Faculty of Graduate Studies

Master Program in Water and Environmental Sciences

Impact of Irrigation with Desalinated Brackish Water on the Productivity and Fruit Quality of Tomato Crop Planted in Heavy Saline Soil at Marj Na'aja Village

تأثير الري بالمياه المالحة المحلاة على إنتاج وجودة ثمار البندورة المزروعة في التربة المالحة في منطقة مرج نعجة

MSc. Program in Water and Environmental Science

Prepared by

Ibtisam I.O. Abu Alhaija

Student ID: 1125227

Supervisor

Dr. Nidal Mahmoud

Date of Defense: March 2015

This Thesis was Submitted in Partial Fulfillment of the Requirements for the Master Degree in Water and Environmental Science from the Faculty of Graduate Studies - Birzeit University- Palestine

Impact of Irrigation with Desalinated Brackish Water on the Productivity and Fruit Qualityof Tomato Crop Planted in Heavy Saline Soil at Marj Na'aja Village

By

Ibtisam I.O. Abu Alhaija (1125227)

This thesis was prepared under the supervision of Dr. Nidal Mahmoud and has been Approved by all members of the examination committee

Dr. Nidal Mahmoud (Supervisor)

.....

Dr. Maher Abu-Madi (Member)

.....

Dr. Ziad Mimi (Member)

.....

Date of Defense: March 2015

The findings, interpretations and conclusions expressed in this study, do not necessary express the views of Birzeit University, the views of the individual members of M.Sc. Committee or the views of their respective employers.

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.

TABLE OF CONTENTS

Acknowledgment……. iii

List of Figures……..... viii

List of Tables…… ix

Abstract…… x

الملخص……... xiii

Abbreviations……... xvi

Chapter One: Introduction…… 1

1.1 Background…… 1

1.2 Research Hypothesis…… 3

1.3 Research Objectives……..…….. 3

1.4 Thesis Out line…….. 4

Chapter Two: Literature Review…….. 5

2.1 Effect of Using Different Irrigation Water of Different Salinity Levels on Productivity and Quality of Tomato Plant……... 5

2.1.1 Effect on Tomato Plant productivity……..... 6

2.1.1.1 Effect of Brackish Water on Tomato Plant Productivity……..... 7

2.1.1.2 Effect of Desalinated Water on Tomato Plant Productivity……. 8

2.1.2 Effect on Tomato Fruit Quality……... 9

2.2 Effect of Using Different Irrigation Water of Different Salinity Levels on Soil and Plant Nutrients Content…… 10

Chapter Three: Materials and Methods ……. 18

3.1 Study Location…… 18

3.2 Greenhouse Experiment …… 19

3.3 Irrigation Water Analysis……... 22

3.4 Soil Analysis……... 23

3.5 Plant Morphology……... 23

3.6 Plant Leaves Analysis…….. 24

3.7 Fruit Quality……... 24

3.8 Statistical Analysis……. 24

Chapter Four: Results and Discussion……. 25

4.1 Introduction……..... 25

4.2 Irrigation Water and Soil Chemical Properties……. 25

4.3 Effect of Irrigation Water of Different Salinity Levels on Plant Growth..... 25

4.3.1 Effect of Irrigation Water of Different Salinity Levels on Plant Height, Stem Diameter, and Chlorosis……. 25

4.3.2 Effect of Irrigation Water of Different Salinity Levels on Fruit Color, Leaves and Fruits Malformation…… 27

4.3.3 Effect of Irrigation Water of Different Salinity Levels on Number of Flowers per Plant……..…… 30

4.3.4 Effect of Irrigation Water of Different Salinity Levels on Number of Fruits per Plant. ……..…… 30

4.3.5 Effect of Irrigation Water of Different Salinity Levels on Fruit Weight……... 31

4.3.6 Effect of Irrigation Water of Different Salinity Levels on Leaf Area Index…. 31

4.3.7 Effect of Irrigation Water of Different Salinity Levels on Average Production per Plant……. 32

4.4 Effect of Irrigation Water of Different Salinity Levels on Fruit Quality…… 35

4.5 Effect of Irrigation Water of Different Salinity Levels on Heavy Saline Soil and Plant Nutrients Content…… 36

4.5.1 Effect of Irrigation Water of Different Salinity Levels on Heavy Saline Soil Macronutrients Content……..…… 36

4.5.1.1 Effect on Total Nitrogen……...…… 36

4.5.1.2 Effect on Phosphorus…… 37

4.5.1.3 Effect on Potassium…….. 37

4.5.1.4 Effect on Calcium……. 38

4.5.1.5 Effect on EC……. 38

4.5.1.6 Effect on pH……. 39

4.5.2 Effect of Irrigation Water of Different Salinity Levels on Plant Macronutrients Content…….. 41

4.5.2.1 Effect on Total Nitrogen……... 41

4.5.2.2 Effect on Phosphorus…… 44

4.5.2.3 Effect on Potassium…….. 47

4.5.2.4 Effect on Calcium……. 51

4.6 Effect of Soil Nutrient Content on Plant Productivity and Fruit Quality ……. 54

Chapter Five: Conclusions and Recommendations…….. 57

5.1 Conclusions…… 57

5.2 Recommendations…….. 57

References…… 58

Annexes…… 67

Annex (1) SPSS Data Results……...…….. 67

Annex (2) Tomato Plant Irrigation Water Requirements…….……. 91

Annex (3) Soil Test Interpretation Guide……. 92

Annex (4) Tomato Plant Leaves Nutrients Content at Different Plant Growth Stages 93

Annex (5) Chlorosis, Malnutrition of Leaves, Malnutrition of Fruits, and Fruit Color Key…… 94

Annex (6) Research Setup Photos…… 95

List of Figures

Figure1: Control Points at Which Salt Transport is Regulated…… 14

Figure 2: Field Experiment Design and Layout……. 21

Figure 3A: Tomato Plant Leaves N Analysis in ppm at Different Plant Growth Stages 41

Figure 3B1: Regression Relation Between Total N in Tomato Plant Leaves and Different Water Salinity Levels at Development Growth Stage …… 42

Figure 3B2: Regression Relation Between Total N in Tomato Plant Leaves and Different Water Salinity Levels at Mid Growth Stage …… 43

Figure 3B3: Regression Relation Between Total N in Tomato Plant Leaves and Different Water Salinity Levels at Late Growth Stage …… 43

Figure 4A: Tomato Plant Leaves P Analysis in ppm at Different Plant Growth Stages. 44

Figure 4B1: Regression Relation Between P in Tomato Plant Leaves and Different Water Salinity Levels at Development Growth Stage …… 45

Figure 4B2: Regression Relation Between P in Tomato Plant Leaves and Different Water Salinity Levels at Mid Growth Stage ……. 46

Figure 4B3: Regression Relation Between P in Tomato Plant Leaves and Different Water Salinity Levels at Late Growth Stage ……. 46

Figure 5A: Tomato Plant Leaves K Analysis in ppm at Different Plant Growth Stages. 47

Figure 5B1: Regression Relation Between K in Tomato Plant Leaves and Different Water Salinity Levels at Development Growth Stage …… 49

Figure 5B2: Regression Relation Between K in Tomato Plant Leaves and Different Water Salinity Levels at Mid Growth Stage …… 49

Figure 5B3: Regression Relation Between K in Tomato Plant Leaves and Different Water Salinity Levels at Late Growth Stage……. 50

Figure 6A: Tomato Plant Leaves Ca Analysis in ppm at Different Plant Growth Stages 51

Figure 6B1: Regression Relation Between Ca in Tomato Plant Leaves and Different Water Salinity Levels at Development Growth Stage …… 52

Figure 6B2 Regression Relation Between Ca in Tomato Plant Leaves and Different Water Salinity Levels at Mid Growth Stage …… 52

Figure 6B3: Regression Relation Between Ca in Tomato Plant Leaves and Different Water Salinity Levels at Late Growth Stage ……. 53

List of Tables

Table 3.1: Quality of Desalinated Water (T1), Blended water (T2 and T3) and Raw Saline Water (T4)……... …… 22

Table 4.1: Effect of Irrigation Water of Different Salinity Levels on Tomato Plant Growth at Different Plant Growth Stages…… 27

Table 4.2: Effect of Irrigation Water of Different Salinity Levels on Tomato Plant Growth at Different Plant Growth Stages …… 29

Table 4.3: Effect of Irrigation Water of Different Salinity Levels on Tomato Plant Growth at Different Plant Growth Stages …… 34

Table 4.4: Effect of Irrigation Water of Different Salinity Levels on Tomato Plant Growth at Different Plant Growth Stages …… 35

Table4.5: Soil Nutrients Before Planting and at the End of Planting Season…… 40

Table 4.6: Effect of Heavy Saline Soil Nutrient Content on Plant Productivity and Fruit Quality…..... 56

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 selected blending ratio were selected first based on the MoA recommendation to the farmers to irrigate with 750 ppm water concentration as at this ratio most of the crops can tolerate this salinity level and by this concentration the amount of water that is produced

from the desalinated unit can be increased, while the 1600 ppm is the salinity threshold for the tomato.

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.

الملخص

تعتبر ملوحة الآبارالزراعية مشكلة كبرى تواجه القطاع الزراعي في فلسطين، في العقود الثلاثة الماضية زادت ملوحة الآبارالزراعية من 570 ملجرام/لتر في العام 1967 لتصل إلى 4500 في العام 2012، وفي بعض الأماكن (الآبار القريبة من البحر الميت) تصل الملوحة إلى 19000 ملجرام/لتر، تعتبر ملوحة المياه في منطقة أريحا ما زالت تحت السيطرة ولكن وبسبب الزراعة المكثفة ، والضخ الجائر من أبار المياه، إضافة إلى الاستخدام المفرط للأسمدة والمبيدات فمن المتوقع تفاقم المشكلة ما لم يتم اتخاذ إجراءات حاسمة.

عام 2012 قامت وزارة الزراعة بتركيب وحدة تحليه للمياه المالحة بسعة إجمالية قدرها 60 متر مكعب/ساعة من المياه العذبة بملوحة تقدر ب 200 ملجرام/لتر ليتم استخدامها في المجال الزراعي فقط لري الأراضي الزراعية في قرية مرج نعجة التي تقع على بعد 40 كيلومتر من الشمال إلى مدينة أريحا.

هدف البحث هو تقييم استخدام المياه المحلاة بدرجات مختلفة وتأثيرها على خصوبة التربة الطينية المالحة و إنتاجية و نوعية ثمار محصول البندورة.

تم اجراء البحث اعتمادا على فرضية ان ري التربة الطينية المالحة باستخدام المياه المحلاه قد يكون له تاثير على خصوبة التربة مما سيكون له اثر سلبي على انتاجية ونوعية ثمار محصول البندورة ولكنه من الممكن معالجة هذا التاثير باستخدام مياه مخلوطة بنسب معينه والتي تم اعتمادها من خلال وزارة الزراعة للتركيز 750 ملجرام/ لتر والتي حددتها الوزارة كون هذه الملوحة تناسب معظم انواع الزراعات- وكذلك فانها ستؤدي الى زيادة كمية المياه المحلاة الناتجة من محطة التحلية، بينما الملوحة 1600 ملجرام/لتر فهي الحد الاقصى للملوحة الذي يمكن ان تتحمله البندورة قبل ان تبدأ في خسارة الانتاج.

تم إجراء البحث خلال الموسم الزراعي الشتوي (2014/2013) حيث تمت زراعة الاشتال في شهر تشرين اول في بيت بلاستيكي في منطقة مرج نعجة، استخدمت أربعة معاملات لنوعية المياه في البحث وقد كانت T1 المياه المحلاة بتركيز ملوحة 200 ملجرام/لتر و معاملتين من المياه المخلوطة T2 بتركيز ملوحة 750ملجرام/لتر و T3 بتركيز 1600 ملجرام/لتر والمعاملة الأخيرة T4 المياه المالحة الخام بتركيز 4500 ملجرام/لتر.

أظهرت النتائج الرئيسية للبحث ما يلي :

ان الري بالمياه المحلاه بتركيز 200 ملجرام/لتر لها تاثير حاد على خصوبة التربة الطينية المالحة وقد ظهر هذا جليا عند مقارنة تركيز العناصر الكبرى في التربة قبل وبعد زراعة ثمار البندورة حيث انخفض تركيز النيتروجين من 24.5 200 ملجرام/لتر الى 10 ملجرام/لتر، الفسفور نقص من 31.25 ملجرام/لتر الى 17 ملجرام/لتر، البوتاسيم نقص من 111 ملجرام/لتر الى 65 ملجرام/لتر، والكالسيوم انخفض من 485 ملجرام/لتر الى 108 ملجرام/لتر، بينما عند الري بالمياه المالحة فان خصوبة التربة اعطت اعلى نتائج في نهاية الموسم الزراعي لثمار البندورة.

إنتاج ثمار البندورة كان الاعلى عند الري بالماء المخلوط بتركيز 750ملجرام/لتر (20كجم/ شتله) تليها الري بالمياه المخلوطة بتركيز 1600 ملجرام/لتر (18.8 كجم/ شتله)، ثم الري بالمياه المالحة الخام بتركيز 4500 ملجرام/لتر (13 كغم/ شتله)، وأقلها إنتاجا كان عند الري بالمياه المحلاة بتركيز 200 ملجرام/لتر (12 كغم/ شتله).

تعتبر كميات الانتاج عند الري بالمياه المخلوطة متوائمة مع كميات الانتاج الحقيقية، حيث ان متوسط انتاجية الشتله -حسب السجلات الزراعية الموثقة في وزارة الزراعة- يبلغ 25 – 28 كغم /شتله وذلك ضمن الظروف المشابهة من حيث الري وتوفر العناصرالغذائية. أما فيما يتعلق بنتائج جودة ثمار

محصول البندورة، فقد تبين أن اجمالي المواد الصلبة السائله (TSS) كانت ألاقل عند 200 ملجرام/لتر والاعلى عندما كان تروى النباتات باستخدام المياه المالحة بتركيز املاح 4500 ملجرام/لتر تليها المياه المخلوطة بتراكيز 750 و 1600 ملجرام/لتر.

النتيجة الرئيسية التي يمكن استنتاجها من هذا البحث أن الري بالمياه المحلاة لها تأثير سلبي على خصوبة التربة الطينية المالحة وعلى إنتاجية وجودة ثمار محصول البندورة، الا أنه يمكن التخفيف من هذه الاثار من خلال الري بالمياه المخلوطة بتركيز 750ملجرام/لتر و بتركيز 1600 ملجرام/لتر حيث تعطي أعلى إنتاجية لمحصول البندورة وكذلك ثمار ذات جودة عالية.

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

Given current demographic trends and future growth projections, as much as 60% of the global population may suffer water scarcity by the year 2025 (Pimentel *et al*., 1999; Rijsberman, 2006). However, water-scarce countries will have to rely more on the use of non-conventional water resources to partly alleviate water scarcity. Non-conventional water resources are either generated as a product of specialized processes such as desalination or need suitable pre-use treatment and/or appropriate soil–water–crop management strategies when used for irrigation (Oweis *et al*., 2000; Hatfield *et al*., 2001; Kijne *et al*., 2003). In water-scarce environments, such water resources are accessed through the desalination of seawater and highly brackish groundwater, the harvesting of rainwater and the use of irrigation consist of wastewater, agricultural drainage water, and groundwater containing different types of salts. It is evident that water-scarce countries are not able to meet their food requirements using the conventional and non-conventional water resources available within their boundaries.

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).

1.4 Thesis Out line

The basic structure of this thesis is organized in five chapters:

Chapter 1: gives an introduction along with a background information, problem definition and study objectives.

Chapter 2: summarizes the literature review related to previous studies.

Chapter 3: deals with the methodology used to achieve the objectives of the study.

Chapter 4: explains the findings, results and discussion

Chapter 5: concludes the results of the study and suggested recommendations.

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. The use of desalinized water as a source of irrigation water for agriculture is on the rise in many countries in the world (Yermiyahu *et al.*, 2007b). Since it is estimated that agricultural irrigation water is responsible for 87% of global water consumption (Shiklomanov, 1997; Döll *et al.*, 2002), the current freshwater resources may soon be insufficient to meet the growing demand for food. 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 effects of a saline soil are two-fold: there are effects of the salt outside the roots, and there are effects of the salt taken up by plants.

The salt in the soil solution (the "osmotic stress") reduces leaf growth and to a lesser extent root growth, and decreases stomatal conductance and thereby photosynthesis (Munns,

1993). The cellular and metabolic processes involved are in common to drought-affected plants. The first effects of soil salinity, especially when it comes to low and moderate salt concentrations, can be attributed to the increase of osmotic value of the soil solution (Munns *et al.,* 1986). With the increasing salinity of soil solution, uptake of water through the root system becomes more difficult which leads to decreased evapotranspiration and yield.

There are several reasons why evapotranspiration decreases with increase in soil salinity. Due to decreased accessibility of water to the root system root growth is reduced which leads to a reduction in the total absorption area for water uptake. At the same time, total leaf area e.g. transpiration surface is reduced. As one of the mechanisms by which plants protect their cells from harmful effect of high concentration of salts is dilution, then increasing of water retention in the tissues of the plant further reduces transpiration. These factors reduce the efficiency of water usage and ultimately result in reduction of vegetable growth and yield.

The vegetation period is shortened, water regime of plants is disrupted and the uptake and distribution of essential elements in both semi-controlled and field conditions is altered (Maksimovic *et al*., 2008; Maksimovic *et al*., 2010).

The rate at which new leaves are produced depends largely on the water potential of the soil solution, in the same way as for a drought-stressed plant. Salts themselves do not build up in the growing tissues at concentrations that inhibit growth: meristematic tissues are fed largely by the phloem from which salt is effectively excluded, and rapidly elongating cells

can accommodate the salt that arrives in the xylem within their expanding vacuoles. So, the salt taken up by the plant does not directly inhibit the growth of new leaves.

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.

Roots must exclude most of the Na+ and Cl- dissolved in the soil solution or the salt will gradually build up with time in the shoot and become so high that it kills it. To prevent salt building up with time in the shoot, roots should exclude 98% of the salt in the soil solution, allowing only 2% to be transported in the xylem to the shoots. This value of 2% can be calculated from the following equation:

The concentration at which NaCl accumulates in the shoot depends on the salt concentration in the soil solution, the percentage of salt taken up by roots, and the percentage of water retained in the leaves:

$$[NaCl]_{shoot} = NaCl]_{soil} \times \frac{\%\ \text{salt taken up}}{\%\ \text{water retained}} \qquad \text{.....Eq.1}$$

Plants retain only about 2% of the water they transpire, i.e. they take up about 50 times more water from the soil than they retain in their shoot tissues.

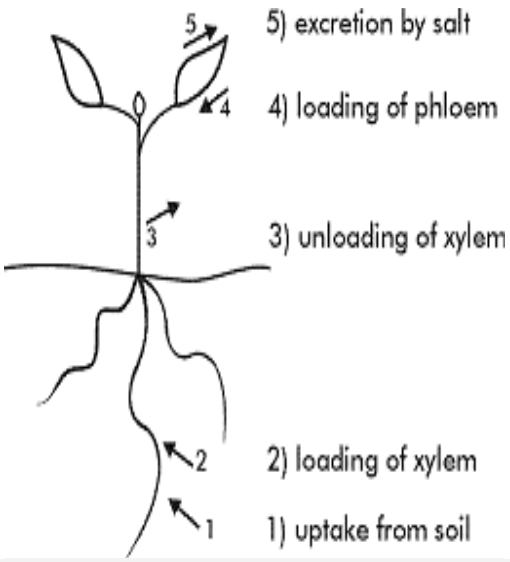

Figure (1) Control points at which salt transport is regulated. These are: 1. selectivity of uptake from the soil solution, 2. loading of the xylem, 3. removal of salt from the xylem in the upper part of the plant, 4. loading of the phloem and 5. excretion through salt glands or bladders. For a salt tolerant plant growing for some time in a soil solution of 100 mM NaCl, the root concentrations of Na^+ and Cl^- are typically about 50mM, the xylem concentration about 5 mM, and the concentration in the oldest leaf as high as 500 mM(Munns et al., 2002).

Control of salt transport into and through the plant takes place at five sites in the plant (Fig. 1). Control occurs in the root cortex, at the loading of the xylem, at the retrieval from the xylem in upper parts of the roots. These three processes serve to reduce the transport to the leaves. Control in the shoot occurs by the exclusion of salt from the phloem sap flowing to meristematic regions of the shoot. An additional mechanism occurs in most halophytes: specialised cells to excrete salt from leaves. However, halophytes also rely on the first four mechanisms to reduce the flux of salt to the leaves – excretion is an additional backup for plants growing in very saline site, and for perennial species.

Exclusion is particularly important for perennial species whose leaves may live for a year or more. For these species there is greater

need to regulate the incoming salt load than for annual species whose leaves may live for only one month.

There are contributory features that function to maintain low rates of salt accumulation in leaves. High shoot/root ratios and high intrinsic growth rates (Pitman, 1984), and absence of an apoplastic pathway in roots (Garcia *et al.,* 1997) all will serve to reduce the rate at which salt enters the transpiration stream and accumulates in the shoot.

Under the conditions of salt stress, the uptake of nitrogen is often disrupted and numerous studies have shown that excess salts can reduce the accumulation of nitrogen in plants (Pardossi *et al*.,1999, Silveira *et al.,* 2001, Wahid *et al*., 2004). Increase in uptake and accumulation of Cl- is accompanied by a reduction in the concentration of NO3- in eggplant (Savvas *et al*., 2000). There are authors who have attributed this reduction to the antagonism between Cl- and NO3- (Bar *et al.,* 1997) and those who explain it by reduced water uptake (Lea-Cox *et al.,* 1993). The rate of nitrate uptake or interactions between NO3- and Cl- is associated with tolerance of examined plant species to salts. Kafkafi *et al*. (1992) found that tomato and melon varieties tolerant of salts have a higher flow rate of NO3- ions than more sensitive varieties.

Level of salinity does not affect necessarily the overall uptake of nitrogen by plants which may continue to accumulate nitrogen in the presence of excess salts despite a reduction in yield of dry matter. With the increase in soil salinity, total removal of nitrogen through the yield often decreases.

The final impact of salinity of soil solution on the concentration of phosphorus in plants depends heavily on plant species, phase of ontogenesis, the type and level of salinity and

concentration of phosphorus that is already present in the soil (Grattan *et al.*, 1999).

In most cases, excess of salts in soil solution leads to a reduction in phosphorus concentration in the tissues of plants, but the results of some studies show that salinity may increase but that does not affect the uptake and accumulation of phosphorus (Sonneveld *et al.*, 1999, Kaya *et al*. 2001). Reduced uptake of phosphorus can also be a consequence of the strong influence of sorption processes that control the concentration of phosphorus in the soil and low solubility of Ca-P minerals (Marschner, 1995).

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).

The cropping pattern in the study region is mainly vegetables and some date palm and field crops, the total cultivated lands equal 111.3 hectare in which 93% of it is cultivated by vegetables. Despite that the agriculture is the main economic activity in the study region, it faces many constrains like, low land quality, water salinity, the low productivity of the crops, low Fruit quality. These constrains affect negatively the marketing and economical value of cultivated vegetable crops (mainly tomato and cucumber), and to overcome these constrains, some wealthy farmers had shift from growing vegetables to another crops that are soil and water salinity resistance crops such as date palm trees.

In the past there were 6 wells in Maraj Na'aja village that were used for irrigation (before 1975). All of these wells are now suffering from salinity problems at different levels, and these days only two out of six wells are used for irrigation. One of these two wells, number

20-17/011, which has the highest salinity level with 4500 ppm, was equipped by water desalination unit to produce 60 m^3/h of high quality water with 640 ppm salinity level. The desalinated water is currently used by farmers to irrigate their farm lands.

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).

The selected blending ratio were selected based on first on the MoA recommendation to the farmers to irrigate with 750 ppm water concentration as most of the crops can tolerate

this salinity level and by this concentration the amount of water that is produced from the desalination unit can be increased, secondly the 1600 ppm is the salinity threshold for tomato crop.

The tomato plants were irrigated every 2-3 days during the growing season (7 months) and the quantity of water needed was re-scheduled according to plant growth stage and climatic conditions, 32 m^3 of irrigation water were used during the irrigation season(8 m^3 per each treatment), detailed irrigation amounts presented in (annex 2). The drip irrigation system was used.

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.

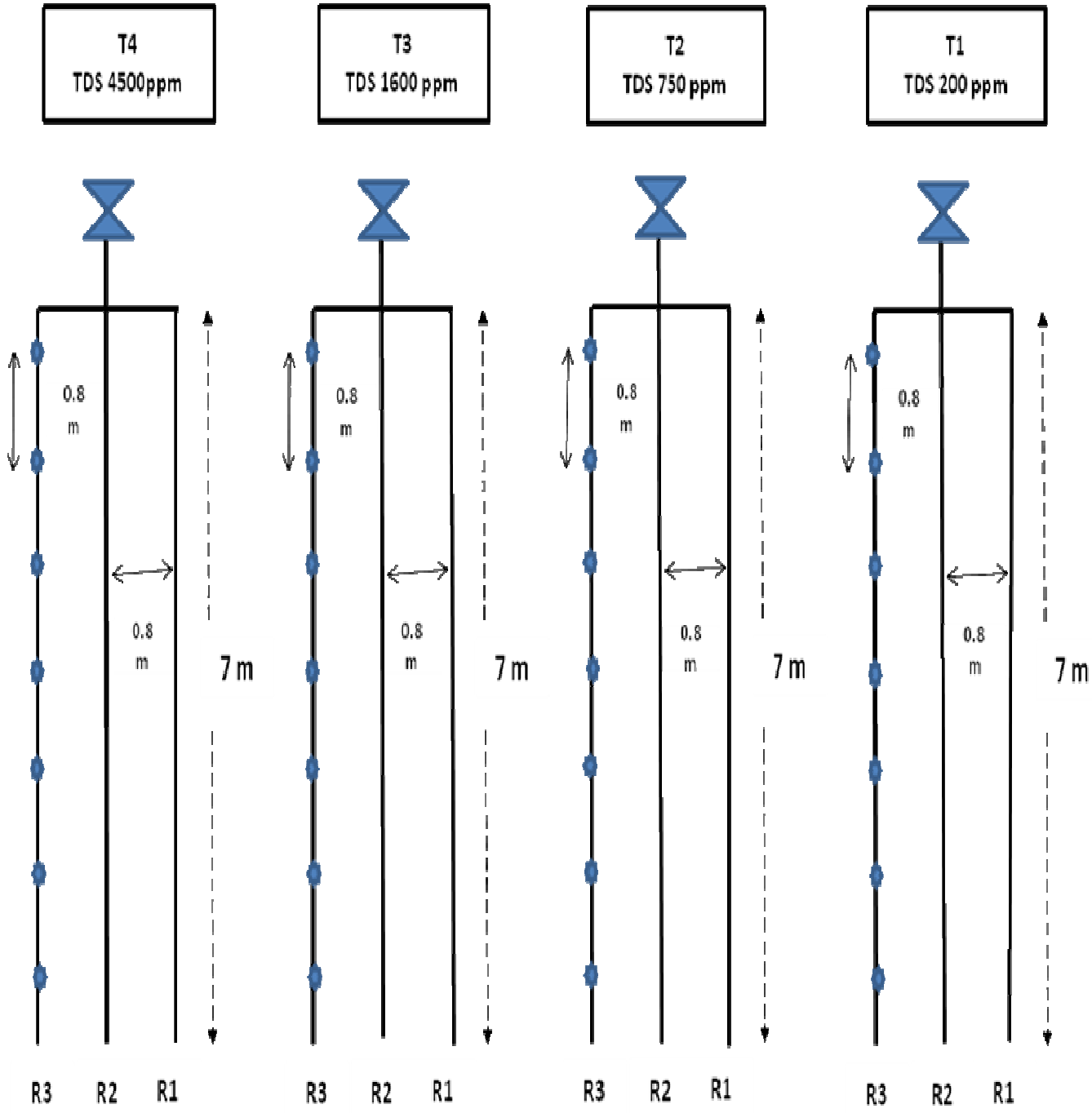

Figure 2: Field experiment design and layout for tomato crop irrigated with 4irrigation water of different salinity treatments

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. All the analyses were done based on ICARDA Manual (Ryan *et al*., 2013) where the Total Nitrogen was analyzed using Kjeldahl method, the Phosphorus was analyzed using the colorimetric method, Potassium was analyzed using the flame photometry method, the Calcium was Analyzed using the versenate method, the EC was analyzed using the conductivity bridge method, and the pH was analyzed using the electronic pH meter method.

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.

LAI = leaf area / ground area, in (m^2 / m^2)……..……. Eq.2

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. All the Analysis were done based on ICARDA Manual (Ryan *et al*., 2013) were the Total Nitrogen was analyzed using Sulfuric- Salicylic Mixture , while the Phosphorus, Potassium , and Calcium were analyzed using the dry ashing method.

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. All the Analysis were done based on ICARDA Manual (Ryan *et al*., 2013), AOAC method, were the TSS was Analyzed using the refractomerter method, the EC was Analyzed using the conductivity meter method, and the pH was Analyzed using the electronic pH meter method.

3.8 Statistical Analysis

All obtained data were subjected to analysis of variance (ANOVA) at p 0.05, and mean separation was conducted using Duncan's Multiple Range Test (DMRT) using (SPSS) software. The SPSS data results were documented in Annex (1).

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

Treatments	Fruit TSS %			Fruit pH			Fruit EC dS/m		
	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) (Annex 3).

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

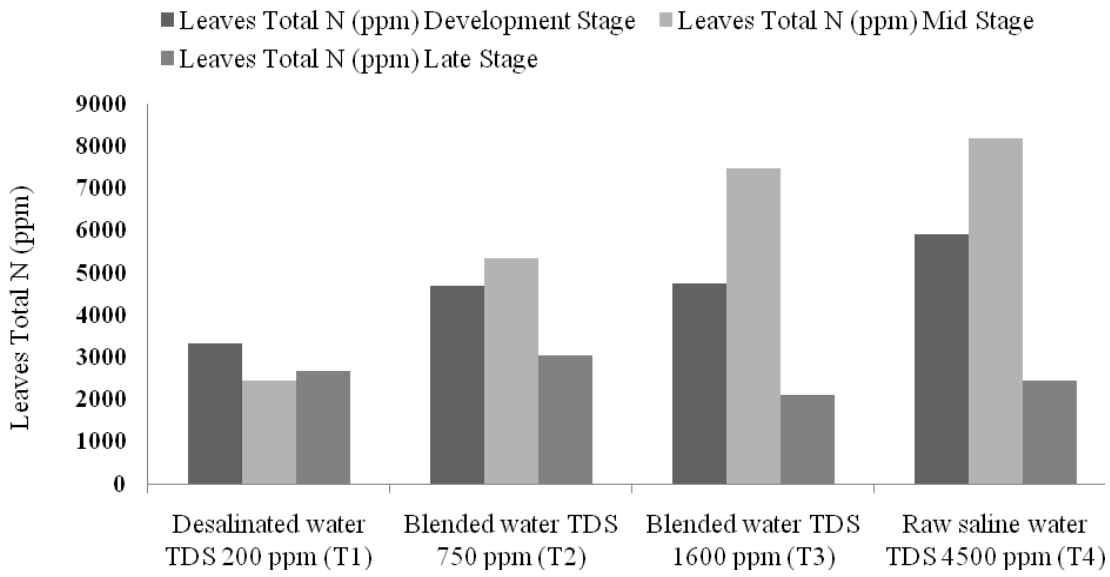

Figure 3A: Total N in tomato plant leaves at different

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.

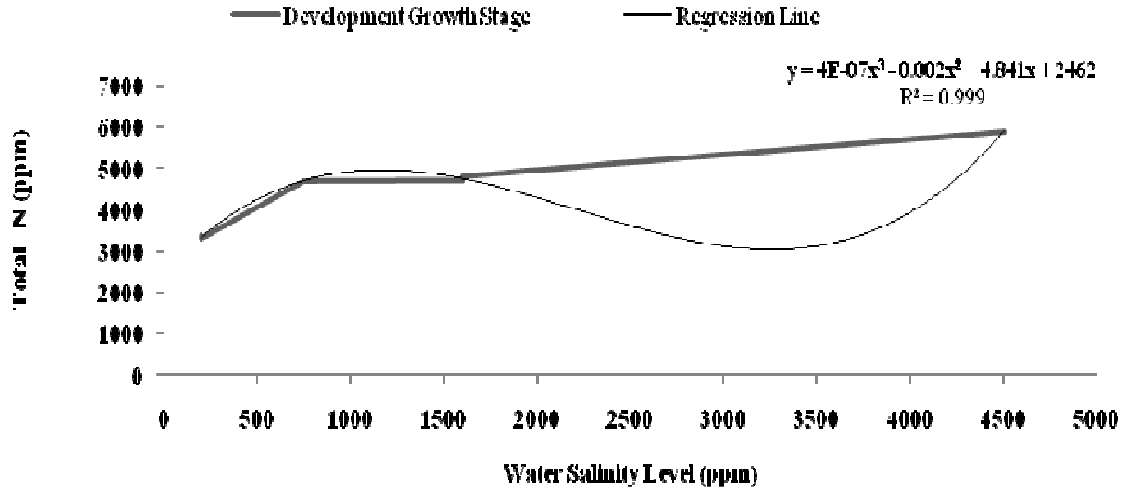

Figure 3B1: Line regression between N content in tomato plant leaves and different water salinitv levels

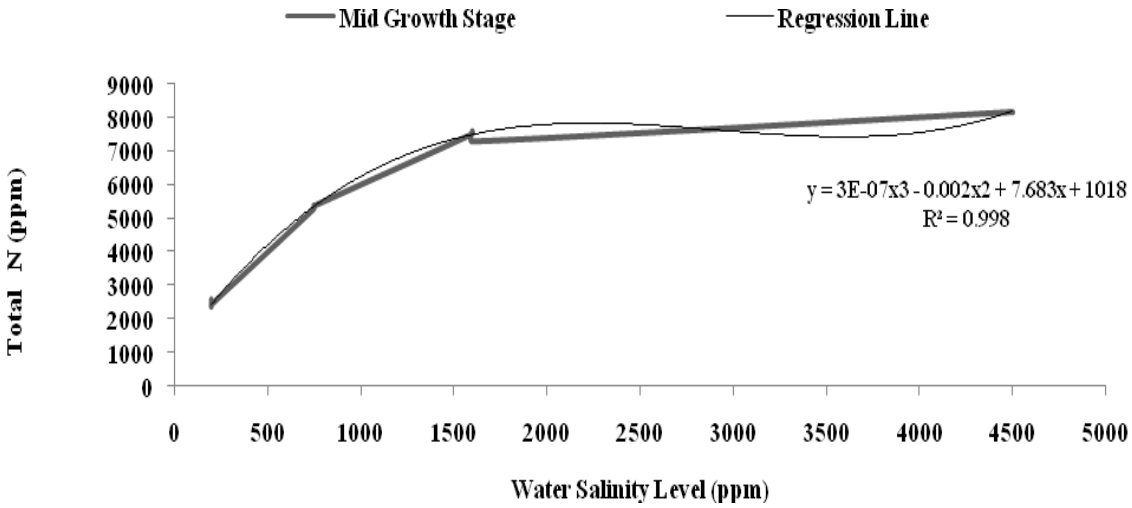

Figure 3B2: Line regression between N content in tomato plant leaves and different water salinity levels

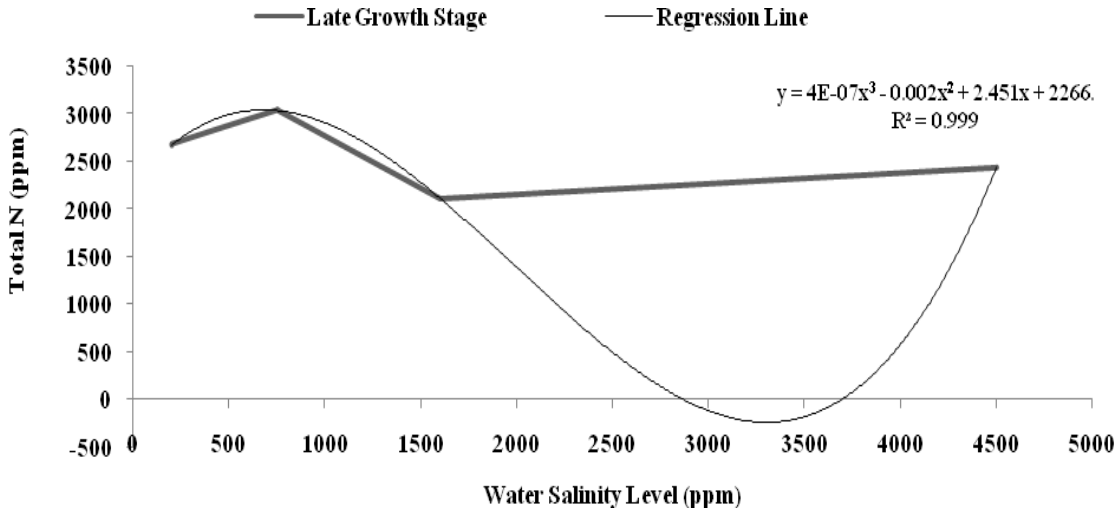

Figure 3B3: Line regression between N content in tomato plant leaves and different water salinity levels

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

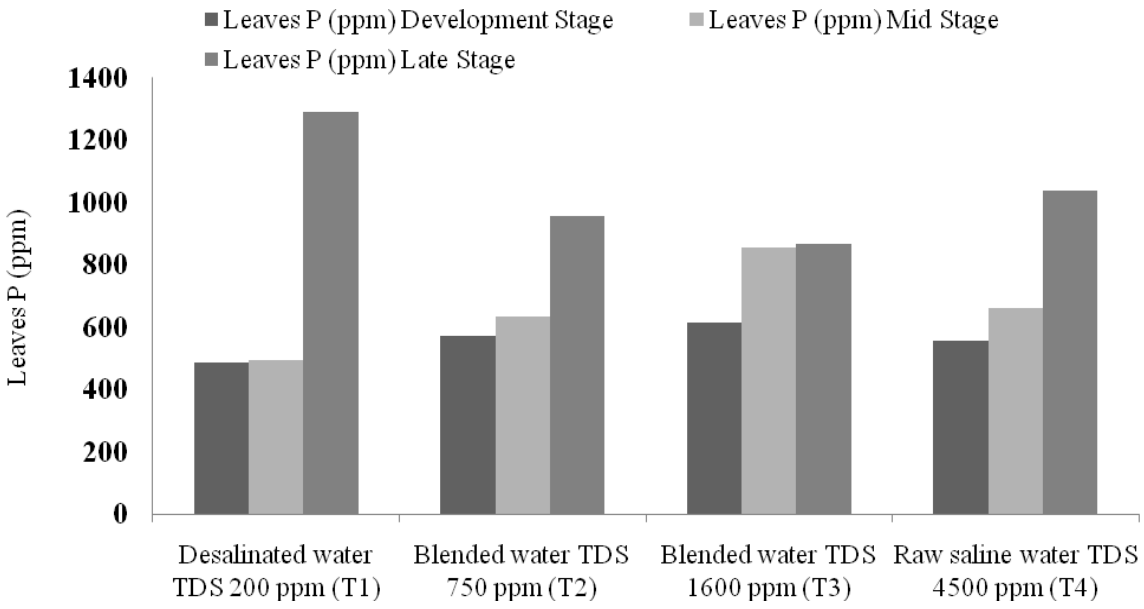

Figure 4A: P in tomato plant leaves at different plant growth stages

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.

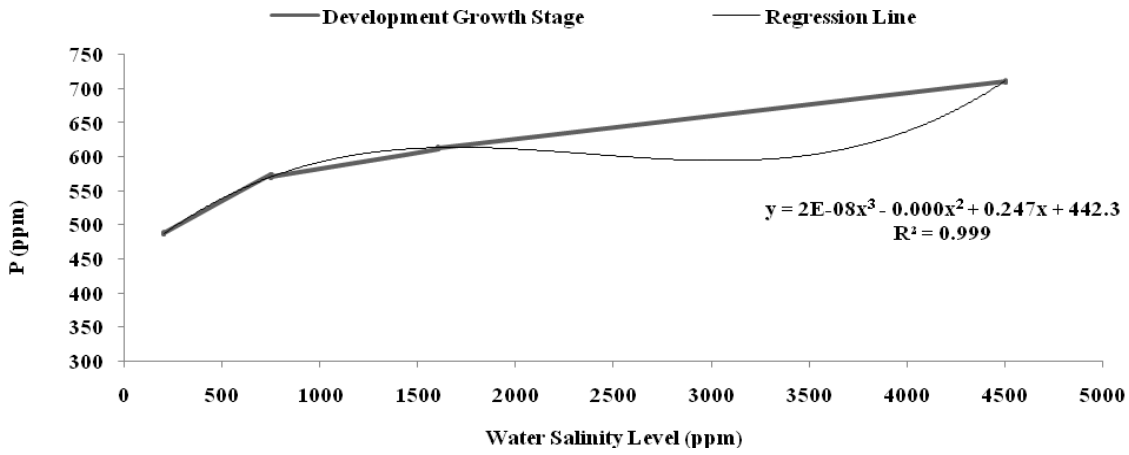

Figure 4B1: Line regression between P content in tomato plant leaves and different water salinity levels

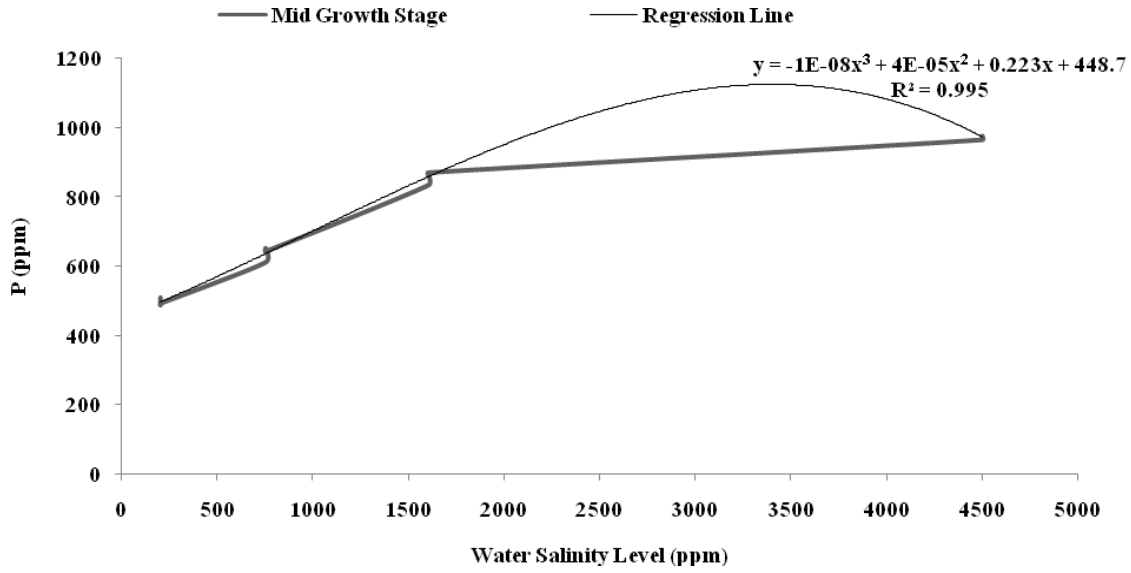

Figure 4B2: Line regression between P content in tomato plant leaves and different water salinity levels

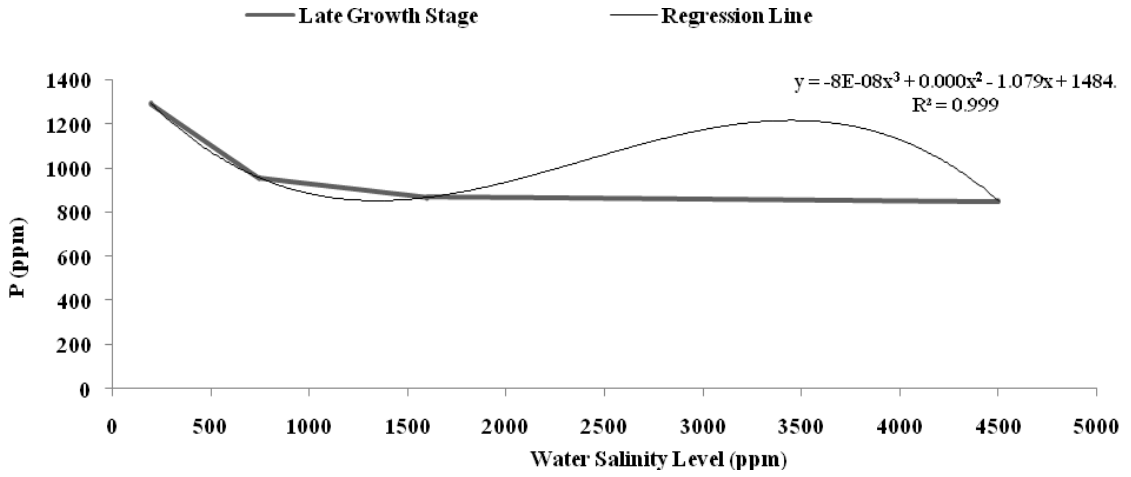

Figure 4B3: Line regression between P content in tomato plant leaves and different water salinity levels

As shown in figures 4B1, 4B2, and 4B3, the coefficient of determination ($R^{2)}$ show clearly 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

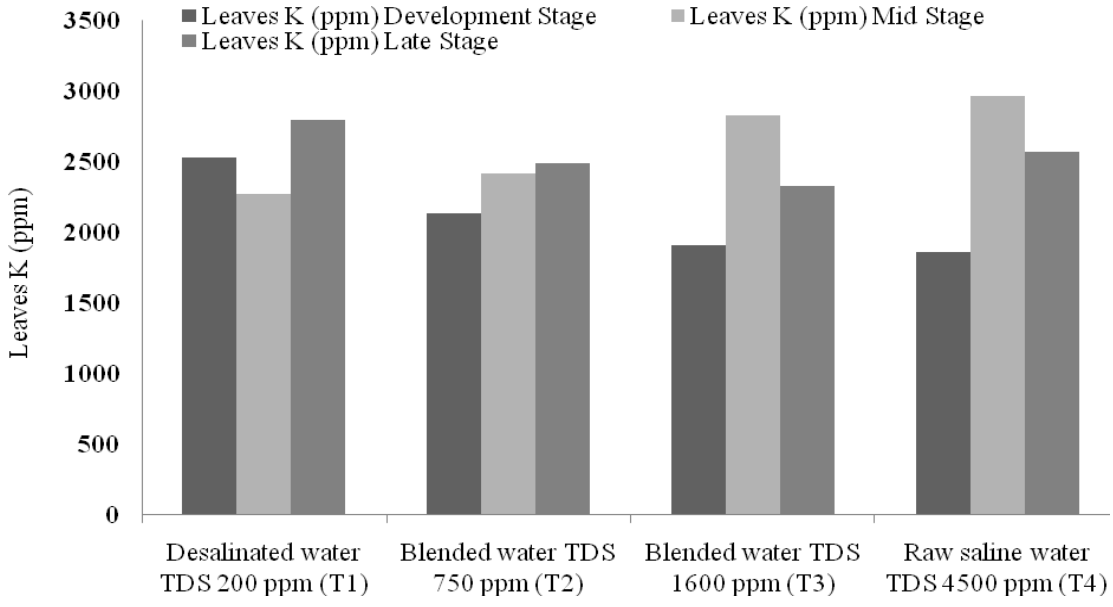

Figure 5A: K in tomato plant leaves at different plant growth stages

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.

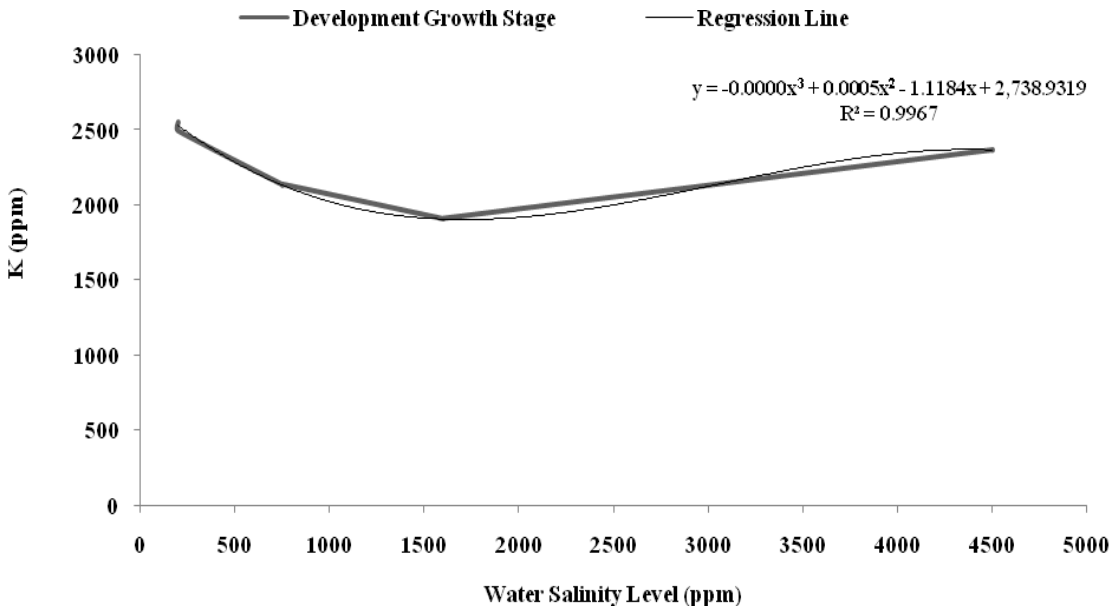

Figure 5B1: Line regression between K content in tomato plant leaves and different water salinity levels

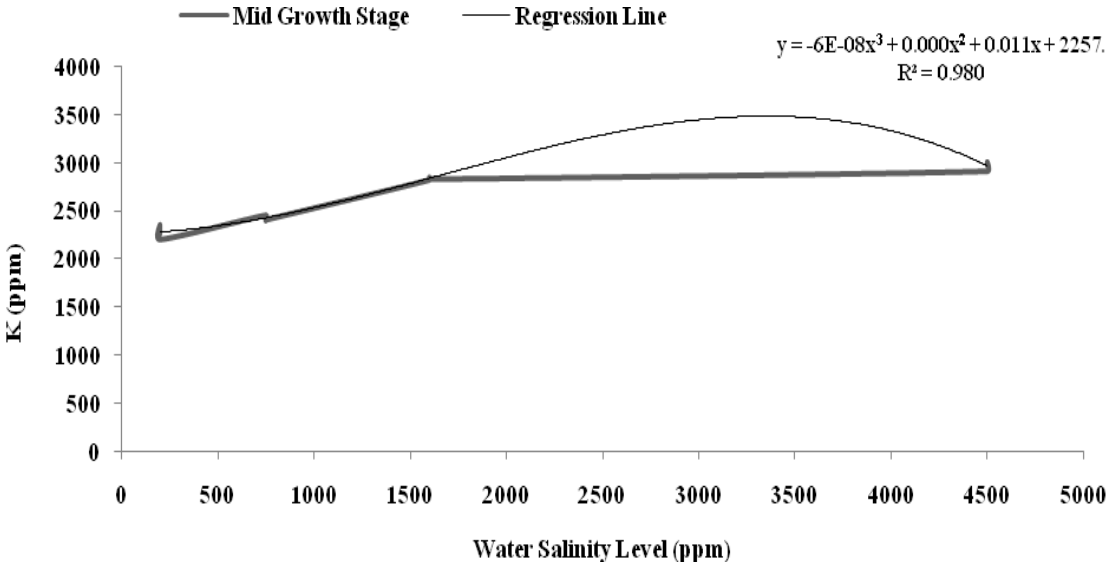

Figure 5B2: Line regression between K content in tomato plant leaves and different water salinity levels

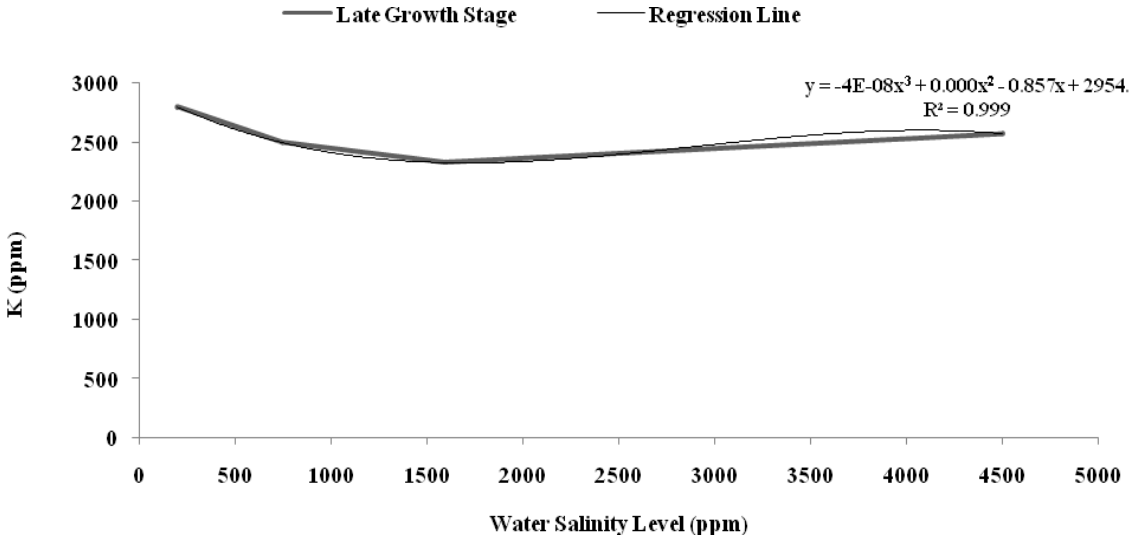

Figure 5B3: Line regression between K content in tomato plant leaves and different water salinity levels

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

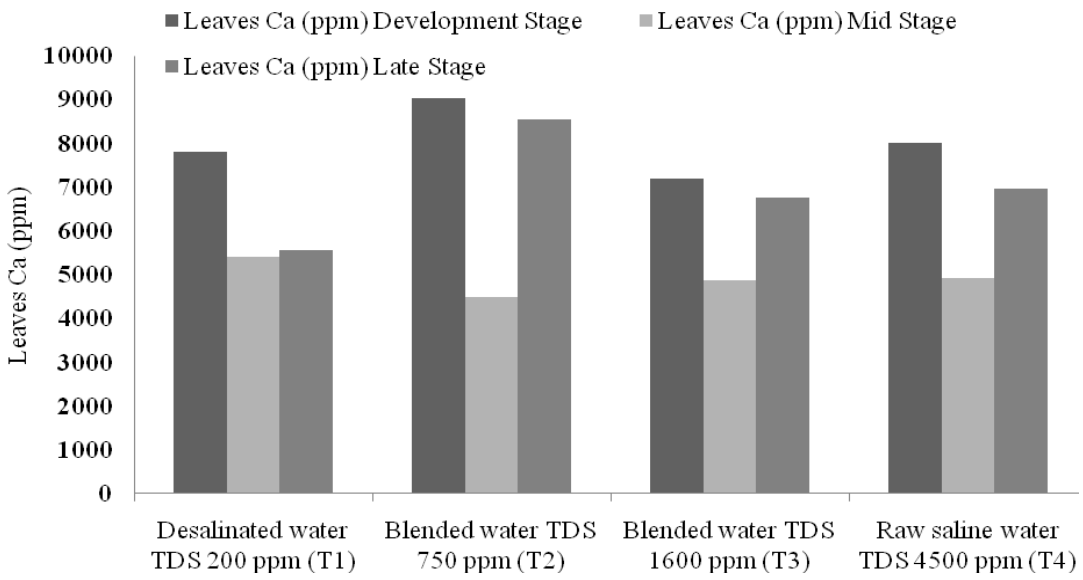

Figure 6A: Ca in tomato plant leaves at different plant growth stages

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.

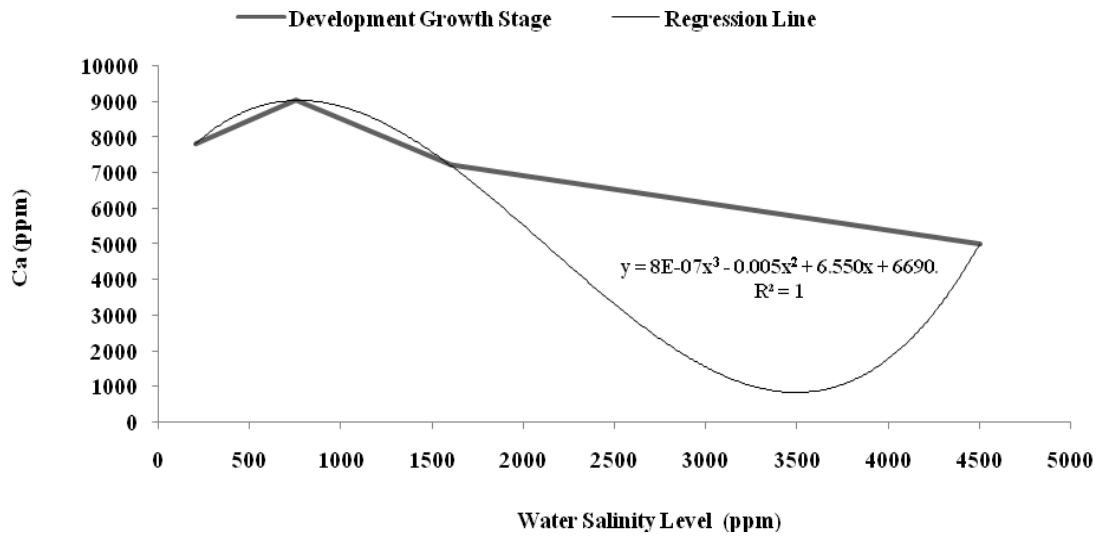

Figure 6B1: Line regression between Ca content in tomato plant leaves and different water salinity levels

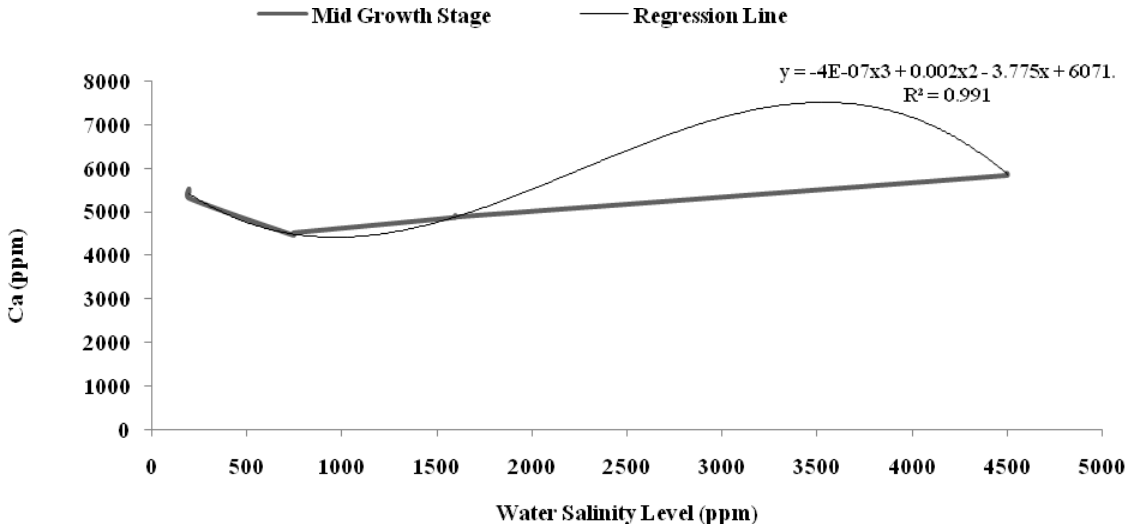

Figure 6B2: Line regression between Ca content in tomato plant leaves and different water salinity levels

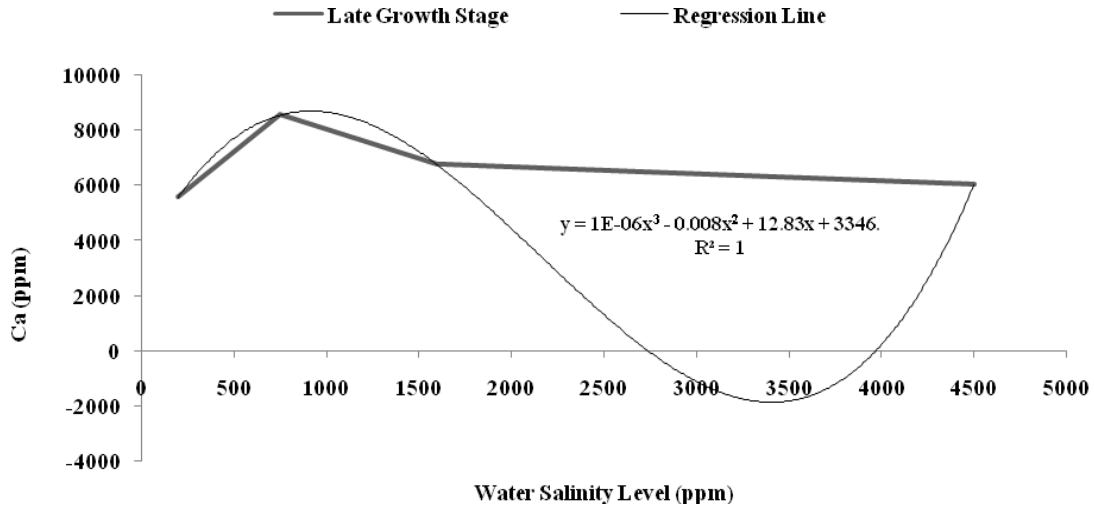

Figure 6B3: Line regression between Ca content in tomato plant leaves and different water salinity levels

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.

Oweis, T., Zhang, H., Pala, M., 2000. Water use efficiency of rainfed and irrigated bread wheat in a Mediterranean environment. Agron. J. 92, 231–238.

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.

PCBS(2007), Agricultural Statistics, Palestinian Central Bureau of Statics, April 2008.

PCBS(2008), Agricultural Statistics, Palestinian Central Bureau of Statics, April 2009.

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., I. Peleg S. R., Dudai N., and Shtienberg D. 2006. Reduction of Botrytis cinerea sporulation in sweet basil by altering the concentrations of nitrogen and calcium in the irrigation solution. Plant Pathol. 55:544–552.

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.

Zhou, Y., and Tol R.S.J. 2005. Evaluating the costs of desalination and water transport. Water Resour. Res. 41:W03003, doi:10.1029/2004WR003749.

Annexes:

Annex (1) SPSS data results

All obtained data were subjected to analysis of variance (ANOVA) at p 0.05, and mean separation was conducted using Duncan's Multiple Range Test (DMRT) using (SPSS) software

One way ANOVA			Sum of Squares	df	Mean Square	F	Sig.
Plant Height	Development Stage	Between Groups	0.32	3.00	0.11	68.65	0.00
		Within Groups	0.01	8.00	0.00		
		Total	0.33	11.00			
	Mid Stage	Between Groups	0.85	3.00	0.28	73.02	0.00
		Within Groups	0.03	8.00	0.00		
		Total	0.88	11.00			
	Late stage	Between Groups	1.20	3.00	0.40	24.78	0.00
		Within Groups	0.13	8.00	0.02		
		Total	1.33	11.00			
Stem Diameter	Development Stage	Between Groups	10.77	3.00	3.59	2.89	0.10
		Within Groups	9.94	8.00	1.24		
		Total	20.70	11.00			
	Mid Stage	Between Groups	6.46	3.00	2.15	1.09	0.41
		Within Groups	15.84	8.00	1.98		
		Total	22.29	11.00			
	Late stage	Between Groups	6.97	3.00	2.32	1.04	0.43
		Within Groups	17.91	8.00	2.24		
		Total	24.88	11.00			
Chlorosis	Development Stage	Between Groups	0.23	3.00	0.08	8.25	0.01
		Within Groups	0.07	8.00	0.01		
		Total	0.30	11.00			
	Mid Stage	Between Groups	0.64	3.00	0.21	12.30	0.00
		Within Groups	0.14	8.00	0.02		
		Total	0.78	11.00			
	Late stage	Between Groups	0.00	3.00	0.00	.	.
		Within Groups	0.00	8.00	0.00		
		Total	0.00	11.00			

One way ANOVA			Sum of Squares	df	Mean Square	F	Sig.
Leaves Malformation	Development Stage	Between Groups	0.03	3.00	0.01	0.73	0.56
		Within Groups	0.09	8.00	0.01		
		Total	0.12	11.00			
	Mid Stage	Between Groups	0.00	3.00	0.00	.	.
		Within Groups	0.00	8.00	0.00		
		Total	0.00	11.00			
	Late stage	Between Groups	0.18	3.00	0.06	1.94	0.20
		Within Groups	0.25	8.00	0.03		
		Total	0.43	11.00			
Fruits Malformation	Development Stage	Between Groups	0.12	3.00	0.04	0.54	0.67
		Within Groups	0.59	8.00	0.07		
		Total	0.71	11.00			
	Mid Stage	Between Groups	0.12	3.00	0.04	0.54	0.67
		Within Groups	0.59	8.00	0.07		
		Total	0.71	11.00			
	Late stage	Between Groups	0.44	3.00	0.15	0.74	0.56
		Within Groups	1.60	8.00	0.20		
		Total	2.04	11.00			
Fruits Color	Development Stage	Between Groups	0.56	3.00	0.19	.	.
		Within Groups	0.00	8.00	0.00		
		Total	0.56	11.00			
	Mid Stage	Between Groups	2.55	3.00	0.85	31.92	0.00
		Within Groups	0.21	8.00	0.03		
		Total	2.77	11.00			
	Late stage	Between Groups	0.04	3.00	0.01	7.56	0.01
		Within Groups	0.01	8.00	0.00		
		Total	0.05	11.00			

One way ANOVA			Sum of Squares	df	Mean Square	F	Sig.
No. of Flowers/Plant	Development Stage	Between Groups	6.83	3.00	2.28	1.25	0.36
		Within Groups	14.60	8.00	1.82		
		Total	21.42	11.00			
	Mid Stage	Between Groups	20.74	3.00	6.91	3.36	0.08
		Within Groups	16.45	8.00	2.06		
		Total	37.19	11.00			
	Late stage	Between Groups	42.15	3.00	14.05	13.30	0.00
		Within Groups	8.45	8.00	1.06		
		Total	50.60	11.00			
No. of Fruits/Plant	Development Stage	Between Groups	13.12	3.00	4.37	3.01	0.09
		Within Groups	11.64	8.00	1.45		
		Total	24.76	11.00			
	Mid Stage	Between Groups	4.94	3.00	1.65	0.63	0.61
		Within Groups	20.83	8.00	2.60		
		Total	25.77	11.00			
	Late stage	Between Groups	12.06	3.00	4.02	12.56	0.00
		Within Groups	2.56	8.00	0.32		
		Total	14.62	11.00			
Fruit Weight	Development Stage	Between Groups	6732.17	3.00	2244.06	85.82	0.00
		Within Groups	209.19	8.00	26.15		
		Total	6941.35	11.00			
	Mid Stage	Between Groups	5242.82	3.00	1747.61	118.93	0.00
		Within Groups	117.56	8.00	14.70		
		Total	5360.38	11.00			
	Late stage	Between Groups	2391.78	3.00	797.26	34.00	0.00
		Within Groups	187.56	8.00	23.45		
		Total	2579.34	11.00			

One way ANOVA			Sum of Squares	df	Mean Square	F	Sig.
Leaf Area Index	Development Stage	Between Groups	2.98	3.00	0.99	44.02	0.00
		Within Groups	0.18	8.00	0.02		
		Total	3.16	11.00			
	Mid Stage	Between Groups	3.09	3.00	1.03	66.04	0.00
		Within Groups	0.12	8.00	0.02		
		Total	3.22	11.00			
	Late stage	Between Groups	3.20	3.00	1.07	87.79	0.00
		Within Groups	0.10	8.00	0.01		
		Total	3.29	11.00			
Average Production/Plant	All stages	Between Groups	140.71	3.00	46.90	33.23	0.00
		Within Groups	11.29	8.00	1.41		
		Total	152.00	11.00			
Fruit pH	Development Stage	Between Groups	0.25	3.00	0.08	43.72	0.00
		Within Groups	0.02	8.00	0.00		
		Total	0.26	11.00			
	Mid Stage	Between Groups	0.06	3.00	0.02	15.30	0.00
		Within Groups	0.01	8.00	0.00		
		Total	0.07	11.00			
	Late stage	Between Groups	0.08	3.00	0.03	38.16	0.00
		Within Groups	0.01	8.00	0.00		
		Total	0.08	11.00			
Fruit TSS	Development Stage	Between Groups	1.48	3.00	0.49	98.44	0.00
		Within Groups	0.04	8.00	0.01		
		Total	1.52	11.00			
	Mid Stage	Between Groups	2.27	3.00	0.75	278.77	0.00
		Within Groups	0.02	8.00	0.00		
		Total	2.29	11.00			
	Late stage	Between Groups	4.25	3.00	1.42	239.52	0.00
		Within Groups	0.05	8.00	0.01		
		Total	4.30	11.00			

One way ANOVA			Sum of Squares	df	Mean Square	F	Sig.
Fruit EC	Development Stage	Between Groups	0.99	3.00	0.33	1102.99	0.00
		Within Groups	0.00	8.00	0.00		
		Total	1.00	11.00			
	Mid Stage	Between Groups	15.26	3.00	5.09	594.52	0.00
		Within Groups	0.07	8.00	0.01		
		Total	15.33	11.00			
	Late stage	Between Groups	0.41	3.00	0.14	159.73	0.00
		Within Groups	0.01	8.00	0.00		
		Total	0.42	11.00			
Leaves Total N	Development Stage	Between Groups	9975404.92	3.00	3325134.97	2788.57	0.00
		Within Groups	9539.33	8.00	1192.42		
		Total	9984944.25	11.00			
	Mid Stage	Between Groups	59757438.25	3.00	19919146.08	1854.01	0.00
		Within Groups	85950.67	8.00	10743.83		
		Total	59843388.92	11.00			
	Late stage	Between Groups	1368524.00	3.00	456174.67	24221.66	0.00
		Within Groups	150.67	8.00	18.83		
		Total	1368674.67	11.00			

One way ANOVA			Sum of Squares	df	Mean Square	F	Sig.
Leaves K	Development Stage	Between Groups	671706.92	3.00	223902.31	802.52	0.00
		Within Groups	2232.00	8.00	279.00		
		Total	673938.92	11.00			
	Mid Stage	Between Groups	974476.33	3.00	324825.44	135.67	0.00
		Within Groups	19153.33	8.00	2394.17		
		Total	993629.67	11.00			
	Late stage	Between Groups	343130.92	3.00	114376.97	13589.34	0.00
		Within Groups	67.33	8.00	8.42		
		Total	343198.25	11.00			
Leaves Ca	Development Stage	Between Groups	25743803.67	3.00	8581267.89	2288338.10	0.00
		Within Groups	30.00	8.00	3.75		
		Total	25743833.67	11.00			
	Mid Stage	Between Groups	3260391.33	3.00	1086797.11	323.93	0.00
		Within Groups	26840.67	8.00	3355.08		
		Total	3287232.00	11.00			
	Late stage	Between Groups	15534314.00	3.00	5178104.67	437586.31	0.00
		Within Groups	94.67	8.00	11.83		
		Total	15534408.67	11.00			

One way ANOVA			Sum of Squares	df	Mean Square	F	Sig.
Leaves P	Development Stage	Between Groups	77658.92	3.00	25886.31	5752.51	0.00
		Within Groups	36.00	8.00	4.50		
		Total	77694.92	11.00			
	Mid Stage	Between Groups	414012.25	3.00	138004.08	535.25	0.00
		Within Groups	2062.67	8.00	257.83		
		Total	416074.92	11.00			
	Late stage	Between Groups	375822.25	3.00	125274.08	13186.75	0.00
		Within Groups	76.00	8.00	9.50		
		Total	375898.25	11.00			

Post Hoc Tests
Homogeneous Subsets

Plant Height Development Stage (m)

Treatments	N	Subset for alpha = .05		
		1.000	2.000	3.000
4	3.000	1.378		
1	3.000		1.613	
2	3.000			1.745
3	3.000			1.798
Sig.		1.000	1.000	0.134

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 3.000.

Plant Height Mid Stage (m)

Treatments	N	Subset for alpha = .05			
		1.000	2.000	3.000	4.000
4	3.000	1.682			
1	3.000		1.833		
2	3.000			2.190	
3	3.000				2.343
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 3.000.

Plant Height Late Stage (m)

Treatments	N	Subset for alpha = .05		
		1.000	2.000	3.000
4	3.000	2.185		
1	3.000	2.265		
2	3.000		2.657	
3	3.000			2.972
Sig.		0.463	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Stem Diameter Development Stage (mm)

Treatments	N	Subset for alpha = .05	
		1.000	2.000
4	3.000	5.067	
1	3.000	6.667	6.667
3	3.000	7.117	7.117
2	3.000		7.583
Sig.		0.063	0.362

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 3.000.

Stem Diameter Mid Stage (mm)

Treatments	N	Subset for alpha = .05
		1.000
4	3.000	7.308
1	3.000	7.650
2	3.000	8.883
3	3.000	8.967
Sig.		0.211

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Stem Diameter Late Stage (mm)

Treatments	N	Subset for alpha = .05
		1.000
4	3.000	7.750
1	3.000	8.022
3	3.000	9.390
2	3.000	9.405
Sig.		0.238

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Chlorosis Development Stage (1-5)

Treatments	N	Subset for alpha = .05	
		1.000	2.000
4	3.000	1.000	
2	3.000	1.167	
3	3.000	1.167	
1	3.000		1.389
Sig.		0.076	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Chlorosis Mid Stage (1-5)

Treatments	N	Subset for alpha = .05	
		1.000	2.000
4	3.000	1.500	
2	3.000	1.583	
3	3.000	1.583	
1	3.000		2.083
Sig.		0.479	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Leaves Malformation Development stage (1-5)

Treatments	N	Subset for alpha = .05
		1.000
1	3.000	1.000
2	3.000	1.000
3	3.000	1.056
4	3.000	1.111
Sig.		0.268

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Leaves Malformation Late Stage (1-5)

Treatments	N	Subset for alpha = .05
		1.000
4	3.000	1.000
3	3.000	1.083
2	3.000	1.167
1	3.000	1.333
Sig.		0.062

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Fruits Malformation Development Stage (1-5)

Treatments	N	Subset for alpha = .05
		1.000
1	3.000	0.833
2	3.000	0.944
3	3.000	1.000
4	3.000	1.111
Sig.		0.273

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Fruits Malformation Mid Stage (1-5)

Treatments	N	Subset for alpha = .05
		1.000
1	3.000	0.833
2	3.000	0.944
3	3.000	1.000
4	3.000	1.111
Sig.		0.273

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Fruits Malformation Late Stage (1-5)

Treatments	N	Subset for alpha = .05
		1.000
1	3.000	1.611
2	3.000	1.639
3	3.000	1.944
4	3.000	2.056
Sig.		0.285

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Fruits Color Mid Stage (1-4)

Treatments	N	Subset for alpha = .05		
		1.000	2.000	3.000
1	3.000	2.300		
4	3.000	2.467	2.467	
2	3.000		2.667	
3	3.000			3.500
Sig.		0.247	0.172	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Fruits Color Late Stage (1-4)

Treatments	N	Subset for alpha = .05	
		1.000	2.000
1	3.000	3.861	
4	3.000	3.861	
2	3.000	3.889	
3	3.000		4.000
Sig.		0.456	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Number of flowers per plant Development Stage

Treatments	N	Subset for alpha = .05
		1.000
1	3.000	11.556
4	3.000	11.722
3	3.000	12.083
2	3.000	13.472
Sig.		0.141

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Number of flowers per Plant Mid Stage

Treatments	N	Subset for alpha = .05	
		1.000	2.000
1	3.000	6.133	
2	3.000	7.933	7.933
3	3.000	8.267	8.267
4	3.000		9.833
Sig.		0.119	0.158

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Number of flowers per Plant Late Stage

Treatments	N	Subset for alpha = .05	
		1.000	2.000
1	3.000	7.917	
3	3.000	8.444	
2	3.000	8.500	
4	3.000		12.583
Sig.		0.523	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Number of Fruits per Plant Development Stage

Treatments	N	Subset for alpha = .05	
		1.000	2.000
1	3.000	7.500	
4	3.000	8.111	8.111
3	3.000	9.444	9.444
2	3.000		10.139
Sig.		0.095	0.084

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Number of Fruits per Plant Mid Stage

Treatments	N	Subset for alpha = .05
		1.000
1	3.000	12.300
2	3.000	12.867
3	3.000	13.400
4	3.000	14.033
Sig.		0.251

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Number of Fruits per Plant Late Stage

Treatments	N	Subset for alpha = .05		
		1.000	2.000	3.000
1	3.000	6.111		
2	3.000	7.056	7.056	
3	3.000		7.556	
4	3.000			8.889
Sig.		0.075	0.311	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Fruit Weight Development Stage (gm)

Treatments	N	Subset for alpha = .05			
		1.000	2.000	3.000	4.000
4	3.000	75.389			
1	3.000		98.222		
3	3.000			123.556	
2	3.000				137.056
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Fruit Weight Mid Stage (gm)

Treatments	N	Subset for alpha = .05			
		1.000	2.000	3.000	4.000
4	3.000	80.800			
1	3.000		90.867		
3	3.000			120.467	
2	3.000				131.967
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Fruit Weight Late Stage (gm)

Treatments	N	Subset for alpha = .05	
		1.000	2.000
4	3.000	86.917	
1	3.000	90.167	
3	3.000		112.056
2	3.000		120.139
Sig.		0.435	0.075

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Leaf Area Index Development Stage

Treatments	N	Subset for alpha = .05			
		1.000	2.000	3.000	4.000
4	3.000	1.367			
1	3.000		1.683		
2	3.000			2.333	
3	3.000				2.617
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Leaf Area Index Mid Stage

Treatments	N	Subset for alpha = .05		
		1.000	2.000	3.000
4	3.000	1.192		
1	3.000		1.517	
2	3.000			2.225
3	3.000			2.438
Sig.		1.000	1.000	0.070

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Leaf Area Index Late Stage

Treatments	N	Subset for alpha = .05		
		1.000	2.000	3.000
4	3.000	1.362		
1	3.000	1.545		
2	3.000		2.340	
3	3.000			2.585
Sig.		0.076	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Average Production per plant (kg)

Treatments	N	Subset for alpha = .05	
		1.000	2.000
1	3.000	12.161	
4	3.000	13.116	
3	3.000		18.756
2	3.000		20.032
Sig.		0.354	0.225

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Fruit pH Development Stage

Treatments	N	Subset for alpha = .05			
		1.000	2.000	3.000	4.000
4	3.000	3.953			
2	3.000		4.083		
1	3.000			4.203	
3	3.000				4.340
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Fruit pH Mid Stage

Treatments	N	Subset for alpha = .05	
		1.000	2.000
4	3.000	4.033	
3	3.000	4.063	
2	3.000		4.157
1	3.000		4.203
Sig.		0.326	0.142

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Fruit pH Late Stage

Treatments	N	Subset for alpha = .05		
		1.000	2.000	3.000
1	3.000	4.067		
4	3.000	4.073		
3	3.000		4.190	
2	3.000			4.257
Sig.		0.761	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Fruit TSS (%) Development Stage

Treatments	N	Subset for alpha = .05		
		1.000	2.000	3.000
3	3.000	3.967		
4	3.000		4.167	
2	3.000		4.233	
1	3.000			4.900
Sig.		1.000	0.282	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Fruit TSS (%) Mid Stage

Treatments	N	Subset for alpha = .05		
		1.000	2.000	3.000
1	3.000	5.183		
3	3.000		5.433	
2	3.000			6.133
4	3.000			6.183
Sig.		1.000	1.000	0.273

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Fruit TSS (%) Late Stage

Treatments	N	Subset for alpha = .05			
		1.000	2.000	3.000	4.000
1	3.000	4.827			
2	3.000		5.353		
4	3.000			5.950	
3	3.000				6.400
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Fruit EC Development Stage

Treatments	N	Subset for alpha = .05			
		1.000	2.000	3.000	4.000
4	3.000	5.500			
2	3.000		5.547		
3	3.000			5.763	
1	3.000				6.227
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Fruit EC Mid Stage

Treatments	N	Subset for alpha = .05			
		1.000	2.000	3.000	4.000
1	3.000	5.077			
3	3.000		5.277		
2	3.000			7.053	
4	3.000				7.707
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Fruit EC late Stage

Treatments	N	Subset for alpha = .05	
		1.000	2.000
2	3.000	4.477	
4	3.000	4.477	
1	3.000		4.837
3	3.000		4.857
Sig.		1.000	0.427

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Leaves Total N (ppm) Development Stage

Treatments	N	Subset for alpha = .05		
		1.000	2.000	3.000
1	3.000	3321.000		
2	3.000		4688.333	
3	3.000		4738.667	
4	3.000			5895.000
Sig.		1.000	0.112	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Leaves Total N (ppm) Mid Stage

Treatments	N	Subset for alpha = .05			
		1.000	2.000	3.000	4.000
1	3.000	2445.667			
2	3.000		5346.667		
3	3.000			7479.667	
4	3.000				8178.333
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Leaves Total N (ppm) Late Stage

Treatments	N	Subset for alpha = .05			
		1.000	2.000	3.000	4.000
3	3.000	2109.667			
4	3.000		2434.333		
1	3.000			2672.333	
2	3.000				3034.333
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Leaves P (ppm) Development Stage

Treatments	N	Subset for alpha = .05			
		1.000	2.000	3.000	4.000
1	3.000	487.333			
2	3.000		570.667		
3	3.000			613.000	
4	3.000				710.667
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Leaves P (ppm) Mid Stage

Treatments	N	Subset for alpha = .05			
		1.000	2.000	3.000	4.000
1	3.000	495.000			
2	3.000		634.333		
3	3.000			856.000	
4	3.000				971.000
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Leaves P (ppm) Late Stage

Treatments	N	Subset for alpha = .05			
		1.000	2.000	3.000	4.000
4	3.000	851.667			
3	3.000		867.667		
2	3.000			955.667	
1	3.000				1290.000
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Leaves K (ppm) Development Stage

Treatments	N	Subset for alpha = .05			
		1.000	2.000	3.000	4.000
3	3.000	1907.333			
2	3.000		2134.333		
4	3.000			2367.667	
1	3.000				2533.000
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Leaves K (ppm) Mid Stage

Treatments	N	Subset for alpha = .05			
		1.000	2.000	3.000	4.000
1	3.000	2272.333			
2	3.000		2419.333		
3	3.000			2833.000	
4	3.000				2964.000
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Leaves K (ppm) Late Stage

Treatments	N	Subset for alpha = .05			
		1.000	2.000	3.000	4.000
3	3.000	2327.000			
2	3.000		2495.000		
4	3.000			2571.667	
1	3.000				2797.333
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Leaves Ca (ppm) Development Stage

Treatments	N	Subset for alpha = .05			
		1.000	2.000	3.000	4.000
4	3.000	4986.000			
3	3.000		7204.667		
1	3.000			7799.333	
2	3.000				9025.333
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Leaves Ca (ppm) Mid Stage

Treatments	N	Subset for alpha = .05			
		1.000	2.000	3.000	4.000
2	3.000	4480.333			
3	3.000		4877.333		
1	3.000			5412.667	
4	3.000				5853.667
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Leaves Ca (ppm) Late Stage

Treatments	N	Subset for alpha = .05			
		1.000	2.000	3.000	4.000
1	3.000	5569.000			
4	3.000		6020.000		
3	3.000			6752.000	
2	3.000				8553.667
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Annex (2): Tomato plant irrigation water requirement

irrigation dates	irrigation quantity (litter /irrigation)	irrigation dates	irrigation quantity (litter /irrigation)	irrigation dates	irrigation quantity (litter /irrigation)
02-Oct	402	22-Dec	228	12-Mar	777
05-Oct	302	25-Dec	60	15-Mar	809
08-Oct	286	28-Dec	181	18-Mar	837
11-Oct	270	31-Dec	63	21-Mar	866
14-Oct	242	03-Jan	76	24-Mar	893
17-Oct	197	06-Jan	284	27-Mar	919
20-Oct	236	09-Jan	74	30-Mar	945
23-Oct	242	12-Jan	302	02-Apr	969
26-Oct	181	15-Jan	79	05-Apr	990
29-Oct	152	18-Jan	244	08-Apr	1011
01-Nov	150	21-Jan	102	11-Apr	1032
04-Nov	239	24-Jan	189	14-Apr	1047
07-Nov	236	27-Jan	236	17-Apr	1063
10-Nov	176	30-Jan	391	20-Apr	1037
13-Nov	221	02-Feb	102	23-Apr	1005
16-Nov	231	05-Feb	417	26-Apr	958
19-Nov	231	08-Feb	423	29-Apr	929
22-Nov	226	11-Feb	473	02-May	866
25-Nov	218	14-Feb	501		
28-Nov	113	17-Feb	530		
01-Dec	207	20-Feb	562		
04-Dec	152	23-Feb	591		
07-Dec	53	26-Feb	622		
10-Dec	105	29-Feb	654		
13-Dec	53	03-Mar	685		
16-Dec	221	06-Mar	717		
19-Dec	55	09-Mar	748		

Annex (3) Soil Test Interpretation Guide*

Element	Low ppm	Medium ppm	High ppm	Excessive
Total N	<10	10-20	20-40	>40
P (Olsen test)	<10	10-20	20-40	>40
K (Extractable)	<150	150-250	250-800	>800
Ca (Extractable)	1000	1000-2000	>2000	
EC ds/cm	<1	1-2	>2	

Soil PH

Level	Value
strongly acid below	5.1
moderately acid	5.2–6.0
slightly acid	6.1–6.5
neutral	6.6–7.3
moderately alkaline	7.4–8.4
strongly alkaline	above 8.5

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

(Annex 4): Tomato plant leaves nutrients content at different plant growth stages.

Treatment	Total N Analysis (ppm)			P Analysis (ppm)			K Analysis (ppm)			Ca Analysis (ppm)		
	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)	3321.0* c++	2445.7 d	2672.3 b	487.3 d	495.0 d	1290.0 a	2533.0 a	2272.3 d	2797.3 a	7799.3 b	5412.7 b	5569.0 d
Blinding water with 750 ppm (T2)	4688.3 b	5346.7 c	3034.3 a	570.7 c	634.3 c	955.7 b	2134.3 c	2419.3 c	2495.0 c	9025.3 a	4480.3 d	8553.7 a
Blending water with 1600 ppm (T3)	4738.7 b	7479.7 b	2109.7 d	613.0 b	856.0 b	867.7 c	1907.3 d	2833.0 b	2327.0 d	7204.7 c	4877.3 c	6752.0 b
Raw saline water with TDS 4500 ppm (T4)	5895.0 a	8178.3 a	2434.3 c	710.7 a	971 a	851.7 d	2367.7 b	2964.0 a	2571.7 b	4986 d	5853.7 a	6020 c

***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) ($p<0.05$)

Annex (5): Chlorosis, fruits and leaves malformation, and fruit color key.

Chlorosis: 1 = green, 5 = complete yellow.

1

5

Malformation of leaves: 1= No malformation, 5= Total malformation

1

5

Malformation of fruits: 1= No malformation, 5= Total malformation

1

5

Fruit Color: 1= lest marketable color green, 4 = favorite marketable color red

1 **4**

Annex (6) Research Set up Photos

Greenhouse experiment

Desalinated water with 200 ppm (T1)

Blended water with 750 ppm (T2)

Blended water with 1600 ppm (T3)

Raw saline water with TDS 4500 ppm (T4)