



## Research Paper

# Impact of surface and ground water salinity on soil and plant productivity in the central rift valley region around Lake Ziway

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## ABSTRACT

Salinization affects many irrigated soils mainly due to the use of brackish water in arid and semi-arid areas. This study was conducted in north western part of Lake Ziway, Adami Tulu Jido Kombolcha Woreda in the Central Rift Valley region of Ethiopia. The aim of the study was to assess the impact of ground and surface water use on soluble salt rise in soil and its effect on plant yield and biomass. Soil and water samples were systematically collected from surface and ground water irrigated fields for laboratory analysis and glasshouse experiment. The ground water had 0.98 ds/m electrical conductivity whereas surface water had 0.61 ds/m. The ground water irrigated soils from the study site had an electrical conductivity of 2.57ds/m while the surface water irrigated soils had 1.2 ds/m. Glass house experiment was carried out and results showed that after glass house experiment, the ground water treated soils were found to have less electrical conductivity of 1.27 ds/m than that of surface water treated soils having 1.37 ds/m. The ground water irrigated soils were not significantly different from the surface water irrigated soils in electrical conductivity level. There was no significant variation between surface and ground water irrigated plants in plant growth parameters ( $P < 0.05$ ). However, the yield was found to be affected by the salinity level. In conclusion, the ground water was found to be slightly saline and soil analysis results before experiment showed a moderately low salinity level. This could have resulted from irrigation water mismanagement. Therefore, there is a need to regulate irrigation water use in the study area.

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**Key words:** Soil salinity, irrigation water, Ethiopia, ground water salinity.

## INTRODUCTION

Salinity has plagued agriculture in arid and semi-arid climates for thousands of years (Steppuhn, 2013). Soil Salinity is one of the most brutal severe environmental factors limiting the productivity of crop plants (Hasanuzzaman et al., 2013). Excess salt in the soil solution may adversely affect plant growth either through osmotic inhibition of water uptake by roots or specific ion effects (Turhan et al., 2009). Salt affected soils are categorized into three main groups namely saline, sodic and saline-sodic. Soil salinity and sodicity levels are dynamic; they change with the amount and quality of infiltrated water, evapotranspiration and rainfall (Oster et al., 2001).

The semi-arid and arid lowlands and valleys in Ethiopia have major problems of salinity and alkalinity. The total land area affected by salinity and sodicity in Ethiopia is estimated at about 11 thousand ha and soils have been reported to occur for the most part of the rift valley zone (Seid and Genanaw, 2013). The naturally salt affected areas are normally found in the arid and semi-arid lowlands and in Rift valley and other areas that are characterized by higher evapotranspiration rates in relation to precipitation (Meron, 2007). Water quality studies revealed that the groundwater and surface water resources of the region are characterized by high salinity that determines their use for

irrigation (Tewodros, 2011). According to Haile (1999), it can be concluded that most of the ground water in the western part of the area are unsuitable for irrigation based on the quality classification of water for irrigation and this is as a result of sodium adsorption ratio, percent sodium and electrical conductivity. In Lake Ziway basin salt incrustation is observed where irrigation is practiced by pumping water from the lake (Paulos, 2001). For gravity-type irrigation development, most traditional household schemes use motor pumps for lifting water at head and most irrigation water users along the river banks and lakeshores are compelled to use and maintain costly water pumps (Edossa, 2014).

The study focused and evaluated the salt content of soils irrigated by surface and ground water in the Rift Valley, north western part of Lake Ziway and observed their effect on plant productivity. The objective of the study is to examine the soil salinity problem in the Rift Valley Region and examine the effect of use of fresh water from the lake and slightly saline shallow ground water on the growth and productivity of plants

## MATERIALS AND METHODS

### Sampling design

Soil samples were collected systematically from ground and surface water irrigated sites. Two sampling sites were chosen, that is, about 16 ha of irrigated fields that are 8 ha irrigated with ground water and 8 ha irrigated with surface water. 5 kg of composited 20 soil samples and 0.5 kg of three composite soils from a single sample point were collected from each sites and labeled as soil type SL1-SL10 from surface water irrigated fields while GL1-GL10 from ground water irrigated fields, where: S represent surface water, G represent ground water and L signifies laboratory. The collected soil samples were used for soil chemical analysis in the Water Works Design and Supervision Enterprise and the level of salinity and the type of ions involved determined.

### Soil sampling and laboratory analysis

For each soil sample, the following soil parameters namely: pH, EC, CEC, exchangeable bases (Na, Ca, Mg and K), soluble cations ( $\text{Na}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  and  $\text{K}^+$ ), soluble anions ( $\text{CO}_3^{2-}$ ,  $\text{HCO}_3^-$ ,  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ) and Organic C, were examined in the water works design and supervision enterprise. pH and electrical conductivity were determined from a soil saturated paste extract (Van Reeuwijk, 1992) using Hannna pH meter of model HI 9023 and conductivity meter of model Lf 90, respectively. Determination of the concentration of each anion and cation was made from saturated paste extract following the procedures for soil analysis prepared by Van

Reeuwijk (1992). For organic carbon determination the Walkley-Black, 1934 procedure was followed. Exchangeable bases and cation exchange capacity (CEC) of the soils were determined by the 1 M ammonium acetate (pH 7) method according to the percolation tube procedure (Van Reeuwijk, 1992). Soluble  $\text{Ca}^{2+}$  was determined by titration of 40 g of soil sample in a 200 ml of distilled water using potassium cyanide and ethylene diamine triacetate (EDTA).  $\text{Mg}^{2+}$  was calculated by subtracting the calcium amount to the total hardness found using the erythrome black tea reagent. Soluble  $\text{Na}^+$  and  $\text{K}^+$  were determined using the Flame Photometer 410 model. Derived calculation for SAR and ESP estimates were made using appropriate formula (Seid and Genanaw, 2013):

$$\text{SAR} = \frac{\text{Na}}{\sqrt{\text{Ca} + \text{Mg} / 2}}$$

$$\text{ESP} = \text{Na} / \text{CEC} \times 100$$

### Water sampling and EC tests

Water collection was done from both lake water and ground water. About 255 L of water was collected by 11 Jeri cans thoroughly washed with hot water to avoid any contamination. The water collected was then brought up to the green house from Ziway to Addis Ababa University. Six Jeri cans were used to bring 127.5 L of water from ground while the other 127.5 L were collected in five Jeri cans from surface water for use in the experiment.

EC-meter Wagtech Model SIN: 1254087 was used to measure and compare the electrical conductivity of water from ground and surface water from Ziway and tap water from Addis Ababa. Three measurements were taken using EC meter Wagtech model from surface, ground and tap water sources. Ten measurements were taken from each water source, that is, an over all of thirty measurements were taken. The average measurement readings were taken from the ten readings recorded for each water source.

### Glasshouse experiment

CRD (Completely Randomized Design) were used for the experimental design. In the design, there are four treatments and three replicates, one watered by ground water, one treated by surface water and 2 watered by tap water. At the first stage of the experiment 24 pots were used, that is, twelve pots for onions and twelve pots for tomatoes Cal J variety but unfortunately the onions bulb red variety failed to germinate due to seed viability problem and the experiment continued with twelve pots where tomatoes germinated in the glasshouse of Addis Ababa University. Sixty tomato seeds with 5 seeds per pot

were sown. A total of 12 samples, 5 kg from each sample point and 6 soil samples within a single diagonal were taken and carefully labelled.

From the total 4 treatments, 2 were for surface and ground water treated soils while the other 2 treatments were used as control factors watered by tap water from Addis Ababa University. Five seeds were placed in each pot. There were four treatments with three replications in the glass house. Pots were given 2.5 L every other day that is 51 days of watering in 108 days of growing period and 3.5 g of urea was applied on each pot.

### Recordings of plant growth parameters

Plants height and number of leaves were recorded every week in Addis Ababa University. Tomato Cal J seeds were sown on December, 2<sup>nd</sup> 2014. After two weeks the seeds germinated. The plants grew and the experiment continued for fourteen weeks.

### Fruit yield and plant dry biomass measurement

Matured fresh tomato fruits were harvested on 18<sup>th</sup> March and the total yield and shoot and root biomass determined after 108 days of growing period. The leaves, stems and roots of plants were separated and oven-dried at 70°C for 7 days based on the method described by Segura et al. (2009) after which the dry biomass was measured. Twenty eight tomato plants were measured for the fresh and dry weight biomass. Their weight was determined in g using an electronic balance.

### Statistical analysis

The experiment was carried out in a completely randomized design with three replicates maintained for each treatment. Data were analyzed by one-way ANOVA. Least significant difference (LSD; at P level of 0.05) values were calculated for comparisons of treatment means. Analysis of variance (ANOVA) was performed by statistical package for social sciences (SPSS) software version 20.0 to know if there is any significant difference between surface and ground water irrigated soils on tomato height, number of leaves and biomass yield and productivity. In addition, significant difference between height, number of leaves and plants sown on soils with different salt contents and water treatments was observed using the least significant difference (LSD) test and comparing among the means.

The EC of the three water sources were tested using paired sample t-test to compare their mean difference. The Pearson correlation (2-tailed) test was used to describe the strength and direction of a linear relationship between two variables, that is, the ground and surface water irrigated

soil as well as, ground and surface water impact on fruit yield and dry biomass. Linear Regression Model was also used to know how well a certain independent variable predicts a dependent variable.

### Description of study area

The study area is situated in East Shewa Zone of Oromia Region, Adami Tulu JidoKombolchaWereda. The area is characterized by shallow to relatively deep groundwater with thick aquifer and relatively good permeability. Lake Ziway is located in the rift floor with an altitude of 1,636 m.a.s.l, catchment area of 7,380 km<sup>2</sup>, a maximum depth of 9 m, minimum depth of 2.5 and a volume of 1,466 mcm (Vallet-Coulomb et al., 2001; Tenalem, 2001). It is one of the freshwater Rift Valley lakes of Ethiopia (Figure 1).

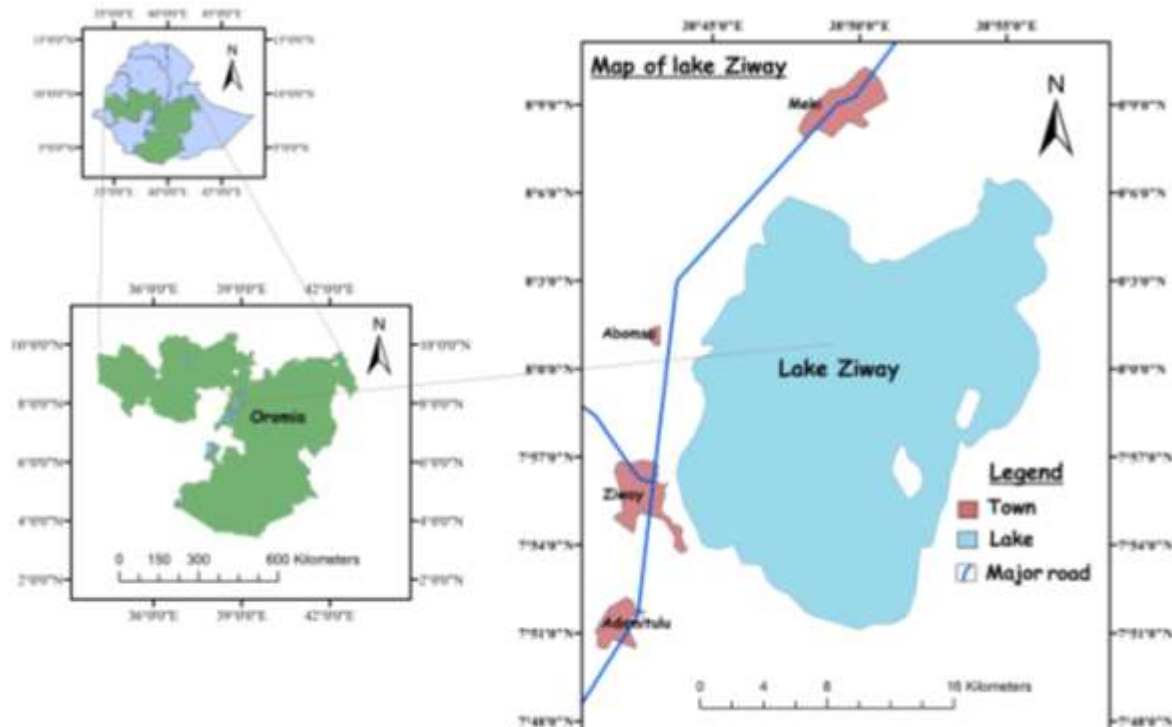
The climate of the area around Lake Ziway has arid characteristics for most of the year and monthly average rainfall never exceeds evaporation. The mean daily temperature at Ziway is 19.3°C. The mean annual temperature of the area is within the range of 16 to 25°C (MoWR, 2006).

The geological and tectonic processes operated by the internal forces in rift system generally govern the geology and geomorphology of the study area. According to Zebene (2004), the region as a whole is affected by extensional tectonics often associated with widespread magmatism and the rift is a consequence of the initial mantle upwelling, the crustal doming and volcanicity. The rift system has also been intimately associated with widespread volcanism (Tenalem, 1998).

In Ziwayarea, gentle levees are formed of sandy clay loams. Soil in the study area is closely related to parent material and degree of weathering. The main parent materials are basalt, ignimbrite, volcanic ash, pumice, riverine and lacustrine alluvium. Weathering varies from deeply weathered basalt in humid highland areas to unweather recent alluvial deposits in the drier central part of the rift valley.

Smallholder irrigated vegetable production in the Central Rift Valley region of Ethiopia is instrumental in ensuring the year-round availability of fresh vegetables in the local market in the country. However, a number of problems constrain irrigated vegetable production in the region. Soil salinity and low moisture are potential environmental problems and production constraints particularly in the semi-arid zone around Lake Ziway. The lowland area of Lake Ziway is the only place irrigated in the Rift valley. Irrigated agriculture, of which mainly smallholder farming, is one of the major water consumers.

A Reconnaissance survey was conducted in Ziway, Adami Tulu JidokombolchaWereda from October, 28<sup>th</sup> to November, 21<sup>st</sup> 2014 to select the study site where ground water and surface water is used for irrigation. Field trip to Ziway Town was made in Adami Tulu JidoKombolcha



**Figure 1:** Location of the study area.

Wereda, which is 160 km south of Addis Ababa from October, 28<sup>th</sup> to November, 21<sup>st</sup> 2015. From the 47 kebeles, five were shortlisted that used both surface and ground water for irrigation. These kebeles were Edo Gojola, Elkachelemo, Abinger mama, Bochesa and Abeyideneba. Edo Gojolakebele was selected for the study site.

## RESULTS AND DISCUSSION

### State of salinity of water used for irrigation around Lake Ziway

#### *State of shallow ground water salinity used for irrigation*

The ground water salinity status according to this study is relatively higher than that of the tap water and the surface water used in the experiment. Ten EC measurements were conducted from each sources of water namely: ground, surface and tap water. The mean EC measurement of the ground water was found to be 1 ds/m (Table 1). According to Silva and Uchida (2000), the value of the ground water salinity is in the range of intermediate salinity which affects crops. As stated by Ayers and Westcot (1985), the value of the EC of the ground water is in the degree of restriction on use that is from slight to moderate.

It was also concluded by Haile (1999) that based on Sodium Adsorption Ratio (SAR), percent sodium and electrical conductivity the quality classification of water for irrigation of the ground water in the western part of the Lake Ziway area was unsuitable for irrigation. Based on this study as well the ground water was found to be slightly saline.

In Pakistan, it was reported by Khan et al. (2014) that soil salinity increased with an increase in water salinity and the actual results showed that EC of the ground water significantly affected the soil properties. The ground water EC in Lasbela region in Pakistan was found in the range of 1 to 3.5 ds/m that is from slightly saline to severely saline, whereas, in Iraq the ground water quality varied from 8 to 12 dS/m. In southern Iraq, groundwater salinity is extremely high (> 30 dS/m). The presence of salts in the subsoil is partly due to high salinity of the groundwater (Qureshi and Al-Falahi, 2015).

#### *State of surface water salinity used for irrigation*

Table 2 shows that the EC of the surface water is highly significant from that of the ground and tap water. The EC of the surface water was found to be 0.6 ds/m which is classified as non-saline, having less value than that of the ground water and higher than that of the tap water.

**Table 1:** Salinity state of ground, surface and tap water.

| Variable | N  | Minimum(ds/m) | Maximum(ds/m) | Mean(ds/m) |
|----------|----|---------------|---------------|------------|
| GWec     | 10 | 0.80          | 1.5           | 0.9800     |
| TWec     | 10 | 0.20          | 0.40          | 0.3000     |
| SWec     | 10 | 0.50          | 0.70          | 0.6100     |

Where: GWec-Ground water EC; TWec -Tap water EC and SWec- surface water EC.

**Table 2:** Paired sample t-test of the ground, surface and tap water used in the experiment.

| Paired sample t-test | Mean | t      | Df | Sig (2. tailed) |
|----------------------|------|--------|----|-----------------|
| Pair 1 GWec-TWec     | 0.68 | 10.002 | 9  | 0.000           |
| Pair 2 GWec-SWec     | 0.37 | 5.286  | 9  | 0.001           |
| Pair 3 SWec-TWec     | 0.31 | 11.196 | 9  | 0.000           |

The value is significantly different at  $P < 0.05$ .

**Table 3:** The Mean EC, SAR, ESP and pH values for soils from surface and ground water irrigated fields.

| Soil salinity parameters | Surface water irrigated soils | Ground water irrigated soils |
|--------------------------|-------------------------------|------------------------------|
| EC (ds/m)                | 1.19                          | 2.57                         |
| SAR                      | 1.44                          | 2.26                         |
| ESP (%)                  | 10.94                         | 14.78                        |
| pH                       | 8.26                          | 8.35                         |

According to Ayers and Westcot (1985) guidelines for interpretation of water quality for irrigation, surface water EC measurement is classified non-saline because the value is below 0.7 ds/m and is suitable for irrigation purposes. The same result was found in Ghana as well stated by Anim et al. (2011), where the surface water samples were found to be suitable for irrigation purposes. The EC of the samples taken from surface water in Ghana were found to be in the range of 0.2 to 0.4 ds/m which is non-saline. In the case of Iraq (Qureshi and Al-Falahi, 2015), historical data on the water salinity of Tigris Rivers at Baghdad city shows that its salinity increased from 0.63 in 1960 to 1.15 ds/m by 2011, respectively.

#### **Comparison of salinity level of the surface, ground and tap water sources**

There is higher significant variation among the three water sources which are surface, ground and tap water as it can be seen in Table 3. The highest EC was recorded by the ground water source different from the other two sources as indicated in Figure 2. Although, the ground water in this study is slightly saline but can hinder the growth of sensitive plants.

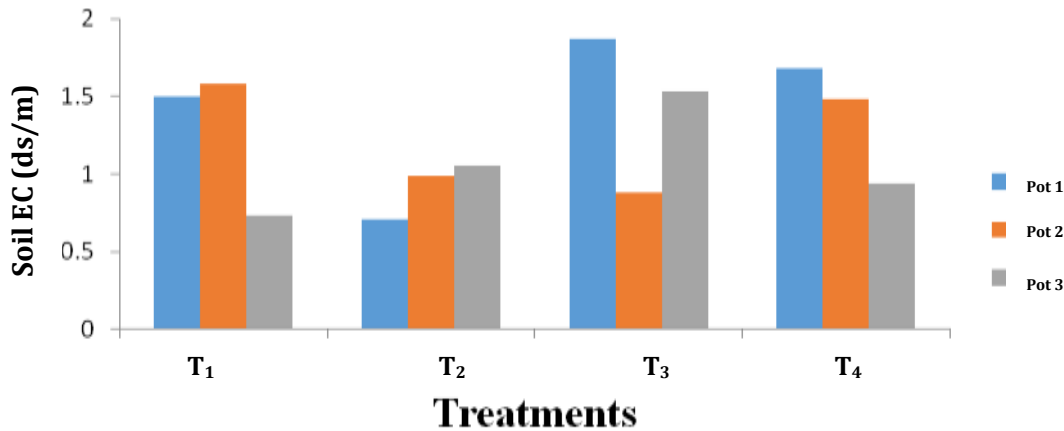
As stated by Qureshi and Al-Falahi (2015), the ground water salinity in Iraq is also significantly different from that

of the surface water and the presence of salts in the subsoil was reported to be partly due to high salinity of the groundwater. Similar result was also found in Zimbabwe Mutema Irrigation Scheme that indicated the groundwater had high concentrations of EC 17.3 ds/m as compared to the surface irrigation water source which had an EC not passing the threshold requirements for cropping (Chemura et al., 2013). The considerably higher soil pH, EC, SAR and ESP in irrigated blocks was directly linked to the use of groundwater for irrigation to the problems of salinity in the scheme. Therefore in this study as well, though the EC value is not the same with the other countries mentioned but when comparing the surface water with the ground water salinity, the ground water source had greater salinity level.

#### **State of surface and ground water irrigated soil salinity**

##### **State of surface water irrigated soil salinity**

The mean EC of the surface water irrigated soils in the study resulted to be 1.2 ds/m which is less than 4 ds/m, pH value of 8.3 and an ESP of 11 which is less than 15. The result as stated by Abrol et al. (1988), classifies the surface water irrigated soils from non-saline to moderately sodic (Rengasamy, 2010).



**Figure 2:** The EC of soils in the four treatments after experiment.

According to the report of Silva and Uchida (2000), salinity standards of the laboratory result shows that EC of the surface water irrigated soil has little or no effect on plants. Although this test does not distinguish between one type of salt and another, it simply provides an overall measure of water-soluble salts.

Soil pH is a good indicator of intensity of acidity or alkalinity of the soil (Seid and Genanaw, 2013). The pH in surface water irrigated soils is 8.3, that is, strongly alkaline. According to Rengasamy (2010), if the SAR or the ESP > 6 and the EC < 4 ds/m then the soil is classified as sodic which corresponds with the surface water irrigated soils. ESP values above 10% are of concern. Excessive sodium levels can occur naturally or can result from irrigation with high-sodium water (Horneck et al., 2011). The ESP of the surface water irrigated soils is above 10% and this shows high levels of sodium which are detrimental to soil structure, soil permeability and plant growth.

The soil tensile strength, a physical measure of the ability of the soils to endure applied forces without being disrupted, is associated with SAR among other factors. The SAR of the surface water irrigated soils were found to be <13 while the ESP was <15. Therefore, the salinity of the surface water irrigated soil is non-saline since the EC measure is in the range of 0 to 2 ds/m. According to the report of Meron (2007), all of the soils in the study around Lake Ziway were saline-sodic. Even though the problem of salt content in the area was in the same category, the absolute concentration of salt was different among the soil types.

#### **State of ground water irrigated soil salinity**

The mean EC measurement of the ground water irrigated soils is 2.6 ds/m which have moderately low salinity, a pH of 8.4 strongly alkaline and an ESP equal to 15 which lies in the category of moderately sodic (Table 4). As ESP

increases, soil structure decreases; the infiltration rate of water into soil and the rate of water movement through soil may be reduced. High concentrations of sodium can be toxic to plants. Sodium hazard also increases as ESP increases. The ESP is used to determine gypsum requirement for treatment of sodium-affected soils (Horneck et al., 2007). Therefore, the salinity class of the ground water irrigated soils is in the range of moderately low since the value of the EC measurement is between 2 to 4 ds/m.

#### **Comparison of the surface and ground water irrigated soil salinity**

Table 5 shows that there is high significance of variance between surface and ground water irrigated soils on their EC measurement. The rest of the salinity measure indices like SAR, ESP and pH of the surface and ground water irrigated soils value are not significantly different.

Table 6 shows the value of the soluble salts, that is, cations from the surface and ground water irrigated soils. The Na soluble cation of the ground water irrigated soil is significantly different from that of the surface water irrigated soil. The remaining soluble cations were not significantly different from one another.

A widely used measure of the deleterious effects of high sodium level is the exchangeable sodium percentage. An ESP value of 15 is often regarded as the boundary between sodic and non-sodic soils, although, it has been realized that this is an arbitrary figure, since the properties of soils often exhibit no sharp change as the content of exchangeable Na increases. In some soils, exchangeable Na content of 2 to 3 cmol(+)/kg soil may be a more suitable criterion for distinguishing sodic samples. In general, soils with exchangeable Na >1 cmol(+)/kg should be regarded as potentially sodic (Seid and Genanaw, 2013).

The cation exchange capacity (CEC) of the soils from ground water irrigated area is high which is 59.22 cmol

**Table 4:** Paired sample t-test for the surface and ground water irrigated soils of their EC, SAR, ESP and pH.

| Paired sample t-test | Mean | Df | Sig. (2-tailed) |
|----------------------|------|----|-----------------|
| Pair 1 SARs-SARg     | 0.82 | 9  | 0.253           |
| pair 2 ECs-ECg       | 1.38 | 9  | 0.003           |
| Pair 3 ESPs-ESPg     | 3.84 | 9  | 0.387           |
| Pair 4 pHs-pHg       | 0.09 | 9  | 0.580           |

The value is significantly different at  $p < 0.05$ . Where SARs- SAR for surface, SARg- SAR for ground, ECs- EC for surface, ECg-EC for ground, ESPs- ESP for surface, ESPg- ESP for ground, pHs- pH for surface and pHg-pH for ground.

**Table 5:** Paired sample t-test for the soluble salts (cations) of soils from surface and ground water irrigated sites.

| Paired sample t-test | Mean  | Df | Sig.(2-tailed) |
|----------------------|-------|----|----------------|
| Pair 1 Nas-Nag       | 1.48  | 9  | 0.020          |
| Pair 2 Ks-Kg         | 0.046 | 9  | 0.191          |
| Pair 3 Mgs-Mgg       | 0.02  | 9  | 0.915          |
| Pair 4 Cas-Cag       | 0.09  | 9  | 0.684          |

The value is significantly different at  $P < 0.05$  Where: where s-subscript means surface and g-subscript means ground.

**Table 6:** Exchangeable bases and cation exchange capacity of soils from the two sites.

| Paired sample t-test | Mean | Df | Sig (2-tailed) |
|----------------------|------|----|----------------|
| Pair 1 exNas-exNag   | 3.21 | 9  | 0.239          |
| Pair 2 exCas-exCag   | 0.89 | 9  | 0.536          |
| Pair 3 exMgs-exMgg   | 0.86 | 9  | 0.26           |
| Pair 4 exKs-exKg     | 0.78 | 9  | 0.032          |
| Pair 5 CECs-CECg     | 3.07 | 9  | 0.335          |

**Table 7:** The EC and SAR values of surface, ground and tap water treated soils after experiment.

| Types of soils                                                                  | EC (ds/m) | SAR |
|---------------------------------------------------------------------------------|-----------|-----|
| Ground water treated soils from ground water irrigated area (T <sub>1</sub> )   | 1.27      | 2.8 |
| Tap water treated soils from ground water irrigated area (T <sub>2</sub> )      | 0.92      | 2.5 |
| Tap water treated soils from surface water irrigated area (T <sub>3</sub> )     | 1.43      | 2.9 |
| surface water treated soils from surface water irrigated area (T <sub>4</sub> ) | 1.37      | 2.8 |

(+)/kg soil, while that of the surface is also high, that is, 56.15 cmol (+)/kg soil and did not have any significant difference between them.

The remaining exchangeable bases were not also significantly different from one another except exchangeable potassium of the ground water irrigated soils which was significantly different from that of the surface water irrigated soils as indicated in Table 7. Therefore, both the

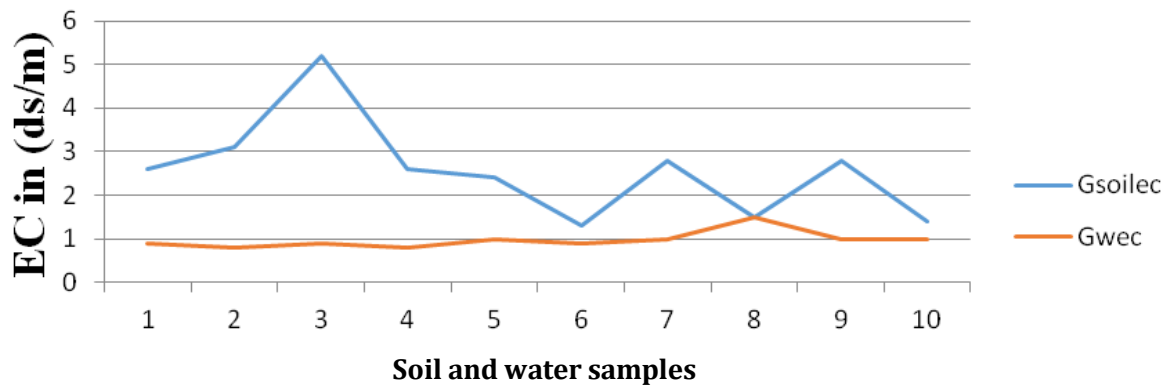
exchangeable Na of the surface and ground water irrigated soils were found to be greater than 1 and shows that they are classified as sodic soils. The soils from ground water irrigated area had more soluble salts and sodium cation than the soils from the surface water irrigated area.

The organic carbon was analyzed for surface and ground water irrigated soils and it was found that the carbon for surface water irrigated soils is 1.5% while that of the



**Table 8:** Impact of ground water salinity on soil salinity before experiment.

| Model      | Unstandardized coefficients |                | t      | Sig.  |
|------------|-----------------------------|----------------|--------|-------|
|            | B                           | Standard error |        |       |
| (Constant) | 4.734                       | 1.844          | 2.567  | 0.033 |
| GWec       | -2.208                      | 1.848          | -1.195 | 0.266 |

**Figure 3:** The ground water irrigated soil EC and ground water EC. Where: GWec: Ground water EC and Gsoilec: Ground water irrigated soil EC.

ground water was found to be less than 1.1%. The soil of the area is under low organic carbon content. This could be due to climatic conditions, tillage practices and the removal of crop residues after harvest as confirmed by Zebene (2004). His results showed higher organic carbon in the study area than this study that is from (2 to 4%).

As stated by Horneck et al. (2011), as OM increases, so does the ability to adsorb and reduce effectiveness of many soil-applied herbicides and Soil OM could increase more than 2% in an area receiving large amounts of compost or other organic residue. Therefore, based on this study organic carbon was found to be low, this might be due to the use of inorganic fertilizers.

### Impact of surface and ground water use on soil salinity development

#### Impact of surface water use on soil salinity

The mean EC of the surface water treated soils once the glass house experiment was terminated was 1.37 ds/m and increased from 1.2 ds/m before experiment (Table 8). Based on the report of Abrol et al. (1998) and Rengasamy (2010), the EC measurement after experiment shows that the surface water irrigated soils is still in the class of non-saline and salinity effects on crops is negligible in this range. The SAR value assesses sodium hazard in soil or irrigation water.

As the SAR increases, soil structure decreases; the infiltration rate of water into soil and the rate of water movement through soil may be reduced and high concentrations of sodium can become toxic to plants (Horneck et al., 2007). In the case of the surface water irrigated soils, the SAR value slightly increased from 1.4 to 2.8 but still is below 5 having less effect.

In treatment three, the tap water treated surface water irrigated soils exhibited the highest EC and SAR values (Figure 3). On the contrary, the lowest average EC and SAR values were observed in tap water treated ground water irrigated soils, that is, treatment 2. When we compare the difference between the ground and surface water treated soils brought from ground water and surface water irrigated fields respectively their EC value did not have significant dissimilarity.

#### Impact of ground water use on soil salinity

The ground water treated soils from ground water irrigated area after experiment had an EC value of 1.27 ds/m which decreased when compared with the result before the experiment from ground water irrigated area having mean EC result of 2.57 ds/m. The EC measurement after experiment shows a decrease in value that shifted the soil class from slightly saline to non-saline class that is in the range of 0 to 2 ds/m (Table 9). The SAR has in the contrary increased slightly from 2.3 to 2.8 but still is below 5 having



**Table 9:** Impact of ground water salinity on soil salinity after experiment.

| Model      | Unstandardized coefficients |                | t      | Sig.  |
|------------|-----------------------------|----------------|--------|-------|
|            | B                           | Standard error |        |       |
| (Constant) | 5.300                       | 5.788          | 0.916  | 0.528 |
| (GWec)     | -4.650                      | 6.668          | -0.697 | 0.612 |

**Table 10:** Mean difference of number of leaves of tomato plants treated with surface, ground and tap water.

| Dependent variable | (i)T | (j)T | Mean difference (i-j) | Standard error | Sig.  |
|--------------------|------|------|-----------------------|----------------|-------|
| Tukey HSD          | SW   | TW   | -11.231               | 3.721          | 0.008 |
|                    | GW   | -    | -0.751                | 5.146          | 0.988 |
|                    | TW   | SW   | 11.231                | 3.721          | 0.008 |
|                    | GW   | -    | 10.481                | 4.810          | 0.076 |
| Number of leaves   | GW   | SW   | 0.751                 | 5.146          | 0.988 |
|                    | TW   | -    | -10.481               | 4.810          | 0.076 |
| LSD                | SW   | TW   | -11.231               | 3.721          | 0.003 |
|                    | GW   | -    | -0.751                | 5.146          | 0.884 |
|                    | TW   | SW   | 11.231                | 3.721          | 0.003 |
|                    | GW   | -    | 10.481                | 4.810          | 0.030 |
|                    | GW   | SW   | 0.751                 | 5.146          | 0.884 |
|                    | TW   | -    | -10.481               | 4.810          | 0.030 |

no significant effect. Therefore, the ground water and tap water treated soils brought from ground water irrigation site decreased the value of EC after the experiment while the surface and tap water treated soils brought from surface water irrigation site increased the EC value. This result seems to be contrary to the reality on the ground and might have been caused by experimental errors. Hence, this need to be checked in future studies. Salinity in shallow groundwater and the root zone are closely correlated as Ahmad and Qureshi (2010) stated.

In this study, the EC of the ground water irrigated soil was found to be greater than that of the ground water and higher measure of soluble salts were found in the soil. From the glasshouse experiment result, the ground water use did not affect the salinity level of the soil used in the experiment. This was proved by the low EC value recorded from the soil after experiment (Table 10).

Table 11 shows the ground water irrigated soil EC, EC soil= 4.734-2.208 (GWec), that is, EC soil= 2.5G Wec. The ground water treated soils brought from ground water irrigated EC is in the range from 0.7 to 1.5 ds/m which is relatively lower than the EC of the ground water though the soil samples were derived from only three pots used in the experiment, still, their EC value was found to be less than that is in the range from 0.7 to 1.6 ds/m than the EC of the soil samples tested before the experiment that ranged from 1.4 to 5.2 ds/m (Figure 4).

## Impact of ground water use on plant growth and productivity

### Impact of ground water irrigated soil on plant growth

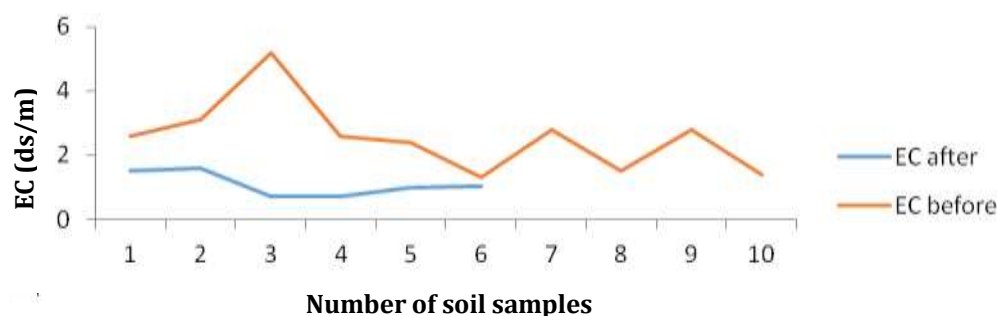
The responses of plants to high salinity may be expected to vary with different growth stages (Afshari et al., 2011). Comparison of the effects of different salinity levels of the surface, ground and tap water treatments on tomato plants was performed based on ANOVA analysis. Although the salinity of the soils in the experiment cannot be considered high since their EC is less than 4 ds/m but there is a slight difference among the surface, ground and tap water treated soils brought from surface and ground water irrigated sites.

The number of leaves of the plants based on the Tukey HSD test and highest significant difference came across plants treated with surface and tap water. There is no significant difference between the surface and ground water treated plants as it can be comprehended in Table 12. The plants treated with ground water and tap water did not have any significant difference between them. In instance of the LSD test, slight difference was verified by tap water and ground water treated plants.

The height of the plants was analyzed by ANOVA using the Tukey (HSD) and LSD tests. Highest significant variance was exhibited between the tap water and surface water treated plants. There was no significant difference between

**Table 11:** Mean difference of height of tomato plants treated with surface, ground and tap water.

| Dependent variable | (i)T | (j)T | Mean difference (i-j) | Standard error | Sig.  |
|--------------------|------|------|-----------------------|----------------|-------|
| Tukey HSD          | SW   | TW   | -5.726                | 1.783          | 0.004 |
|                    | GW   | -    | -1.362                | 2.451          | 0.844 |
|                    | TW   | SW   | 5.726                 | 1.783          | 0.004 |
|                    | -    | GW   | 4.364                 | 2.288          | 0.138 |
| Height of plants   | GW   | SW   | 1.362                 | 2.451          | 0.844 |
|                    | -    | TW   | -4.364                | 2.288          | 0.138 |
| LSD                | SW   | TW   | -5.726                | 1.783          | 0.001 |
|                    |      | GW   | -1.362                | 2.451          | 0.579 |
|                    | TW   | SW   | 5.726                 | 1.783          | 0.001 |
|                    | -    | GW   | 4.364                 | 2.288          | 0.057 |
|                    | GW   | SW   | 1.362                 | 2.451          | 0.579 |
|                    | -    | TW   | -4.364                | 2.288          | 0.057 |

**Figure 4:** The Ground water treated soil EC after experiment with that of the soils from ground water irrigated sites before experiment.**Table 12:** ANOVA result for the response of tomato plants between soils from the surface and ground water irrigated sites.

| ANOVA                          | Sum of squares | Df  | Mean square | Sig. |
|--------------------------------|----------------|-----|-------------|------|
| Between groups                 | 9591.942       | 2   | 4795.971    |      |
| Number of leaves within groups | 276126.313     | 315 | 876.591     | 0.05 |
| Total                          | 285718.255     | 317 |             |      |
| Between groups                 | 2328.582       | 2   | 1164.291    |      |
| Height of plants within groups | 66399.554      | 323 | 205.571     | 0.04 |
| Total                          | 68728.135      | 325 |             |      |

the ground and the surface water treated plants besides the ground water and tap water treated plants. Table 13 directs that the growth response parameters of tomato plants, that is, height of plants recorded every week demonstrated that there has been a slight difference between groups.

The groups represent the type of soil and water used in the experiments which are four. The plants which were in the group treated with tap water performed well on the number of plants growth parameters which were highly significant from the surface and ground water treated

**Table 13:** Correlations of the soil salinity after experiment and fruit yield of plants.

| Variable   |                     | EC     | Mean fruit |
|------------|---------------------|--------|------------|
| EC         | Pearson correlation | 1      | -0.832     |
|            | Sig. (2-tailed)     | -      | 0.168      |
|            | N                   | 4      | 4          |
| Mean fruit | Pearson correlation | -0.832 | 1          |
|            | Sig. (2-tailed)     | 0.168  | -          |
|            | N                   | 4      | 4          |

**Table 14:** The impact of soil salinity after experiment on fruit yield of plants.

| Linear regression model | Unstandardized coefficients |                | t      | Sig.  |
|-------------------------|-----------------------------|----------------|--------|-------|
|                         | B                           | Standard error |        |       |
| (Constant)              | 53.902                      | 9.450          | 5.704  | 0.029 |
| EC                      | -15.856                     | 7.482          | -2.119 | 0.168 |

**Table 15:** Correlations of the soil salinity and shoot biomass of plants.

| Variable |                     | EC     | DW shoot |
|----------|---------------------|--------|----------|
| EC       | Pearson correlation | 1      | -0.851   |
|          | Sig. (2-tailed)     | -      | 0.149    |
|          | N                   | 4      | 4        |
| DW shoot | Pearson correlation | -0.851 | 1        |
|          | Sig. (2-tailed)     | 0.149  | -        |
|          | N                   | 4      | 4        |

plants. Therefore, in this study and in agreement with previous studies, salinity reduced plant height (Hassan et al., 1999; Sonneveld, 2000; Amico et al., 2003; Hajer et al., 2006).

Antagonistically, there has been no difference between the means of the surface and ground water treated plants grown on soils brought from surface and ground water irrigated sites. This can be explained by the EC of the soils analyzed after the experiment that in ground and tap water treated soils there has been a decrease in their EC value while in surface water treated soils, establishments of soluble salts were recognized, that is, their EC value increased. In ground water treated soils there was a decrease in their EC value from those tested before the experiment. Accordingly, it is rational if there has been no difference on the response of the surface and ground water treated plants since the soil EC was approximate as shown in Table 14.

The performance of the plants regarding number of leaves shows that there was no difference between ground and surface water treated plants. The height of the plants

had highest significance of variance between the tap and surface water treatment in a way that tap water treated plants was longer than surface water treated plants similar to tap water and ground water treated plants. Only a slight difference in height of the plants was observed between groups as listed in Table 15.

### Impact of ground water irrigated soil on productivity

#### Impact of soil salinity on fruit yield

Highest fruit yield was observed by tap water treated tomatoes ( $T_2$ ) on soils from ground water irrigated sites while the lowest yield was attained by tap water treated tomatoes ( $T_3$ ) on soils from surface water irrigated sites as indicated in Figure 5. This resulted due to the salinity difference of the soils conducted after experiment in a way that as soil salinity increased fruit yield decreased.

The correlation coefficient of soil EC and fruit yield was -0.832 (Table 16). This value of  $r$  suggests a strong negative



**Figure 5:** Tomato plants in glass house.

**Table 16:** The impact of soil salinity after experiment on shoot biomass of plants.

| Linear regression model | Unstandardized coefficients |                | t      | Sig.  |
|-------------------------|-----------------------------|----------------|--------|-------|
|                         | B                           | Standard error |        |       |
| (Constant)              | 12.635                      | 2.766          | 4.568  | 0.045 |
| EC                      | -5.018                      | 2.190          | -2.292 | 0.149 |

linear correlation since the value is negative and close to -1. Since the value of  $r$  suggests a strong negative linear correlation, the data points should be clustered closely about a negatively sloping regression line as shown in Figure 6. The EC of the soils after experiment were:  $T_1$  (1.27 ds/m),  $T_2$  (0.92 ds/m),  $T_3$  (1.43 ds/m) and  $T_4$  (1.37 ds/m) where  $T_1$  was ground water treated,  $T_4$  was surface water treated, whereas  $T_2$  and  $T_3$  were tap water treated in relation to their fruit yield as displayed in Figure 7.

Table 17 shows that fruit yield = 53.902-15.856 (soil EC), while fruit yield = 38.046 (soil EC). Corresponding to the linear regression line equation, it can be predicted that the mean fruit yield is affected by the soil EC in such a way that for every increase in EC of the soil the fruit yield decreases by 38.04 g representing 69% of the tomato plants. In agreement with this study, other studies also stated that salinity reduced fresh weight of vegetable crops such as tomatoes (Sonneveld, 2000; Amico et al., 2003, Hajer et al., 2006). Similar result was also found by Mitchell and Shanon (1991), which confirms that salinity is an important factor determining the yield of tomato fruit primarily because it affects fruit water accumulation.

### Soil salinity and plant dry biomass

#### Shoot biomass in relation to soil salinity

The highest shoot dry weight was performed by the tap water treated soils brought from ground water irrigated

site  $T_2$  as indicated in Figure 8. The lowest shoot dry weight was that of the surface water treated  $T_4$  and ground water treated  $T_1$  plants which were approximate to each other and almost similar.  $T_3$  that is tap water treated soils from surface water irrigated sites shoot dry weight was found to be in between of the highest and lowest performance of treatments in the experiment.

The correlation coefficient between soil salinity and shoot dry weight was -0.851 as depicted in Table 18. This value of  $r$  suggests a strong negative linear correlation since the value is negative and close to -1. Since the value of  $r$  suggests a strong negative linear correlation, the data points should be clustered closely about a negatively sloping regression line (Figure 9). As indicated in Table 19, dry weight shoot = 12.635-5.018 (EC soil), that is, the dry weight of the shoot will decreased by 7.62 g for every increase in the EC of the soil representing 72% of the tomato plants. Therefore, in this study, the dry weight shoot of tomatoes decreased with increasing soil EC as also stated by Li, (2000), Katerji et al. (2002) and Hussein et al. (2012).

#### Root biomass in relation to soil salinity

The highest dry weight roots of  $T_1$  and  $T_3$  were similar to one another that were  $T_1$  (ground water treated) while  $T_3$  (tap water treated plants grown on surface water irrigated soils) as indicated in Figure 10. The lowest dry weight of the root was recorded by  $T_2$  (Tap water treated plants grown on ground water irrigated soils). The correlation



**Figure 6:** Tomato plants grown on soils from ground water irrigation sites.



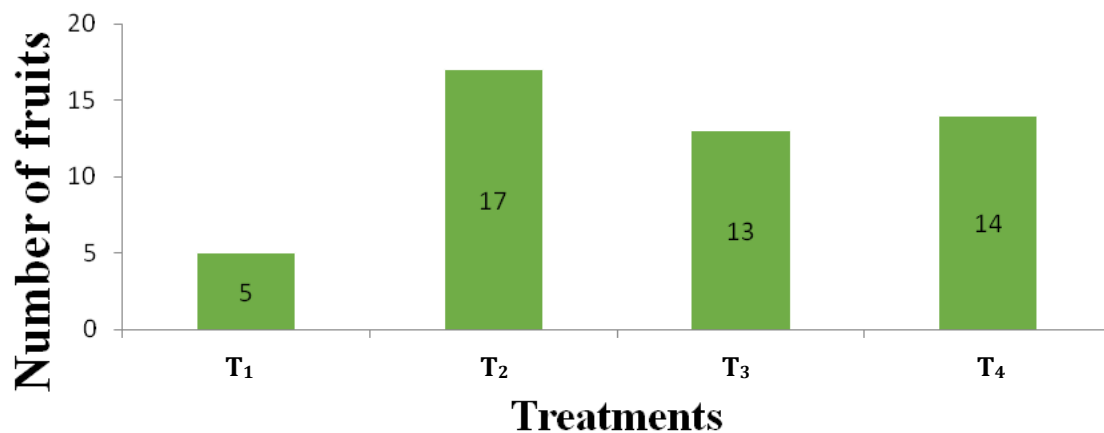
**Figure 7:** Tomato Plants grown on soils from surface water irrigated sites.

**Table 17:** Correlations of the soil salinity after experiment and the root biomass of plants.

|         | Variable            | Soil EC | DW root |
|---------|---------------------|---------|---------|
| EC soil | Pearson correlation | 1       | 0.641   |
|         | Sig. (2-tailed)     | -       | 0.359   |
|         | N                   | 4       | 4       |
| DW root | Pearson correlation | 0.641   | 1       |
|         | Sig. (2-tailed)     | 0.359   | -       |
|         | N                   | 4       | 4       |

coefficient between the soil EC and root dry weight was 0.641. This value of  $r$  suggests a positive linear correlation since the value is positive and close to +1.

The root dry weight  $= 0.216 + 0.747(\text{EC soil})$ , that is, a positive relationship was exhibited between the dry weight root and the soil EC but is insignificant. As the soil EC

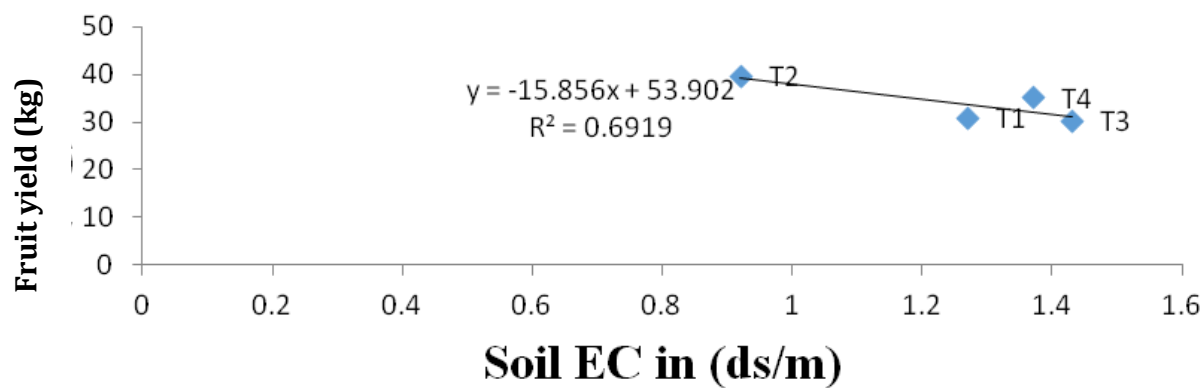


**Figure 8:** Number of fruits per treatment.

**Table 18:** The impact of soil salinity after experiment on root biomass of plants.

| Linear regression model | Unstandardized coefficients |                | t     | Sig.  |
|-------------------------|-----------------------------|----------------|-------|-------|
|                         | B                           | Standard error |       |       |
| (Constant)              | 0.216                       | 0.799          | 270   | 0.813 |
| EC of soil              | 0.747                       | 0.633          | 1.180 | 0.359 |

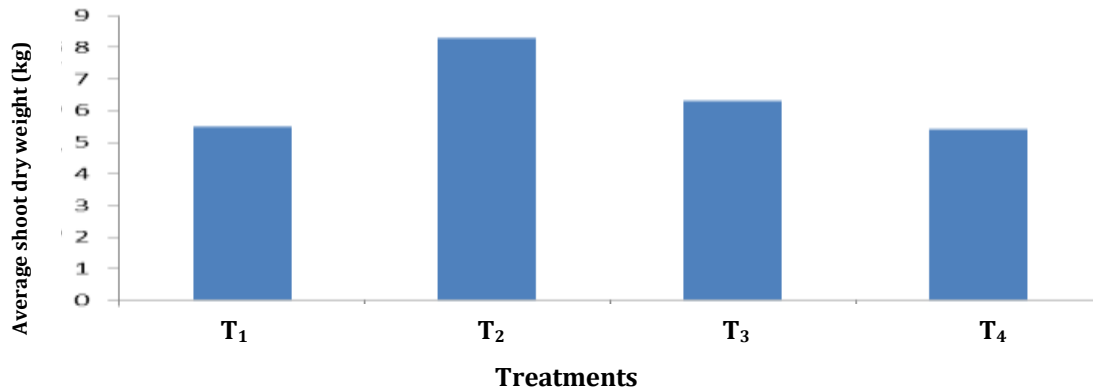
Dependent variable: Dry weight of root.



**Figure 9:** Impact of soil salinity on plant fruit yield.

**Table 19:** Correlations of water salinity and average fresh weight of fruits.

| Variable |                     | EC water | M fruit |
|----------|---------------------|----------|---------|
| EC water | Pearson correlation | 1        | -0.426  |
|          | Sig. (2-tailed)     | -        | 0.574   |
|          | N                   | 4        | 4       |
| M fruit  | Pearson correlation | -0.426   | 1       |
|          | Sig. (2-tailed)     | 0.574    | -       |
|          | N                   | 4        | 4       |



**Figure 10:** Variation in shoot dry weight in different treatments.

**Table 20:** The impact of water salinity on fruit yield.

| Linear regression model | Unstandardized coefficients |                | t     | Sig.  |
|-------------------------|-----------------------------|----------------|-------|-------|
|                         | B                           | Standard error |       |       |
| (Constant)              | 37.258                      | 5.292          | 7.041 | 0.020 |
| EC water                | -5.728                      | 8.605          | -666  | 0.574 |

Dependent variable: average fruit fresh weight.

increases the dry weight of the root also increased by 0.96 g. Therefore, as the p value indicated there is no significant difference among the root dry weight of plants in the four treatments.

According to the report of Singh et al. (2012), in spite of the negative effects of salt on roots, the root growth in tomato appears to be less affected, whereas, shoot was affected drastically which agrees with the finding of this study. They also stated that increasing salt stress negatively affected growth and development of tomato and root/shoot dry weight ratio was higher.

### Impact of ground water use on plant biomass productivity

#### Impact of water salinity on fruit yield

Highest fruit yield was observed by tap water treated tomatoes (T<sub>2</sub>) grown on soils from ground water irrigated sites while the lowest yield was attained by tap water treated tomatoes (T<sub>3</sub>) on soils from surface water irrigated sites. This resulted due to the salinity difference of the water used in the experiment in a way that as water salinity increased fruit yield decreased. The correlation coefficient between water EC and fruit yield was -0.426 as listed in Table 20. This value of r suggests no correlation since the value is close to 0. Since the value of r in the Table 20 suggests negative linear correlation, the data points should

be clustered far apart about a negatively sloping regression line (Figure 11).

Table 21 shows the average fresh weight of fruits and EC of the water with fruit yield=37.256-5.728(EC water). It can therefore be predicted from the linear regression equation that for every increase in water EC, there is a decrease of average fresh weight of fruits by 31.5 g. Although this result only represents 18% of the plants as indicated in Figure 12, it cannot be concluded that for every slight difference of surface, tap and ground water sources there is a decrease in fruit yield.

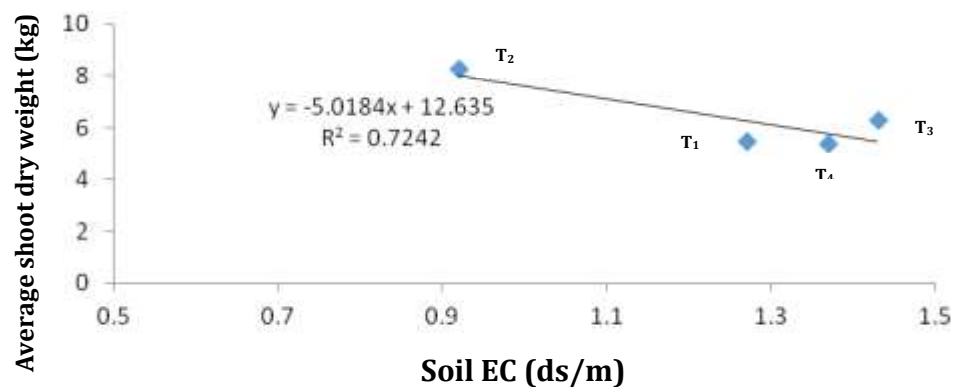
### Impact of water salinity on plant biomass

#### Water salinity and shoot biomass

The water salinity and shoot dry weights are signified in Figure 13 indicating that when the water salinity increased there is a decrease in average shoot dry weight of tomato plants. The highest shoot biomass was exhibited by T<sub>2</sub> while the lowest shoot biomass was recorded by T<sub>4</sub> and T<sub>1</sub>.

Table 21 shows that the r value, that is, the correlation coefficient between the water EC and shoot dry biomass is close to -1, having a value of -0.688, suggesting that there is a strong negative linear correlation. Since the value of r in Table 22 suggests a negative linear correlation, the data points should be clustered closely about a negatively sloping regression line as shown in Figure 14.

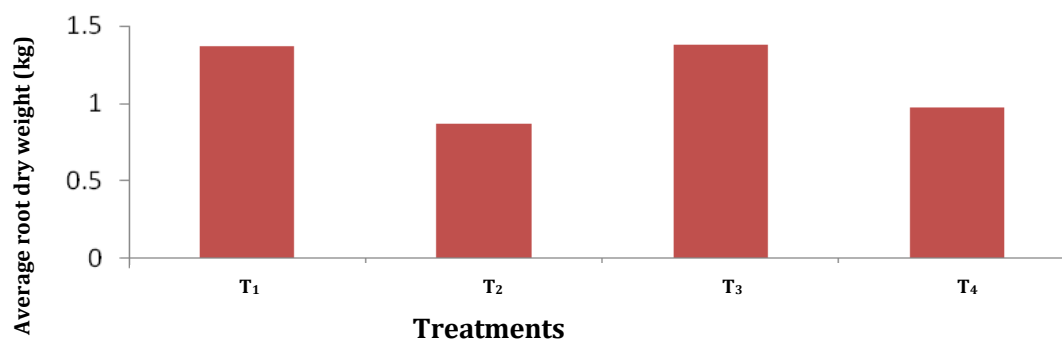




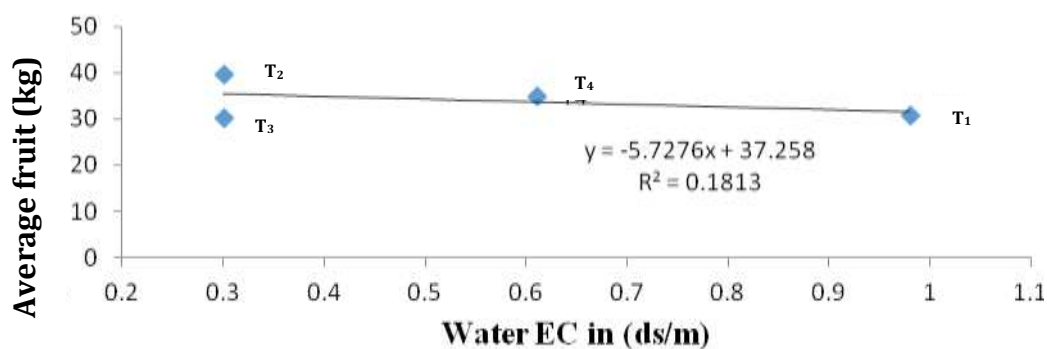
**Figure 11:** Impact of soil salinity on plant shoots biomass.

**Table 21:** Correlations of water salinity with shoot biomass.

| Variable |                     | EC water | DW shoot |
|----------|---------------------|----------|----------|
| EC water | Pearson correlation | 1        | -0.688   |
|          | Sig. (2-tailed)     |          | 0.312    |
|          | N                   | 4        | 4        |
| DW shoot | Pearson correlation | -0.688   | 1        |
|          | Sig. (2-tailed)     | 0.312    |          |
|          | N                   | 4        | 4        |



**Figure 12:** Variations in root dry weight in different treatments.

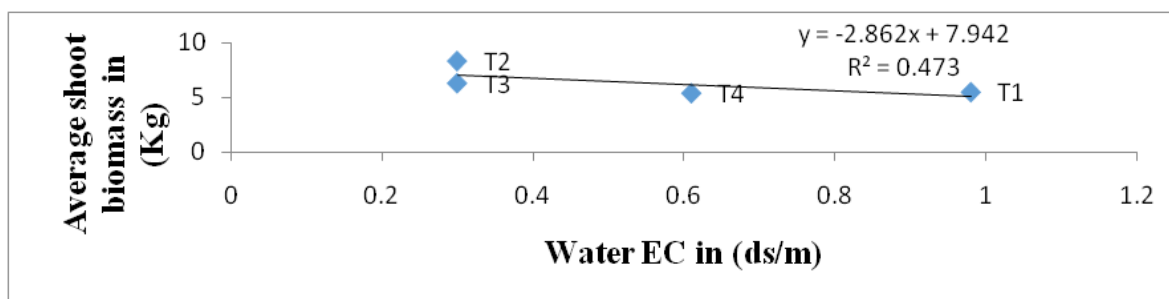


**Figure 13:** The impact of water salinity on fruit yield.

**Table 22:** The impact of water salinity on shoot biomass.

| Linear regression model | Unstandardized coefficients |                | t      | Sig.  |
|-------------------------|-----------------------------|----------------|--------|-------|
|                         | B                           | Standard error |        |       |
| (Constant)              | 7.942                       | 1.313          | -      | 0.026 |
| EC water                | -2.862                      | 2.136          | -1.340 | 0.312 |

Dependent variable: Dry weight of shoot.

**Figure 14:** Impact of water salinity on shoot biomass.**Table 23:** Correlations of water salinity with shoot biomass of plants.

| Variable |                     | EC water | DW root |
|----------|---------------------|----------|---------|
| EC water | Pearson correlation | 1        | 0.373   |
|          | Sig. (2-tailed)     | -        | 0.627   |
|          | N                   | 4        | 4       |
| Dw root  | Pearson correlation | 0.373    | 1       |
|          | Sig. (2-tailed)     | 0.627    | -       |
|          | N                   | 4        | 4       |

The impact of water salinity on the shoot dry weight of tomato plants can be seen from Table 22 and  $DW_{shoot} = 7.942 - 2.862 (EC \text{ water})$ . It can be predicted that as the water salinity increases, the shoot dry weight of the plants would decrease by 5.08 g, although this result represents only 47% of the plants as indicated in Figure 14; it cannot be concluded that the water salinity increase had such a decreasing impact on shoot dry weight and is insignificant.

#### ***The impact of ground water use on root biomass***

Similar to the soil salinity, the dry weight root of tomato plants also responded in such a way to water salinity. As it can be contemplated from Table 23, the  $r$  value, that is, the correlation coefficient between the water EC and root dry biomass is close to 0, having a value of 0.373. The value of  $r$  in Table 23 suggests no strong negative or positive linear

correlation between water salinity and root dry weight. Therefore, further regression equation could not be employed since there is no correlation between water salinity and root dry weight.

In this study, it is confirmed that the soil salinity had significant effect on fruit yield and shoot dry weight of the plants and that for every increase in soil salinity, there is a decrease in fruit yield and shoot biomass. For every increase in soil salinity, the impact on root dry weight was insignificant. The impact of water salinity on fruit yield, shoot and root dry weight was insignificant and no positive or negative correlation was exhibited.

#### **Conclusion**

Surface water use may not cause soil salinity development. Soil salinity may be a longer process due to mismanagement

of irrigation water. Ground water was found to be slightly saline having an immediate effect on soil salinity development. The experimental study showed no significant increase in soil salinity level.

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