

## RESEARCH ARTICLE

## EFFECT OF SALINE AND NON-SALINE WATER ON OKRA CROP PRODUCTION

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## ARTICLE DETAILS

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## ABSTRACT

Under the situation of acute water crises and the regular or occasional use of marginal to saline groundwater by the farming community to cultivate the crops, the research needs to be conducted on the use of marginal to saline groundwater based on the guidelines and strategies for the effective use be developed. In context of this, the experiment was conducted at the field research station of the laboratory of the Department of Land and Water Management (LWM) Faculty of Agricultural Engineering (FAE), Sindh Agriculture University (SAU) Tandojam during the year 2019. The experiment was arranged in a completely randomized design with three treatments of varying water qualities with three replications were deployed. The treatments were:  $W_1$  = non-Saline water (canal water)  $EC = 1.0 \text{ dS m}^{-1}$ ,  $W_2$  = Saline water (groundwater)  $EC = 4 \text{ dS m}^{-1}$  and  $W_3$  = Saline water (groundwater)  $EC = 6 \text{ dS m}^{-1}$ . Okra crop was grown on ridges. The results showed that the soil EC decreased  $0.76 \text{ dS m}^{-1}$  under  $T_1$ , and increased  $0.83$  and  $1.33 \text{ dS m}^{-1}$  under  $T_2$  and  $T_3$ , respectively. The soil pH decreased by  $0.29$ ,  $0.43$ , and  $0.44$  under  $T_1$ ,  $T_2$ , and  $T_3$ . The soil Mg increased  $21.57$ ,  $22.11$ , and  $27.03$ ; soil SAR increased  $6.15$ ,  $7.82$ , and  $8.91$ ; and soil ESP increased  $6.51$ ,  $8.61$ , and  $10.33$  under  $T_1$ ,  $T_2$ , and  $T_3$ , respectively. The soil Ca decreased  $1.34$  under  $T_1$  treatment; and increased  $0.30$  and  $10.28$  under  $T_2$  and  $T_3$ , respectively. The maximum yield of  $18500 \text{ kg ha}^{-1}$  was found with  $T_1$  followed by  $17391 \text{ kg ha}^{-1}$  with  $T_2$  and the lowest yield of  $16836 \text{ kg ha}^{-1}$  was found with  $T_3$ . The highest water productivity of  $1.91 \text{ kg m}^{-3}$  was found with  $T_1$  treatment followed by  $1.79 \text{ kg m}^{-3}$  with  $T_2$  treatment and the lowest water productivity of  $1.73 \text{ kg m}^{-3}$  was found with  $T_3$  treatment.

## KEYWORDS

Marginal and wastewater, Okra crop, EC, pH, Cutthroat flume

## 1. INTRODUCTION

African origin vegetable known as Okra, belongs to the family of Malvaceae. The vegetable gives annual production, shrubby type, and rich with different proteins, vitamins, carbohydrate, and minerals. The small farmers acquire good income from this vegetable in many regions of the world. The good quality irrigation water scarcity in the arid and semi-arid regions is a major issue for successful cropping. During the critical growth stages of the crops grown, skipping irrigation or applying saline water due to the scarcity of good quality water causes severe yield losses. The Nonavailability of good quality water obliges the farming communities to utilize the marginal to saline water for irrigation purposes for their crop survival. The possible sources of the marginal to saline water in the arid and semi-arid regions are (i) the agricultural drainage water and (ii) salty groundwater (Bhatti et al., 2015).

Pakistan is one of the South Asian countries having arid to semi-arid climatic regions, where the gigantic irrigation network and groundwater are the dominant sources of irrigation water for agriculture (Shah et al., 2021). Due to the decrease in river flow and high cropping intensity, the available good quality surface water resources are insufficient to meet the water demand by the crops during their entire cropping cycle (Kahlowan and Azam, 2003; Shah et al., 2021). The application of saline irrigation water for crop cultivation imparts a negative impact on the soil, water, and plant relationships. The impact varies with the water salinity as the high-water salinity responds with high impact and low salinity responses with low impact. The impact of water salinity on soil, water, and plant

relationships results in the lower crop growth rate and severe yield losses with the low quality of the plant products (Pascale et al., 2013; Plaut et al., 2013).

Irrigated agriculture in the all-climatic regions (humid, arid, and semi-arid) is under serious threat due to the increasing soil salinity. This had caused the following of about  $40,000 \text{ ha/year}$  of agricultural land for cropping throughout the world. According to the study report prepared by the United Nations (UN), the salinity level (slightly to higher levels) has affected about 50% of the irrigated area of the world. The salinity concentration varies with the climatic regions having higher precipitation rates. The higher precipitation in the humid and sub-humid climatic regions may leach out the salts accumulated around the crop root zone in the soil. The situation of accumulation of salinity in the soil becomes serious in the arid to semi-arid climatic regions where the rainfall is meager and the good quality water is insufficient to meet both i.e., irrigation water requirement and salt leaching (Lamsal et al., 1999; Unlukara et al., 2008).

The use of saline water is inevitable due to the increasing demand for good quality water from the agricultural sector having higher cropping intensity, the rapidly growing industrialization, and urbanization, the household use from the ever-increasing population and other users. The high salty irrigation water does not have high value; even the studies conducted worldwide had made the guidelines with regards to the salt tolerance of the more than 130 crop species (Shannon and Grieve 1999; Unlukara et al., 2008). Under the situation of acute water crises and the

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regular or occasional use of marginal to saline groundwater by the farming community to cultivate the crops, the research needs to be conducted on the use of marginal to saline groundwater based on the guidelines and strategies for the effective use be developed. In this way, the effective strategies will help the farming community for the sustainable use of marginal and saline groundwater with minimum yield reduction and imperiling soil health. The present study was thus conducted to assess the impact of different irrigation water quality on the soil health and yield of Okra plants under the climatic condition of Tandojam.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

This experiment was conducted at the field research station of the FAE, SAU Tandojam, 2019. The experimental area is located at latitude 25° 25'.07.11" N and longitude of 68° 31' 49.2" E at an elevation of about 12.8 m above mean sea level (MSL). The experimental design was a completely randomized design (CRD). The experiment was conducted on an area of 148 m<sup>2</sup> that was divided into three subplots each of length and width of 11 and 4.5 m. The furrows were made manually using the spade. The width of each ridge and furrow was kept as 0.5 m. The length of each furrow and ridge was kept at 10 m. Three ridges and four furrows were made in each replicated plot. The schematic diagram of the experimental trial is depicted in the (Figure 1). Three treatments of varying water qualities were deployed in the experiment with three replications. In this way, nine plots were prepared and used in the experiment. The treatments were: T<sub>1</sub> = Non-Saline water (canal water EC<sub>w</sub> ≤ 1.0 dS/m), T<sub>2</sub> = saline water (groundwater EC<sub>w</sub> = 4.0 dS/m) and T<sub>3</sub> = Saline water (groundwater EC<sub>w</sub> = 6 dS/m).

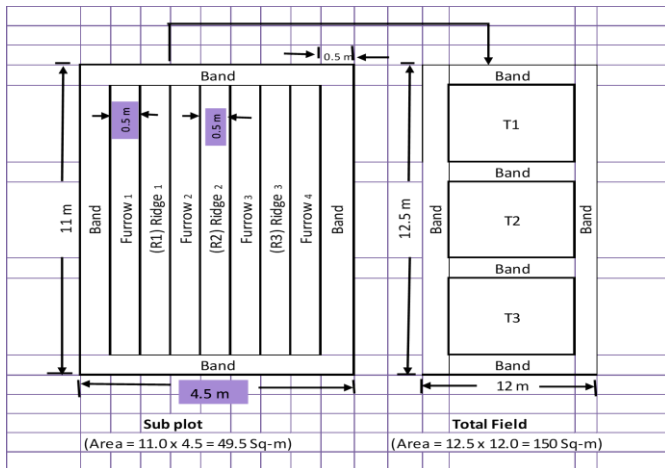


Figure 1: The layout of the experimental field

### 2.1 Water Sampling and Analysis

The quality of water is the main factor in increasing or decreasing soil salinity. Therefore, the water samples were collected and analyzed for pH and electrical conductivity (EC<sub>w</sub>). The electrical conductivity of the water sample (EC<sub>w</sub>) was measured with help of a digital EC meter, while the pH of water samples was measured by using a digital pH meter. The EC<sub>w</sub> of groundwater was 1.9 dS/m and pH were 7.3.

### 2.2 Soil Sampling and Analysis

The soil samples were collected from the top of ridges before the execution of the experiment and immediately after harvesting the crop. The sampling depths varied. It was 0-20, 20-40, and 40-60cm from the soil surface. These samples were collected and brought for analysis in the laboratory of LWM, FAE. These soil samples were analyzed for EC<sub>e</sub>, pH, Ca, Mg, Na, SAR, and ESP.

The soil EC<sub>e</sub> (dSm<sup>-1</sup>) and pH were determined by digital EC and pH meters available in the laboratory of the Department of LWM. The procedure for the analysis of EC and pH was adopted as per the recommendations made (U.S Salinity Laboratory Staff, 1954).

The soil SAR was determined by using the equation developed given below (Fresenius et al., 1988):

$$SAR = \frac{Ca^{++}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}} \quad (1)$$

Whereas; SAR = Sodium adsorption ratio, Na<sup>+</sup> = Sodium, Ca<sup>++</sup> = Calcium, Mg<sup>++</sup> = Magnesium.

The soluble calcium (Ca<sup>++</sup>) and Magnesium (Mg<sup>++</sup>) were determined by titration method, while the sodium (Na<sup>+</sup>) was analyzed by EEL flame photometer instrument according to recommendations made (Fresenius et al., 1988).

The soil exchangeable sodium percentage was determined by using the formula developed as given below (Fresenius et al., 1988):

$$ESP = \frac{100(-0.0126 + 0.01475 * SAR)}{1 + (-0.0126 + 0.01475 * SAR)} \quad (2)$$

### 2.3 Water Application

The saline water of the required EC (4 and 6dS/m) was prepared manually by mixing the 0.2 mg Sodium Chloride (NaCl) salt in 1 liter of fresh water (1 dS/m) to increase EC of 1 dS/m (Siyal et al., 2015). Thus, the required quantity of saline water was prepared in drums (220 liters). Each time the EC of the saline water was measured with an EC meter then applied in each plot under saline water treatment.

In order to allow the germination of seeds, the canal water was used for soaking dose in all designed treatments plots. The irrigations after germination of seeds were applied at 15 days intervals, scheduled based on the recommendations given in (FAO, 2005). The required depth of irrigation water was determined using the field data, plugged-in the equation given below:

$$R = \frac{(F.C - M.C)}{100} \times \rho_b \times d_r \quad (3)$$

Whereas, R= depth of water required (cm), F.C= Field capacity of the soil (%), M.C= Moisture content one day before applying irrigation (%), d<sub>r</sub> = Root depth of plant at the time of irrigation (cm), ρ<sub>b</sub> = Bulk density of soil sample (g/cm<sup>3</sup>).

The field capacity of the soil was determined by the core method (Veihmeyer and Hendricksen, 1931). The root depth of the okra plant was considered as 15, 30, and 45 cm up to 25, 26-55, and 56-110 days after sowing.

### 2.4 Measurement of Discharge and Irrigation Time

A cut-throat flume having the dimensions of 8" × 1.5' was installed at the center of the field channel to measure the discharge. The data on upstream and downstream depths were recorded and the submergence (S = H<sub>d</sub>/H<sub>u</sub>) value was calculated. The equations 4 & 5 used for measuring discharge were selected based on the submergence values. While, the Table 1 show gives information about the time required for irrigation and plot information.

i. Formula for free flow (if H<sub>d</sub>/H<sub>u</sub> < 0.68)

$$Q_f = C_f (h_u)^{n_f} \quad (4)$$

Whereas; Q<sub>f</sub> = Free flow discharge rate (m<sup>3</sup> sec<sup>-1</sup>), C<sub>f</sub> = Free flow coefficient (dimensionless), H<sub>u</sub> = Head at upstream (inches), H<sub>d</sub> = Head at downstream (inches), n<sub>f</sub> = free flow exponent (dimensionless).

ii. Formula for submerged flow (if H<sub>d</sub>/H<sub>u</sub> > 0.68)

$$Q_s = \frac{[C_s (h_u - h_d)^{n_s}]}{[-\log(S)]^{n_s}} \quad (5)$$

Whereas; Q<sub>s</sub> = submerged flow discharged rate (m<sup>3</sup> sec<sup>-1</sup>), C<sub>s</sub> = submerged flow coefficient, H<sub>u</sub> = upstream depth (inches), H<sub>d</sub> = downstream depth (inches), n<sub>s</sub> = submerged flow exponent (Dimensionless), C<sub>f</sub> = Free flow coefficient (dimensionless), S = submergence (Dimensionless).

The time required to irrigate the crop was calculated (Table. 1) using the following equation:

$$T = \frac{AD}{Q} \quad (6)$$

Whereas; T = required time (seconds), A = area of the plot (m<sup>2</sup>), D = depth of water to be applied (m), Q = discharge of the field channel (m<sup>3</sup>/sec).

Table 1: Time Required to Irrigate the Experimental Plot		
Length of Furrow	10	m
Width of Furrow	0.5	m
Area of Furrow	5	m <sup>2</sup>
Number of Furrows Per Plot	4	
Discharge of Field Channel	0.0058	m <sup>3</sup> /sec
Root Depth of The Crop	0.2032	m
Time Required to Irrigate Each Plot	700.69	seconds

2.5 Fertilization

The fertilizers NPK were applied based on the recommendations of (Firoz, 2009). The NPK fertilizers were applied at the rate of 100-120-0 kg ha<sup>-1</sup>. Urea, Di-ammonium phosphate, and potash were applied as the possible source of NPK. Half of the NP was applied as basal dose, and the remaining split was applied into two parts during mid (26-55 days after sowing) and final (56-110 days after sowing) growth stages.

2.6 Harvesting and Agronomical Parameters of Crop

The green Okra pods were picked every 2-3 days during the final growth stages. The agronomic variables of the okra plant such as (i) plant height, (ii) leaf area (iii) number of leaves per plant, (iv) plant height was also measured. A cloth measuring scale was used to record the plant height. A planimeter was used to determine the leaf area of the Okra. The number of leaves was counted by selecting five plants per replication and then was averaged to get the single unit.

3. RESULTS AND DISCUSSION

3.1 Chemical Parameters

In order to examine the impact of different saline water applications on the soil chemical properties, the soil samples were collected pre- and post-experiment from the depths of 0-20 cm, 20-40 cm, and 40-60 cm. The average values of EC<sub>e</sub>, pH, Mg, Ca, Na, SAR, and ESP at different depths of the soil before sowing of the crop and after subsequent irrigations are given in Table. 2. The average values of EC<sub>e</sub> at different depths of the soil before the crop sowing was 3.96, 3.57, and 4.74dS m<sup>-1</sup> under treatments T<sub>1</sub>, T<sub>2</sub> and T<sub>3</sub>, respectively (Figures 2, 3 and 4). The average values of EC<sub>e</sub> at different depths of soil after subsequent irrigations applied decreased under T<sub>1</sub> treatment, whereas it increased under T<sub>2</sub> and T<sub>3</sub> treatments.

The results depicted that the EC<sub>e</sub> increased maximum under T<sub>3</sub> treatment as compared to T<sub>2</sub> treatment. This is because relatively high-level salty water (EC<sub>e</sub> = 6 dS m<sup>-1</sup>) was applied under T<sub>3</sub> treatment compared to low-level salty water (EC<sub>e</sub> = 4 dS m<sup>-1</sup>) applied under T<sub>2</sub> treatment. With the application of freshwater, the EC<sub>e</sub> of the soil profile was decreased because the available salts were leached down due to the downward movement of irrigation water. The results are in close agreement with the statement after experimentation made, that the application of saline water for crop irrigation may cause an increase in the soil EC<sub>e</sub> (Kim et al., 2016). The difference in EC<sub>e</sub> values pre-sowing and after 4<sup>th</sup> irrigation was found non-significant (p<0.05).

The average values of pH at different depths of the soil before the crop sowing was 8.79, 8.84, and 8.96 under treatments T<sub>1</sub>, T<sub>2</sub>, and T<sub>3</sub>, respectively. The average values of pH at different depths of soil after subsequent irrigations applied decreased under all treatments under T<sub>1</sub>, T<sub>2</sub> and T<sub>3</sub> treatments. This is because the acidification process in response to urea fertilizer application to the soil for crop production causes a decrease in soil pH values. The maximum decrease in pH values under T<sub>3</sub> as compared to T<sub>2</sub> treatment is because of the relatively high acidity of salty water (EC<sub>w</sub> = 6 dS m<sup>-1</sup>) applied under T<sub>3</sub> treatment compared to low acidity level salty water (EC<sub>w</sub> = 4 dS m<sup>-1</sup>) applied under T<sub>2</sub> treatment. The difference in pH values pre-sowing and after 4<sup>th</sup> irrigation was found significant (p<0.05).

The average values of Mg at different depths of the soil before the crop sowing was 4.76, 10.42, and 9.53 meq/L under treatments T<sub>1</sub>, T<sub>2</sub>, and T<sub>3</sub>, respectively. The average values of Mg at different depths of soil after subsequent irrigations applied increased under all treatments under T<sub>1</sub>, T<sub>2</sub> and T<sub>3</sub> treatments. The results indicate that the use of high-level salty water may bring maximum Mg to the soil. The difference in Mg values pre-sowing and after 4<sup>th</sup> irrigation was found significant (p<0.05). The average values of Ca at different depths of the soil before the crop sowing were

19.12, 24.50, and 11.28meq/L under treatments T<sub>1</sub>, T<sub>2</sub>, and T<sub>3</sub>, respectively. The average values of Ca at different depths of soil after subsequent irrigations applied decreased under T<sub>1</sub> treatment, whereas it increased under T<sub>2</sub> and T<sub>3</sub> treatments. The difference in Ca values pre-sowing and after subsequent irrigations was found non-significant (p<0.05).

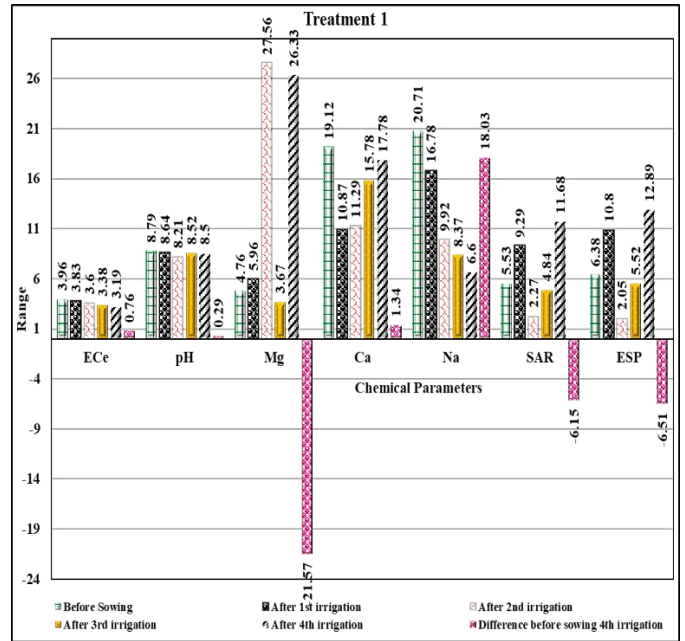


Figure 2: Chemical properties of the soil before sowing of crop and after subsequent irrigation in T<sub>1</sub>

The average values of Na at different depths of the soil before the crop sowing was 20.71, 18.07, and 26.60 mg/L under treatments T<sub>1</sub>, T<sub>2</sub>, and T<sub>3</sub>, respectively. The average values of Na at different depths of soil after subsequent irrigations applied decreased under T<sub>1</sub> treatment, whereas it increased under T<sub>2</sub> and T<sub>3</sub> treatments. The results depicted that the Na increased maximum under T<sub>3</sub> treatment as compared to the T<sub>2</sub> treatment. This is because relatively high-level salty water (EC<sub>w</sub> = 6 dS m<sup>-1</sup>) is applied under T<sub>3</sub> treatment compared to low-level salty water (EC<sub>w</sub> = 4 dS m<sup>-1</sup>) applied under T<sub>2</sub> treatment. The results are in close agreement with the statement after experimentation made by that the application of saline water for crop irrigation may cause an increase in the soil Na (Kim et al., 2016). The difference in Na values pre-sowing and after 4<sup>th</sup> irrigation was found non-significant (p<0.05).

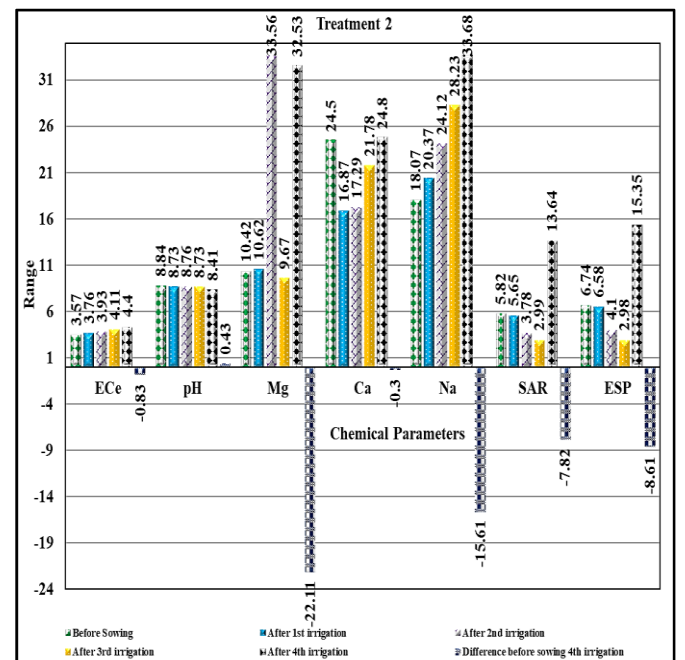


Figure 3: Chemical properties of the soil before sowing of crop and after subsequent irrigation in T<sub>2</sub>

The average values of SAR at different depths of the soil before the crop sowing was 5.53, 5.82, and 5.81 under treatments T<sub>1</sub>, T<sub>2</sub>, and T<sub>3</sub>, respectively. The average values of SAR at different depths of soil after subsequent irrigations applied increased under all treatments under T<sub>1</sub>, T<sub>2</sub>, and T<sub>3</sub> treatments respectively. The results depicted that the SAR increased maximum under T<sub>3</sub> treatment followed by T<sub>2</sub> and T<sub>1</sub> treatment, indicating maximum salt accumulation where relatively high-level salty water (EC<sub>w</sub> = 6 dS m<sup>-1</sup>) applied under T<sub>3</sub> treatment compared to low-level salty water (EC<sub>w</sub> = 4 dS m<sup>-1</sup>) applied under T<sub>2</sub> treatment. The difference in SAR values pre-sowing and after 4<sup>th</sup> irrigation was found significant (p<0.05).

The average values of ESP at different depths of the soil before the crop sowing was 6.38, 6.74, and 6.52 % under treatments T<sub>1</sub>, T<sub>2</sub>, and T<sub>3</sub>, respectively. The average values of ESP at different depths of soil after subsequent irrigations applied increased under T<sub>1</sub>, T<sub>2</sub>, and T<sub>3</sub> treatments, respectively. The results depicted that the ESP increased maximum under T<sub>3</sub> treatment followed by T<sub>2</sub> and T<sub>1</sub> treatment, indicating maximum salt accumulation where relatively high-level salty water (EC<sub>w</sub> = 6 dS m<sup>-1</sup>) applied under T<sub>3</sub> treatment compared to low-level salty water (EC<sub>w</sub> = 4 dS m<sup>-1</sup>) applied under T<sub>2</sub> treatment. The difference in ESP values pre-sowing and after 4<sup>th</sup> irrigation was found significant (p<0.05).

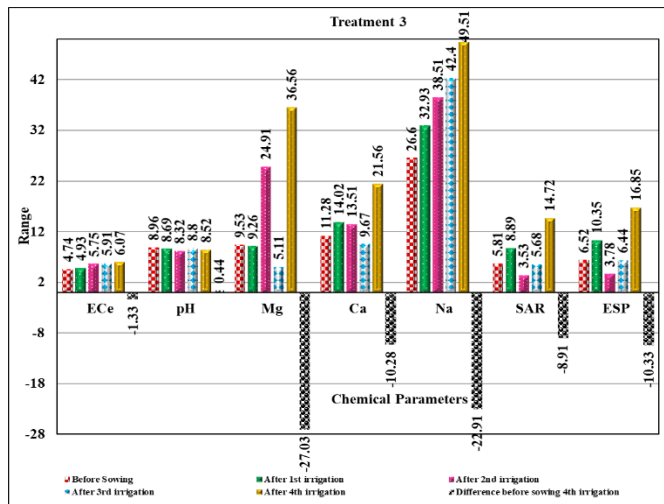


Figure 4: Chemical properties of the soil before sowing of crop and after subsequent irrigation in T<sub>3</sub>

Table 2: Chemical Properties of The Soil Before Sowing of Crop and After Subsequent Irrigation

Treatments	Chemical Property	Before Sowing	After 1 <sup>st</sup> Irrigation	After 2 <sup>nd</sup> Irrigation	After 3 <sup>rd</sup> Irrigation	After 4 <sup>th</sup> Irrigation	Difference (Before Sowing-4 <sup>th</sup> Irrigation)
T <sub>1</sub>	ECe	3.96	3.83	3.60	3.38	3.19	0.76
	pH	8.79	8.64	8.21	8.52	8.50	0.29
	Mg	4.76	5.96	27.56	3.67	26.33	-21.57
	Ca	19.12	10.87	11.29	15.78	17.78	1.34
	Na	20.71	16.78	9.92	8.37	6.60	18.03
	SAR	5.53	9.29	2.27	4.84	11.68	-6.15
	ESP	6.38	10.80	2.05	5.52	12.89	-6.51
T <sub>2</sub>	ECe	3.57	3.76	3.93	4.11	4.40	-0.83
	pH	8.84	8.73	8.76	8.73	8.41	0.43
	Mg	10.42	10.62	33.56	9.67	32.53	-22.11
	Ca	24.50	16.87	17.29	21.78	24.80	-0.30
	Na	18.07	20.37	24.12	28.23	33.68	-15.61
	SAR	5.82	5.65	3.78	2.99	13.64	-7.82
	ESP	6.74	6.58	4.10	2.98	15.35	-8.61
T <sub>3</sub>	ECe	4.74	4.93	5.75	5.91	6.07	-1.33
	pH	8.96	8.69	8.32	8.80	8.52	0.44
	Mg	9.53	9.26	24.91	5.11	36.56	-27.03
	Ca	11.28	14.02	13.51	9.67	21.56	-10.28
	Na	26.60	32.93	38.51	42.40	49.51	-22.91
	SAR	5.81	8.89	3.53	5.68	14.72	-8.91
	ESP	6.52	10.35	3.78	6.44	16.85	-10.33

### 3.2 Agronomic Parameters

The results on agronomic parameters of okra such as the number of leaves plant<sup>-1</sup>, leaf area, and plant height are given in the Table 3. Randomly ten plants were picked from each plot and the leaves per plant were counted and averaged. The highest average number of leaves plant<sup>-1</sup> was 9.3 found under T<sub>1</sub> treatment followed by 6.3 under T<sub>2</sub> treatment and the lowest number of leaves plant<sup>-1</sup> was 4.6 found under T<sub>3</sub> treatment (Figure 5). The results are in good agreement with (Kim et al., 2008). They concluded that under high salinity levels, the crop growth, leaf surface expansion, and primary carbon metabolism of many crops are negatively affected due to osmotic effect, water deficit, nutritional imbalance, and oxidative stress. The results are in good agreement with (Shannon and Grieve 1998;

Rameshwaran et al., 2015). They concluded that the salinity problem is a critical constraint to vegetable production due to the rapid accumulation of salts in the soil.

Table 3: Agronomic Parameters of Okra Crop

Treatments	Leaves Plant <sup>-1</sup> (Nos.)	Leaf Area (cm <sup>2</sup> )	Plant Height (cm)
T <sub>1</sub>	9.3	41.87	36.2
T <sub>2</sub>	6.3	26.63	28.5
T <sub>3</sub>	4.6	14.57	25

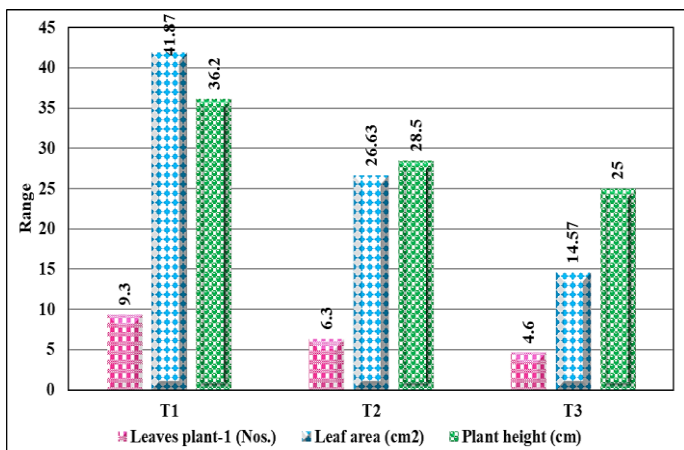


Figure 5: Agronomic parameters of Okra crop

3.3 Crop Water Productivity

Four irrigations were applied to all treatments. The total quantity of irrigation water applied to the crop under all treatments was the same i.e., 3283.71 m<sup>3</sup> ha<sup>-1</sup>. The maximum yield of 18500 kg ha<sup>-1</sup> was found with T<sub>1</sub> treatment followed by 17391 kg ha<sup>-1</sup> with T<sub>2</sub> treatment and the lowest yield of 16836 kg ha<sup>-1</sup> was found with T<sub>3</sub> treatment (Figure 6). A similar trend of yield was observed for crop water productivity. The highest water productivity of 5.63 kg m<sup>-3</sup> was found with T<sub>1</sub> treatment followed by 5.30 kg m<sup>-3</sup> with T<sub>2</sub> treatment and the lowest water productivity of 5.13 kg m<sup>-3</sup> was found with T<sub>3</sub> treatment. The results indicate the increase in irrigation water salinity may cause yield and water productivity reduction. The results are in good agreement with (De Pascale et al., 2013; Plaut et al., 2013). They concluded that the use of saline irrigation water has an adverse effect on soil–water–plant relations, occasionally severely restricting the normal physiological activity and productive capacity of the crops. The difference in yield and water productivity among different treatments was found significant (p<0.05). The results regarding the quantity of irrigation water applied, yield, and water productivity of Okra crop is given in Table 4.

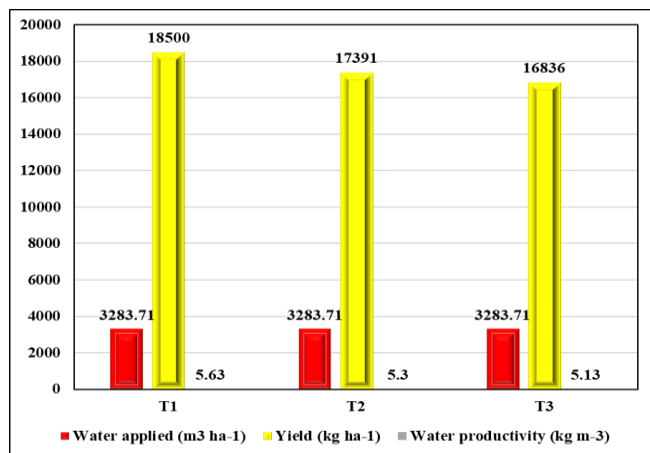


Figure 6: Shows column chart of Crop water productivity

Table 4: Crop Water Productivity of Okra Crop

Treatments	Water applied (m <sup>3</sup> ha <sup>-1</sup> )	Yield (kg ha <sup>-1</sup> )	Water productivity (kg m <sup>-3</sup> )
T <sub>1</sub>	3283.71	18500	5.63
T <sub>2</sub>	3283.71	17391	5.30
T <sub>3</sub>	3283.71	16836	5.13

4. CONCLUSION

The soil EC, Ca, and Na decreased under T<sub>1</sub> treatment and increased under T<sub>2</sub> and T<sub>3</sub> treatments. The pH decreased whereas Mg, SAR, and ESP increased under T<sub>1</sub>, T<sub>2</sub>, and T<sub>3</sub> treatments. Application of good quality water (T<sub>1</sub> treatment) resulted in producing 6 and 9% maximum Okra yield over T<sub>2</sub> (ECw = 4 dS m<sup>-1</sup>) and T<sub>3</sub> (ECw = 6 dS m<sup>-1</sup>) treatments. Application of good quality water (T<sub>1</sub> treatment) resulted in 6.3 and 9.4% higher water

productivity over T<sub>2</sub> (EC = 4 dS m<sup>-1</sup>) and T<sub>3</sub> (ECw = 6 dS m<sup>-1</sup>) treatments respectively. The all-agronomic parameters of okra were better with T<sub>1</sub> treatment as compared to T<sub>2</sub> and T<sub>3</sub> treatments. The leaves plant<sup>-1</sup> were found to be 29 and 51% higher; leaf area was found to be 36 and 65% higher; and plant height were found to be 21 and 31% higher with good quality water used in T<sub>1</sub> treatment (ECw = 1 dS m<sup>-1</sup>) as compared to saline water used in T<sub>2</sub> (ECw = 4 dS m<sup>-1</sup>) and T<sub>3</sub> (ECw = 6 dS m<sup>-1</sup>) treatments respectively. Application of T<sub>2</sub> treatment (ECw = 4 dS m<sup>-1</sup>) resulted in 3 and 3.4% higher yield and water productivity over major saline water T<sub>3</sub> (ECw = 6 dS m<sup>-1</sup>) treatments respectively. Hence, it is concluded that saline stress highly impacts on growth in Okra plants. While the fertilizer was more effective for early growth. The overall experiment gives best and understanding knowledge of saline and non-saline water impacts over the Okra as well as performance of treatments in context of production, yield and water productivity. The treatment T<sub>2</sub> is better technique for growing Okra and it saves water and suitable for water shortage regions.

SUGGESTIONS

The overall performance of T<sub>1</sub> treatment was best in terms of producing higher yields and achieving high water productivity without degrading the soil. The response of T<sub>2</sub> (ECw = 4 dS m<sup>-1</sup>) has been seen better as this treatment produced a 6% minimum yield with 6.3 % lower water productivity and 21-36 lower agronomic parameters. To cope with the water shortages issues, the T<sub>2</sub> treatment (ECw = 4 dS m<sup>-1</sup>) may be applied for growing okra.

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