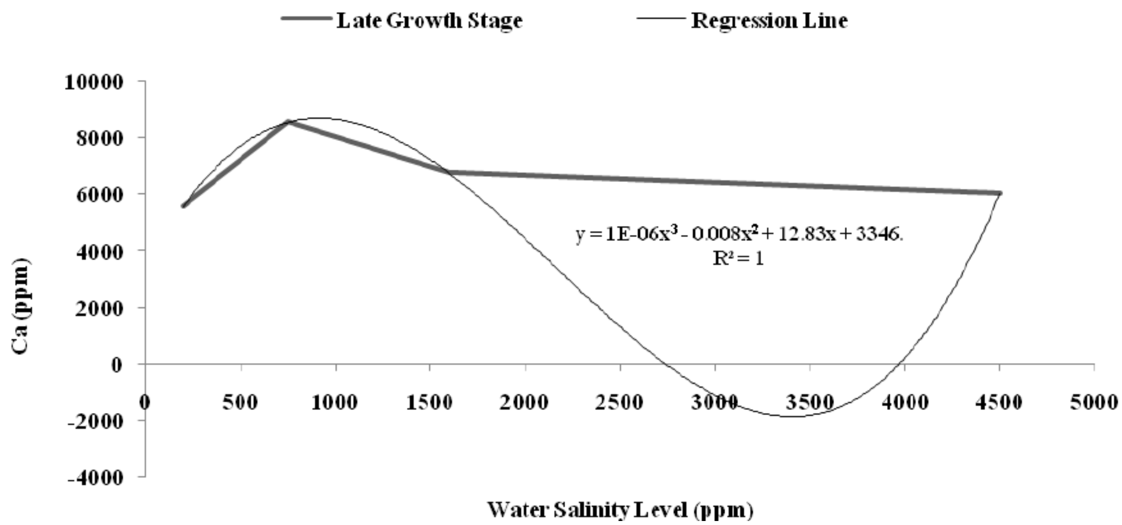

Figure 5B3: Line regression between Ca content in tomato plant leaves and different water salinity levels

As shown in figures 6B1, 6B2, and 6B3, the coefficient of determination (R^2) show clearly that there is a strong relation between the water salinity and the Ca concentration in the plant leaves in the three growth stages namely; development, mid, and late growth stage. The coefficient of determination is more than 0.99 for the three aforementioned growth stages.

Scientifically, the uptake of Ca from the soil solution is affected by many elements as ion interactions, precipitation, and increases in ionic strength that reduce the activity of Ca and all these factors could increase or decrease the Ca uptake under saline conditions.

In General, the nutrient concentration in the irrigation water has an effect on the availability of nutrients in soil solution which will has its effect on plant growth and yield quantity and quality, this is mostly true for the desalinated water with TDS 200 ppm (T1), but for the saline raw water 4500 ppm (T4) it is not the limiting factor as the nutrient were available with high concentration but due to the osmatic stress in the soil solution were the water and nutrient uptake through the root system became difficult and leads to reduction in the yield, also we shouldn't neglect the fact that irrigation with water of different salinity might had effect the soil physical properties which has an influence on the availability of the nutrients in the soil solution and the ability of the plant nutrient uptake (Francisco *et al.,* 2013).

Furthermore Hu *et al*. (1997) founded that K, Ca, and P concentration decreased in plant leaves as irrigation water salinity increased, but the total N concentration was not affected by the water salinity. Also (Afishari *et al.,* 2011, and Malasha *et al.,* 2008) stated the same results for K, P, N, and Ca.

4.6 Effect of heavy saline soil nutrient content on plant productivity and fruit quality

The soil considered as a neutral factor as soil nutrient content (N, P, K, Ca) were the same for all water treatments at the beginning of the cultivation season, but as shown in Table (4.6) the soil nutrient content values were decreased at the end of the agricultural season, the reduction in the soil fertility would be the only indicator to show the Effect of irrigation water of different salinity levels on the soil nutrient content and the effect of the changes in the soil fertility on the tomato plant productivity and the fruit quality.

As shown in Table (4.6) when the soil was irrigated with desalinated water with TDS 200 ppm the soil macronutrients content, the plant production, and the fruit quality were the least (except for the fruit pH were the pH increase as the water salinity decrease), this may due to the low nutrient content in the irrigation water and the nutrient leaching from the soil profile which led to low nutrient content in the soil solution.

It is clearly shown that, the highest results for both the plant production and fruit quality were at irrigation with blended water of TDS 750 ppm and TDS 1600 ppm, this result can be explained as the irrigation water and the soil macronutrients content act as a source of nutrition and gave the plant a plenty source of essential macronutrients elements compared with the other two treatments namely irrigation with desalinated water of TDS 200 ppm and 4500 ppm.

The production of tomato plant under irrigation with TDS 4500 ppm was the minimum compared with the other two treatments TDS 750 ppm and 1600 ppm, but the fruit quality indicators TSS and EC were the highest, this can be explained in a way that the plant under this treatment (TDS 4500 ppm) was exposed to higher stress due to irrigation with raw saline water, thus gave a high preferable fruit TSS and EC.

The fruit quality in terms of TSS and average fruit production had showed different responses as the TSS showed negative response with the increase in the water desalination, except for the blended water with TDS 1600 ppm which gave lower results than blended water with TDS 750 ppm, the average fruit production response positively with the increase in the water desalination except for the pure desalinated water with TDS 200 ppm, these result aligned with the results found by Tantawy *et al*. (2009).

Table 4.6: Effect of Heavy Saline Soil Nutrient Content on Plant Productivity and Fruit Quality

Treatment	Soil Parameter[+]						Fruit Parameters			
	N	P	K	Ca	EC	pH	Average Production /plant	pH	TSS	EC
Before irrigation (blank):	24.5	31.25	111	485	7.4	8.3				
At the end of the planting season:										
Desalinated water with TDS 200 ppm (T1)	10	17	65	108	1.87	8.15	12.16 b	4.2 a[++]	5.2 c	5.1 d
Blended water with TDS 750 ppm (T2)	13	22	78	264	3.11	8.07	20.03 a	4.2 a	6.1 a	7.1 b
Blended water with TDS 1600 ppm (T3)	15	24	89.5	393	4.13	8.05	18.76 a	4.1 b	5.4 b	5.3 c
Raw saline water with TDS 4500 ppm (T4)	18	27	95.5	395	4.47	8.01	13.16 b	4.0 b	6.2 a	7.7 a

[+]: all parameters are in ppm, except EC (dS/m), TSS (%) and pH (-)
[++]: Letters represent statistical groups (a= the highest value, d= is the lowest) ($p<0.05$).

Chapter Five: Conclusions and Recommendations

In this research the results show that irrigating heavy saline soil with desalinated water has detrimental effects on the soil fertility, tomato plant productivity and fruit quality as it decrease dramatically as water salinity decrease. Therefore, negative aspects had been alleviated by irrigating with blended water that has positive effects on soil fertility and tomato plant productivity and fruit quality.

5.1 Conclusions

- The heavy saline soil macronutrient content (N, P, K, and Ca) decrease with decreasing the water salinity, the decrease ranges from 45-77% and the highest decrease was for the Ca.
- Desalinated water, and raw saline water, gave the lowest level of tomato crop production with only 12 kg, and 13 kg respectively; when it is grown in heavy saline soils this effect can be alleviated by irrigation with blended water.
- Irrigating heavy saline soil with raw saline water and blended water with TDS 750 ppm gave the best fruit quality results, while desalinated water gave the lowest fruit quality

5.2 Recommendations

Based on the results of this research several issues still need to be further investigated. Specifically it is recommended to:

- Plant more than one season to measure the long effect of desalinated water on the fertility of heavy saline soil and plant growth.
- Measure the effect of the desalinated water on the soil and water movement in heavy saline soil within soil profile.
- Study the amount of fertilizers needed under different water salinity levels.

References

Afshari H., Ashraf S., Ebadi H., Abbaspour S J. H., Daliri M. S., and Toudar S. R., (2011). Study of the effects irrigation water salinity and pH on Production and Relative Absorption of some elements nutrient by the tomato plant. American Journal of Applied Sciences 8 (8): 766-772.

Al- Omran A., (2008). Effect of saline water and Drip Irrigation on tomato Yield in sandy calcareous soil amended with natural conditions, 2nd international salinity forum.

Alam S.M., Naqvi S.S.M., Azmi A.R., (1989). Effect of salt stress on growth of tomato. Pak J SciIndust Res 32:110.

Al-Omran A. M., Al-Harbi A. R., Wahb-Allah M. A., Nadeem M., AL-Eter A., (2010). Impact of irrigation water quality, irrigation systems, irrigation rates and soil amendments on tomato production in sandy calcareous soil. Turk J Agric For 34 (2010) 59-73 © TÜB? TAK doi: 10.3906/tar-0902-22.

Al-Yahyai R., Al-Ismaily S. and Al-Rawahy S. A., (2010). Growing Tomatoes under Saline Field Conditions and the Role of Fertilizers. A Monograph on Management of Salt-Affected Soils and Water for Sustainable Agriculture, 83-88.

Andrea G., Messalem R., (2009). The advantages of NF desalination of brackish water for sustainable irrigation: The case of the Arava Valley in Israel. Desalination and Water Treatment 10 (2009) 101-107.

Awad A.S., Edwards D.G., and Campbell L.C., (1990). Phosphorus enhancement of salt tolerance of tomato Crop Sci 30:123.

Bar, Y., Apelbaum, A., Kafkafi, U. & Goren, R. (1997). Relationship between chloride and

Ben-Gal A., Yermiyahu U., and Cohen S., (2009). Fertilization and Blended Alternatives for Irrigation with Desalinated Water. Journal of Environmental Quality. 38:529-536.

Boamah P. O., Sam-Amoah L. K. and Onumah J., (2011). Effect of Salinity Level of Irrigation Water on the Yield of Tomato. ARPN Journal of Agricultural and Biological Science. VOL. 6, NO. 8.

Boursier P. and Lauchli A., (1990). Growth responses and mineral nutrient relations of salt-stressed sor-ghum. Crop Sci 30:1226.

De Pascale S., Maggio A., Ruggiero C., Barbieri G. (2003a) Growth, water relations, and ion content of field grown celery under saline irrigation (Apium graveolens L. var. dulce [Mill.] pers.). Journal of the American Society for Horticultural Science, 128, 136-143, ISSN 0003 1062.

De Pascale S., Ruggiero C., Barbieri G., Maggio A. (2003b) Physiological response of pepper (Capsicum annuum L.) to salinity and drought. Journal of the American Society for Horticultural Science, 128, 48-54, ISSN 0003 1062.

Díaza Francisco J., Tejedora M., Jiménez C., Grattan S. R., Dorta M., Hernández J. M., 2012. The imprint of desalinated seawater on recycled wastewater: Consequences for irrigation in Lanzarote Island, Spain. Agricultural Water Management 116 (2013) 62-72.

Döll, P., and Siebert. S. 2002. Global modeling of irrigation water requirements. Water Resour.Res., doi: 10.1029/2001WR000355.

El Malki S., El Habbani R., Tahaikt M., Zeraouli M. and Elmidaoui A., (2007). The desalination of salt water destine to irrigation by electro dialysis and its effects on the germination, growth and seed yield of wheat (Triticum durum Desf. Var. Karim). African Journal of Agricultural Research Vol. 2 (2) pp. 041-046.

Estefan g., Sommer R., and Ryan J., (2013), Methods of Soil, Plant, and Water Analysis. A manual for West Asia and North Africa region third edition.

Experimental Botany, 46, 171-179, ISSN 0098 8472.

Flowers T. 2006. Preface. J. Exp. Bot. 57, p. iv.

Garcia A, Rizzo C.A., Ud-Din J., Bartos S.L., Senadhira D., Flowers T.J., Yeo A.R. 1997. Sodium and potassium transport to the xylem are inherited independently in rice, and the mechanism of sodium: potassium selectivity differs between rice and wheat. Plant Cell Environ. 20:1167-1174.

Greenway H., Munns R. 1980. Mechanisms of salt tolerance in nonhalophytes. Annu. Rev. Plant Physiol. 31:149-190.

Hatfield, J.L., Sauer, T.J., Prueger, J.H., 2001. Managing soils to achieve greater water use efficiency. Argon. J. 93, 271–280.

Heuvelink E. (1999). Evaluation of a Dynamic Simulation Model for Tomato Crop Growth and Development. Annals of Botany 83: 413-422.

Heuvelink E., Bakker M.J., Elings A., Kaarsemaker R. and Marcelis L.F.M., (2005). Effect of Leaf Area on Tomato Yield. Proc. IC on Greensys. Eds.: G. van Straten et al., Acta Hort. 691.

Hillel D. 2000. Salinity Management for Sustainable Irrigation. The World Bank, Washington, D.C.

Hopkins B.G., Horneck D.A., Stevens R. G., Ellsworth J.W., Sullivan D.M., (2007). Managing Irrigation Water Quality for Crop Production in the Pacific North West, University of Idaho, PNW 597-E.

Hu Y. and Schmidhalder U., (1997). Interactive Effects of Salinity and Macronutrients on Wheat. Jornal of Plant Nutrition 20 (9), 1196-1182.

Kahlaoui B., Hachicha1 M., Rejeb S., Rejeb M.N., Hanchi B. and Misle E., (2011). Effects of Saline Water on Tomato under Subsurface Drip Irrigation: Nutritional and Foliar Aspect. J. Soil Sci. Plant Nutr. 11 (1): 69 - 86.

Kahlaoui B., Hachicha M., Rejeb, S., Misle E., Rouaissi M., Rejeb M. N. and Hanchi B., (2011). Effect of Saline Water on Tomato under Subsurface Drip Irrigation: Yield and Fruit Quality. Australian Journal of Basic and Applied Sciences, 5(9): 517-529.

Kijne, J.W., Barker, R., Molden, D., 2003. Water Productivity in Agriculture: Limits and Opportunities for Improvement. CABI Publishing, Wallingford, UK, 332 pp.

Lahaye P.A. and Epstein E., (1971). Calcium and salt tolerance by bean plants. Plant Physiology 25:213.

Läuchli, A. and Epstein E. 1990. Plant responses to saline and sodic conditions. In K.K. Tanji (ed). Agricultural salinity assessment and management. ASCE manuals and reports on engineering practice No, 71. pp 113–137 ASCE New York

Maggio, A., De Pascale, S., Fagnano, M. & Barbieri, G. (2011). Saline agriculture in Mediterranean environments. Italian journal of Agronomy, 6, 36-43, ISSN 1125 4718.

Mahrous F.N., Mikkelson D.S. and Haffaz A.A., (1983). Effect of soil salinity on the electro chemical and chemical kinetics of some plant nutrients in submerged soils. Plant and Soil. 75: 45 5-472.

Maksimović, I., Belić, S., Putnik-Delić, M. & Gani, I. (2008). The effect of sodium concentration in the irrigation water on pea yield and composition. Proceedings of ECO Conference 2008, Novi Sad, pp. 231-235, ISBN 97886 83117 356.

Maksimović, I., Putnik-Delić, M., Gani, I., Marić, J. & Ilin, Ž. (2010). Growth, ion composition, and stomatal conductance of peas exposed to salinity. Central European Journal of Biology, 5, 682-691, ISSN 1895 104X.

Malasha N.M., Alia F.A., Fatahallaa M.A., khatab E. A., Hatem M.K., Tawfic S.,(2008). Response of tomato to irrigation with saline water applied by different irrigation methods and water management strategies. International Journal of Plant Production 2 (2), April 2008. ISSN: 1735-6814 (Print), 1735-8043.

Martinez B., J., and Koo-Oshima. S. 2006. FAO Expert Consultation on Water Desalination for Agricultural Applications, Rome (Italy). 26–27 Apr 2004/FAO, Rome (Italy). FAO Land and Water Discussion Paper, no. 5; Land and Water Development Div. 48 p. ISSN 1729-0554.

Martinez-Beltran J, Manzur C.L. 2005. Overview of salinity problems in the world and FAO strategies to address the problem. In: Proceedings of the International Salinity Forum, Riverside, California, April 2005, pp. 311–313.

Marx E.S., Hart J., and Stevens R.G., (1996). Soil Test Interpretation Guide. Oregon State University.

MoA (2010), Agricultural Sector Strategy" Shared Vision 2011-2013". Ministry of Agriculture, July 2010.

Muhammad S., Akbar M., and Neue H.U., (1987). Effect of Na/Ca and Na/K ratios in saline culture solution on the growth and mineral nutrition of rice (Oryza sativa L.). Plant Soil 104:57.

Munns R (2002) Comparative physiology of salt and water stress. Plant Cell Environ. 25, 239-250.

Munns R. 1993. Physiological processes limiting plant growth in saline soil: some dogmas and hypotheses. Plant Cell Environ. 16:15-24.

Murat T., Yildirim M., Karablik S., (2014). Macronutrient concentration and remobilization in spring wheat organs during grain filling Turk. J Agric For 38: 488-494.

Neumann, P. (1997). Salinity resistance and plant growth revisited. Plant, Cell and Environment, 20, 1193-1198, ISSN 0140 7791.
nitrate and its effect on growth and mineral composition of avocado and citrus plants. Journal of Plant Nutrition, 20, 715-731, ISSN 0190 4167.

Pardossi, A., Bagnoli, G. Malorgio, F. Campiotti, C.A. & Tognoni, F. (1999). NaCl effects on celery (Apium graveolens L.) grown in NFT. Sciencia Horticulturae, 81, 229–42, ISSN 0304 4238.

Patil V.C, Al-Gaadi K.A., and Wahb-Allah M.A., (2011). Effects of quality of water and irrigation regimes on temporal changes in soil EC and yield of greenhouse-grown bell pepper (Capsicum annum L.). The Second Global Workshop on Proximal Soil Sensing - Montreal.

PCBS (2009), Agricultural Statistics, Palestinian Central Bureau of Statics, April 2010.

Pimentel, D., Bailey, O., Kim, P., Mullaney, E., Calabrese, J., Walman, L., Nelson, F., Yao, X., 1999. Will limits of the Earth's resources control human numbers? Environ. Sustain. Dev. 1, 19–39.

Pitman MG. and A. Läuchli. 2002. Global impact of salinity and agricultural ecosystems. In: Salinity: Environment – Plants – Molecules, A. Läuchli and U. Lüttge (Eds.). Kluwer Academic Publishers, Dordrecht, pp. 3–20.

PWA (2012), Annual water status report 2011. Palestinian water Authority, December, 2012.

Rijsberman, F.R., 2006. Water scarcity: fact or fiction? Agric. Water Manage. 80, 5–22.

Romero-Aranda R., Soria T, and Cuartero J., (2002). Greenhouse Mist Improves Yield of Tomato Plants Grown under Saline Conditions. J. Amer. Hort. Sci.127: 644-648.

Savvas, D. & Lenz, F. (2000). Effects of NaCl or nutrient-induced salinity on growth, yield, and composition of eggplants grown in rockwool. Scientia Horticulturae, 84, 37-47, ISSN 0304 4238.

Sharpley A.N., Meisinger J.J., Power J.F., and Suarez D.L., (1992). Root extraction of nutrients associated with long-terms soil management. In: B. Steward, ed. Advances in Soil Science. Berlin: Springer-Verlag: 151-217.

Shiklomanov, I.A. 1997. Assessment of water resources and water availability in the world, comprehensive assessment of the freshwater resources of the world. Stockholm Environment Institute, Stockholm.

Silveira, J.A.G., Melo, A.R.B., Viégas, R.A. & Oliveira, J.T.A. (2001). Salinity-induced effects on nitrogen assimilation related to growth in cowpea plants. Environmental and

Tantawy A. S., Abdel-Mawgoud A. M. R., El-Nemr M.A. and Chamoun Y. G., (2009). Alleviation of Salinity Effects on Tomato Plants by Application of Amino Acids and Growth Regulators. European Journal of Scientific Research, ISSN 1450-216X Vol.30 No.3 (2009), pp.484-494, © EuroJournals Publishing, Inc.

Wahid, A., Hameed, M. & Rasul, E. (2004). Salt-induced injury symptom, changes in nutrient and pigment composition and yield characteristics of mungbean. International Journal of Agricultural Biology, 6, 1143–52, ISSN 1560 8530.

Yermiyahu U., Ben Gal A. S. C., Shemer. D., Golan D.R., and Bar Tal A. 2007a. Irrigation of crops with desalinated water. Report submitted to Chief Scientist, Israel Ministry of Agriculture and Rural Development. Project # 301-00527-05, 15 pp.

Yermiyahu, U., Tal A., Ben-Gal A., Bar-Tal A., Tarchisky J., and Lahav O. 2007b. Rethinking desalinated water quality and agriculture. Science 318:920–921.