UNIVERISIDAD POLITÉCNICA DE VALENCIA

Máster Universitario en Producción Vegetal y
Ecosistemas Agroforestales

Effects of salinity of irrigation water on growth, fruit yield and fruit quality of two tomato (*Lycopersicon esculentum* Mill.) cultivars grown in hydroponic system.

MASTER THESIS

BY

Abdelsattar Gamal Abdelsattar Abdelkhalik

B.Sc. Agric. Sci. (Horticulture), Fac. Agric., Fayoum Univ., 2009

Supervisor

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Director Centro de Experiencias de Cajamar en Paiporta, Valencia.

Valencia, Spain

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Approval Sheet

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Date: 08 /09 / 2014

RESUMEN

El manejo del riego inadecuado y el uso de la solución de nutrientes en los cultivos hidropónicos, lo que requiere alta aplicación de fertilizantes conduce a la salinización moderada del agua y suelos que es la forma más extensa y dañina de la salinización. El objetivo de este trabajo para investigar la respuesta del crecimiento, el rendimiento y la calidad de los frutos del tomate a la salinidad del agua de riego y evaluación de la respuesta de dos cultivares de tomate marmande a diferentes niveles de salinidad. El experimento llevado a cabo en invernadero y el sistema hidropónico de sustrato de fibra de coco con dos cultivares (Dumas y Raf) y dos niveles de salinidad (3.3 dS m^{-1} es el control y 5.3 dS m^{-1}) dispuestos en un diseño de bloques al azar con tres repeticiones. Los tratamientos de salinidad se iniciaron inmediatamente después del trasplante.

Los resultados mostraron que los parámetros de crecimiento de plantas fueron afectados por el tratamiento de la salinidad sobre todo en primera etapa de desarrollo de la planta, probablemente debido al hecho de que las plantas jóvenes fueron más sensibles a las condiciones salinas. La reducción en el crecimiento podría ser un resultado de la salinidad, que causan estrés de agua debido a los efectos osmóticos. Además de en nuestro experimento, las plantas cultivadas bajo tratamiento salino tienen una mayor contenido de Na^{+} en las hojas, que se podría producir efectos tóxicos. El rendimiento total de los frutos más alto se encontraba bajo control (3.132 kg/planta), seguido por el alto nivel de salinidad (2.613 kg/planta), el rendimiento comercial de los frutos y peso del fruto disminuyeron significativamente con el aumento de nivel de la CE de 3,3 dS m^{-1} a 5,3 dS m^{-1}. El control tenía significativamente mayor número de los frutos, en el otro lado, cv. Raf tenía un número mayor de frutas más de Dumas. Mientras que el rendimiento no comercial de los frutos no fue afectada por el tratamiento de la salinidad. La reducción en el rendimiento total de los frutos se debió a una disminución del peso de la fruta. La apariencia de los frutos con BER aumenta con alto nivel de salinidad (0.127 kg/planta) más que en el control (0,045 kg/planta), mientras que el tratamiento de la salinidad no afectó en la apariencia de cracking, catface, los frutos pequeña y deforme. La salinidad no mejoró la calidad del fruto como sólidos solubles totales, acidez, color y sabor. En caso de sólidos solubles totales probablemente, debido al aumento de los sólidos solubles totales en los frutos es un efecto acumulativo en el tiempo del desarrollo y

maduración del fruto, y en la etapa de madurez de los frutos probados el tratamiento de salinidad, no alcanzó a su efecto claro. WUE tanto en términos de rendimiento total y comercial de los frutos no fue afectada por el aumento del nivel de la CE del agua de riego, pero IWUE en ambos casos, como términos de rendimiento total y comercial de los frutos se encontró a disminuir con el aumento de nivel de la CE en la solución nutritiva. Los cultivares se comportaron de manera diferente en respuesta a la salinidad; Raf fue más sensible para el tallo peso fresco y seco, mientras que Dumas era más sensible para el peso de la fruta. Aparte de eso, el comportamiento de los dos cultivares fue similar bajo la salinidad.

Palabras clave: *Lycopersicon esculentum;* Crecimiento; rendimiento; La calidad del fruto; La salinidad; hidropónico; Eficiencia del uso del agua; Eficiencia del uso del agua de riego.

ABSTRACT

Inadequate irrigation management and using nutrient solution in hydroponic culture, which necessitates high fertilizer application leads to moderate salinization of water and soils that is the most extensive and harmful form of salinization. We investigated the response of tomato growth, yield and fruit quality to salinity of irrigation water, and evaluation the response of two cultivars of tomato marmande to different salinity levels. The experiment carried out under greenhouse and hydroponic system of coconut fiber substrate with two cultivars (Dumas and Raf) and two salinity levels (3.3 dS m^{-1} is the control and 5.3 dS $m^{-}1$) arranged in a randomized block design with three replications. The salinity treatments were initiated immediately after transplant.

The results showed that the plant growth parameters were affected by salinity treatment especially at first stage of plant development probably, due to the fact that young plants were more sensitive to saline conditions. The reduction in growth could be a result of salinity, which cause water stress due to osmotic effects. In addition to in our experiment, plants grown under salinity treatment had a higher absorption of Na^{+}, which could be produce toxic effects. The highest total fruit yield was under control (3.132 kg/plant) followed by the high salinity level (2.613 kg/plant), marketable fruit yield and fruit weight significantly decreased with increase of EC level from 3.3 dS m^{-1} to 5.3 dS m^{-1}. The control had a significantly higher fruit number, on the other side; cv. Raf had a higher fruit number more than Dumas. While the unmarketable fruit yield was not affected by salinity treatment. The total fruit yield reduction resulted from a decrease of fruit weight. The appearance of fruit with BER increased with high level of salinity (0.127 kg/plant) more than the control (0.045 kg/plant), while salinity treatment did not affect on appearance of cracking, catface, small and deformed fruit. Salinity did not improve fruit quality as TSS, acidity, colour and taste. In case of TSS probably, due to increase in TSS in fruit is a cumulative effect over time of the fruit development and ripening, and at the maturity stage of tested fruits the salinity treatment not reached to their clear effect. WUE in both terms of total and marketable fruit yield was not affected by increasing of EC level of irrigation water, but IWUE in both cases, as terms of total and marketable fruit yield was found to decrease with increase of EC level in the nutrient solution. Cultivars behaved differently in response to salinity; Raf was more sensitive for stem fresh and dry weight, while Dumas was

more sensitive for fruit weight. Apart from that, the behavior of the two cultivars was similar under salinity.

Keywords: *Lycopersicon esculentum*; Growth; Yield; Fruit quality; Salinity; Hydroponic; Water use efficiency; Irrigation water use efficiency.

Acknowledgements

Thanks ALLAH for helping me achieving this work. Without his guidance, this work would never have been accomplished.

There are a number of people I would like to acknowledge, who have helped me in various ways; I would like to begin by giving a special thanks to my supervisor, DR. D. Bernardo Pascual España for guiding me through this whole process, also gratitude to my other tutor, DR. Carlos Baixauli Soria, who has given me the opportunity to do this work, also for helping me in completing the work, and to Dr. D. San Alberto Bautista, for his invaluable help in all statistical calculations as well as its natural goodness and patience.

Thanks for of the foundation Cajamar, specially the center experiences in Paiporta, Valencia, which allowed me to implement the experiment field.

Also i want to thank all the technicians in the center experiences of foundation Cajamar Valencia.

Finally my family, fill my life, thank for my wife and my son, who bore the fatigue of alienation and distance from her family for two years in order to help me to end this work. My Family in Egypt, my father, my mother and my brothers thank for them, because without their permanent support and motivate for me, i couldn’t arrived at this stage of my life.

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List of Abbreviations

%	Percent
°C	Degree centigrade
cm	Centimeter
cvs.	Cultivars
dS m^{-1}	Decisiemens per meter
df	Degree of freedom
EC	Electrical conductivity
e.g.	for example
g	Gram
h	Hour
ha	Hectar
Kg	Kilogram
L	Liter
m	Meter
mm	Millimeter
mMol	Millimole
meq	Milliequivalents
TSS	Total soluble solids
pH	Soil reaction
WUE	Water use efficiency
IWUE	Irrigation water use efficiency

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1. INTRODUCTION

1. Introduction

1.1. Tomato plant

Tomato is one of the most widely grown vegetables in the world and a common component of the Mediterranean diet (Dorais *et al*., 2001; Chookhampaeng *et al.*, 2008). It belongs to family solanaceae and their scientific name *Lycopersicon esculentum* Mill, however more modern tends towards the name *Lycopersicon lycopersicon* (Maroto, 2002). The tomato genome is composed of approximately 950 megabytes of DNA, more than 75% of which is heterochromatin and largely devoid of genes (Prohens and Nuez, 2008).

Table 1.1. The botanical classification of tomato (Victor and Ronald, 2008; Jones, 2008).

Order	*Solanales*
Suborder	*Solanineae*
Family	*Solanaceae*
Tribe	*Solaneae*
Genus	*Lycopersicon*
Subgenus	*Eulycopersicon*
Species	*Lycopersicon esculentum*

1.1.1. Economic importance

Tomato is among the ten most important fruits and vegetables in terms of consumption. World tomato production in 2012 was about 161.793.834 tonnes of fresh fruit from an estimated area harvested 4.803.680 ha (Faostat, 2012). The major tomato growing countries are China, India, USA, Turkey, Egypt, Italy, Iran, Brazil, Spain and Uzbekistan (Figure 1.1, Faostat, 2012). There has been a steady increase in the annual worldwide production of

tomatoes as can be gleaned from (Table 1.2). Spanish production has a sustained growth in recent years, due to increased production of tomato industry, which is truncated from the year 2006 due to an adjustment of the sector.

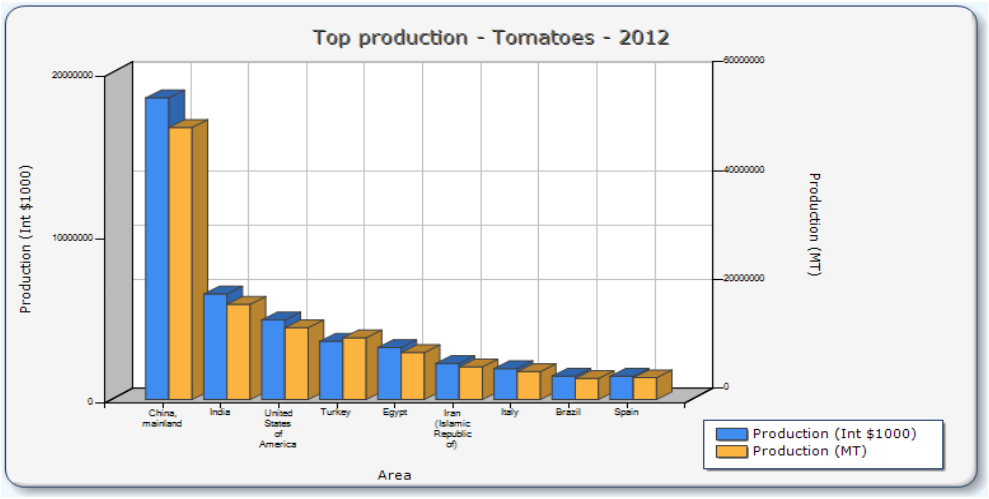

Figure 1.1. Top production countries of tomatoes and production value (Faostat, 2012).

Table 1.2. Annual worldwide production of tomatoes in the last ten years.

Year	Tomato Production (tonnes)
2003	119.472.305
2004	128.424.454
2005	129.367.348
2006	131.278.298
2007	137.858.813
2008	141.224.118
2009	154.569.777
2010	152.171.087
2011	159.347.031
2012	161.793.834

The cultivated area in Spain increased in the last ten years with maximum in 2005, while it is minimum in 2011, however the yield per hectare increased with last years and become higher in 2011, due to improvement the system production techniques (Ministerio Agricultura, Pesca y Alimentación (MAPA), 2012; Figure 1.2).

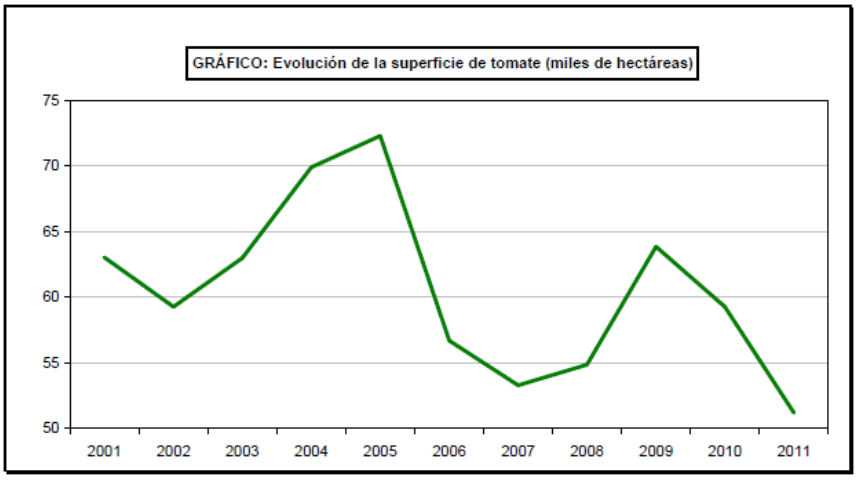

Figure 1.2. Evolution of the cultivated area of tomato (thousands of ha) in Spain (Ministerio Agricultura, Pesca y Alimentación (MAPA), 2012).

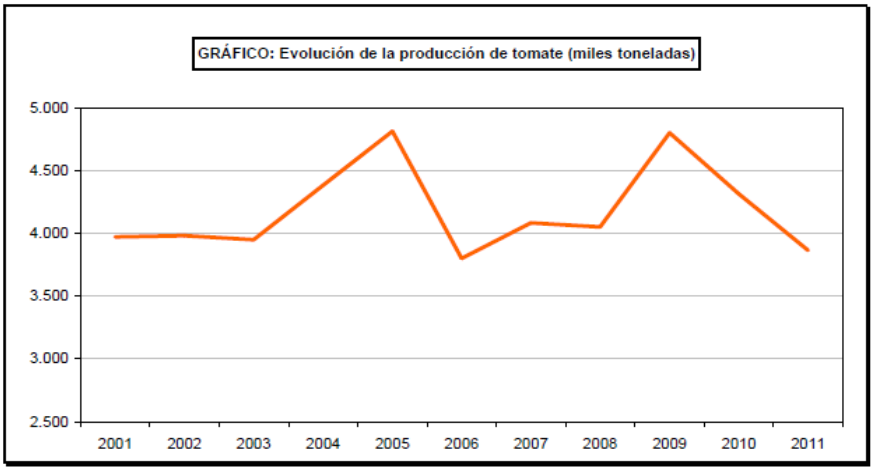

Figure 1.3. Evolution of the production of tomato (thousands of ha) in spain (Ministerio Agricultura, Pesca y Alimentación (MAPA), 2012).

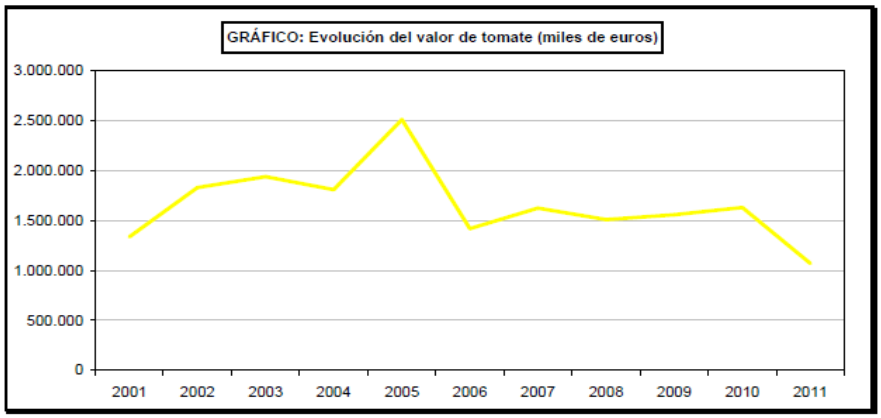

Figure 1.4. Evolution of the tomato value (thousands of euros) in spain (Ministerio Agricultura, Pesca y Alimentación (MAPA), 2012).

Table 1.3. Historical series of area and production according to harvest time in Spain (Ministerio Agricultura, Pesca y Alimentación (MAPA), 2012).

Años	Recolección del 1-I al 31-V		Recolección del 1-VI al 30-IX		Recolección del 1-X al 31-XII	
	Superficie (miles de hectáreas)	Producción (miles de toneladas)	Superficie (miles de hectáreas)	Producción (miles de toneladas)	Superficie (miles de hectáreas)	Producción (miles de toneladas)
2001	11,8	1.002,0	42,4	2.306,7	8,9	662,9
2002	11,6	1.010,3	39,3	2.278,7	8,6	698,3
2003	12,0	1.056,3	43,0	2.244,4	8,0	646,6
2004	11,9	1.091,6	49,0	2.595,6	9,0	696,0
2005	11,1	893,2	52,0	3.239,1	9,1	678,0
2006	11,3	947,8	35,9	2.147,4	9,4	705,4
2007	11,6	1.039,1	33,5	2.134,8	8,2	907,5
2008	12,1	1.201,9	35,0	2.157,1	7,8	690,8
2009	11,7	1.048,7	45,4	3.182,5	6,8	566,9
2010	10,7	946,2	42,3	2.862,3	6,2	504,2
2011	6,5	603,3	35,6	2.389,2	9,1	871,7

1.1.2. Origin and distribution

Tomato has its origin in the South American Andes region that includes parts of Colombia, Ecuador, Peru, Bolivia and Chile (Yuling and Lindhout, 2007). Other hypothesis that origin of tomato in Peru-Ecuador area, from which spread to central and South America (Maroto 2002; Naika *et al*., 2005). Tomatoes were domesticated in America; however, the original site of domestication and the early events of domestication are largely obscure (Yuling and Lindhout, 2007). The cultivated tomato was brought to Europe by the Spanish conquistadors in the sixteenth century (Maroto, 2002; Yuling and Lindhout, 2007). Later introduced from Europe to southern and eastern Asia, Africa and the Middle East (Figure 1.5,

Yuling and Lindhout, 2007). In the seventeenth century it was cultivated for food in Italy (Maroto, 2002).

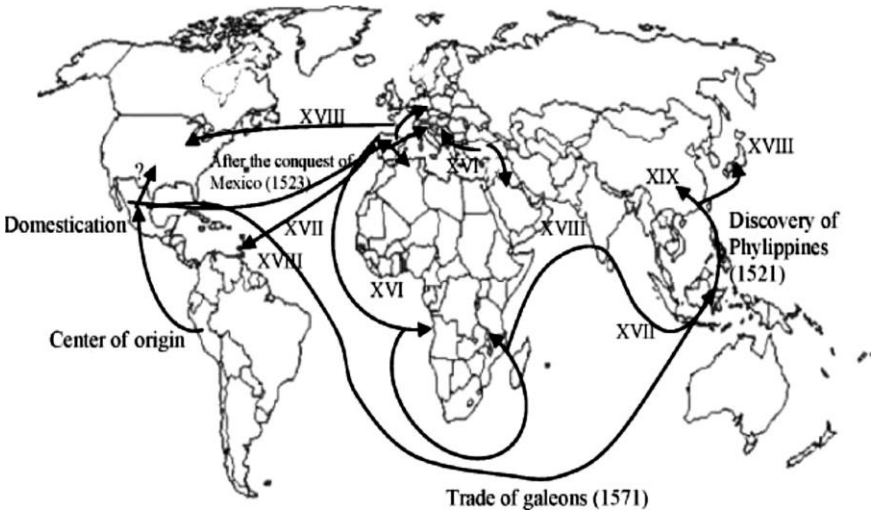

Figure 1.5. Possible spreading routes of the tomato beginning in the 16th century (Prohens and Nuez, 2008).

1.1.3. Nutritional value and uses

Tomatoes are one of the most widely eaten vegetables in the world. Perceived flavor is derived from a combination of taste and smell. Over 400 volatile compounds have been identified in tomatoes, of which about 30 are thought to contribute to aroma. The traditional taste of a tomato results from the sugar and organic acid content of the fruit (Harland and Sofia, 2009). Jones *et al*. (1991) told that flavor of tomato comes mainly from its sugars (fructose, glucose, sucrose) and organic acids (malic and citric). As the fruit ripens the content of fructose and glucose increases and the content of acids decreases.

The tomato has greatly experienced due to the great diversity of uses and its adaptation to different cropping systems (Prohens and Nuez, 2008). Tomatoes can be consumed in various forms, exist three major processed products are: (i) tomato preserves (e.g. whole peeled tomatoes, tomato juice, tomato pulp, tomato puree, tomato paste, pickled tomatoes); (ii) dried tomatoes (tomato powder, tomato flakes, dried tomato fruits); and (iii) tomato-based foods (e.g. tomato soup, tomato sauces, chilli sauce, ketchup), also can consumed raw (Heuvelink, 2005).

Prohens and Nuez, (2008) reported that exist two groups of tomato depend on their use: for fresh consumption and for processing. Within each of these groups, specific cropping systems exist that require adapted varietal types. Varieties for fresh consumption are cultivated in greenhouses and in the open air, while varieties for processing are only cultivated in the open air.

Figure 1.6. Canned tomato.

Figure 1.7. Tomato juice.

The consumption of tomato actually is so extensive that it is almost impossible to dissociate it from the menus of fast foods and pizza parlours. Its per capita consumption in fresh and processed form surpasses 20 kg/year (Jones *et al*. 1991). According to Maroto (2002) the consumption in most of European countries about 10 kg per person/year, however in Spain and Italy this amount increases dramatically.

The fruit is a source of potassium, vitamin C, folic acid and carotenoids, with lycopene (antioxidant) being predominant. It also contains vitamin E, vitamin K and flavonoids. It has a low calorie content of around 20 kcal/100 g of fruit.

Can use tomatoes as a model crop for physiological, cellular, biochemical, molecular and genetic studies because they are easily grown, have a short life cycle (Heuvelink, 2005).

1.1.4. Plant Characteristics

The tomato is an herbaceous annual, but their vegetative growth can extend a several years (perennial) in favorable conditions (Maroto 2002; Jones, 2008).

Tomato has a wide root system; tap root can grows to a depth of 50-60 cm deep. The main root produces dense lateral or secondary roots and reinforced by the presence of large numbers of adventitious roots arising from the base of the stem if favorable conditions are provided (Maroto, 2002; Naika *et al*, 2005). Although the root system can deepen up to 1.5 m depth, most of them situated in the first 50 cm (Maroto, 2002). Layer of moist peat or compost at the stem base will encourage new roots to form at this point (Mashego, 2001).

The stem is coarse, angular and coated by hairs that are visible, many of which, to be of glandular nature that give the plant a characteristic odor. Stem is erect in first growth stage, with increase stem weight, becomes prostrate on the soil (Maroto, 2002).

Stem development is variable according to cultivars, existing two types of growth:

- *Cultivars with stem of determinate development*, when principal stem produce several lateral orders of inflorescences, normally each 1 or 2 leaves, stop their growth result of formation of terminal inflorescences.
- *Cultivars with stem of indeterminate development*, that always have in their apex one meristem of growth produce continued elongation of the main stem, that produce inflorescences in lateral position. Normally each three leaves (Maroto, 2002). In other way, indeterminate cultivars continuously producing three nodes between each inflorescence (Jones, 2008).

The regular tomato leaf is compound and imparipinnate alternately arranged on the stem, composed of 7-9 leaflets, which has a serrated or lobed, irregular edge, or margin. Leaflets are ovate to oblong, covered with glandular hairs as stem which gives the characteristic odor of tomato. Small pinnates appear between larger leaflets (Maroto, 2002; Harland and Sofia, 2009).

Tomato flowering produce in form simple or branched raceme. In each inflorescence produces 3-10 flowers, occasionally can reach to 50 (Maroto, 2002). Flower is bisexual, regular. Grow opposite or between leaves. Calyx tube is short and hairy, sepals are persistent. Usually 6 petals up to 1 cm in length yellow and reflexed when mature. Six stamens, anthers are bright yellow in colour surrounding the style with an elongated sterile tip. Ovary is superior. Mostly self- but partly also cross pollinated (Naika *et al*., 2005).

Fruit are fleshy berry, globular, pyriform to oblate in shape, colour generally red at maturation; however, some varieties present other colorations as yellow, violet. Interior of fruit exist 2-30 of carpels locules. The placentation can be or no regular. Fruit diameters vary between 3 and 16 cm (Maroto, 2002). The fruits may be a single color, speckled or striped with a different color, or multicolored (Harland and Sofia, 2009).

The seeds are grayish, small size, discoidal, coated with villus. In 1 g of seeds contain up to 350 seeds, their germination capacity until 4 or 5 years (Maroto, 2002).

Figure 1.8. Indeterminate varieties, produce a range of fruit shapes and colours. Their fruiting season is longer too (Harland and Sofia, 2009).

Figure 1.9. Determinate varieties, these short and shapely plants have many sideshoots, which means the plant sprawls out in all directions (Harland and Sofia, 2009).

1.1.5. Ecological adaptation

The tomato is plant of warm climate. Optimum temperature of germination between 18-20 °C. Adequate temperature of plant growth is 18-20 °C during daytime and 15 °C during nighttime. The optimum temperature of flowering 22-25 °C during daytime and 13-17 °C during night. While during fruit production tomatoes require daytime temperature about 25 °C

and 18 °C at night. Tomatoes require a certain alternation of temperature, in other way, should be subject to a certain thermoperiodism (Maroto, 2002). Adams *et al.* (2001), were studied response of tomato grown under different temperature 14, 18, 22 and 26 °C and observed that plant grown under temperature of 26 °C had poor fruit set and fruits tended to be either parthenocarpic or have low seed numbers, while plants grown at 22 °C and 18 °C produced normal fruits and had a normal vegetative growth, whereas plants grown at 14 °C reduced their growth, Furthermore, produce more no marketable fruits. Excessive high temperature cause drop of flowers and newly fruits set (Maroto, 2002). In addition, high air temperature, greater than 35 °C, reduces fruit set and inhibits development of normal fruit color (Jones, 2008). The tomato plant cannot tolerate frost (Maroto, 2002; Jones, 2008), Low temperature also produce floral abscission (Maroto, 2002). Blossom drop will occur when the air temperature, particularly at night, drops below 12.7 °C (Jones, 2008), whereas, temperature below 0 °C totally destroy the plant (Maroto, 2002).

The relative humidity has a great interest especially at pollen dehiscence and pollination, adequate humidity between 55-60 % (Maroto, 2002). The tomato plant grown better in relatively dry air conditions, as high relative humidity tends to be associated with both insect and disease problems (Jones, 2008).

Regarding to soils, tomato not have specific requirements, however grown better in loose soils, deep and well drained. Can grow without excessive problems in soil with pH rather high, also resistant to certain acidity. Best yield with pH 6.5 and 6.9 (Maroto, 2002). The tomato plant has moderately tolerance to soil salinity, which is a growing problem worldwide, resulting from over fertilization or the use of saline (brackish) irrigation water. A soil salinity measurement (EC) of less than 2.5 dS m^{-1} will not affect plant growth (Jones, 2008).

1.1.6. Greenhouse production

The growing of tomato plants in enclosed shelters is widely practiced. Greenhouse tomato production in precisely controlled environments is increasing in many parts of the world. In the greenhouse the tomato plant can continue productive for 6 to 9 months (Gruda, 2009).

Greenhouse cultivation can achieves many goals as, get production out of season, the most common is obtain of early production and late production that achieved higher economical returns, tomato classical production in summer, cultivation under greenhouse can advance harvest up to end of winter or beginning of spring, exist great interest to extend the production under greenhouse to autumn and winter. Increase production levels under greenhouse as result of the best care for crop and better condition of physical environment offered under greenhouse. In addition to improve commercial quality of the crops (Maroto, 2008).

There have been a number of developments that have influenced the ability of growers to produce high production and quality fruit in a greenhouse environment. They include: i) using soilless culture, which permits to avoid soil problems (Jones, 2008; Gruda, 2009), ii) using cultivars and hybrids specifically for greenhouse conditions, which are resistance or tolerance to common tomato plant diseases and insects, and having significantly increased fruit yield potentials, iii) use of bumblebees for pollination of flowers eliminates the need to hand pollinate, a major labor-intensive operation and use of predator insects and integrated pest management procedures can either eliminate or reduce the need for chemicals to control plant insects and disease, iv) computer control of the growing system and greenhouse continuously and automatically monitors the greenhouse environment, these factors led to increase production through increase yield per plant or unit of space (Jones, 2008).

Some cultural practices carried out inside greenhouse on tomato:

Pruning: is important for tomatoes, especially indeterminate cultivars. It improves the light penetration and air circulation. The need for pruning depends on the type of plant and the size and quality of the fruit. If plants are not pruned, they will grow at random and fruit will be smaller (Naika *et al.*, 2005). Firstly can left 1, 2 or 3 branches per plant according to the systems that wants to use. With only branch obtain early production; however, with 2 or 3 branches the productivity is higher. Pruning to one branch usually use planting distance more narrow, especially in regard to distance between plants. When the plant is formed exist different pruning systems as candelabra pruning and hardy pruning. In conjunction with these systems of pruning eliminate the side shoots each 10 or 15 days (Maroto, 2002). Remove any yellow or decaying foliage as soon as possible to avoid the spread of disease and allow higher

aeration (Maroto, 2002; Naika *et al.*, 2005). In any case, must be emphasize that the incidence of a particular type of pruning on tomato productivity is linked to the density of planting and the variety (Maroto, 2002).

Nipping: is consist of remove the small side-shoots and only one main stem remains. The fruit clusters grow along this main stem. (Maroto, 2002; Naika *et al.*, 2005). Nipping regulates and shortens the vegetative cycle, defining the length of the plant (Maroto, 2002). This process enhances fruit size (Maroto, 2002; Naika *et al.*, 2005).

Support systems: Placing trusses or pillars for a plant develops the maximum vertical direction is a common practice in tomato cultivation (Maroto, 2002). Today the most support system used in greenhouse with nylon cord, plants supported by nylon cord longitudinal running the top of greenhouse. Support system helps to obtain cleaner and healthy fruits, no contacted with the soil, improve the aeration and lighting between plants and facilitate the cultural practices (Maroto, 2002), fruit yield and size, reduce fruit rot, and make spraying and harvesting easier (Naika *et al.*, 2005).

1.1.7. Soilless culture systems

The soilless culture is defined as the cultivation of plants in systems without soil "*in situ"*. Soilless culture systems consider the most intensive production method in today's horticulture industry, are based on environmentally friendly technology, which can result in higher yields, even in areas with adverse growing conditions (Gruda, 2009). Hydroponic cultivation has agreed advantages, permits a good control of plant growth and development, and is currently in practice all over the world which can result in higher yields (Jones, 2008; Libia *et al.*, 2012), better using of fertilizers, higher control of plant nutrition, lower possibility occur of water limitations (Maroto, 2008), shown minimum problem with weeds, low water loss, improves roots development and reduced application of agrochemicals and low phytosanitary problems (Jones, 2008; Maroto, 2008). On the other hand, has some problems, it present high cost of implantations, important maintenance expenses (Maroto, 2008).

In recent years, a multitude of innovative cultivation procedures using other system as cultivation in bags or buckets of sand, gravel and on substances of inert organic as perlite, pine bark, rockwool slabs, coconut fiber slabs and sometimes expanded clay (Jones, 2008: Maroto,

2008). Coconut fiber is a plant material originating from the residual of the coconut industry, used the short fibers and medullary tissue powder in variable proportions as substrate. Coconut fiber is a light material and has a very high total porosity above 93%. Present acceptable amounts of water readily available and well aerated. The coconut fiber is slightly contracted when allowed to dry (Baixauli and Aguilar, 2002). In addition to great development in nutrient solutions. These cultivation methods developed and appear various hydroponic growing systems (Jones, 2008).

There are basically three hydroponic growing systems that are being used today to grow tomatoes commercially: flood-and-drain, the nutrient film technique (NFT), and drip irrigation growing in either rock wool slabs or perlite-containing bags or buckets, which provide a degree of nutrient element control not possible in soil, thus eliminating soil factors that are difficult to control (Jones, 2008). Tomato plants have been grown successfully in nutrient film technique (Maroto, 2002).

Among factors affecting hydroponic production systems, the nutrient solution is considered to be one of the most important determining factors of crop yield and quality. The nutrient solution for hydroponic systems is an aqueous solution containing mainly inorganic ions from soluble salts of essential elements for higher plants. Currently 17 elements are considered essential for most plants, these are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, copper, zinc, manganese, molybdenum, boron, chlorine and nickel. All this elements are supplied through using artificial products, with the exception of carbon, hydrogen and oxygen, which are supplied from the atmosphere (Toshiki, 2012). The temperature of nutrient solution must be about 20 ºC. Also climate condition as environmental temperature, relative humidity and adequate lighting have importance when associated of hydroponic system with greenhouse cultivation (Maroto, 2008).

The pH of nutrient solution is extremely important and should be consistent with the plant that is growing (Maroto, 2008). Most of the plants can tolerate nutrient solution with pH between 6 and 6.5 (Jones, 2008), or between 5 and 6.5 (Maroto, 2008). However, the commercial solution with pH 6 and 6.5. Alkaline pH can induce the precipitation of iron, manganese, phosphate, magnesium and calcium in form of insoluble salts, not convenient to

the plant, while solution with pH too acidic induce deficiency of calcium and low utilization of ammonium cations (Maroto, 2008).

The nutrient solution composition of is frequently adjusted based on growing method, stage of plant growth, and changing environmental conditions. There are a considerable number of nutrient solution formulations that are recommended for the hydroponic production of greenhouse tomatoes. In general, most of the formulations are slight variations of the Hoagland and Arnon (1950) formulation, and experience has shown that there is little difference based on what formulation is selected, in cajamar used a nutrient solution given by Sonneveld and Straver. The best way to determine if the formulation chosen is providing all the nutrient element needs of the tomato plant is to periodically test the plant by means of a plant analysis (Jones, 2008).

1.2. Salinity

Salinity is one of the most important factor limiting fruit growth and production of several horticultural crops (Savvas et al., 2007; Azarmi *et al.*, 2010; Carillo *et al.*, 2011; Zeinolabedin, 2012). Salinity is an environmental stresses that effect on growth and development in plants (Afshari *et al.*, 2011), and is a widely recognized problem in irrigated regions throughout the world. On the other hand, salinization continues to increase, particularly in the arid and semiarid regions (Yokas *et al.*, 2008; Abu-Khadejeh *et al*., 2012).

Salinization occurs by natural phenomena or by the action of man. Salinization occurs by natural phenomena forming soil by weathering of rock with high content of bicarbonate, sulfate or sodium chloride, calcium or magnesium, because these salts are dissolved by rainwater, that evaporate accumulates in low areas and depressions. Also introgression seawater in coastal areas and marshes leads to phenomena of salinization. All these forms of salinization are estimated that affect 3.23×10^6 km^2, which represents 26% of the cultivated land in the world. Salinization by the action of man occurs by inadequate management of irrigation water, which leads to a progressive accumulation in soil of dissolved salts in irrigation water and leave unserviceable agriculturally areas, where there was good soil and where they had made costly investments for its transformation into irrigated, this form of salinization affects about a third of the 2.3×10^6 km^2 of existing irrigated area in the world (Nuez, 1995). Worldwide, more than 45 million ha of irrigated land have been damaged by

salt, and 1.5 million ha are taken out of production each year as a result of high salinity levels in the soil (Carillo *et al.*, 2011). Most of the salt stress in nature is due to sodium chloride salt (Abu-Khadejeh *et al*., 2012).

Salinity can damage the plant through two ways, its osmotic effect and specific toxic effects of ions that called the salt-specific or ionic effect of salinity (Yokas *et al.,* 2008; Maroto, 2008; Azarmi *et al.*, 2010; Parvaiz and Prasad, 2012). In case of osmotic effect, presence of salts in the soil and water originates low osmotic potential (Yokas *et al.,* 2008; Maroto, 2008; Azarmi *et al.*, 2010; Parvaiz and Prasad, 2012), which led to reduce the ability of the plant to take up water, and this leads to reduction in the growth rate (Yokas *et al.,* 2008; Parvaiz and Prasad, 2012), also can occur decrease in water activity (Azarmi *et al.*, 2010). The osmotic effects of salinity stress can be observed immediately after salt application and are believed to continue for the duration of exposure, resulting in inhibited cell expansion and cell division, as well as stomatal closure (T. J. Flowers, 2004). Salinity increases the osmotic pressure in the root environment and significantly decreases fresh yield of tomato. It is known that salinity reduces yield. Uptake of water into the fruits is reduced by a high osmotic pressure of the irrigation water, and as a result the fruit size is smaller (Chookhampaeng *et al*., 2008). To balance the osmotic potential, maintaining its value in the intercellular still lower than the soil (Maroto, 2008).

On the other hand, for specific toxic effects, if an excessive amount of salt enters the plant in the transpiration stream, produce several effects in the plant as, cause injury to cells in the transpiring leaves (Yokas *et al.,* 2008; Parvaiz and Prasad, 2012), disturbing the uptake of essential nutrients (Azarmi *et al.*, 2010). Absorption of saline ions by plant cause synthesized higher concentrations of molecules as sucrose, proline and glycine, while the absorption of sodium cations can destroy the chlorophyll, in addition to difficult absorption of potassium (Maroto, 2008). During long-term exposure to salinity, plants exposure to ionic stress, which could be lead to premature senescence of adult leaves, and thus a reduction in the photosynthetic area available to growth (Carillo *et al.*, 2011). Resulting in further reduction in plant growth.

In general, enzymes and metabolic activities in plants are highly influenced by both amount and type of salts. The response of plant growth and yield to salinity is the resultant of

various salt effects, including reduced carbon fixation due to specific ion toxicity, restriction of photosynthesis due to partial stomata closure, waste of energy in the processes of osmotic adaptation and ion exclusion and growth limitations originating from nutritional imbalances (Azarmi *et al*., 2010).

Tomato growth response to salinity has two phases. In the first phase there would be a large decrease in growth rate caused by the salt outside the roots, i.e. an 'osmotic' response. In the second phase there would be an additional decline in growth caused by salt having built up to toxic levels within plants (Abu-Khadejeh *et al*. 2012).

Inadequate irrigation management leads to moderate salinization of water and soils (secondary salinization) that is the most extensive and harmful form of salinization as it affects 20% of irrigated land world-wide and 50% of the irrigation schemes (Nuez, 1995; Bolarin *et al.*, 2011), grown tomato in moderate salinity can affects negatively their growth and production (Bolarin *et al.*, 2011). Aquifers water can cause nitrate pollution and salt accumulation. To avoid problems caused by accumulation of salts, need to drain a proportion of applied nutrient solution. In marketable soilless vegetable production, leaching fractions of 30–40% of applied water are normally used (Magan *et al.*, 2008).

On the other hand, in greenhouse production especially in hydroponic culture, using nutrient solution, which necessitates high fertilizer application. The plant did not absorb all the nutrients, tending to concentrate salts in the substrate (Van iersel, 1999; Ludwing *et al.*, 2013).

In applying saline/brackish water for irrigation, an integrated approach, which should account for soil, crop and water management at the same time, should be adopted. This approach needs calculation of crop water requirements which are essential for water saving, controlling water table level and drainage volume, and of course the final yield (Reina-Sánchez *et al.*, 2005). Water use efficiency (WUE) and irrigation water use efficiency (IWUE) are common indicators employed to assess the efficiency of the use of irrigation water in crop production. WUE in agronomical and biological terms gram fruit and gram dry matter per litre transpired water, respectively (Reina-Sánchez et al., 2005). Also can determined as higher efficiency in plant dry matter and fruit formation will lead to relatively less uptake of toxic ions (Na^+) (Cuartero and Fernandez-Muñoz, 1999). According to Medrano et al. (2005), WUE (g L^{-1}) was calculated as the ratio between marketable yield (g m^{-2}) and water uptake (L m^{-2}).

Tomato could act as a model crop for saline water use because it is already grown in large areas with saline conditions, and because there is a wealth of important knowledge of the physiology and genetics of this species (Cuartero and Fernandez-Muñoz, 1999).

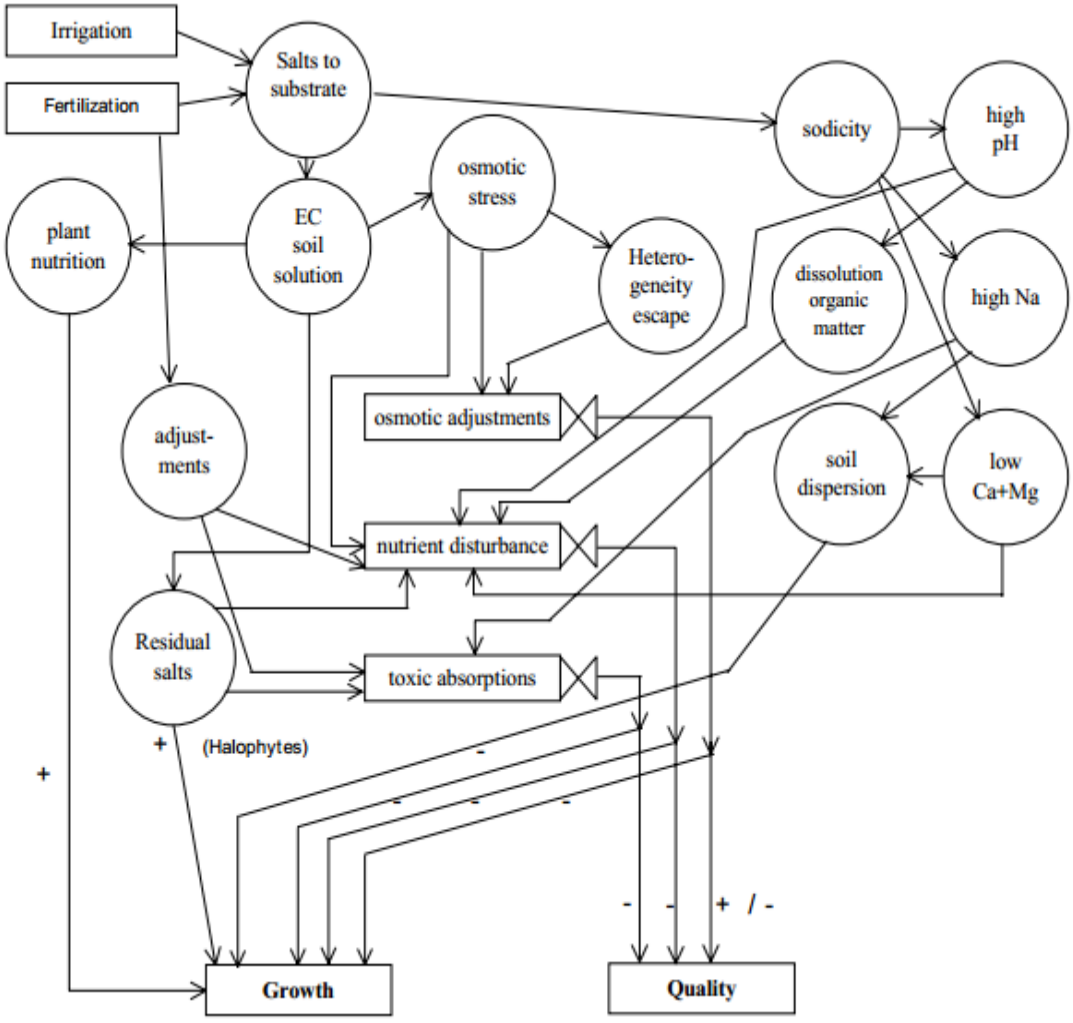

Figure 1.10. Relation diagram for salinity effects (Sonneveld, 2000).

1.2.1. Effect of salinity on tomato growth

Salinity treatments caused the retardation in growth and development of tomato plants during both vegetative and reproductive phases (Chookhampaeng *et al.*, 2008). Stressed plants produce a smaller root system, a mature leaves curled and succulents, a smaller young leaves,

more intense green colored and rolled up on them (Figure 1.3; Nuez, 1995). Treatment with 25 mM NaCl did not affect in plant height and increase in stem diameter. Whilst higher concentrations of 50 and 100 mM NaCl caused 25.1% and 30.9% reductions in plant height and 9.88% and 16.3% reductions in stem diameter respectively. The number of lateral shoots was drastically reduced from 15.5 to 7.5 (51.6%) and 5.75 (62.9%) shoots per plant when treated with 50 and 100 mM NaCl respectively. Salinity treatment at 50 and 100 mM had less effect on the fresh weight of shoots (22.6% and 23.1% reduction, respectively) than on that of roots (42.8% and 48.3% reduction, respectively), whereas the reverse was observed with the dry weight. On a dry weight basis, NaCl at 50 and 100 mM had more deleterious effects on shoot growth (13.9% and 20.4% reduction, respectively) than root growth (7.4% and 14.1% reduction, respectively). In non-stressed condition, the plants flowered at the age of 52.75 days. Under 50 and 100 mM NaCl stress, flowering was significantly delayed for 12 days. Although 25 mM NaCl had no significant deleterious effects on any of the vegetative parameters and the time of flowering, it did cause significant reduction in mature fruit size (Chookhampaeng *et al*., 2008).

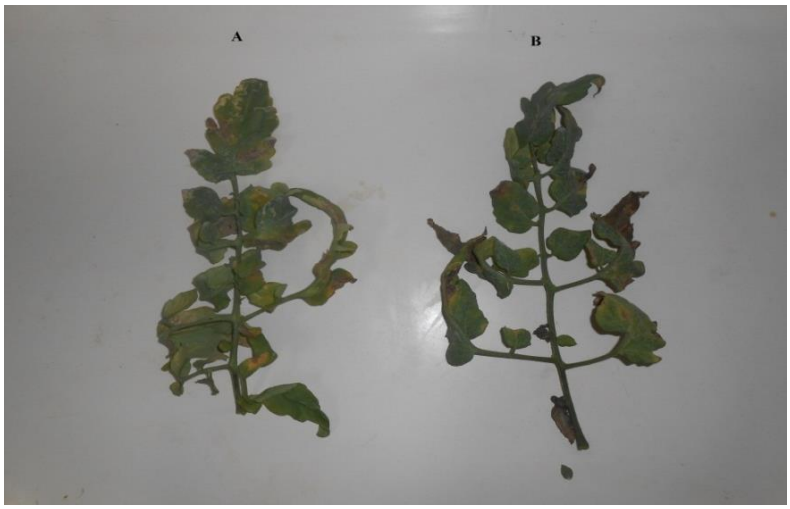

Figure 1.11. Adult leaves curled with small leaflets exposure to irrigation water salinity 5.3 dS m^{-1}; A: cv. Raf, B: cv. Dumas (Source: from treatments of this study).

Azarmi *et al.*, (2010) mentioned that growth parameters such as plant height, leaf number, leaf area, stem and leaf dry weight were significantly declined with increasing

salinity. The plant height decreased 5.6, 11.8, 17.1 and 21% at EC of 3, 4, 5 and 6 dS m^{-1}, respectively, compared with EC of 2.5 dS m^{-1}. Leaf number was significantly reduced at EC of above 3 dS m^{-1}. Nutrient solution with 6 dS m^{-1} EC decreased leaf number to 42% in comparison to 2.5 dS m^{-1}. The highest total leaf area was recorded from the leaves of plants fed with EC of 2.5 dS m^{-1} and then decreased with increasing salinity levels. When EC of nutrient solution increased from 2.5 to 6 dS m^{-1}, stem dry weight decreased to 55.3%. Leaf dry weight at EC of 6 dS m^{-1} decreased up to 36.5% compared with 2.5 dS m^{-1}. Fruit dry weight percentage increased 2, 4.4, 6 and 8.7% at EC of 3, 4, 5 and 6 dS m^{-1}, respectively, in comparison to 2.5 dS m^{-1}.

Irrigation water with high level of NaCl reduced plant dry weight (Yokas *et al.*, 2008). The biomass yield was already reduced at the 2.5 dS m^{-1} salinity level and the reduction continued to increase as the salinity increased from 2.5 to 10.0 dS m^{-1}. The average decrease in biomass yield caused by an increase in salinity from 2.5 to 5.0 dS m^{-1} was approximately 37%, as the salinity increases further to 10.0 dS m^{-1} a further yield reduction of approximately 60% was obtained (Yurtseven *et al.*, 2005).

1.2.2. Salinity and fruit yield of tomato

Stressed plants produced flowers and fruits more slowly and the fruits are smaller compared to the non-stressed plants (Chookhampaeng *et al.*, 2008). Reduced total and marketable fruit yield with increasing salinity was a consequence of reductions in fruit fresh weight and fruit number. Both fruit weight and fruit number showed a threshold response with a subsequent linear decrease at higher EC values. Fruit weight was more sensitive to increasing salinity, having lower threshold EC value ($EC_{t)}$ values and larger slope values than fruit number. Threshold values for average fruit weight were 3.0 dS m^{-1} for both total and marketable fruit, and for fruit number, EC_t were 4.4 dS m^{-1} for both total and marketable fruit. Averaged over the three experiments, reductions in fruit weight were 6.5 and 6.1% per dS m^{-1}, respectively, for total and marketable fruit; with no significant differences between experiments. The corresponding value for total fruit number was 2.0% per dS m^{-1} (Magan *et al.*, 2008).

The average fruit fresh weight of control and NaCl treatment was 188.4 g and 113.7 g, respectively, a significant difference between the treatments was observed (Sato *et al.*, 2006).

Fruit yield per plant and average fruit weight decreased in the plants grown under salinity, the highest reduction in fruit yield was in the 90 mM NaCl treatment (Yokas *et al.,* 2008). Salinity levels, strongly affected the fruit height and diameter, and these parameters decreased linearly with increasing salinity levels from 2.5 to 10 dS m^{-1} (Yurtseven *et al.*, 2005). The highest fruit weight was recorded from plants fed with 2.5 dS m^{-1} and then decreased with increasing salinity levels. Total fruit yield was reduced 8.7, 21.7, 36 and 48.9% at EC of 3, 4, 5 and 6 dS m^{-1}, respectively, compared to 2.5 dS m^{-1} (Azarmi *et al.*, 2010).

At the low level of NaCl stress (25 mM), the number of mature fruits was reduced from 16.5 to 10.25 per plant (37.9% reduction) and the average fruit weight was reduced from 45.56 g to 38.94 g (14.5% reduction). At 50 and 100 mM NaCl, the number of mature fruits per plant was drastically reduced by 53.0% and 51.5%, and the average fruit weight was reduced by 54.2% and 58.7%, respectively (Chookhampaeng *et al*., 2008).

1.2.3. Effect of salinity on tomato fruit quality

Fruit quality properties like total soluble solids (TSS), fruit dry weight percentage and titratable acidity, improved with increasing salinity while fruit weight reduced with increasing salinity. TSS was increased at EC of above 3 dS m^{-1}. When EC of nutrient solution increased from 2.5 to 6 dS m^{-1}, TSS increased to 13.4%. Titratable acidity at EC of 6 dS m^{-1} increased up to 28.9% in comparison to 2.5 dS m^{-1}. Juice pH was not significantly affected by salinity treatments (Azarmi *et al.*, 2010).

The TSS was not affected by low salinities (2.5 dS m^{-1}) but subsequently, it showed a great increase with increasing salinity levels. Compared with the control, the 10 dS m^{-1} salinity level caused a 100% increase in TSS of the fruit. Where fruit TSS ranged between 10.36% and 5.43% for the 10 and 0.25 dS m^{-1} salinity levels (Yurtseven *et al.*, 2005).

Sato *et al*., (2006) among index graded by taste panel, juiciness, sweetness, acidity, umami, aroma, and overall preference had significantly higher scores for control than NaCl treatment fruit. Interestingly, peel hardness graded by the panel was significantly higher in NaCl treatment than control, however, physical peel hardness measured by the 1 mm diameter plunger was significantly higher in control. Soluble solids content of NaCl treatment and

control was 6.12 and 7.78%, respectively with significant difference. NaCl enrichment in the nutrient solution increased tritratable acidity of tomato fruit (Sato *et al*., 2006).

1.3. Objectives of the study

Most of irrigation water used for vegetable production under greenhouse has a high salt concentration especially when use aquifers water, in addition to mixing with fertilizer in order to form nutrient solution in hydroponic cultivation; this can cause salt accumulation in the root system environment as in substrate systems. In addition to most of the studies used one cultivar of tomato. Therefore the objective of this experiment was to:

- Assess the effects of salinity of irrigation water on vegetative growth, fruit yield, yield components and several quality parameters of tomato grown in hydroponic culture inside greenhouse.
- Evaluate the response of two cultivars of tomato marmande to different salinity levels.

2. MATERIALS AND METHODS

2. Material and methods

2.1. Experiment location

The experiment was carried out during year of 2013 and 2014 at the Center Experiences of Cajamar in Paiporta, Valencia province, Spain. The geographical location is latitude 39° 41' N, longitude 0° 25' W and 17 m elevation.

2.2. Greenhouse design and managements

The experiment was conducted in a greenhouse type venlo covered of glass crystal 3 mm (Figure 2.1). It has a roof windows opening alternating; one window in eastern side and other in western. The greenhouses measured 53.50 m long by 19.50 m wide. It had a north-south orientation with crops rows aligned in the same direction. The soil of greenhouse was covered by horsal bio are flat braid woven, made from polylactic acid with weight 130 g/m^2, it has a resistance to weeds growth.

Figure 2.1. Greenhouse type "Venlo" with glass cover.

Climate management inside the greenhouse were achieved by used a program of MCU Plus (is computer program achieved by Agriware company; *http://www.agriware.com/mcu-plus-4.html*, Figure 2.2) with meteorological station (Figure 2.3) include vane to determine wind direction, anemometer to measure winds speed, rain sensor, luxometer for measure solar

radiation and sensor measures temperature inside the greenhouse. This program in contact with the roof windows, where management the temperature inside the greenhouse by natural ventilation. At a height temperature approximately about 30 °C are open windows automatically, as well as at low temperature about 13 °C and generally at night is close windows. The roof windows were closed daily before sundown about two hours to prevent loss the temperature inside the greenhouse. When exist hard winds or warm winds in a direction, the windows facing this winds were closed with open the other windows for ventilation.

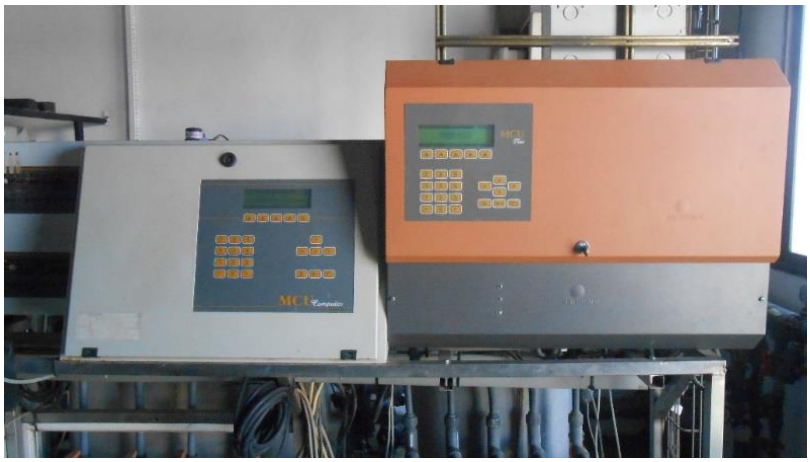

Figure 2.2. MCU plus Computer program.

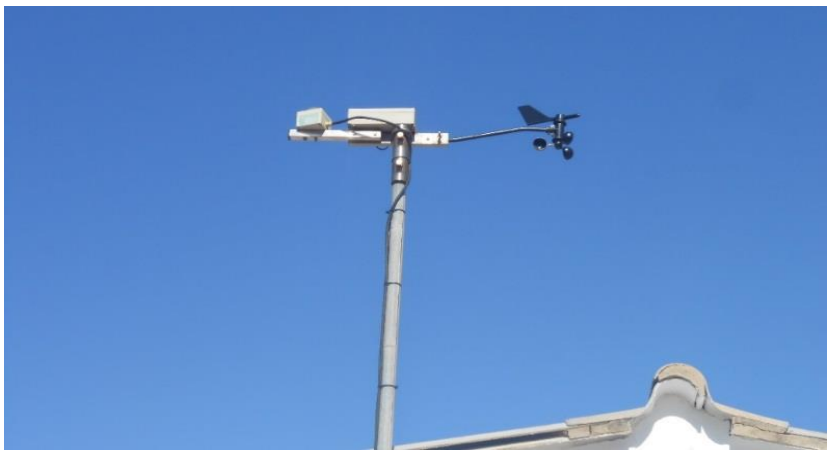

Figure 2.3. Meteorological station include vane for determine wind direction, anemometer, rain sensor, and luxometer.

2.3. Plant Material details and managements

The seeds of two tomato cvs. Raf and Dumas (belongs to marmande type) were used in this study. Raf seeds collected from Clause company, while Dumas seeds collected from Syngenta company (MR8217). Cv. Raf are average earliness and resistant to *Fusarium oxysporum f.sp. lycopersici.* While, cv. Dumas are vigorous plant with good leaf cover that allow to maintain good long-cycle production, dark green fruit with very good color in ripening fruit and bright green neck shoulders uniformly covering the fruit and good red color at maturity, with high consistency. It has a high resistant to Tobacco Mosaic Virus (TMV) strain 0, *Cladosporium fulvum* strain A-E and Tomato Mosaic Virus (ToMV) strain 0-2 (http://www.syngenta.es).

Seeds were sown on 18 July 2013 into foam trays filled with peat. Tomato seedlings transplanted into coconut fiber slabs (© physical and chemical properties of coconut fiber showed in Table 2.1) in greenhouse on 23 august 2013, at the 4–5th true leaf stage. Coconut fiber slabs were irrigated before planting to wash or reduce their EC drainage values below 1 dS m^{-1}, prior to saturation with nutrient solution.

Table 2.1. Physical and chemical properties of coconut fiber.

Electrical Conductivity, EC	<7 dS m^{-1}
PH	5.5 to 6.5
Organic matter	100 % (60% Coconut fiber and 40% Chips of Coconut).
Water retention capacity	8 times its weight
Dimensions expanded	100 x 20 x 12 cm
Volume	24 L

Plants were vertically supported by nylon cord guides, were pruned and managed following local practices. Regular pruning was conducted such that all auxiliary shoots were removed and only the main stem was left. The main stem was modified on nylon filament with the removal of the auxiliary shoots once a week.

Pollination of the flowers was entomophilous, through introduction inside the greenhouse a two hive of bumble bees (*Bombus terrestris*) of "Syngenta bioline ®".

The integrated control of the principal pest of tomato was applied. The plants were attacked by insects especially *Tuta absoluta*, leaf miner and white fly, used different strategies to reduce the population and control of pests. Used sexual attractants for monitoring of the of pests. The predator *Nesidiocoris tenuis* was released to the greenhouse for the biological control of white fly and *Tuta absoluta.* The commercial product Digline I was used to release the parasitoid *Diglyphus isaea* for the biological control of leaf miner. The greenhouse contain sublimating sulfur device in order to prevent powdery mildew disease. Throughout the entire cultivation cycle performed different treatments of fungicide, acaricides and insecticides to prevent any damage caused by these organisms. Chemical control shows in Table 2.2.

Table 2.2. Phytosanitary treatments performed during the crop cycle and active material of the products used.

Application time	Treatments (commercial products)	Treatments (active substances)	Doses
2-Sep-13	Oberon + Costar	Spiromesifen + Bacillus thuringiensis	0.04 % + 0.1 %
8-oct-13	Oberon + Costar	Spiromesifen + Bacillus thuringiensis	0.06 % + 0.1 %
11-Oct-13	Trigard	Cyromazine	100 g/ha (with irrigation)
15-Oct-13	Nimros quattro + Costar	Bupirimate + Bacillus thuringiensis	0.2 % + 0.1 %
24-Oct-13	Trigard	Cyromazine	100 g/ha (with irrigation)
31-Oct-13	Steward + Covicampo 50	Indoxacarb + Oxicloruro de cobre 50 %.	0.125 g/ha + 0.35%
15-Nov-13	Meristem + Covicampo 50	Bacillus thuringiensis + Oxicloruro de cobre 50 %.	0.1 % + 0.35 %
13-Dec-13	Revus + Score + Meristem	Mandipropamid + Difenoconazole + Bacillus thuringiensis	0.6 l/ha + 0.8 l/ha + 0.1 %
10-Jan-14	Crotene + Meristem	Chlorothalonil + Bacillus thuringiensis	0.3 % + 0.1 %

2.4. Treatments and experimental design

The experiment was carried out to study effect of two level of salinity of EC 3.3 dS m^{-1} (control) and 5.3 dS m^{-1} on production and quality of two cultivars of tomatoes *Lycopersicon esculentum* marmande type (Table 2.3).

The salinity treatments were applied from the first transplanting day with nutrient solution by drip irrigation. The nutrient solution with an EC of 3.3 dS m^{-1} was compared to nutrient solutions with a higher salinity (Table 2.3). The 3.3 dS m^{-1} nutrient solution prepared by use irrigation water of aquifers with 2.13 dS m^{-1}**,** the addition of fertilizers to form a complete nutrient solution generally result in access to the first level of salinity 3.3 dS m^{-1} (Table 2.4). The increase in EC of the higher salinity treatment (5.3 dS m^{-1}) was obtained by adding sodium chloride to a nutrient solution, where there are two tanks; one filled with nutrient solution and other for sodium chloride solution. Sodium chloride was used for increasing salinity because in the cropping conditions of SE Spain, the accumulation of both sodium and chloride is a major consideration in the management of recirculating solutions in soilless cropping (Magan *et al.*, 2008).

Table 2.3. The treatments of the experiment (Target electrical conductivity and cultivars of tomatoes).

Cultivars	Dumas
	Raf
Salinity	3.3 dS m^{-1} (Control)
	5.3 dS m^{-1} (Salinity treatment)

Table 2.4. The composition of nutrient solution of the treatments and irrigation water expressed with mMol/L.

	Irrigation water	**Nutrient solution 3.3 dS m^{-1}**	**Nutrient solution 5.3 dS m^{-1}**
NO^-_3	5.48	15.08	15.08
$H_2PO^-_4$	0.00	1.75	1.75
$SO2^-_4$	4.77	5.07	5.07
HCO_3^-	3.61	0.61	0.61
Cl^-	5.53	5,53	25.53
NH_4^+	0.00	1.00	1.00
K^+	0.15	7.50	7.50
$Ca2^+$	6.69	6.69	6.69
$Mg2^+$	2.90	3.20	3.20
Na^+	4.44	4.44	24.44
pH	7.38	5.5	5.5
EC (dS m^{-1})	2.13	3.3	5.3

The experimental design was a randomised block design. The experiment consist of 2 salinity level × 2 cultivars × 3 replications, which form 12 experimental units. The slabs of coconut fiber placed beside each other in rows (Figure 2.4 and 2.5), with distance between adjacent rows 1.55 m. Each plot consisted of a row contain 23 slabs of coconut fiber, and four plants were transplanted per each slab of coconut fiber (Figure 2.4).

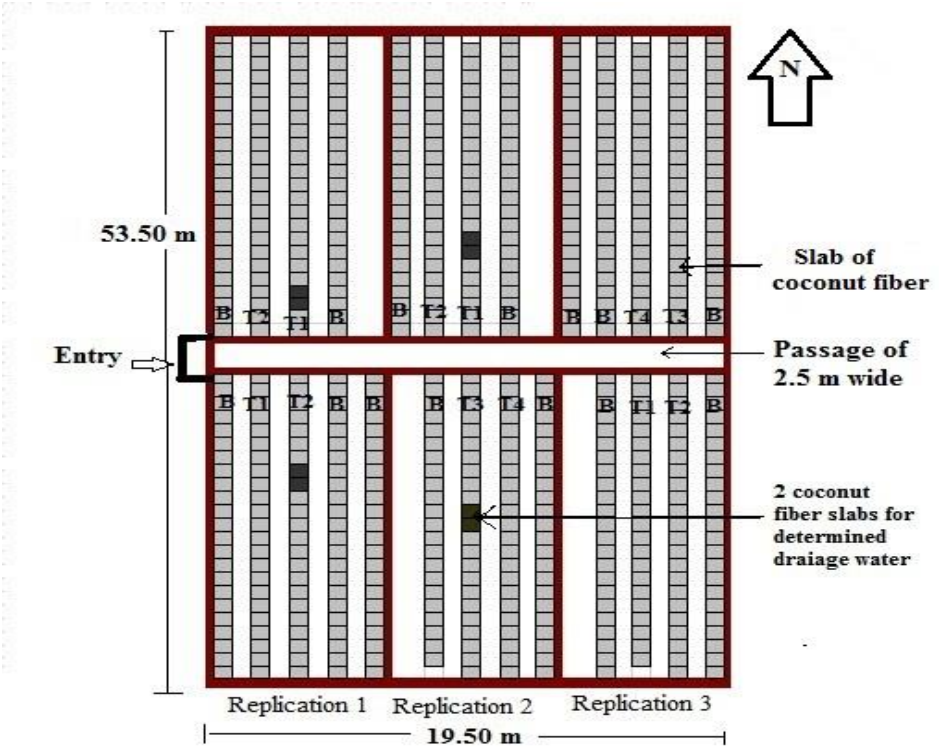

Figure 2.4. Plan of the greenhouse used for the experiment. The symbols B, T1, T2, T3 and T4 indicate the rows corresponding to border, salinity level 3.3 dS m^{-1} (control) with cv. Dumas, salinity level 3.3 dS m^{-1} (control) with cv. Raf, salinity level 5.3 dS m^{-1} with cv. Dumas and salinity level 5.3 dS m^{-1} with cv. Raf, respectively.

Figure 2.5. The slabs of coconut fiber placed beside each other in rows, each row are an experimental unit.

2.5. Nutrient solution and Irrigation management

The nutrient solution was applied by a drip irrigation system with four emitters per a slab of coconut fiber (one dripper per plant) with discharge of 2 L h^{-1}. The composition of nutrient solution shown in Table 2.4. The quantity of irrigation water controlled by the number of irrigation, which varied according to the plant growth stage and incident solar radiation. Applied water and the percentage of drainage water were measured daily (exceed in week end) only in cv. Dumas, from the following equation. Also EC and pH of drainage water were measured daily (exceed in week end) by pH/EC Meter (Figure 2.6 and Table 2.5).

$$\text{The percentage drainage water} = \frac{\frac{L}{\text{Number of emitters}}}{E} \times 100.$$

Where, L volume of drainage water, E volume of entry water.

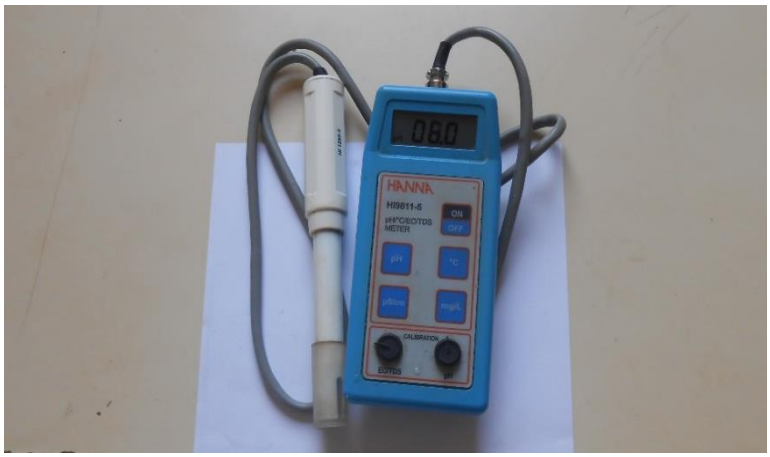

Figure 2.6. The pH/EC Meter used for measure pH and EC of the drainage water.

The electrical conductivity of drainage water was maintained below EC 5 dS m^{-1} and 9 dS m^{-1} in the salinity treatments 3.3 dS m^{-1} (control) and 5.3 dS m^{-1}, respectively, by the use of a high leaching fraction. When increase of this range, must be modified the quantity of irrigation water by increasing water to wash the salinity that accumulated in the coconut fiber slabs (Table 2.5). The drainage water was analysed for determined their composition. The mean of analysis of drainage water is shown in Table 2.6.

Table 2.5. Means of EC, pH and the percentage of drainage water at intervals of the tomato growth period (only in cv. Dumas).

Treatments	October			November			December			January		
	Drainage %	EC	PH	Drainage %	EC	PH	Drainage %	EC	PH	Drainage %	EC	pH
Control (3.3 dS m^{-1})	33.70	6.17	6.93	31.75	5.35	6.78	30.00	5.02	6.93	26.35	5.89	6.52
5.3 dS m^{-1}	46.78	9.34	6.28	41.21	8.04	6.19	40.01	8.71	6.42	41.61	8.90	6.426

Table 2.6. Composition of the drainage water sample collected at the end of November only for cv. Dumas.

Treatments	3.3 dS m^{-1} (Control)	5.3 dS m^{-1}
NO^-_3	17.49	25.34
$H_2PO^-_4$	0.04	0.12
SO^{2-}_4	9.63	9.37
HCO_3^-	0.98	0.66
Cl^-	17.23	42.06
NH_4^+	0.07	0.08
K^+	5.58	12.53
Ca^{2+}	7.73	7.61
Mg^{2+}	6.95	6.83
Na^+	18.70	45.89
Fe	2.40	7.16
Mn	1.37	2.91
Zn	16.52	20.80
Cu	0.16	1.10
B	27.75	38.85
Mo	0.10	0.10
Al	0.37	0.37

2.6. Measurements

2.6.1. Vegetative growth parameters

All the vegetative parameters were taken 3 times at intervals (October, November and December) during tomato growth. Begin after transplanting of plants by 46, days for vegetative parameters (at the beginning of October).

- Ten plants per each experimental unit of all replications were determined to measure:
  - Plant height (cm).
  - Stem diameter (mm): determined in 1 cm below the cotyledons with digital caliper (Figure 2.7).
- One plant were cut per each experimental unit of all replications for determine:
  - Leaf number.
  - Leaf length.
  - Leaf width (measured in the longest leaflet).
  - Stem fresh weight.
  - Leaf fresh weight.
  - Green fruit fresh weight.
  - Ripe/ripening fruit fresh weight

Stem fresh weight, leaf fresh weight, green fruit fresh weight and ripe/ripening fruit fresh weight were used to determine the fresh biomass.

- Then stem, leave green fruits also were taken a sample of red fruits, were dried in oven at 65 ºC for 72 h (Figure 2.8), in order to determine:
  - Stem dry weight
  - Leaf dry weight
  - Green fruit dry weight
  - Dry weight of ripe/ripening fruit.

The dried parameters used for determine the biomass of the aerial part of the plant (It was difficult to extract the roots, because there are possibility to use the substrates of coconut fiber slabs in the next years).

The mineral elements as N (%) , P (%), K (%) , Ca (%), Mg (%), Na (%), Fe (mg/kg), Mn (mg/kg), Zn (mg/kg), Cu (mg/kg), B (mg/kg), Mo (mg/kg) and Al (mg/kg) were determined only in cv. Raf by collect sampling of fresh leaves (20 g leaves per each plot). The samples were sent to G.E. COTA/2, S.L. Laboratory Analysis (www.cota2.com) to perform foliar analysis.

Figure 2.7. Determine stem diameter by using digital caliper.

Figure 2.8. Drying of stems, leaves, green fruits and ripe/ripening fruits in the oven at 65 ºC for 72 h.

2.6.2. Production parameters

The fruit harvesting were started in day 14 October 2013 and lasted until 28 January 2014 with two weekly harvests, but at the end of harvest, fruit was harvested weekly.

Twelve plants were determined on each experimental unit of the tree replications in order to determine the production parameters. Fruits yield was classified as marketable or unmarketable fruits. The unmarketable fruit yields were separated to fruit with virus diseases, physiological disorders which classified according to the nature of the blemish: fruits with cracking, with blossom end rot (BER), with blotching, catface and other; which are small and deformed fruits (Figure 2.9).

Figure 2.9. Physiological disorder of fruit; A: catface, B: Cracking, C: small and deformed fruit, D: BER.

Registering these data for each plot, and obtaining the following parameters:

- Total fruit yield (kg/plant).
- Marketable fruit weight (kg/plant).
- Fruit number of marketable yield per plant.
- Mean fruit weight of marketable yield (g/fruit).
- Unmarketable fruit weight (kg/plant).which include the following categories:
    - Fruit weight with BER (kg/plant).
    - Fruit weight with catface (kg/plant).
    - Fruit weight with cracking (kg/plant).
    - Fruit weight of small and deformed fruits (kg/plant).

All the production characters that mentioned previously were determined during:

- October.
- November without accumulation.
- December without accumulation.
- January without accumulation.
- Total accumulated production.

2.6.3. Measurements of fruit quality

Also the parameters of fruit quality were measured three times on intervals at October, November and December. Three marketable fruits were collected from each treatment for determine:

- Fruit firmness; by using hand penetrometer (fruit pressure tester, FT 327, Italy, Figure 2.10).

After measuring fruit firmness, the three fruits of each treatment being squeezed to obtain the juice for the following measurements:

- Total soluble solids (ºBrix) was assessed using a digital refractometer (Atago®, PR-101α, Brix 0-45%), Japan, Figure 2.11).

- Titratable acidity was determined as citric acid (%), by titration with 0.1 M NaOH, using 20 ml of juice, acidity was calculated by using the following equation:

$$\textbf{\% Citric acid} = \frac{V_1 \times N \times K}{V_2} \times 100$$

V_1: Volume of NaOH consumed (ml).

V_2: Volume of juice sample in ml (20 ml).

N: Normality of NaOH (0.1 meq/ml).

K: Equivalent weight of citric acid (0.064/meq).

Figure 2.10. Hand penetrometer (Fruit pressure tester, FT 327) using for determined fruit firmness.

Fruit colour was periodically evaluated during harvest at October, November and December. Three marketable fruits homogenized selected from each plot. The measurements were taken using a Minolta CR-300 chromameter (Figure 2.12) and the results are given as *a* and *b* Hunter chromacity coordinates and *l.* Colour readings of:

- *a* denote green or red colour when it is negative or positive, respectively.
- *b* denote blue (non-existence for tomato) or yellow when it is negative or positive, respectively.

- *l* that quantifying the surface fruit lightness, always is positive varying between 0 (black lightness) and 100 (white lightness).

Four repining fruits of each plot were collected to determine organoleptic characters, fruits were cut to pieces similar in size and shape, then divided into two dishes, one without adding spices and other were spiced (Figure 2.13), and overall preference as 1-5 (5 as the strongest), used for determine:

- Taste without spices
- Taste with spices (sale with olive oil).
- Grain texture without spices
- Grain texture with spices (sale with olive oil).

Figure 2.11. Refractometer (Atago®, PR-101α, Brix 0-45%), using for measure Brix % (total soluble solids).

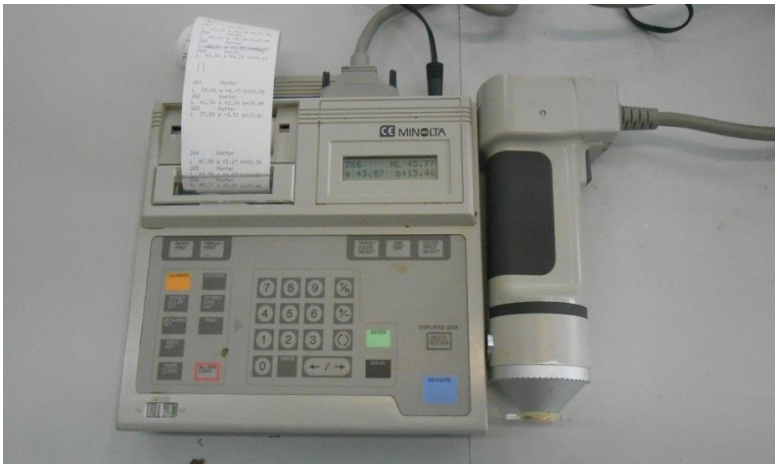

Figure 2.12. Minolta CR-300 chromameter used for determine fruit colour *a*, *b* and *l*.

Figure 2.13. Organoleptic characters; A: were control (3.3 dS m^{-1}) and cv. Dumas with spices, B: control (3.3 dS m^{-1}) and cv. Dumas without spices, C: control (3.3 dS m^{-1}) and cv. Raf without spices, D: control (3.3 dS m^{-1}) and cv. Raf with spices, E: 5.3 dS m^{-1} and cv. Dumas with spices, F: 5.3 dS m^{-1} and cv. Dumas without spices, G: 5.3 dS m^{-1} and cv. Raf without spices, H: 5.3 dS m^{-1} and cv. Raf with spices.

2.6.4. Water use efficiency

Water use efficiency (WUE) calculated as total fruit yield (kg/m^2) and marketable fruit yield kg/m^2) of each month (October, November, December and January) during tomato

growth period and total cycle of tomato growth/net water, respectively. As mentioned previously supply and drainage water have been measured daily in order to calculate net water (is include the water uptake by plant and the water in the substrate (slab of coconut fiber). Net water used was calculated by subtracting from the water supplied the water drained (m^3/m^2).

Irrigation water use efficiency (IWUE) calculated as total fruit yield (kg/m^2) and marketable fruit yield (kg/m^2) of each month (October, November, December and January) during tomato growth period and total cycle of tomato growth/water applied, respectively (Howell, 2001).

WUE was calculated in terms of total fruit yield according to the following function:

$$WUE_{(kg/m^3)} = \frac{\text{Total fruit yield } (kg/m^2)}{\text{Net water } (m^3/m^2)} \text{ also as } \frac{\text{Marketable fruit yield } (kg/m^2)}{\text{Net water } (m^3/m^2)}$$

IWUE was calculated in terms of marketable fruit yield according to the following function:

$$IWUE_{(kg/m^3)} = \frac{\text{Total fruit yield } (kg/m^2)}{\text{Water applied } (m^3/m^2)} \text{ also as } \frac{\text{Marketable fruit yield } (kg/m^2)}{\text{Water applied } (m^3/m^2)}$$

2.7. Statistical analysis

Statistical analyses were conducted with Statgraphics Plus for Windows 5.1, 2005; Statistical Graphics Corporation, Rockville, MD.

For all parameters, which were taken at different times (October, November, December and January for yield only) during plant growth, were conducted the statistical analysis with a multifactor analysis of variance (ANOVA) and separation of means according to LSD ($P \leq 0.01$ or $P \leq 0.05$) for each parameter in order to determine the differences between the parameters. The standard deviation is calculated as the square root of the quotient between the absolute value of the residual sum of squares and degrees of freedom for error. The statistical analysis of foliar analysis was conducted with one-way of analysis of variance (ANOVA).

3. RESULTS

3. Results

3.1. Vegetative growth parameters

Generally the control had a higher plant height more than salinity treatment, with significant difference only at first stage of plant development (at October) (at $P \leq 0.01$, Table 3.1). Plants of cv. Dumas were higher than those cv. Raf, with significant difference at November and December ($P \leq 0.01$, Table 3.1). The results were not shown any interaction between salinity and cultivars for plant height.

Table 3.1. Effects of salinity and cultivars on plant height (cm) at different times during tomato growth (October, November and December).

Factors	October	November	December
Salinity			
3.3 ds m^{-1} (Control)	124.80 a	209.20	240.36
5.3 ds m^{-1}	115.31 b	207.78	234.13
Cultivars			
Dumas	120.81	223.85 a	259.93 a
Raf	119.3	193.13 b	214.567 b
ANOVA (df)		**% Sum of squares**	
Factor			
Salinity	53.13**	0.15 n.s.	1.71 n.s.
Cultivars	1.36 n.s.	72.83 **	90.64 **
Interaction			
Cultivars × Salinity	4.69 n.s.	4.63 n.s.	1.00 n.s.
Residual	40.70	22.36	6.64
Standard deviation	5.07	10.42	8.09

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

The results showed that the stem diameter was increased with salinity treatment (5.3 dS m^{-1}) than the control (3.3 dS m^{-1}) at October (at $P \leq 0.05$, Table 3.2), with advance plant development in November was not found significant difference between the salinity treatment and the control, while at December stem diameter found to decrease with increase EC of irrigation water (at $P \leq 0.01$, Table 3.2). The two cultivars have almost similar stem diameter in

October, after which; cv. Dumas had a large stem diameter more than Raf with a statistical significant difference only at November (at $P \leq 0.05$, Table 3.2). Salinity and cultivars interaction was no significant.

Table 3.2. Effects of salinity and cultivars on stem diameter (mm) at different times during tomato growth (October, November and December).

Factors	October	November	December
Salinity			
3.3 ds m^{-1} (Control)	7.31 b	8.58	9.56 a
5.3 ds m^{-1}	7.89 a	8.18	8.70 b
Cultivars			
Dumas	7.57	8.63 a	9.16
Raf	7.63	8.14 b	9.10
ANOVA (df)		**% Sum of squares**	
Factor			
Salinity	45.46 *	18.93 n.s.	75.70 **
Cultivars	0.47 n.s.	28.97 *	0.34 n.s.
Interaction			
Cultivars × Salinity	4.10 n.s.	13.94 n.s.	1.33 n.s.
Residual	49.95	38.32	22.61
Standard deviation	0.36	0.34	0.28

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

The result of leaf number presented in Table 3.3. The general tendency was higher leaf number in the control with significant difference at the first period of plant growth (in October at $P \leq 0.01$and in November at $P \leq 0.05$). However, during December differences among salinity treatments were not significant. Dumas and Raf have a similar leaf number at October, although in November and December the number of leaves which formed by Dumas were significantly higher than those formed by Raf (at $P \leq 0.01$). Salinity and cultivar interaction was no significant in case of leaf number.

The leaf length was reduced significantly with salinity treatment (5.3 dS m^{-1}) than the control (3.3 ds m^{-1}) throughout of the plant growth cycle (at $P \leq 0.01$ of October, at $P \leq 0.05$ of November and at $P \leq 0.05$ of December; Table 3.4). Plants of cv. Dumas had a higher leaf length more than Raf throughout the plant growth cycle with significant difference only at

December (at $P \leq 0.01$, Table 3.4). The result of leaf length not showed significant interaction between the salinity and cultivars.

Table 3.3. Effects of salinity and cultivars on leaf number/plant at different times during tomato growth (October, November and December).

Factors	October	November	December
Salinity			
3.3 ds m^{-1} (Control)	22.00 a	29.83 a	37.66
5.3 ds m^{-1}	19.66 b	27.16 b	35.50
Cultivars			
Dumas	21.00	30.66 a	38.66 a
Raf	20.66	26.33 b	34.50 b
ANOVA (df)	**% Sum of squares**		
Factor			
Salinity	5.90 **	20.71 *	13.99 n.s.
Cultivars	1.20 n.s.	54.69 **	51.61 **
Interaction			
Cultivars × Salinity	1.20 n.s.	1.29 n.s.	0.74 n.s.
Residual	38.55	23.30	33.69
Standard deviation	1.15	1.73	2.06

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

The leaf width was reduced significantly during October and November with increasing EC of irrigation water (at $P \leq 0.01$, Table 3.4). Whilst, the results not shown significant difference between salinity treatment and the control at December for leaf width (Table 3.4). Dumas had leaf width drastically larger than Raf through the plant growth (at $P \leq 0.01$, Table 3.4). Leaf width not showed any interaction between salinity of irrigation water and the cultivars (Table 3.4).

The control (3.3 dS m^{-1}) had a higher leaf fresh and dry weight with significant difference in October and December (at $P \leq 0.01$, Table 3.5), while was not observed difference during November (Table 3.5). Leaf fresh and dry weight was not significantly changed for the two cultivars in October, while in both instance, at November and December dumas had a greater value than Raf (at $P \leq 0.01$, Table 3.5). Salinity and cultivar interaction was no significant for leaf fresh and dry weight (Table 3.5).

Table 3.4. Effects of salinity and cultivars on leaf length and leaf width (cm) at different times during tomato growth (October, November and December).

Factors	**Leaf length (cm)**			**Leaf width (cm)**		
	October	November	December	October	November	December
Salinity						
3.3 ds m^{-1} (Control)	40.68 a	42.20 a	42.80 a	39.03 a	39.03 a	40.13
5.3 ds m^{-1}	36.93 b	39.23 b	40.53 b	34.51 b	36.36 b	38.2
Cultivars						
Dumas	39.31	41.86	44.36 a	39.40 a	40.33 a	42.73 a
Raf	38.30	39.56	38.96 b	34.15 b	35.06 b	35.60 b
ANOVA (df)			**% Sum of squares**			
Factor						
Salinity	56.27 **	32.63 *	12.40 *	35.05 **	17.61 **	5.00 n.s.
Cultivars	4.13 n.s.	19.61 n.s.	70.39 **	47.36 **	66.95 **	68.17 **
Interaction						
Cultivars × Salinity	0.40 n.s.	4.48 n.s.	0.09 n.s.	5.26 n.s.	0.68 n.s.	1.00 n.s.
Residual	39.18	43.27	17.10	12.31	15.19 n.s.	25.80
Standard deviation	1.91	2.09	1.62	1.63	1.53	2.68

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

Table 3.5. Effects of salinity and cultivars on fresh and dry weight of leaves (g/plant) at different times during tomato growth (October, November and December).

Factors	**Leaf fresh weight (g/plant)**			**Leaf dry weight (g/plant)**		
	October	November	December	October	November	December
Salinity						
3.3 ds m^{-1} (Control)	390.48 a	409.73	613.75 a	36.81 a	41.22	63.34 a
5.3 ds m^{-1}	268.67 b	356.12	490.43 b	25.85 b	37.34	51.43 b
Cultivars						
Dumas	358.38	450.16 a	651.84 a	33.885	46.07 a	67.79 a
Raf	300.78	315.70 b	452.34 b	28.785	32.49 b	46.99 b
ANOVA (df)			**% Sum of squares**			
Factor						
Salinity	53.72 **	91.03 n.s.	21.92 **	53.25 **	4.31 n.s.	19.29 **
Cultivars	12.01 n.s.	57.84 **	57.39 **	11.53 n.s.	52.92 **	58.85 **
Interaction						
Cultivars × Salinity	1.39 n.s.	3.44 n.s.	5.97 n.s.	2.83 n.s.	2.35 n.s.	7.64 n.s.
Residual	32.86	29.51	14.69	31.37	40.39	14.20
Standard deviation	58.33	58.82	61.81	5.23	7.26	6.25

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

Stem fresh weight was decrease corresponded to increase EC of irrigation water from 3.3 dS m^{-1} to 5.3 dS m^{-1} throughout plant growth cycle with (at $P \leq 0.01$, Table 3.6). For the stem

dry weight were observed significant difference in October and December between the salinity treatment 5.3 dS m^{-1} and the control 3.3 dS m^{-1} (at $P \leq 0.01$, Table 3.6). While exist no significant difference between salinity treatments for stem dry weight at November (Table 3.6). The stem fresh weight was nearly similar in Dumas and Raf until October (Table 3.6). In November and December, exist significantly different between the cultivars for stem fresh weight, Dumas had a higher stem fresh weight per plant than Raf (at $P \leq 0.05$ of November and at $P \leq 0.01$ of December, Table 3.6). The effect of cultivars on stem dry weight was not significant in October and November, but in December there was significant difference between the two cultivars (at $P \leq 0.05$, Table 3.6). It was found interaction between salinity of irrigation water and the cultivars for stem fresh weight only in December, the stem fresh weight was reduced in both cultivars with the increase EC of nutrient solution, but Raf had highly reduction in stem fresh weight at December than Dumas (at $P \leq 0.01$, Table 3.6, Figure 3.1). Also, the stem dry weight of cv. Raf was significantly reduced with increasing salinity of irrigation water from 3.3 dS m^{-1} (control) to 5.3 dS m^{-1} than Dumas (at $P \leq 0.05$), while stem dry weight of Dumas was constant (Table 3.6, Figure 3.2).

Table 3.6. Effects of salinity and cultivars on stem fresh and dry weight (g/plant) at different times during tomato growth (October, November and December).

Factors	**Stem fresh weight (g/plant)**			**Stem dry weight (g/plant)**		
	October	November	December	October	November	December
Salinity						
3.3 ds m^{-1} (Control)	189.25 a	235.18 a	283.93 a	17.99 a	23.43	31.75 a
5.3 ds m^{-1}	118.06 b	168.07 b	216.59 b	11.52 b	18.68	25.08 b
Cultivars						
Dumas	157.08	220.67 a	269.205 a	14.26	22.50	30.88 a
Raf	150.23	182.58 b	231.32 b	15.25	19.61	25.95 b
ANOVA (df)			**% Sum of squares**			
Factor						
Salinity	71.90 **	65.15 **	58.42 **	73.26 **	22.53 n.s.	35.26 **
Cultivars	0.66 n.s.	18.09 *	18.49 **	1.71 n.s.	8.37 n.s.	19.37 *
Interaction						
Cultivars × Salinity	0.027 n.s.	0.14 n.s.	15.37 **	0.71 n.s.	1.31 n.s.	20.18 *
Residual	27.39	25.60	7.70	24.30	67.77	24.54
Standard deviation	26.91	27.75	14.97	2.28	5.04	3.40

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

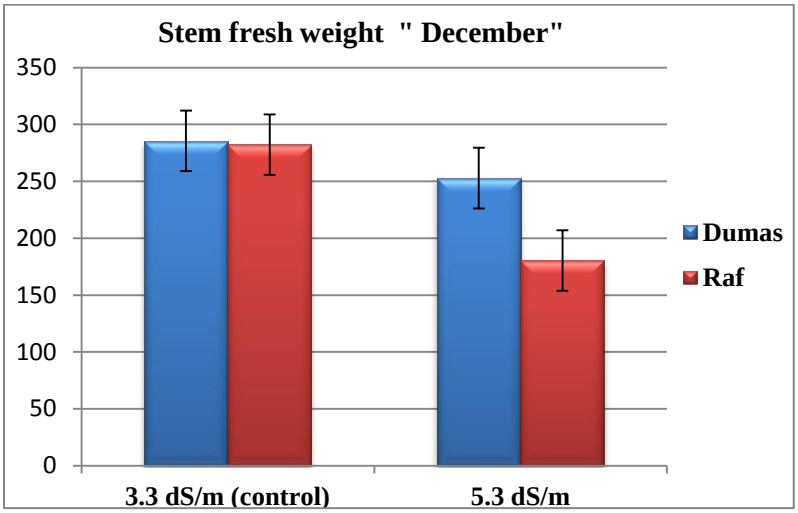

Figure 3.1. Analysis of the interaction between salinity of irrigation water and tomato cultivars for stem fresh weight at December.

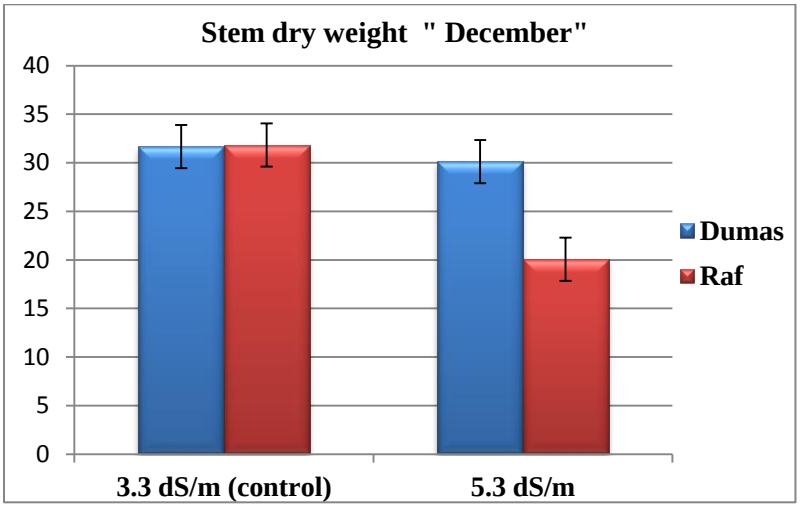

Figure 3.2. Analysis of the interaction between salinity of irrigation water and tomato cultivars for stem dry weight at December.

The results of green fruit fresh and dry weight presented in Table 3.7. Plants grown under the control (3.3 dS m^{-1}) resulted in significantly higher green fruit fresh weight than salinity treatment (5.3 dS m^{-1}) at October (at $P \leq 0.01$) and November ($P \leq 0.05$), but was not observed this difference in December. On the other hand, the salinity of irrigation water did not

affect on the green fruit dry weight. Dumas and Raf were not shown significant difference in case of green fruit fresh weight during October and November, but in December cv. Dumas had a greater green fruit fresh weight than Raf (at $P \leq 0.05$). On the other hand, was not found significant difference between the cultivars for green fruit dry weight in all plant growth cycle. Green fruit fresh and dry weight was not shown any significant interaction between the salinity and cultivars.

Table 3.7. Effects of salinity and cultivars on fresh and dry weight of green fruit (g/plant) at different times during tomato growth (October, November and December).

Factors	**Green fruit fresh weight (g/plant)**			**Green fruit dry weight (g/plant)**		
	October	November	December	October	November	December
Salinity						
3.3 ds m^{-1} (Control)	825.16 a	1006.17 a	1562.5	41.9833	59.6433	66.63
5.3 ds m^{-1}	589.55 b	809.05 b	1422.5	46.0367	49.75	64.655
Cultivars						
Dumas	751.17	830.0	1752.50 a	44.345	49.6067	71.1533
Raf	663.548	985.222	1232.50 b	43.675	59.7867	60.1317
ANOVA (df)			**% Sum of squares**			
Factor						
Salinity	51.01 **	33.37 *	2.49 n.s.	7.68 n.s.	11.76 n.s.	0.12 n.s.
Cultivars	7.05 n.s.	20.69 n.s.	34.35 *	0.21 n.s.	0.83 n.s.	3.76 n.s.
Interaction						
Cultivars × Salinity	15.00 n.s.	9.09 n.s.	12.03 n.s.	1.26 n.s.	0.59 n.s.	1.73 n.s.
Residual	26.92	36.83	46.84	90.84	86.80	94.83
Standard deviation	104.82	126.81	371.82	8.53	16.71	33.80

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

The results of fresh and dry weight of ripe/ripening fruit are illustrated in Table 3.8. Generally, the control had higher fresh (at $P \leq 0.01$) and dry (at $P \leq 0.05$) ripe/ripening fruit weight than the salinity treatment at November and for ripe/ripening fruit dry weight (at $P \leq 0.05$) at December. Raf had a higher fresh and dry ripe/ripening fruit weight more than Dumas at November (at $P \leq 0.01$ for fresh ripe/ripening fruit weight and at $P \leq 0.05$ for ripe/ripening fruit dry weight), while the reverse was found at December (at $P \leq 0.01$). The effect of the interaction between the salinity and cultivars on fresh and dry weight of ripe/ripening fruit was not statistically significant.

Table 3.8. Effects of salinity and cultivars on fresh and dry weight of ripe/ripening fruit (g/plant) at different times during tomato growth (November and December).

Factors	**Fresh weight of ripe/ripening fruit (g/plant)**		**Dry weight of ripe/ripening fruit (g/plant)**	
	November	December	November	December
Salinity				
3.3 ds m^{-1} (Control)	833,681 a	766,875	45,1934 a	51,5791 a
5.3 ds m^{-1}	544,375 b	608,819	33,4043 b	40,561 b
Cultivars				
Dumas	537,708 b	801,389 a	32,4492 b	55,6768 a
Raf	840,347 a	574,306 b	46,1485 a	36,4633 b
ANOVA (df)	**% Sum of squares**			
Factor				
Salinity	31.38 **	19.71 n.s.	22.49 *	16.46 *
Cultivars	34.33 **	40.70 **	30.37 *	50.07 **
Interaction				
Cultivars × Salinity	8.18 n.s.	5.89 n.s.	12.70 n.s.	7.86 n.s.
Residual	26.09	33.69	34.42	25.59
Standard deviation	161.54	126.51	8.93	8.41

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

Fresh biomass weight was significantly decrease with increase salinity of irrigation water in October and November (at $P \leq 0.05$ for October and $P \leq 0.01$ for November, Table 3.9), however at December the result not showed variation between the salinity treatments (Table 3.9). Similar tendency was observed for dry biomass, exist significant difference between salinity treatment and the control at October and November (at $P \leq 0.05$), while in December the result showed no significant difference between treatments (Table 3.9). Fresh and dry biomass was almost similar in the two cultivars during October and November, while in December Dumas had greater fresh and dry biomass than Raf (at $P \leq 0.01$, Table 3.9). Salinity and cultivars interaction no significant for fresh and dry biomass (Table 3.9).

The content of leaves from Na, Mn, Zn were significantly higher when plants were irrigated with EC of water 5.3 dS m^{-1} than when irrigated with EC water 3.3 dS m^{-1} (at $P \leq 0.05$ for Mn, Zn and at $P \leq 0.01$for Na), the contrast was found for Al and Mg (at $P \leq 0.01$ for Al and at $P \leq 0.05$ for Mg), while was not observed significant difference between salinity treatment and the control for N, P, K, Ca, Fe, Cu, and B (Table 3.10).

Table 3.9. Effects of salinity and cultivars on fresh and dry biomass of aerial plant part (g/plant) at different times during tomato growth (October, November and December).

Factors	**Fresh biomass (g/plant)**			**Dry biomass (g/plant)**		
	October	November	December	October	November	December
Salinity						
3.3 ds m^{-1} (Control)	1382.59 a	2473.14 a	3227.06	100.84 a	169.49 a	236.59
5.3 ds m^{-1}	976.29 b	1877.63 b	2730.63	79.36 b	139.18 b	210.26
Cultivars						
Dumas	1205.55	2026.92	3474.94 a	92.49	150.63	254.22 a
Raf	1153.34	2323.85	2482.75 b	87.71	158.04	192.63 b
ANOVA (df)			**% Sum of squares**			
Factor						
Salinity	51.49 *	58.39 **	13.96 n.s.	45.15 *	49.55 *	11.47 n.s.
Cultivars	0.85 n.s.	14.51 n.s.	54.16 **	2.23 n.s.	2.96 n.s.	62.79 **
Interaction						
Cultivars × Salinity	0.74 n.s.	0.12 n.s.	7.88 n.s.	0.005 n.s.	0.85 n.s.	4.23 n.s.
Residual	46.91	26.96	24.38	52.60	46.62	29.95
Standard deviation	237.47	247.77	407.63	14.20	18.00	26.25

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

Table 3.10. Effect of the salinity of irrigation water on the content of tomato leaves (cv. Raf) from mineral elements.

Treatments	**Control (3.3 dS m^{-1})**	**5.3 dS m^{-1}**	
N (%)	4.96	4.71	n.s.
P (%)	0.43	0.42	n.s.
K (%)	3.48	3.48	n.s.
Ca (%)	1.49	1.42	n.s.
Mg (%)	0,45 a	0,39 b	*
Na (%)	0,15 b	0,30 a	**
Fe (mg/kg)	76.67	91.00	n.s.
Mn (mg/kg)	79,33 b	125,67 a	*
Zn (mg/kg)	31,00 b	39,33 a	*
Cu (mg/kg)	858.33	1054.67	n.s.
B (mg/kg)	20.67	21.33	n.s.
Mo (mg/kg)	0.98	1.12	n.s.
Al (mg/kg)	268,67 a	238,33 b	**

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

3.2. Tomato production parameters

3.2.1. Production parameters of October

Salinity treatment (5.3 dS m^{-1}) did not have any effect on total fruit yield (Table 3.11). The marketable fruit yield was significantly decreased with increase EC of irrigation water (at $P \leq 0.01$, Table 3. 11). The salinity of irrigation water was not affected on unmarketable fruit yield, where not found significant difference between salinity treatment (5.3 dS m^{-1}) and the control (3.3 dS m^{-1}). The control had significantly higher mean fruit weight than salinity treatment (at $P \leq 0.01$, Table 3. 11). For the two cultivars was not observed significant difference for total fruit yield, marketable fruit yield and unmarketable fruit yield (Table 3.11). While Dumas had higher mean fruit weight than Raf (at $P \leq 0.01$, Table 3.11). The interaction between both studied factors had little effect on production parameters at October (Table 3.11).

Table 3.11. Effects of salinity of irrigation water and cultivars on total fruit yield, marketable fruit yield, unmarketable fruit yield and mean fruit weight during October.

Factors	Total fruit yield (kg/plant)	Marketable fruit yield (kg/plant)	Unmarketable fruit yield (kg/plant)	Mean fruit weight (g/fruit)
Salinity				
3.3 ds m^{-1} (Control)	0.763	0.573 a	0.191	161.087 a
5.3 ds m^{-1}	0.653	0.425 b	0.228	133.017 b
Cultivars				
Dumas	0.743	0.508	0.236	182.970 a
Raf	0.673	0.490	0.183	111.133 b
ANOVA (df)		**% Sum of squares**		
Factor				
Salinity	24.01 n.s.	62.45 **	5.45 n.s.	12.69 **
Cultivars	0.97 n.s.	0.95 n.s.	11.53 n.s.	83.16 **
Interaction				
Cultivars × Salinity	2.66 n.s.	0.38 n.s.	10.13 n.s.	1.34 n.s.
Residual	63.59	36.20	72.88	2.78
Standard deviation	0.10	0.06	0.08	8.05

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

Increase EC of irrigation water from 3.3 dS m^{-1} to 5.3 dS m^{-1} did not have effect on the appearance of blemishes as catface, BER, cracking, small and deformed fruits in tomato fruit

(Table 3.12). Dumas cv. had a significantly higher appearance of fruits with catface and BER than Raf (at $P \leq 0.01$ for catface and at $P \leq 0.05$ for BER, Table 3.12). In case of fruits with cracking were not observed significant difference between the two cultivars (Table 3.12). While, Raf had higher small and deformed fruits than Dumas (at $P \leq 0.01$, Table 3.12). In case of fruit blemish was not observed any interaction between salinity and cultivars (Table 3.12).

Table 3.12. Effects of salinity of irrigation water and cultivars on the unmarketable fruit according to the nature of the blemish as catface, BER, cracking and small and deformed fruits during October, all parameters expressed with kg/plant.

Factors	**Catface**	**BER**	**Cracking**	**Small and deformed fruits**
Salinity				
3.3 ds m^{-1} (Control)	0.163	0.0183	0.003	0.010
5.3 ds m^{-1}	0.143	0.0566	0.005	0.021
Cultivars				
Dumas	0.228 a	0.083 a	0.00	0.00 b
Raf	0.078 b	0.066 b	0.008	0.031 a
ANOVA (df)		**% Sum of squares**		
Factor				
Salinity	1.07 n.s.	16.19 n.s.	0.93 n.s.	7.17 n.s.
Cultivars	60.33 **	37.49 *	23.36 n.s.	52.85 **
Interaction				
Cultivars × Salinity	0.26 n.s.	5.18 n.s.	0.93 n.s.	7.17 n.s.
Residual	3.31	41.13	74.76	32.79
Standard deviation	0.07	0.03	0.009	0.01

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

3.2.2. Production parameters of November without accumulation

Salinity treatment (5.3 dS m^{-1}) result in reduction of the total fruit yield of November without accumulation (at $P \leq 0.01$, Table 3.13). Similar tendency was observed for marketable fruit yield, which significantly reduced corresponding to increase of EC of irrigation water from 3.3 dS m^{-1} (control) to EC 5.3 dS m^{-1} (at $P \leq 0.01$, Table 3. 13). On the other hand, cv. Raf had a significantly higher total and marketable fruit yield more than Dumas (at $P \leq 0.01$, Table 3.13). However, the results were not shown significant difference between salinity treatment and the control for the unmarketable fruit yield, also was not observed significant

difference between the two cultivars for unmarketable fruit weight (Table 3.13). Mean fruit weight was significantly affected by salinity treatment; the control had a higher value than salinity treatment, in addition to cv. Dumas had a drastically higher mean fruit weight rather than Raf (at $P \leq 0.01$, Table 3.13). Salinity and cultivars interaction was significant only for marketable fruit yield (Table 13, Figure 3.3).

The salinity treatment was not affected on appearance of catface, cracking, small and deformed fruits (Table 3.14). Although BER was significantly increased with increase of salinity of irrigation water (at $P \leq 0.01$, Table 3.14). The result not showed a great variation between the cultivars for catface, cracking, small and deformed fruits (Table 3.14). While, Raf had a significantly higher fruits with BER than Dumas (at $P \leq 0.01$, Table 3.14). The results not showed any interaction between salinity and cultivars for incidence fruit with physiological disorders (Table 3.14).

Table 3.13. Effects of salinity of irrigation water and cultivars on total fruit yield, marketable fruit yield, unmarketable fruit yield and mean fruit weight during November production without accumulation.

Factors	**Total fruit yield (kg/plant)**	**Marketable fruit yield (kg/plant)**	**Unmarketable fruit yield (kg/plant)**	**Mean fruit weight (g/fruit)**
Salinity				
3.3 ds m^{-1} (Control)	0.833 a	0.696 a	0.137	209.52 a
5.3 ds m^{-1}	0.544 b	0.397 b	0.147	185.68 b
Cultivars				
Dumas	0.537 b	0.428 b	0.109	224.34 a
Raf	0.840 a	0.665 a	0.174	170.86 b
ANOVA (df)		**% Sum of squares**		
Factor				
Salinity	31.38 **	30.08 **	0.42 n.s.	15.46 **
Cultivars	34.33 **	28.48 **	17.96 n.s.	77.77 **
Interaction				
Cultivars × Salinity	8.19 n.s.	12.78 *	3.32 n.s.	0.06 n.s.
Residual	23.09	13.42	81.07	6.69
Standard deviation	0.16	0.09	0.08	9.61

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

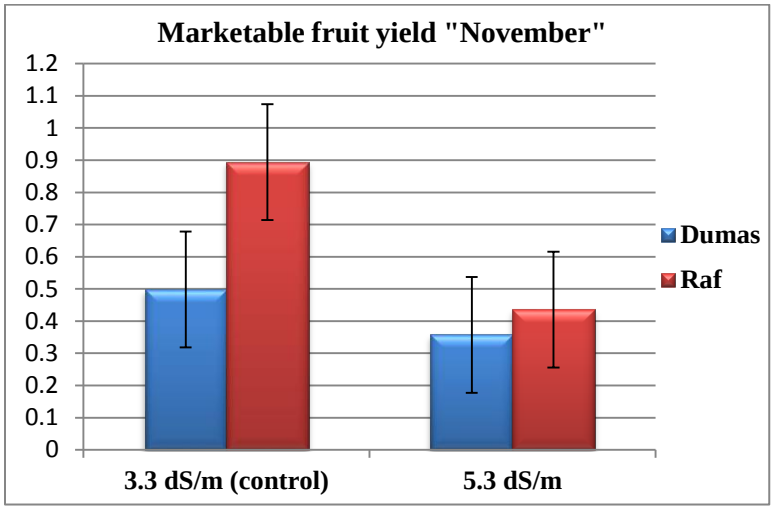

Figure 3.3. Analysis of the interaction between the two salinity level of irrigation water and the two tomato cultivars for marketable fruit yield (kg/plant) of November production without accumulation.

Table 3.14. Effects of salinity of irrigation water and cultivars on the unmarketable fruit according to the nature of the blemish as catface, BER, cracking and small and deformed fruits during November production without accumulation, all parameters expressed with kg/plant.

Factors	Catface	BER	Cracking	Small and deformed fruits
Salinity				
3.3 ds m^{-1} (Control)	0.102	0.025 b	0.00	0.009
5.3 ds m^{-1}	0.076	0.063 a	0.002	0.004
Cultivars				
Dumas	0.087	0.019 b	0.00	0.003
Raf	0.091	0.070 a	0.002	0.011
ANOVA (df)		**% Sum of squares**		
Factor				
Salinity	55.34 n.s.	28.12 **	9.09 n.s.	41.36 n.s.
Cultivars	0.12 n.s.	49.68 **	9.09 n.s.	12.77 n.s.
Interaction				
Cultivars × Salinity	1.96 n.s.	2.29 n.s.	9.09 n.s.	9.49 n.s.
Residual	92.37	22.19	72.72	73.58
Standard deviation	0.06	0.06	3.96	0.01

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

3.2.3. Production parameters of December without accumulation

Total fruit yield, marketable fruit yield and mean fruit weight was not affected by increase EC of irrigation water (Table 15). Total fruit yield, marketable fruit yield and mean fruit weight were significantly varied between the cultivars; Dumas had a higher total fruit yield, marketable fruit yield and mean fruit weight compared to Raf (at $P \leq 0.05$ for total fruit yield and at $P \leq 0.01$for marketable fruit yield and mean fruit weight, Table 3.15). The unmarketable fruit yield was significantly decreased with salinity treatment than control (at $P \leq 0.05$, Table 3. 15). While, was not found any significant difference between the cultivars for the unmarketable fruit yield during December production (Table 3.15). It was detected significant effect on the unmarketable fruit yield of December without accumulation among the interaction between salinity and cultivars; the unmarketable fruit yield of cv. Raf was reduced with increase EC of irrigation water, while the reverse was found in Dumas cultivar (Table 3.15, Figure 3.4).

From the obtained results was observed no significant difference between irrigation water with EC 5.3 dS m^{-1} and EC 3.3 dS m^{-1} (control) for catface, BER, cracking, small and deformed fruits (Table 3.16). In case of fruits with catface, cracking and BER were not found significant difference between the cultivars (Table 3.16). While, Raf had a higher small and deformed fruits than Dumas (at $P \leq 0.05$, Table 3.16). The interaction of different EC of nutrient solution and cultivars had significant effect only on small and deformed fruit; Raf was reduced appearance of small and deformed fruits with increase EC of irrigation water, while Dumas was increased small and deformed fruits with increase EC of irrigation water (Table 3.16, Figure 3.5).

Table 3.15. Effects of salinity of irrigation water and cultivars on total fruit yield, marketable fruit yield, unmarketable fruit yield and mean fruit weight during December production without accumulation.

Factors	Total fruit yield (kg/plant)	Marketable fruit yield (kg/plant)	Unmarketable fruit yield (kg/plant)	Mean fruit weight (g/fruit)
Salinity				
3.3 ds m^{-1} (Control)	0.766	0.707	0.058 a	205.803
5.3 ds m^{-1}	0.608	0.588	0.020 b	190.240
Cultivars				
Dumas	0.801 a	0.776 a	0.025	220.393 a
Raf	0.574 b	0.520 b	0.054	175.651 b
ANOVA (df)		**% Sum of squares**		
Factor				
Salinity	19.71 n.s.	10.58 n.s.	22.60 *	7.56 n.s.
Cultivars	40.70 *	48.83 **	12.70 n.s.	62.50 **
Interaction				
Cultivars × Salinity	5.89 n.s.	13.24 n.s.	33.15 *	4.44 n.s.
Residual	33.69	27.33	31.53	25.48
Standard deviation	0.12	0.11	0.02	17.49

n.s., *, **: no significant differences, significant differences at P ≤ 0.05 and significant differences at P ≤ 0.01. Different letters in the same column indicate a statistically significant difference (at P ≤0.01 and/or P ≤ 0.05).

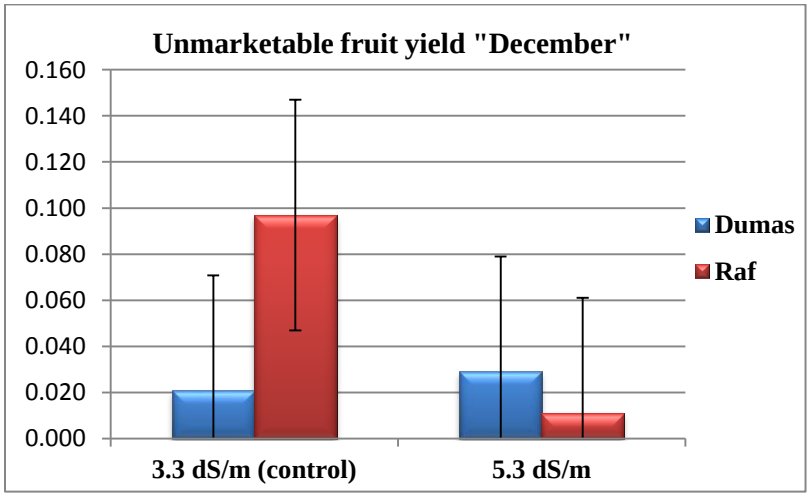

Figure 3.4. Analysis of the interaction between the two salinity levels of irrigation water and the two tomato cultivars for unmarketable fruit yield (kg/plant) of December production without accumulation.

Table 3.16. Effects of salinity of irrigation water and cultivars on the unmarketable fruit according to the nature of the blemish as catface, BER, cracking and small and deformed fruits during December production without accumulation, all parameters expressed with kg/plant.

Factors	Catface	BER	Cracking	Small and deformed fruits
Salinity				
3.3 ds m^{-1} (Control)	0.022	0.002	0.015	0.018
5.3 ds m^{-1}	0.002	0.0037	0.008	0.005
Cultivars				
Dumas	0.009	0.003	0.008	0.004 b
Raf	0.017	0.002	0.015	0.019 a
ANOVA (df)	**% Sum of squares**			
Factor				
Salinity	12.01 n.s.	3.16 n.s.	7.76 n.s.	14.79 n.s.
Cultivars	1.88 n.s.	3.16 n.s.	7.76 n.s.	20.14 *
Interaction				
Cultivars × Salinity	5.85 n.s.	3.21 n.s.	5.61 n.s.	37.59 **
Residual	80.32	6.04	78.84	27.46
Standard deviation	0.03	0.004	0.01	0.01

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

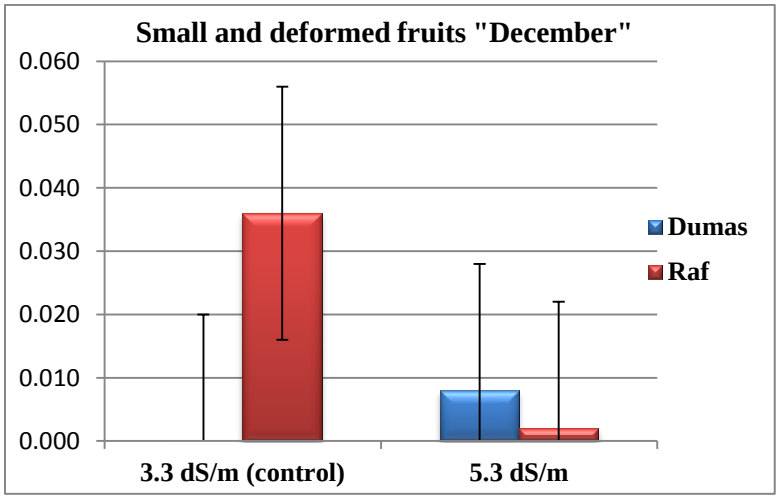

Figure 3.5. Analysis of the interaction between the two salinity levels and the tomato cultivars for small and deformed fruit (kg/plant) of December production without accumulation.

3.2.4. Production parameters of January without accumulation

Total fruit yield, marketable fruit yield and unmarketable fruit yield were not affected by salinity treatment (Table 3.17). Mean fruit weight was significantly reduced corresponding to

increase EC of irrigation water from 3.3 dS m^{-1} to EC 5.3 dS m^{-1} (at $P \leq 0.01$, Table 3.17). In January production without accumulation; Dumas had a greater total fruit yield, marketable fruit yield and mean fruit weight than Raf (at $P \leq 0.01$, Table 3.17). The unmarketable fruit yield was presented few variations between the cultivars (Table 3.17). From the obtained results were observed significant difference in the behavior of the cultivars with increase EC of irrigation water only for total and marketable fruit yield in January without accumulation, cv. Dumas was reduced the total and marketable fruit yield with increase EC of irrigation water, while cv. Raf was showed the reverse (Table 3.17, Figure 3.6 and 3.7).

The appearance of fruit with catface, BER, cracking, small and deformed fruits were not influenced by increase EC of irrigation water (Table 3.18). The appearance fruits with catface, cracking and BER were not presented significant difference between the cultivars (Table 3.18). Whereas Raf had a higher small and deformed fruits than Dumas (at $P \leq 0.05$, Table 3.18). The results not showed any interaction between salinity and cultivars for incidence fruit with physiological disorders at January (Table 3.18).

Table 3.17. Effects of salinity of irrigation water and cultivars on total fruit yield, marketable fruit yield, unmarketable fruit yield and mean fruit weight during January production without accumulation.

Factors	**Total fruit yield (kg/plant)**	**Marketable fruit yield (kg/plant)**	**Unmarketable fruit yield (kg/plant)**	**Mean fruit weight (g/fruit)**
Salinity				
3.3 ds m^{-1} (Control)	0.767	0.727	0.039	215.041 a
5.3 ds m^{-1}	0.808	0.743	0.064	186.258 b
Cultivars				
Dumas	1.015 a	0.974 a	0.041	212.018 a
Raf	0.560 b	0.497 b	0.062	189.282 b
ANOVA (df)	**% Sum of squares**			
Factor				
Salinity	0.57 n.s.	0.08 n.s.	15.53 n.s.	46.10 **
Cultivars	70.33 **	68.38 **	11.38 n.s.	28.76 **
Interaction				
Cultivars × Salinity	13.01 *	13.00 *	3.56 n.s.	8.32 n.s.
Residual	16.07	18.53	69.50	16.80
Standard deviation	0.13	0.15	0.03	10.64

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

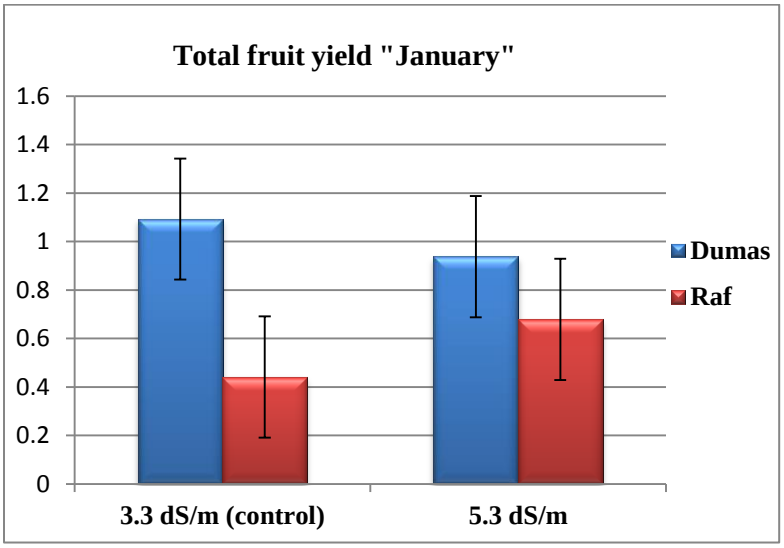

Figure 3.6. Analysis of the interaction between the salinity of irrigation water and the cultivars for total fruit yield (kg/plant) of January production without accumulation.

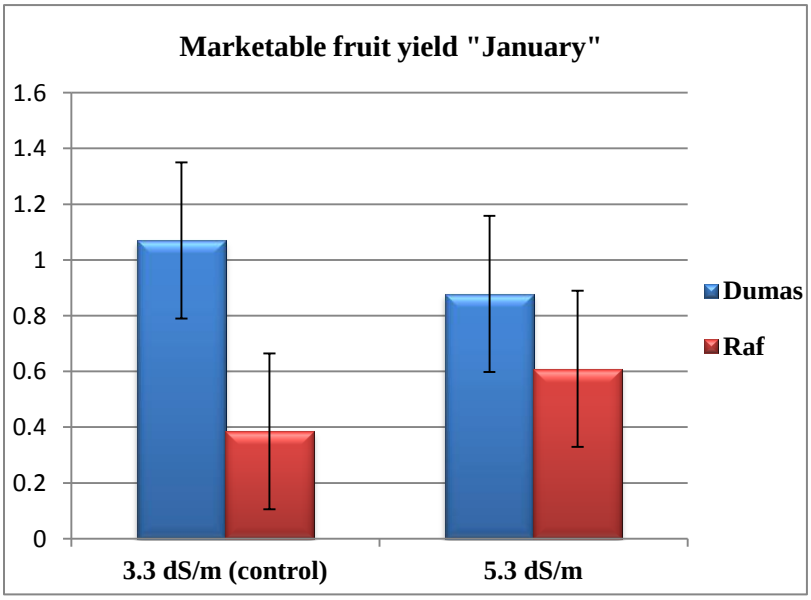

Figure 3.7. Analysis of the interaction between the two salinity levels of irrigation water and the cultivars for marketable fruit yield (kg/plant) of January production without accumulation.

Table 3.18. Effects of salinity of irrigation water and cultivars on the unmarketable fruit according to the nature of the blemish as catface, BER, cracking and small and deformed fruits during January production without accumulation, all parameters expressed with kg/plant.

Factors	Catface	BER	Cracking	Small and deformed fruits
Salinity				
3.3 ds m^{-1} (Control)	0.013	0.000	0.008	0.017
5.3 ds m^{-1}	0.032	0.002	0.016	0.013
Cultivars				
Dumas	0.019	0.00	0.015	0.006 b
Raf	0.027	0.002	0.009	0.024 a
ANOVA (df)	**% Sum of squares**			
Factor				
Salinity	24.43 n.s.	9.09 n.s.	4.10 n.s.	1.70 n.s.
Cultivars	4.70 n.s.	9.09 n.s.	3.35 n.s.	40.00 *
Interaction				
Cultivars × Salinity	0.02 n.s.	9.09 n.s.	24.20 n.s.	1.21 n.s.
Residual	70.84	72.72	0.38	57.07
Standard deviation	0.02	0.003	0.01	0.01

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

3.2.5. Production parameters of total accumulated yield

Total fruit yield, marketable fruit yield and mean fruit weight were influenced by salinity treatment; these parameters were significantly reduced with salinity treatment more than control (at $P \leq 0.01$, Table 3.19). In the other hand, from the results was detected that Dumas had a significantly higher total accumulated fruit yield, accumulated marketable fruit yield and mean fruit weight than Raf (at $P \leq 0.01$, Table 3.19). The behavior of cultivars for mean fruit weight of total accumulated production were significantly changed under salinity condition, both of the cultivars were reduced the mean fruit weight with increase EC of irrigation water from 3.3 dS m^{-1} (control) to 5.3 dS m^{-1}, but this reduction was drastically higher in Dumas than Raf (Table 3.19, Figure 3.8). The fruit number was significantly affected by salinity treatment; the control had a significantly higher fruit number (at $P \leq 0.05$, Table 3.19). Concerning the cultivars cv. Raf had a higher fruit number more than Dumas (at $P \leq 0.01$, Table 3.19). No significant effects for the two studied factors were noticed on total fruit yield, marketable fruit yield and fruit number (Table 3.19).

Whereas was observed no significant difference between salinity treatment and control for unmarketable fruit yield (Table 3.20). Also, cvs. Dumas and Raf have a similar value for the unmarketable fruit yield (Table 3.20). The salinity treatment did not have effect on appearance of catface, cracking, small and deformed fruits, but BER was affected by salinity treatment, observe increasing the fruits with BER with salinity treatment than control (at $P \leq 0.01$, Table 3.20). The appearance of fruits with catface was higher in Dumas (at $P \leq 0.05$), while cv. Raf had a higher appearance of fruit with BER, small and deformed (at $P \leq 0.01$). Fruit with cracking was not presented significant difference between the two tomato cultivars (Table 3.20). The interaction treatments of salinity and cultivars had no significant effect on incidence of fruit with blemish (Table 3.20).

Table 3.19. Effects of salinity of irrigation water and cultivars on total fruit yield, marketable fruit yield, fruit number and mean fruit weight of total accumulated production.

Factors	**Total fruit yield (kg/plant)**	**Marketable fruit yield (kg/plant)**	**Fruit Number**	**Mean fruit weight (g/fruit)**
Salinity				
3.3 ds m^{-1} (Control)	3.132 a	2.704 a	12,597 a	193.734 a
5.3 ds m^{-1}	2.613 b	2.154 b	11,458 b	169.319 b
Cultivars				
Dumas	3.097 a	2.685 a	11,180 b	207.995 a
Raf	2.648 b	2.17 b	12,875 a	155.058 b
ANOVA (df)		**% Sum of squares**		
Factor				
Salinity	46.18 **	44.68 **	21.64 *	17.13 **
Cultivars	34.58 **	38.88 **	47.91 **	80.55 **
Interaction				
Cultivars × Salinity	5.17 n.s.	4.35 n.s.	0.46 n.s.	1.32 *
Residual	14.05	12.07	29.97	0.98
Standard deviation	0.18	0.17	0.82	3.58

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

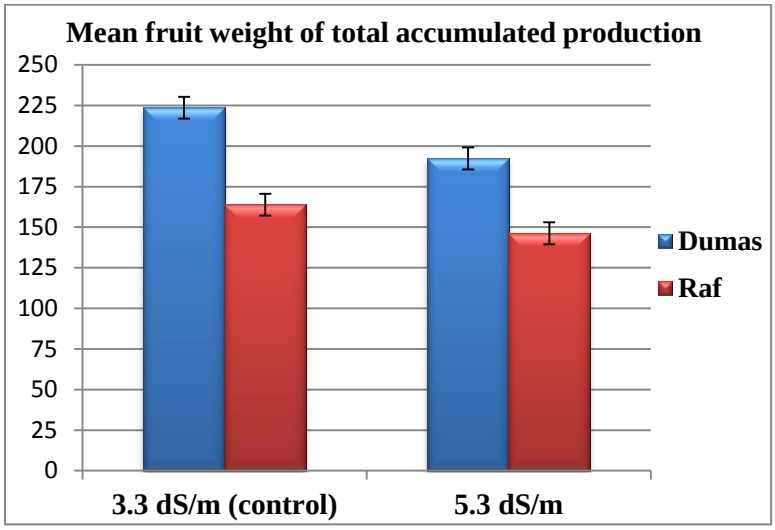

Figure 3.8. Analysis of the interaction between the two salinity level of irrigation water and the two tomato cultivars for mean fruit weight (g/plant) of total accumulated production.

Table 3.20. Effects of salinity of irrigation water and cultivars on the unmarketable fruit according to the nature of the blemish as catface, BER, cracking and small and deformed fruits of total accumulated production, all parameters expressed with kg/plant.

Factors	Unmarketable fruit yield (kg/plant)	Catface	BER	Cracking	Small and deformed fruits
Salinity					
3.3 ds m^{-1} (Control)	0.428	0.302	0.045 b	0.026	0.053
5.3 ds m^{-1}	0.459	0.255	0.127 a	0.031	0.045
Cultivars					
Dumas	0.411	0.342 a	0.031 b	0.024	0.013 b
Raf	0.475	0.214 b	0.141 a	0.034	0.085 a
ANOVA (df)			**% Sum of squares**		
Factor					
Salinity	3.54 n.s.	5.62 n.s.	26.29 *	1.32 n.s.	1.01 n.s.
Cultivars	15.05 n.s.	40.92 *	47.55 **	5.16 n.s.	74.16 **
Interaction					
Cultivars × Salinity	0.01 n.s.	0.44 n.s.	1.45 n.s.	16.47 n.s.	20.72 n.s.
Residual	81.38	52.99	24.69	77.03	22.74
Standard deviation	0.09	0.08	0.04	0.02	0.02

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

3.3. Fruit quality parameters

TSS (°Brix) of fruits was not influenced by the salinity of irrigation water throughout the fruits harvest (Table 3.21). The results showed no significant difference between the cultivars for TSS during October, but at November Dumas had a higher TSS than Raf (at $P \leq 0.05$, Table 3.21), conversely in December, Raf had a higher TSS than Dumas (at $P \leq 0.05$, Table 3.21). The interaction of salinity and cultivars had no significant effect on TSS (Table 3.21). With higher EC level of nutrient solution was significantly increased the acidity of fruits only during October (at $P \leq 0.05$, Table 3.21). Whereas, fruit acidity was not affected by salinity treatment during November and December (Table 3.21). Throughout the harvest period cv. Dumas had a significantly higher acidity more than Raf (at $P \leq 0.01$, Table 3.21). The salinity and cultivars interaction was not affected on acidity percentage (Table 3.21). Salinity treatment had no significant effect on fruit firmness during all the harvest period (Table 3.22). Regarding to the effect of cultivars; Dumas had a higher fruit firmness than Raf at October and November (at $P \leq 0.01$ in October and at $P \leq 0.01$ in November, Table 3.22). While, was not observed this difference between the cultivars in December (Table 3.22). The behavior of cultivars for fruit firmness was similarly under salinity condition (Table 3.22). Fruit colour *a* was not influenced by salinity treatments (Table 3.23). On the other hand, cv. Raf had a higher intensity red colour more than Dumas at October and November, but the reverse was observed in December (at $P \leq 0.01$ in October and November and at $P \leq 0.05$ in December, Table 3.23). It was detected interaction between salinity and the cultivars for fruit colour index *a* only at December (at $P \leq 0.01$); Raf had a significant increase of intensity red colour with increase EC of irrigation water (Table 3.23, Figure 3.9).

The salinity had no significant effect on fruit colour *b* during the harvest period (Table 3.24). While was found significant difference between the cultivars for fruit colour *b* only at October (at $P \leq 0.05$), but not observed this difference in November and December (Table 3.24). Salinity treatment did not have a significant effect on the behavior of the cultivars for fruit colour *b* (Table 3.24). Surface fruit lightness *l* was significantly affected by salinity of irrigation water only during October (at $P \leq 0.01$, Table 3.25). In contrast, during November and December the surface fruit lightness *l* not influenced by salinity treatment (Table 3.25). Whilst cv. Raf had a higher surface fruit lightness *l* than Dumas during all the harvest period

(at $P \leq 0.01$, Table 3.25). For fruit lightness *l* was not observed interaction among salinity treatments and the cultivars (Table 3.25).

Table 3.21. Effects of salinity and cultivars on TSS (°Brix) and acidity % of fruits at different times during tomato growth (October, November and December).

Factors	**TSS (°Brix)**			**Acidity %**		
	October	November	December	October	November	December
Salinity						
3.3 ds m^{-1} (Control)	4.34	4.76	4.70	0.78 b	0.86	0.79
5.3 ds m^{-1}	4.50	4.90	4.75	0.93 a	0.92	0.84
Cultivars						
Dumas	4.38	4.99 a	4.59 b	0.96 a	1.09 a	0.99 a
Raf	4.45	4.67 b	4.87 a	0.75 b	0.69 b	0.64 b
ANOVA (df)			**% Sum of squares**			
Factor						
Salinity	8.83 n.s.	6.82 n.s.	1.42 n.s.	24.11 *	1.96 n.s.	1.40 n.s.
Cultivars	19.79 n.s.	38.48 *	45.72 *	43.56 **	84.55 **	87.41 **
Interaction						
Cultivars × Salinity	8.83 n.s.	8.63 n.s.	0.63 n.s.	0.82 n.s.	0.15 n.s.	3.90 n.s.
Residual	80.37	42.21	52.21	31.51	13.32	7.27
Standard deviation	10.04	0.21	0.18	0.10	0.09	0.06

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

Table 3.22. Effects of salinity and cultivars on fruit firmness (kg/cm^2) at different times during tomato growth (October, November and December).

Factors	**October**	**November**	**December**
Salinity			
3.3 ds m^{-1} (Control)	2.15	2.62	1.92
5.3 ds m^{-1}	2.12	2.40	1.94
Cultivars			
Dumas	2.59 a	2.26 b	2.11
Raf	1.68 b	2.76 a	1.75
ANOVA (df)		**% Sum of squares**	
Factor			
Salinity	0.093 n.s.	6.51 n.s.	0.06 n.s.
Cultivars	85.71 **	35.34 *	31.13 n.s.
Interaction			
Cultivars × Salinity	0.72 n.s.	3.00 n.s.	0.21 n.s.
Residual	13.46	55.12	68.58
Standard deviation	0.22	0.38	0.32

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

Table 3.23. Effects of salinity and cultivars on internal fruits colour *a* at different times during tomato growth (October, November and December).

Factors	October	November	December
Salinity			
3.3 ds m^{-1} (Control)	2.23	0.24	3.94
5.3 ds m^{-1}	2.12	-0.02	4.65
Cultivars			
Dumas	0.13 b	-3.85 b	5.21 a
Raf	4.22 a	4.08 a	3.38 b
ANOVA (df)		**% Sum of squares**	
Factor			
Salinity	0.05 n.s.	0.10 n.s.	3.59 n.s.
Cultivars	71.79 **	96.73 **	24.04 *
Interaction			
Cultivars × Salinity	1.89 n.s.	1.02 n.s.	40.93 **
Residual	26.25	2.12	31.41
Standard deviation	1.72	0.72	1.27

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

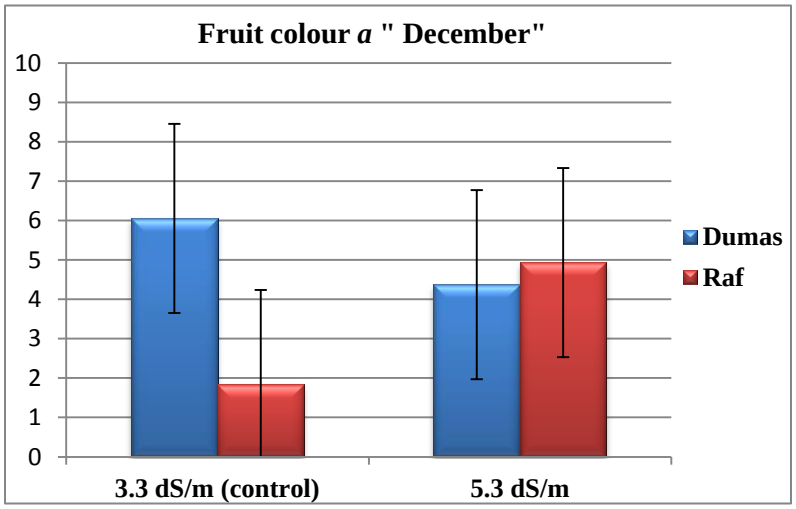

Figure 3.9. Analysis of the interaction between the salinity levels of irrigation water and the two tomato cultivars for internal fruit colour *a* weight at December.

Table 3.24. Effects of salinity and cultivars on fruit colour *b* at different times during tomato growth (October, November and December).

Factors	October	November	December
Salinity			
3.3 ds m^{-1} (Control)	16.0733	15.2667	15.3183
5.3 ds m^{-1}	15.7617	15.1017	15.4183
Cultivars			
Dumas	15.4067 b	15.1967	15.14
Raf	16.4283 a	15.1717	15.5967
ANOVA (df)		**% Sum of squares**	
Factor			
Salinity	4.17 n.s.	5.70 n.s.	0.89 n.s.
Cultivars	44.86 *	0.13 n.s.	18.72 n.s.
Interaction			
Cultivars × Salinity	4.08 n.s.	15.84 n.s.	1.93 n.s.
Residual	46.87	78.31	78.44
Standard deviation	0.63	0.37	0.57

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

Table 3.25. Effects of salinity and cultivars on flesh fruit lightness *l* at different times during tomato growth (October, November and December).

Factors	October	November	December
Salinity			
3.3 ds m^{-1} (Control)	44.80 a	42.89	41.90
5.3 ds m^{-1}	42.28 b	42.17	42.11
Cultivars			
Dumas	41.34 b	40.24 b	40.17 b
Raf	45.73 a	44.81 a	43.83 a
ANOVA (df)		**% Sum of squares**	
Factor			
Salinity	22.79 **	1.88 n.s.	0.17 n.s.
Cultivars	69.21 **	76.58 **	54.62 **
Interaction			
Cultivars × Salinity	0.59 n.s.	0.54 n.s.	0.81 n.s.
Residual	7.38	20.98	44.37
Standard deviation	0.87	1.46	2.02

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

The organoleptic characters as grain texture with spices, taste with spices and taste without spices had no significant difference among salinity treatment and the control (Table 3.26), but was found significant difference for grain texture without spices between salinity treatment and the control (at $P \leq 0.05$, Table 3.26). Dumas and Raf were similar for grain texture of fruit, but when added a spices to the pieces of fruits observed significant difference between cultivars (at $P \leq 0.01$, Table 3.26). Raf had a significant score of fruit taste without adding spices than Dumas (at $P \leq 0.01$, Table 3.26). While, when adding spices to fruit pieces was observed no significant difference between the cultivars (Table 3.26). The result not showed any interaction between the salinity and cultivars for the organoleptic characters (Table 3.26).

Table 3.26. Effects of salinity and cultivars on organoleptic characters of tomato fruits.

Factors	**Grain texture with spices**	**Grain texture without spices**	**Taste with spices**	**Taste without spices**
Salinity				
3.3 ds m^{-1} (Control)	2.00	3.00 a	2.83	2.33
5.3 ds m^{-1}	1.50	1.83 b	3.16	2.50
Cultivars				
Dumas	2.33 a	2.66	2.66	2.00 b
Raf	1.16 b	2.16	3.33	2.83 a
ANOVA (df)		**% Sum of squares**		
Factor				
Salinity	9.09 n.s.	45.79 *	5.55 n.s.	2.85 n.s.
Cultivars	49.49 **	8.41 n.s.	22.22 n.s.	71.42 **
Interaction				
Cultivars × Salinity	1.01 n.s.	0.93 n.s.	5.55 n.s.	2.85 n.s.
Residual	40.40	44.85	66.66	22.85
Standard deviation	0.64	2.23	0.70	0.28

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

3.4. Water use efficiency

3.4.1. Irrigation water use efficiency (IWUE)

IWUE as terms of total fruit yield, the general trend was of higher value in the control with the exception of January. The results shown significant difference both in November (at P

≤ 0.05), and Total Cycle (at P ≤ 0.01, Table 3.27).The two cultivars had a similar IWUE during October, while in November Dumas require more water to produce higher fruits yield than Raf. The value of IWUE in December, January and total cycle was higher in cv. Dumas than Raf (at P ≤ 0.05 in December, at P ≤ 0.01 in January and total cycle, Table 3.27). Salinity and cultivars interaction was significant only for total fruit yield at January (Table 3.27, Figure 3.10).

Regarding to IWUE as terms of marketable fruit yield had a similar tendency of IWUE IWUE as terms of total fruit yield, where IWUE was higher in control in comparison of the salinity treatment; with significant difference at October, November and total growth cycle (at P ≤ 0.01, Table 3.28). At October not observed significant difference between both cultivars, whereas at November Raf had a higher IWUE more than Dumas (at P ≤ 0.01, Table 3.28). The reverse was found at December, January and total growth cycle (at P ≤ 0.01, Table 3.28). Salinity and cultivars interaction was significant for IWUE as terms of marketable fruit yield at November and January; IWUE was decreased in both cultivars with greater reduction in Raf more than Dumas (Table 3.28, Figure 3.12 and 3.12).

Table 3.27. Effect of salinity of irrigation water and cultivars on IWUE (kg/m^3) as terms total fruit yield during harvest at October, November, December, January and total cycle.

Factors	**IWUE (total fruit yield)**				
	October	November	December	January	Total cycle
Salinity					
3.3 ds m^{-1} (Control)	16.6	27.1 a	36.3	46.2	21.5 a
5.3 ds m^{-1}	13.9	17.6 b	30.5	49.2	18.2 b
Cultivar					
Dumas	16.0	17.4 b	38.9 a	61.5 a	21.4 a
Raf	14.5	27.3 a	27.9 b	33.9 b	18.3 b
ANOVA (df)	**% Sum of squares**				
Factor					
Salinity	29.50 n.s.	31.67 *	12.18 n.s.	0.88 n.s.	42.57 **
Cultivars	8.90 n.s.	34.18 **	44.29 *	70.22 **	36.90 **
Interaction					
Cultivar × Salinity	2.91 n.s.	8.19 n.s.	5.58 n.s.	12.70 *	5.36 n.s.
Residual	58.66	25.92	37.93	16.19	15.15
Standard deviation	2.35	5.25	6.21	8.09	1.00

n.s., *, **: no significant differences, significant differences at P ≤ 0.05 and significant differences at P ≤ 0.01. Different letters in the same column indicate a statistically significant difference (at P ≤0.01 and/or P ≤ 0.05).

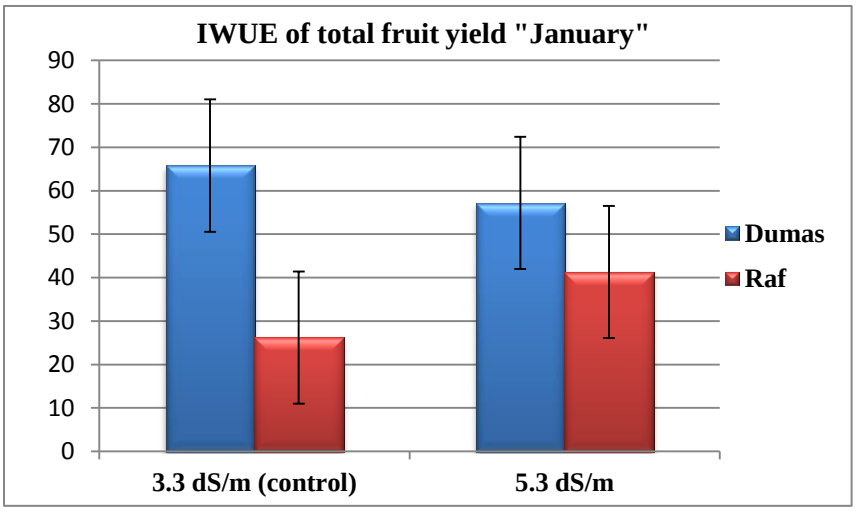

Figure 3.10. Analysis of the interaction between salinity levels of irrigation water and the tomato cultivars for IWUE as total fruit yield at January.

Table 3.28. Effect of salinity of irrigation water and cultivars on IWUE (kg/m^3) as terms of marketable fruit yield during harvest at October, November, December, January and total cycle.

Factors	**IWUE (marketable fruit yield)**				
	October	November	December	January	Total cycle
Salinity					
3.3 ds m^{-1} (Control)	12.4 a	22.6 a	33.5	43.8	18.6 a
5.3 ds m^{-1}	9.0 b	12.8 b	29.5	45.3	15.0 b
Cultivars					
Dumas	10.9	13.9 a	37.7 a	58.9 a	18.6 a
Raf	10.5	21.6 b	25.4 b	30.1 b	15.0 b
ANOVA (df)	**% Sum of squares**				
Factor					
Salinity	65.99 **	45.53 **	5.54 n.s.	0.19 n.s.	41.82 **
Cultivars	0.78 n.s.	28.36 **	51.41 **	68.37 **	40.85 **
Interaction					
Cultivars × Salinity	0.29 n.s.	12.76 *	12.80 n.s.	12.70 *	4.41 n.s.
Residual	32.92	13.33	30.44	18.72	12.89
Standard deviation	1.46	3.24	5.80	9.23	1.22

n.s., *, **: no significant differences, significant differences at P ≤ 0.05 and significant differences at P ≤ 0.01. Different letters in the same column indicate a statistically significant difference (at P ≤0.01 and/or P ≤ 0.05).

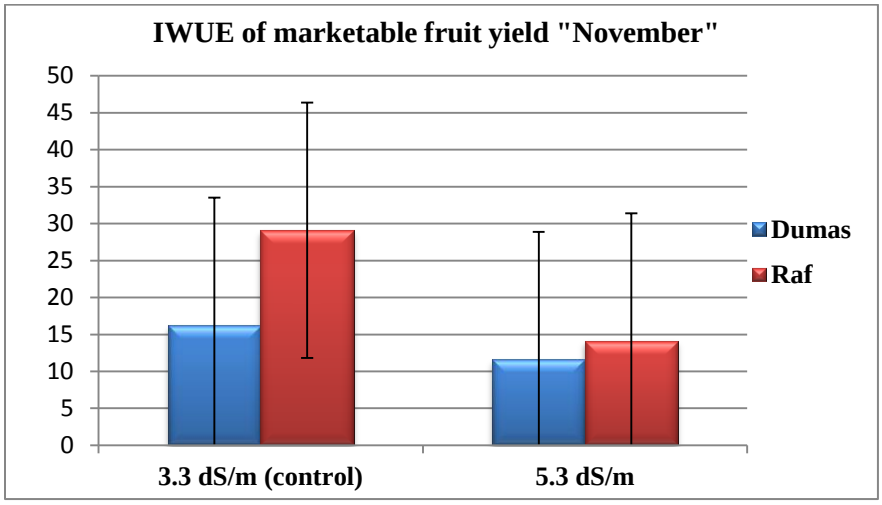

Figure 3.11. Analysis of the interaction between salinity levels of irrigation water and the tomato cultivars for IWUE as marketable fruit yield at November.

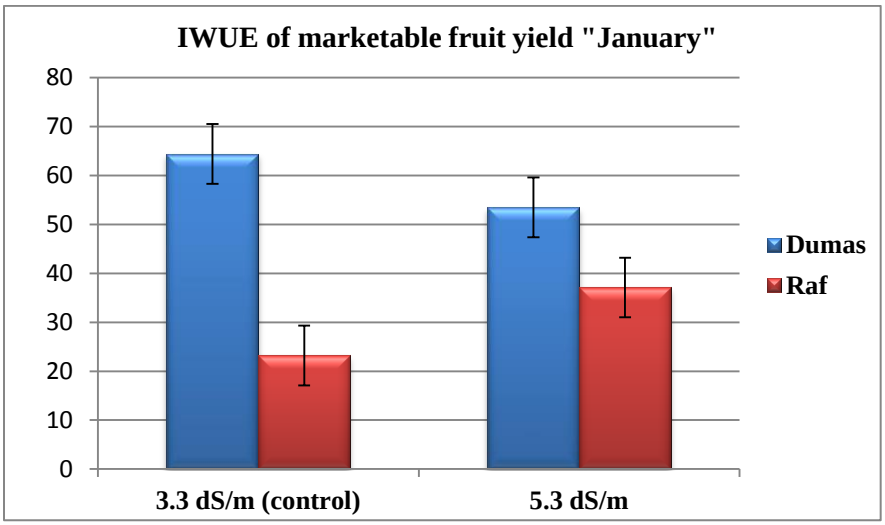

Figure 3.12. Analysis of the interaction between salinity levels of irrigation water and the tomato cultivars for IWUE as marketable fruit yield at January.

3.4.2. Water use efficiency (WUE)

The results of WUE as terms of total fruit yield presented in table 3.29, the salinity treatment did not have a statistically significant effect on net WUE at October, November, December and total growth cycle. Whereas at January the WUE was increased in salinity

treatment more than control (at $P \leq 0.05$). At the beginning of harvest (at October) was not observed any significant different between the cultivars for WUE, with advance the harvest Raf had WUE higher than Dumas at November (at $P \leq 0.05$), the opposite happened at December (at $P \leq 0.05$), January and total cycle (at $P \leq 0.01$).

For WUE as terms of marketable fruit yield, WUE was not affected by salinity treatment at October, December, January, and total growth cycle (Table 3.30). While at November was observed significant difference between salinity treatment and the control for WUE (at $P \leq 0.01$, Table 3.30). The obtained results not shown significant differences among both cultivars for WUE at October, this observation significantly changed during November; Raf had a higher WUE compared to Dumas (at $P \leq 0.01$). The contrast was found during December, January and total fruit yield of all harvest cycle, where Dumas had a higher net WUE rather than Raf (at $P \leq 0.01$, Table 3.30). WUE as term of marketable fruit yield at November was decreased in both cultivars under salinity treatment with drastically reduction in Raf more than Dumas (Table 3.30, Figure 3.13).

Table 3.29. Effect of salinity of irrigation water and cultivars on WUE (kg/m^3) as terms of total fruit yield during harvest at October, November, December, January and total cycle.

Factors	**WUE (total fruit yield)**				
	October	November	December	January	Total cycle
Salinity					
3.3 ds m^{-1} (Control)	25.8	39.7	51.9	62.7 b	30.5
5.3 ds m^{-1}	26.1	30.0	51.0	84.4 a	30.3
Cultivars					
Dumas	26.7	27.4 a	59.7 a	93.6 a	32.7 a
Raf	24.4	42.7 b	43.2 b	53.5 b	28.1 b
ANOVA (df)	**% Sum of squares**				
Factor					
Salinity	2.06 n.s.	17.50 n.s.	0.15 n.s.	17.37 *	0.21 n.s.
Cultivars	10.54 n.s.	41.75 *	49.28 *	59.67 **	63.78 **
Interaction					
Cultivars × Salinity	2.57 n.s.	7.74 n.s.	4.02 n.s.	6.33 n.s.	6.17 n.s.
Residual	84.82	32.98	46.53	16.61	29.82
Standard deviation	4.12	8.17	9.82	12.98	1.94

n.s., *, **: no significant differences, significant differences at $P \leq 0.05$ and significant differences at $P \leq 0.01$. Different letters in the same column indicate a statistically significant difference (at $P \leq 0.01$ and/or $P \leq 0.05$).

Table 3.30. Effect of salinity of irrigation water and cultivars on WUE (kg/m^3) as terms of marketable fruit yield during harvest at October, November, December, January and total cycle.

Factors	WUE (marketable fruit yield)				
	October	November	December	January	Total cycle
Salinity					
3.3 ds m^{-1} (Control)	18.7	33.2 a	47.9	59.5	26.4
5.3 ds m^{-1}	17.0	21.9 b	49.3	77.6	24.9
Cultivars					
Dumas	18.2	21.7 b	57.7 a	89.6 a	28.3 a
Raf	17.5	33.3 a	39.4 b	47.5 b	23.0 b
ANOVA (df)	% Sum of squares				
Factor					
Salinity	14.89 n.s.	32.92 **	0.30 n.s.	11.42 n.s.	4.64 n.s.
Cultivars	2.17 n.s.	34.77 **	52.92 **	61.19 **	65.79 **
Interaction					
Cultivars × Salinity	1.00 n.s.	13.68 *	10.19 n.s.	6.74 n.s.	4.31 n.s.
Residual	81.93	18.60	36.57	20.62	25.24
Standard deviation	2.50	5.20	9.22	4.94	2.01

n.s., *, **: no significant differences, significant differences at P ≤ 0.05 and significant differences at P ≤ 0.01. Different letters in the same column indicate a statistically significant difference (at P ≤0.01 and/or P ≤ 0.05).

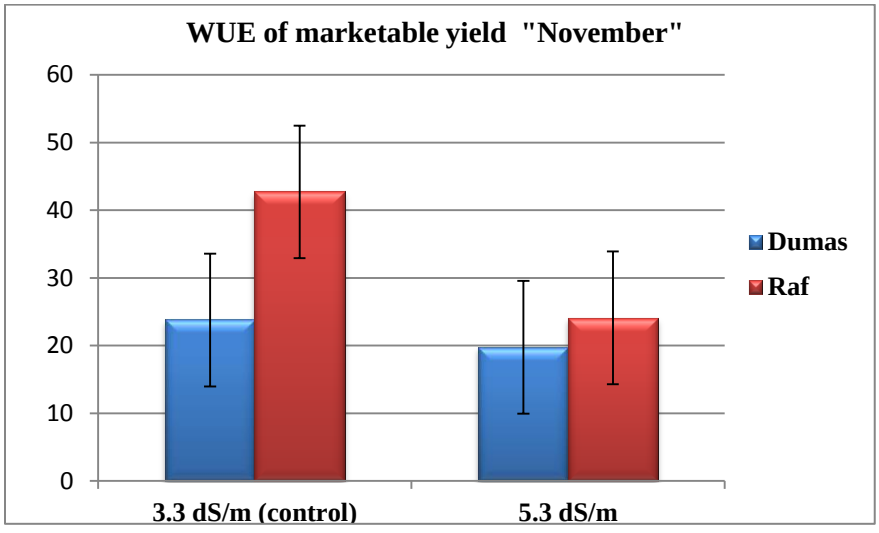

Figure 3.13. Analysis of the interaction between salinity levels of irrigation water and the tomato cultivars for WUE as marketable fruit yield at November.

4. DISCUSSION

4. Discussion

In this study, we demonstrated the response of tomato growth, yield and quality to salinity of irrigation water, in addition to evaluate the behavior of two tomato cultivars under hydroponic system.

The above results show that the most of vegetative growth parameters was affected by water stress due to the high salinity treatment especially at the first stage of plant growth. The plant height, leaf number, leaf width, leaf length, fresh biomass and dry biomass were significantly affected by salinity treatment at first plant growth and then at the end of plant growth always the control had a higher value for these measurements but without significant difference, which generally agreed with the results reported by Romero-Aranda *et al.* (2001), Yurtseven *et al.* (2005), Babu *et al.* (2012) and Bustomi *et al.* (2014). Babu *et al.* (2012) was found significant decrease in leaf area, plant height and dry matter weight % of tomato with application elevated salt treatment. Bustomi *et al.* (2014) mentioned that the plant height was significantly affected by water stress due to the high salinity of treatments, but was not affected by the low salinity treatments. The reduction in plant growth characters of our results probably due to the tomato seedling or the young plants drastically affected by salinity, whilst at the flowering and fruiting stages, tomato plants are able to withstand NaCl concentrations which are sufficient to kill them at the seedling stage (Cuartero and Fernandez-Muñoz, 1999). On the other hand, according to our results was observed reduction in the leaf number, leaf width, leaf length and leaf dry weight in stressed plants, which may be cause reduction in photosynthetic rate. Furthermore, reduction in leaf growth rate has been related to reduction in cell turgor, to cell wall rheological properties and to reduction in photosynthetic rate (Cuartero and Fernandez-Muñoz, 1999). The reduction in growth could be a result of salinity, which cause water stress due to osmotic effects (Yokas *et al.,* 2008; Maroto, 2008). Reina-Sánchez *et al.* (2005) found that reduction in plant water uptake by salinity of irrigation water in four cultivar, where the daily plant water uptake about 1.70 L plant^{-1} in the control at 75 day after transplant, whilst the daily plant water uptake lower than 0.95 L plant^{-1} for salinity treatment. In addition to in our experiment, plants grown under salinity treatment had a higher content from Na^+ in the leaves, which could be produce toxic effects. Similar results have been reported by Ben-Gal and Shani (2002), Yokas *et al.* (2008) and Abu-Khadejeh *et al*. (2012); that increased Na^+

in leave and shoots with increased NaCl levels in hydroponic solution. Under saline condition as soon as new cell starts its elongation process, the excess of Na^+, Cl^- and other ions modifies the metabolic activities of cell wall, which causes deposition of several materials on cell wall and limits the cell wall elasticity (Yasar *et al.*, 2006). The Na^+ accumulation in plants cause many deleterious effects such as necrosis of leaves and reduced shoot and root growth (Babu *et al.*, 2012). Stem fresh and dry weight of cv. Raf was reduced under saline condition in comparison of cv. Dumas.

According to our results of the all cycle, total fruit yield, marketable fruit yield and fruit weight found to decrease with increase EC of nutrient solution. This agreed with Y.L. Li *et al.* (2001), Reina-Sánchez *et al.* (2005), Magan *et al.* (2008) and Bustomi *et al.* (2014). Yield reduction in saline condition due to reduction in fruit weight (Y.L. Li *et al.*, 2001; Reina-Sánchez *et al.*, 2005). Also in our results the fruit yield was reduced with reduction of fruit weight. According to Y.L. Li *et al.* (2001), the fresh yield was reduced about 20 to 28% by salinity, in addition to reduction of marketable fresh yield about 10% by salinity. The unmarketable fruit yield not influenced by salinity of irrigation water. Plants grown under Salinity condition present a higher appearance of BER symptoms, similar results reported by Y.L. Li *et al.* (2001), Magan *et al.* (2008) and Hossain and Nonami (2012). BER are caused by a local Ca^{2+} deficiency at the distal placental fruit tissue (Cuartero and Fernandez-Muñoz, 1999; Maroto, 2002). Irregular irrigation, salinity and generally all factors that can induce low translocation of Ca also could be cause incidence of BER (Maroto, 2002). In our result, Ca content in the leaves was higher in control without significant difference, whilst Na^+ concentration in the leaves was drastically higher in the leaves of plants under salinity condition. Yokas *et al.* (2008), reported that salinity dominated by Na salts not only reduces Ca availability, but also reduces Ca transport and mobility to growing regions of the plant, which affects the quality of both vegetative and reproductive organs.

On the other hand, there is different between the cultivars behavior for fruit weight under salinity stress, cv. Dumas was reduced their fruit weight than Raf.

Salinity did not improve fruit quality as TSS, acidity, colour and taste. TSS content is the most important quality criterion for tomato paste processing and serves as the base for fixing the price to be paid to the producer (Cuartero and Fernandez-Muñoz, 1999). In our experiment

TSS was measured at ripening stage (breaker and turning stage) and our result are relatively agreed that reported by Wu and Kubota (2008) were measured TSS of tomato fruit under salinity condition (4.5 dS m^{-1}) at different ripeness stages and salinity treatment increased TSS of fruits at all stages except at breaker and turning stages. In addition to, they suggested that increase in TSS was a cumulative effect over time of the fruit development and ripening. On the other hand, Cuartero and Fernandez-Muñoz (1999) and Serio *et al*. (2004) reported that the use of moderately saline irrigation water (3-6 dS m^{-1}) is recommended to improve fruit quality.

WUE in both terms of total fruit yield and marketable fruit yield was not affected by increasing of EC level of irrigation water. Similar results have been reported by Romero-Aranda *et al.* (2001) obtained a constant WUE in the range of tested salinities in cv. Moneymaker. Although Reina-Sánchez *et al.* (2005) found a decrease in total fruit yield and marketable fruit yield of tomato produced per liter, this discrepancy could be attributed to the cultivars used are different. IWUE in both cases, as terms of total fruit yield and marketable fruit yield was found to decrease with increase of salinity level from 3.3 dS m^{-1} to 5.3 dS m^{-1}, similar trend was found by Zayton *et al*. (2009) was observed that the I_1 (EC 1.25 dS m^{-1}) treatments had the greatest IWUE of 4.05 kg/m^3 followed by I_2 (EC 2.5 dS m^{-1}) and I_3 (EC 5 dS m^{-1}), respectively. However, I_4 (EC 10 dS m^{-1}) treatments had the lowest IWUE value of 1.83 kg/m^3. We have observed natural difference between cultivars for WUE and IWUE.

5. CONCLUSIONS

5. Conclusions

1. Plant growth as plant height, leaf number, leaf width, leaf length, fresh biomass and dry biomass was affected by high salinity of irrigation water especially at first stage of plant development due to the fact that young plants were more sensitive to saline conditions.
2. The yield of tomatoes as total and marketable fruit yield decreased with increasing EC of irrigation water. Furthermore, salinity treatment reduced the average fruit weight.
3. Increasing the salinity level increased the incidence of BER, but it did not affect the appearance of cracking, catface, small and deformed fruits.
4. Fruit quality improvement with the moderate saline level was not observed, due to the maturity stage of tested fruits.
5. Increasing NaCl concentration in the nutrient solution was not affected on WUE in both terms of total and marketable fruit yield, while higher NaCl concentration decreased IWUE in both terms of total and marketable fruit yield.
6. Cultivars behaved differently in response to salinity; Raf was more sensitive for stem fresh and dry weight, while Dumas was more sensitive for fruit weight. Apart from that, the behavior of the two cultivars was similar under salinity.

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