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**Research Article**

# Cumulative Effect of Saline Water on Carrot Production from Farmlands of Yebrage Hawariat, East Gojjam, Ethiopia

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**Abstract:** Irrigation plays a crucial role in addressing the main challenges caused by food insecurity and rainfall uncertainty. Determining availability of water for irrigation is required on both its quantity and quality. Quality should infer how well a water supply fulfills the needs of intended use. Water used for irrigation always contains some dissolved salts. So the suitability of water for irrigation will be determined by the amount and kind of salts present. The main objective of this study was determining the salinity threshold value of carrot in order to address the commutative effect of salt on carrot production. The experiment was designed in Randomized Complete Block Design (RCBD) and conducted at Debre Markos Soil Laboratory with seven (0.4, 0.8, 1.2, 1.6, 2.0, 2.4 and 2.8 dS/m, respectively) salinity levels and three replications. The major findings indicated that the yield of salinity levels are 0.4, 0.8, 1.2, 1.6, 2.0, 2.4 and 2.8 dS/m and the yield are 8526, 8895, 9026, 7703, 6526, 5526 and 4466 kg/ha, respectively. The corresponding dry matter percentages were also 808, 784, 808, 692, 537, 534 and 303 kg/ha, respectively consequently. This showed that carrot would give maximum yield and dry matter when its salinity level on irrigation water is at threshold level (1.2 dS/m), but shows a higher reduction, which might even tend to zero yield provided when there is further addition of salt above the threshold level.

**Keywords:** Carrot-yield, cumulative effect, salinity, threshold value

## INTRODUCTION

Irrigation plays a crucial role in addressing the main challenges caused by food insecurity and rainfall uncertainty.

FAO (2002), Najarchi *et al*. (2011) and Kuslu *et al*. (2010) estimated that 80% of the additional production required to meet the demands of the future will have to come from intensification and yield increase. Intensification of agricultural production by using selected seed and fertilizer in the rain fed system is expected to face daunting challenge due to the vagaries of weather and rainfall uncertainty. Most Ethiopian farmers depend on rain-fed agriculture. However, rainfall is very erratic and drought occurs very frequently.

Consequently, the country is finding it difficult to cope with drought shocks because of its frequency and increasing population pressure. Under such circumstances, the only reliable way to stabilize agricultural productivity is through irrigation. It has been loudly and clearly said that if the country is to feed its ever increasing population and to lessen the risk of catastrophes caused by drought and increase in population density in the arid and sparsely populated areas, irrigation development is an important issue.

The total area under irrigation is estimated to be about 250,000 ha compared to the 3.5 Mha potential irrigable land with surface water (Awulachew *et al*., 2005). And it is also necessary to determine the availability of water for irrigation in terms of quantity and quality; however, the quality need has often been neglected (Clemens, 2007). Quality should infer how well a water supply fulfills the needs of intended use. If two different water supplies are available, one will usually produce results or causes fever problems than the other and is therefore, considered more acceptable or of better quality; it is associated with the amount and type of ions present.

Water used for irrigation always contains some dissolved salts (Clemens, 2007; Thomas and Harry, 1980) hence the suitability of water for irrigation will be determined by the amount and kind of salts present. The salts include relatively small but important amount of dissolved solids originating from dissolution or weather in of rocks, soil, lime, gypsum and other salt sources as water passes over or percolates through them. Usually salts present in the soil that affect crop growth are applied with irrigation water and remains behind the soil as water evaporates or is used by crop.

In irrigated agriculture (Bekele and Tilahun, 2007), many salinity problems are associated with or strongly influenced by a shallow water table, with in 2 m of the

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surface (Samson *et al*., 2006). Hence the harm full effect of salinity increases. Excessive salt results in slow rate of growth, wilting or darker, bluish green color and sometimes thicker, waxier leaves symptoms vary with growth stage being more noticeable if the salts affect the plant during the early stage of growth.

And also salinity influences crop physiology, cell enlargement and division, the productivity of proteins and nucleic acid and the rate of increase in plant mass are physiologically processes (Fereres and Sariano, 2007; Negaz *et al*., 2012) that are related by high level of salinity. Therefore; some of the management practices that can help to overcome high salinity problem of the irrigation water are more frequent irrigation, selection of salt tolerant crops and varieties, using internal drainage system and by leaching with excess water, etc. However, reducing salinity using more frequent irrigation, internal drainage system and leaching with excess water is not economical in water stressed areas.

Especially the drainage system even using excess water may not be a solution since at farmers' condition the tillage implement can plow only at a shallower depth year after year. This result in forming strong soil layer at the base of the root depth, which may prevent leaching of salt to the lower strata; hence studying by assuming this condition is important. Crops may vary greatly in their tolerance to saline water from more tolerant to more sensitive crops. So, proper choice of crops can result in good returns even using high salinity level. However, for more sensitive crops like carrot, which is among the vital crops both for consumption and as source of income in Ethiopia use of saline water for growth is questionable? Due to this determination of salinity threshold value at farmer`s level is important in attaining the acceptable yield of the crop by using the specified quality of water.

This study was, therefore, proposed and executed with the specific objective of determining the salinity threshold value of carrot in order to address the commutative effect of salt on carrot production.

## MATERIALS AND METHODS

**Description of the study area:** The study areas are located in North-western part of Ethiopia: Yebrage, which is located 300 km from Addis Ababa. The area has an annual rainfall of 1200 mm and average minimum and maximum temperatures of 11.9 and 29.0°C, respectively. The altitude is about 2450 m.a.s.l and at a latitude and longitude of 10°20'02"N and 37°43'47"E, (Maliszewska-Kordybach *et al*., 2008), respectively. The major crops grown include maize, sorghum, peanut, beans, seeds, teff (Eragrestis), soybean, haricot peas, onion, tomato, potato and carrot.

**Experimental design and treatment setting:** The experimental design was Randomized Complete Block Design (RCBD) with seven treatments and three replications. The seven treatments were with different salt concentrations as 0.4, 0.8, 1.2, 1.6, 2.0, 2.4 and 2.8 dS/m at 25°, respectively. The treatments were conducted in 21 pots filled with sandy loam soil and the pots were non-perforated to see the cumulative effect of salt on crops. The pots were placed under plastic cover (shed) to control the rain fall effect on the experiment. In each pot seeds were sown by driving and after germination only two plants remain on each pot others were thinned. Each pot has surface area of 0.038 $m^2$.

According to the irrigation interval and water requirement of the plant calculated below each pot was irrigated with water of different level of salinity as indicated in the above.

**Soil sampling and measurements:** Soil samples were taken from the experimental plots where soils are taken in to pots for each treatment after the seasonal rain stopped and before the first irrigation started. Samples were taken randomly from fourteen places in a depth range of (0-30 and 30-50 cm) by using auger. After taking samples from the selected sites and depths, physical and chemical parameters such as soil moisture content, field capacity and permanent wilting point values were measured at Debre Markos Soil Laboratory. The laboratory determination of EC is accomplished using a conductivity cell consisting of metal electrodes and the measurement is expressed in specific conductivity unit. The soil infiltration rates were measured with the help of double ring infiltromter in the experimental site.

Gravimetric method was used to measure soil water content. The soil samples were placed in an oven for 24 h at 105°C in order to determine the soil moisture content. The moisture content of the soil samples on volume bases were determined by multiplying the gravimetric water content on weight basis by the bulk density.

The soil bulk density is defined as the oven dry weight of soil in a given volume as it occurs in the field and this was determined using undisturbed soil samples taken with core sampler. Soil bulk-density data was measured on 18 cores of 98.17 $cm^3$ volume in the field at two depths 0-30 and 30-50 cm, oven dried for 24 h at 105°C.

Water content on mass basis ($\theta_m$) was measured using Eq. (1) (Michael, 1997; Vanyine and Nagyjanos, 2012):

$$\theta_m = \left[ \frac{M_w \times 100}{M_s} \right] \quad (1)$$

where,

$\theta_m$ = Water content on mass basis (%)
$M_w$ = Mass of water (gm)
$M_s$ = Mass of soil after oven dry (gm)

The volumetric water content was estimated from gravimetric water content using Eq. (2) (Michael, 1997):

$$\theta_v = \theta_m \times \rho_b \quad (2)$$

where,
$\theta_v$ = Volumetric water content (%)
$\theta_m$ = Water content on mass basis (%)
$\rho_b$ = Soil bulk density (g/cm$^3$)

Both the water content at field capacity and permanent wilting point were measured using pressure plate apparatus and the available water, which is the water between field capacity and permanent wilting point, was computed using Eq. (3) (Michael, 1997; Mirza *et al*., 2012):

$$TAW = 10\left[\theta_{FC} - \theta_{PWP}\right] \quad (3)$$

where,
TAW = Available water, mm/m
$\theta_{Fc}$ = Field capacity in volume basis (%)
$\theta_{pwp}$ = Permanent wilting point percent by volume

**Weather data:** The 10 year temperature, humidity, sunshine hours, wind speed, rainfall and other necessary data were collected from Metrological Station. The data were used to estimate the crop water requirement using the CROPWAT model (Smith *et al*., 2002).

**Crop and irrigation water requirement of carrot:** The values of $ET_o$ estimated by using CROPWAT model based on climatological parameters need to be adjusted for actual crop $ET_o$. The crop water requirement of the test crop was calculated by multiplying the reference $ET_o$ with crop coefficient ($K_c$) (Negaz *et al*., 2013). The water requirement ($ET_c$) of carrot was calculated using crop coefficient approach on the basis of meeting the evapotranspiration (Allen *et al*., 1998) rate of a disease free crop, growing in large field under optimal soil conditions including sufficient water and fertility and achieving full production potential under the given growing environment.

Statistical analysis of monthly reference Evapotranspiration ($ET_o$) calculated for individual years for historical records (1995-2004) at Meteorological Station. The crop coefficient of carrot is as given in CROPWAT software.

The $K_c$ values for carrot lies between 0.4 and 0.5 for initial stage, 0.7-0.8 for crop development stages, 0.9-1.0 for mid-season stage and 0.9-1.0 for late season stage. Other crops data such as stage lengths (in days), rooting depths (m) and depletion level (P) and yield response factors ($K_y$) were adopted from CROPWAT software (FAO, 2002).

**Water application depth and irrigation interval:** The design depth of application and irrigation interval, which are a function of intake characteristics and water storage capacities of the soil were determined by CROPWAT model (Smith *et al*., 2002). All treatments were conducted according to the initial plan and received irrigation applications with specified salinity levels.

**Method of panting:** In each pot seeds were sown by driving and after germination only two plants remain on each pot others were thinned.

The fertilizer was applied at a rate of 300 kg/ha DAP and 400 kg/ha Urea. Weed control was made using hand weeding and cultivation. Disease was controlled by using pesticide which was sprayed at a rate of 3 kg/ha in ten days interval for a month.

**Yield measurement:** With the intention of comparing the yield and yield related parameters performance of the seven salinity levels on Carrot bulb yield, Carrot dry matter percentage and Saturated extract of the soil at harvest time were collected from all pots, weighed and converted to hectare basis and analyzed statistically.

**Data analysis:** Data were analyzed using ANOVA technique and GenStat software. Mean separation was made using the LSD.

## RESULTS AND DISCUSSION

**Soil characterization:** The results of particle size distribution analysis of soil in the experimental site are presented in Table 1.

Table 2 provides results of, field capacity, permanent wilting point and total available water of soil of the experimental site. The basic infiltration rate of the soil was 26 mm/h.

Table 2 also shows the values of TAW, FC and PWP.

Mean values of TAW were 125.0 mm/m at the top and 123.0 mm/m in the subsurface soil. Representative value of TAW was computed by considering 30 cm depth form the surface and 20 cm depth for the subsurface soil and was found to be 124.0 mm/m depth of soil (Table 2).

From soil laboratory test it is reported that the EC of soil is 0.512 gm/L, hence the value of EC (gm/L) that may be accumulated at harvest would be shown by subtracting the accumulated salt per each liter of water application from standard extract of soil at each treatment and it is shown in Table 3 and 4. This comes from added amount of salt during irrigation.

Table 1: Average particle size distribution

| Depth (cm) | Particle size distribution (%) Sand | Silt | Clay | Textural class (USDA) |
|---|---|---|---|---|
| 0-30 | 71 | 18 | 11 | Sandy loam |
| 30-50 | 70 | 20 | 10 | Sandy loam |

Table 2: Average field capacity, PWP and TAW

| Sampling depth (cm) | FC (%) V/V | PWP (%) V/V | TAW mm/m |
|---|---|---|---|
| 0-30 | 23.0 | 10.5 | 125.0 |
| 30-50 | 21.8 | 9.5 | 123.0 |
| Average | 22.4 | 10.0 | 124.0 |

FC: Field capacity; PWP: Permanent wilting point; TAW: Total allowable water

Table 3: EC of salinity level at each treatment at crop harvest

| Salinity level (dS/m) | EC (gm/L) |
|---|---|
| 0.4 | 0.672 |
| 0.8 | 0.688 |
| 1.2 | 0.900 |
| 1.6 | 0.990 |
| 2.0 | 1.485 |
| 2.4 | 1.970 |
| 2.8 | 2.150 |

Table 4: The accumulated salt at each treatment at harvest

| Salinity level (dS/m) | EC (gm/L) |
|---|---|
| 0.4 | 0.160 |
| 0.8 | 0.176 |
| 1.2 | 0.388 |
| 1.6 | 0.478 |
| 2.0 | 0.973 |
| 2.4 | 1.458 |
| 2.8 | 1.638 |

Table 5: The effect of salinity level on carrot yield

| Salinity level (dS/m) | Yield (kg/ha)* |
|---|---|
| 0.4 | 8526 |
| 0.8 | 8895 |
| 1.2 | 9026 |
| 1.6 | 7703 |
| 2.0 | 6579 |
| 2.4 | 5526 |
| 2.8 | 4466 |
| LSD (0.05) | 4.27 |
| CV | 15.50 |

*: Mean of three observations

This shows in the absence of drainage there is an accumulation of listed amount of salt for every application of water.

**Yield performance:** The mean effects of salinity level on yield are presented in Table 5. The treatments that received 0.4, 0.8, 1.2, 1.6, 2.0, 2.4 and 2.8 dS/m, respectively salinity level of the irrigation water requirement throughout the growing season produced 8526, 8895, 9026, 7703, 6579, 5526 and 4466 kg/ha, respectively. The corresponding dry matter percentages were also 808, 784, 808, 692, 537, 534 and 303 kg/ha, respectively consequently. This showed that carrot would give maximum yield and dry matter when its salinity level on irrigation water is at threshold level (1.2 dS/m).

Comparing the means of yields obtained, the treatment provided with 0.4 dS/m salinity level of irrigation application was significantly lower than the other three salinity level of irrigation application rates of 2, 2.4 and 2.8 dS/m, respectively ($p<0.05$). However, the difference (0.4 dS/m salinity level of irrigation application) between 0.8, 1.2 and 1.6 dS/m, respectively salinity level of irrigation water application rates exhibited no significant difference ($p>0.05$) and the treatment provided with 0.8 dS/m salinity level of irrigation application was significantly lower than the salinity level of irrigation application rate of 1.6, 2.0, 2.4 and 2.8 dS/m, respectively ($p<0.05$). However, the difference (0.8 dS/m salinity level of irrigation application) between 1.2 dS/m salinity level of irrigation water application rates exhibited no significant difference ($p>0.05$) and also the treatment provided with 1.2 dSm salinity level of irrigation application was significantly lower than the other three salinity level of irrigation application rates of 2, 2.4 and 2.8 dS/m, respectively ($p<0.05$). The treatment provided with 1.6 dS/m salinity level of irrigation application was significantly lower than the other two salinity level of irrigation application rates of 2.4 and 2.8 dS/m ($p<0.05$). However, the difference (1.6 dS/m salinity level of irrigation application) between 2.0 dS/m salinity level of irrigation water application rates exhibited no significant difference ($p>0.05$). The treatment provided with 2.0 dS/m salinity level of irrigation application was significantly lower than the salinity level of irrigation application rates of 2.8 dS/m ($p<0.05$). However, the difference (2.0 dS/m salinity level of irrigation application) between 2.4 dS/m salinity level of irrigation water application rates exhibited no significant difference ($p>0.05$) and finally, the treatment provided with 2.4 dS/m salinity level of irrigation application rates exhibited no significant difference with salinity level of 2.8 dS/m ($p>0.05$); The highest yield was obtained when the salinity level of irrigation water is 0.8 dS/m the was applied. This showed that carrot would give maximum yield when its salinity level on irrigation water is below threshold level.

The effect of salinity level on carrot dry matter yield converted on hectare basis is presented in Table 6. Comparing the means of carrot dry matter obtained, the treatment provided with 0.4 dS/m salinity level of irrigation application was significantly lower than the other three salinity level of irrigation application rates of 2, 2.4 and 2.8 dS/m, respectively ($p<0.05$). However, the difference (0.4 dS/m salinity level of irrigation application) between 0.8, 1.2 and 1.6 dS/m, respectively salinity level of irrigation water application rates exhibited no significant difference ($p>0.05$); and the treatment provided with 0.8 dS/m salinity level of irrigation application was significantly lower than the salinity level of irrigation application rate of 2.0, 2.4 and 2.8 dS/m ($p<0.05$). However, the difference (0.8 dS/m salinity level of irrigation application) between

Table 6: The effect of salinity level on carrot dry matter

| Salinity level (dS/m) | Dry matter yield (kg/ha)* |
|---|---|
| 0.4 | 808 a |
| 0.8 | 784 a |
| 1.2 | 808 |
| 1.6 | 692 |
| 2.0 | 537 |
| 2.4 | 534 |
| 2.8 | 303 |
| LSD (0.05) | 0.44 |
| CV | 17 |

*: Mean of three observations

Table 7: Relative yield reduction of carrot

| Salinity level (dS/m) | Actual yield | Yield reduction (%) | Rank |
|---|---|---|---|
| 0.4 | 8526 | 5.54 | 5 |
| 0.8 | 8895 | 1.45 | 6 |
| 1.2 | 9026 | - | - |
| 1.6 | 7703 | 14.66 | 4 |
| 2.0 | 6579 | 27.11 | 3 |
| 2.4 | 5526 | 38.78 | 2 |
| 2.8 | 4466 | 50.50 | 1 |

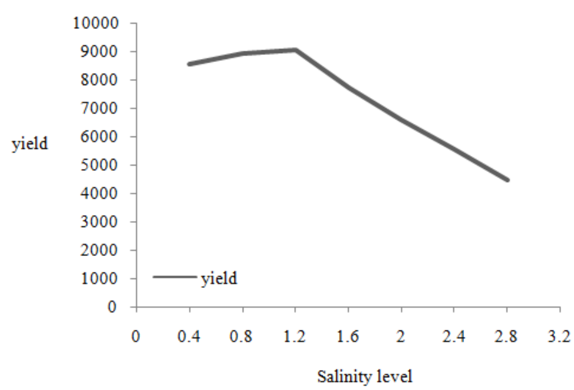


Fig. 1: Yield salinity level relationships

1.2 and 1.6 dS/m salinity level of irrigation water application rates exhibited no significant difference (p>0.05) and also the treatment provided with 1.2 dS/m salinity level of irrigation application was significantly lower than the other three salinity level of irrigation application rates of 2, 2.4 and 2.8 dS/m, respectively (p<0.05). However, the difference (1.2 dS/m salinity level of irrigation application) between 1.6 dS/m salinity level of irrigation water application rates exhibited no significant difference (p>0.05). The treatment provided with 1.6 dS/m salinity level of irrigation application was significantly lower than the other two salinity level of irrigation application rates of 2.4 and 2.8 dS/m (p<0.05). However, the difference (1.6 dS/m salinity level of irrigation application) between 2.0 dS/m salinity level of irrigation water application rates exhibited no significant difference (p>0.05). The treatment provided with 2.0 dS/m salinity level of irrigation application was significantly lower than the salinity level of irrigation application rates of 2.8 dS/m (p<0.05). However, the difference (2.0 dS/m salinity level of irrigation application) between 2.4 dS/m salinity level of irrigation water application rates exhibited no significant difference (p>0.05) and finally, the treatment provided with 2.4 dS/m salinity level of irrigation application rates exhibited significance difference with treatment of 2.8 dS/m of salinity level.

The relative yield reductions compared to different salinity level are presented in Table 7.

The Relative yield reductions for 0.4, 0.8, 1.6, 2.0, 2.4 and 2.8 dS/m, respectively salinity level in irrigation water application were 500 kg/ha or 5.54%, 131 kg/ha or 1.45%, 1323 kg/ha or 14.66%, 2447 kg/ha or 27.1%, 3500 kg/ha or 38.78% and 4560 kg/ha or 50.5%, respectively. Many studies have been reported on the salinity level of irrigation of carrots (James, 1988). They proved that the bulb yield and dry matter production of carrot at harvest are highly affected by the salinity level.

**Yield-salinity-relationship:** Yield difference between treatments can be attributed to their respective salinity levels. The relationship between yield (kg/ha) and the level of salinity (dS/m) for each treatment is presented in Fig. 1. As the salinity level increases, the yield decreases for the salinity level ranges considered in this study.

From Fig. 1, it can be generalized that about 98% of the yield variability between treatments can be attributed to the difference in the amount of salinity level through irrigation. And also what was observed in this experiment is that the salinity threshold value is 1.2 dS/m, hence; the yield as well as dry matter show a higher reduction, which might even tend to zero yield provided when there is further addition of salt, in agreement with what have been reported earlier by (Nabil, 2002; Vijay, 2011).

**The effect of salinity level on soil extraction:** With the intention of comparing soil extraction on seven salinity levels and the result obtained is presented in Table 3. The highest value was obtained under 2.8 dS/m salinity level irrigation water application and lowest value was obtained under the 0.4 dS/m salinity level irrigation water application.

## CONCLUSION

This study showed that most Ethiopian farmers depend on rain-fed agriculture. However, rainfall is very erratic and drought occurs very frequently; therefore, wise use of irrigation water using appropriate irrigation systems and management is an important consideration in the drought prone areas for improved crop production.

One of the salinity management practices which could result in lowering salinity level is drainage system, which is maintaining the salinity level below the optimum level throughout the growing season and it is possible to identify which salinity level would have a limited effect on crop production.

In the experiment, an attempt was made to evaluate cumulative effect of saline water on carrot production and to determine the salinity threshold value for carrot by applying 0.4, 0.8, 1.2, 1.6, 2.0, 2.4 and 2.8 dS/m, respectively of salinity levels on water requirement using carrot as a test crop.

The mean effects of salinity level on yield are presented in Table 5. The treatments that received 0.4, 0.8, 1.2, 1.6, 2.0, 2.4 and 2.8 dS/m, respectively salinity level of the irrigation water requirement throughout the growing season produced 8526, 8895, 9026, 7703, 6579, 5526 and 4466 kg/ha, respectively. The corresponding dry matter percentages were also 808, 784, 808, 692, 537, 534 and 303 kg/ha consequently. This showed that carrot would give maximum yield and dry matter when its salinity level on irrigation water is at threshold level (1.2 dS/m) and beyond the salinity level of 1.2 ds/m the yield as well as dry matter shows a higher reduction, which might even tend to zero yield provided there is further addition of salt. The saturated extract result shows that in the absence of drainage there is an accumulation of salt for every application of water.

Irrigation treatments had significant effects on salinity level, yield and its component parameters of carrot yields. Carrot yields were influenced by irrigation treatments in the experiment. The yields are greatly dependent on timing, amount and frequency of irrigation applied. If the salinity level is below the threshold level, there in no significant change on yield with salinity, but the yield decreased as the salinity level was beyond the salinity threshold value.

The statistical analysis shows that there is a significant difference among the treatments for mean of carrot yield and dry matter. Water is considered saline when it contains high levels of soluble salts, which can have negative impacts on crop growth or toxic effects under hyper-saline conditions. For irrigated lands, poor irrigation water quality, defined as water with elevated levels of soluble salts, as well as poor drainage due to high water table and low soil permeability can also result in accumulation of high salt levels. In addition, salt-affected soils can be caused by salt water spills from oil field activities as well as high rates of manure and sludge applications. Results of this study are encouraging for future research on agriculture, especially for long-term investigation. Future investigations should focus on this issue and evaluate the efficiency of other crops like onion, potato, tomato, soybean, haricot bean, sorghum and maize growing under irrigation in this area; hence salinity threshold value and the effect of salinity on carrot yield should be tested for all these crops.

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