PSM Biological Research ISSN(Online): 2517-9586

Research Article 2020 | Volume 5 | Issue 4 | 147-156

Article Info

Open Access

**Citation:** Hameed, D.A., Al.Maqtari, M.A., 2020. Possibility of Plantation of Barley and Corn Plants Irrigated with Saline Water in Yemen. PSM Biol. Res., 5(4): 147-156.

**Received:** October 13, 2020

**Accepted:** October 23, 2020

**Online first:** October 25, 2020

**Published:** October 31, 2020

***Corresponding Author:**
Maher Ali Al.Maqtari

**Email:**
al.maqtarimaher@yahoo.com





# Possibility of Plantation of Barley and Corn Plants Irrigated with Saline Water in Yemen

**Dheya Abdul Hameed, Maher Ali Al.Maqtari***

Department of Chemistry, Faculty of Science, Sana'a University, Sana'a, Yemen.

**Abstract:**
The current study investigated the response of barley and corn plants to foliar application with proline, potassium nitrate fertilization. The effect of leaching fraction irrigation on both the growth and chemical composition of corn and barley plants and the salt accumulation in soil was also determined. The treatments included irrigation waters of different salinity (3.36, 5.88 or 7.95 dS/m), three rates of $KNO_3$ (0, 4, and 8 g/pot) fertilizer, and foliar application with three rates of proline (0, 100, and 200 mg/L). The first experiment was irrigated with leaching fraction and the second without leaching fraction. The effect of these parameters on the salt accumulation in soil was discussed. The obtained results showed that the dry weight of shoots of corn and barley were decreased as the salinity of irrigation water increased. The high salinity of water increased the shoot contents of $Na^{+}$, $Cl^{-}$, proline, and decreased $NO^{-}_3$ contents with or without leaching fraction, but the values without leaching fraction were higher than those of with leaching fraction. Besides, increasing the salinity of irrigation water decreased K content in the shoot, which was higher with leaching than without leaching. On the other hand, $KNO_3$ fertilization or proline spraying decreased $Na^{+}$, $Cl^{-}$ contents, and increased $K^{+}$ or $NO^{-}_3$ contents in plant shoot of both crops and their values without leaching were higher than with leaching. The Electrical conductivity (EC) values of soil were increased with both increasing salinity of irrigation water and $KNO_3$ fertilization. The decreased plant growth due to water salinity was partially offset by $KNO_3$ fertilization, proline spraying, and leaching fraction application. Besides, $KNO_3$ fertilization was more effective than proline for reducing the adverse effect of water salinity.
**Keywords:** Seawater, saline water, irrigation, salinity, proline, potassium nitrate fertilization, soil, fertilizer application.

## INTRODUCTION

Yemen is located in the South East of the Arabian Peninsula. It lies between 120° and 17°N Latitude and 43° and 56°E Longitude. The country has rugged surface features composed of mountains, hills, plateaus, plains, valleys, and gorges. The varied topographic features and the variable climatic conditions of the country are among the major factors that resulted in diversified crop genetic resources in particular and vegetation and flora types in general (Shahin, 2007). Nearly two decades ago, many internationally known scientists and plant collectors have recognized Yemen as one of the important regions of Asia in particular and worldwide in general. The utilization of various sources of water is necessary for Yemen due to the increasing population and the consequent need for agricultural expansion. The main problem to be considered in using different sources of water is the salinity hazards. Soil salinity is being progressively exacerbated by agronomic practices such as irrigation and fertilization, especially in arid regions. The effect of salinity on plant growth may be more related to the $Na^+/K^+$ ratio of the plant tissue than to absolute $Na^+$ concentrations. Thus, the cultivars which can minimize this ratio may be more salt-tolerant than those with lower $K^+$ concentration (Benzyl and Reuveni, 1994; Lingle *et al.,* 2000).

Soil salinity and solidity are global problems that are common in different parts of the world. It affects more than 10 percent of arable land especially in West and South Asia and North Africa. The use of diversified crops, nonconventional water resources, and rehabilitation of marginal lands are alternate options to produce more food to face climate change projections (Hussain *et al.,* 2020). Bray et al. (2000) reported that salinization is fast growing on a global scale, decreasing average yield for most important crops by more than 50%. Currently, saline soils occur in at least 100 countries (Qadir *et al.,* 2006) in total covering 932.2 Mha (Rengasamy, 2006) with hotspots in Pakistan, China, United States, India, Argentina, Sudan, and many countries in Central and Western Asia (FAO, 2020; Ghassemi *et al.,* 1995) as well as in the Mediterranean coastline (Wichelns and Qadir, 2014).

Salinity is a severe problem, which not only reduces the agricultural potential but also creates serious effects on the livelihood of farmers (Haider and Hossain, 2013). Higher germination percentage is the key factor in higher crop production (Nadeem *et al.,* 2017). Securing and augmenting agricultural yield in times of global warming and population increase is urgent and should, aside from ameliorating saline soils, include attempts to increase crop plant salt tolerance (Zörb *et al.,* 2019). Several physical, chemical, and biological soil management measures help to facilitate the safe use of saline water in crop production. The benefits anticipated from soil management practices to facilitate the safe use of saline water for irrigation will not be realized unless adequate supply of plant nutrients as fertilizers. Saline water irrigation containing phosphorus and potassium is essential for optimum crop productivity. Therefore, investigating the fertilizer management to maximize crop production under existing salinity is of greater importance. Application of Potassium improved growth and yield under water stress possibly by regulating photosynthesis (Gupta *et al.,* 1989). Proline accumulation is fast and is thought to function in salt stress adaptation (Berteli *et al.,* 1995), through the protection of plant tissue against osmotic stress and/or acting as enzyme protector (Solomon *et al.,* 1994; Liu and Zhu, 1997).

The barley plant is considered one of the most important cereal crops in Yemen. It is quite important and considered as a moderate salt-tolerant plant crop in arid regions, poor and saline soils (Liu and Zhu, 1997, Saied *et al.,* 1996). Corn is the world's third most important crop after wheat and rice, about half of this is grown in developing countries, where corn flour is a staple food for poor people and corn stalks provide dry season food for farm animals (Al-

Jobory *et al.,* 2017). This study was conducted to determine the possibility of compensating the negative effect of irrigation water salinity by foliar application to the plants with proline, potassium nitrate fertilization, and leaching fraction application, on both the growth and chemical composition of corn and barley plants and the salt accumulation in soil (figure 1). The objective of this study was to investigate the possibility of the plantation of barley and corn plants in salinity soil area without and with foliar applications irrigated with seawater in the Republic of Yemen.

**(a)** **(b)**

**Fig. 1.** Corn (a) and Barley (b) seeds.

## MATERIALS AND METHODS

### Collection of Samples

Seeds of both barley and corn plants were kindly provided by the Yemen Ministry of Agriculture. Four kilograms of saline soil (without foliar application and with foliar application), Passed through a 2 mm filter, packed in plastic pots with a height 35 cm and diameter 15 cm with a hole in its bottom for drainage.

### Experimental Layout and Measurements

The soil in each pot was irrigated with seawater before planting the seeds of corn and barley to achieve a suitable seeding medium. The plant shoots were collected after 60 days from planting, washed with tap water then by distilled water, dried in an oven at 65$^o$C for 48 hours and the dry weights were recorded. Sub-samples of plants were ground using stainless steel mill. The oven-dried plant material was wet digested and the concentrations of Na, K was determined (Jalilian *et al.,* 2014). Besides, the concentrations of Cl and $NO_3$ were determined according to the methods outlined by Chapman and Pratt (1961) and Cataldo et al. (1975). The proline content in plant leaves was determined according to the method of (Bates *et al.,* 1973). After plant harvest, soil samples were collected from each pot and their salinity was determined (Black, (ed) 1965).

### Statistical Analysis

The results were analyzed using the SAS Statistical software 9.2.

## RESULTS AND DISCUSSION

The main chemicals and physical characteristics of the soil were determined and the obtained data are presented in Table 1.

**Table 1.** The main chemical and physical characteristics of the used soil.

| Soil properties | Value | Soil properties | Value |
|---|---|---|---|
| pH | 8.31 | **Particle size distribution** | |
| EC** (dS/m) | 2.55 | Sand (%) | 64.1 |
| Total CaCO3 (%) | 31 | Silt (%) | 15.5 |
| O.C. (%) | 0.32 | Clay (%) | 21.2 |
| Field capacity (%) | 17.0 | Soil texture | Sandy Clay Loam |

The first one (S1) was with seawater of 3.36 dS/m and the other two (S2, and S3) were 5.88 and 7.95 dS/m respectively. The main chemical compositions of seawater are given in Table 2.

**Table 2.** Chemical composition of the irrigation waters.

| Water quality | pH | $EC_w$ dS/m | Cations, meq/ L | | | | Anions, meq/L | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Ca+2 | Mg+2 | Na+ | K+ | Cl- | $SO_4^{-2}$ | $HCO_3$ |
| S1 | 7.94 | 3.36 | 2.09 | 4.52 | 22.89 | 0.39 | 26.12 | 6.09 | 12.58 |
| S2 | 7.84 | 5.88 | 4.44 | 8.34 | 39.11 | 0.73 | 44.42 | 11.22 | 0.31 |
| S3 | 7.72 | 7.95 | 6.87 | 11.8 | 51.99 | 0.84 | 56.99 | 16.75 | 0.43 |

**$EC_w$=Electrical conductivity**

In this study, two experiments were carried out. The first one included the leaching fraction application. The desired leaching fraction was added to the amount of water required to keep the soil moisture content at field capacity. The second experiment was carried out without applying the leaching fraction.

Table 3 showed that the corn and barley shoots of plant dry weight was markedly decreased from 6.31 and 6.22 g/pot with water salinity of 3.36 and 5.88 dS/m to 4.82 and 4.77 g/pot, respectively. However, with increasing water salinity to 7.95 dS/m, there was a significant decrease in plant dry weights with or without leaching treatment. In this concern, it is also clear that the dry weight of corn and barley plants had decreased significantly from 5.02 g/pot to 2.36 g/pot with increasing water salinity from 3.36 to 7.95 dS/m without leaching fraction treatment. These results clearly showed that applying leaching fraction at any salinity level had decreased the harmful effect of salinity of irrigation water especially at water salinity of 3.36 dS/m. It is also clear that the harmful effect of salinity was greater without leaching the treatment. This is due to the accumulation of salts in the root zone, which did not occur using the leaching fraction (Gendy and Hammad, 1993; Nessim *et al.,* 2008; Abou Hussien *et al.,* 1994), have also reported similar results.

**Table 3.** Effect of irrigation water salinity, Potassium nitrate, and proline on the mean dry weight of corn and barley plants grown in soil with or without leaching.

| Treatment | with leaching | without leaching | with leaching | without leaching |
|---|---|---|---|---|
| | Dry weight (g/pot) Corn | | Dry weight (g/pot) Barley | |
| The salinity of irrigation water (S), dS/m | | | | |
| 3.36 | 6.23 | 5.01 | 6.22 | 5.02 |
| 5.88 | 4.82 | 4.01 | 4.77 | 3.95 |
| 7.95 | 3.02 | 2.34 | 3.09 | 2.36 |
| L.S.D $_{0.05}$ | 0.21 | 0.13 | 0.26 | 0.11 |
| Potassium nitrate (K), g/pot | | | | |
| 0 | 5.0 | 4.12 | 4.99 | 4.10 |
| 4 | 5.13 | 4.39 | 5.12 | 4.36 |
| 8 | 5.29 | 4.59 | 5.29 | 4.58 |
| L.S.D 0.05 | 0.04 | 0.09 | .003 | .09 |
| Proline (P), mg/L | | | | |
| 0 | 5.10 | 4.27 | 5.10 | 4.26 |
| 100 | 5.19 | 4.39 | 5.16 | 4.35 |
| 200 | 5.21 | 4.50 | 5.21 | 4.42 |
| L.S.D 0.05 | 0.05 | .0.03 | 0.04 | 0.03 |

Table 3 indicated a significant increase in the dry weight of corn and barley plants, with or without leaching treatment by the application of potassium nitrate fertilizer up to 8 g /pot. The relative increases in plant dry weights with potassium nitrate applications indicate the beneficial effect of applying potassium nitrate fertilizer for decreasing the harmful effect of salinity on plant growth. This is evident for plants grown without leaching treatment than with leaching treatment.

Similar results were found by (Badr and Shafei, 2002), who reported that increasing the $K^+$ application could be useful to overcome the adverse effect of salinity (NaCl) on the growth of the wheat plant. It can be stated that the ability of plants to retain $K^+$ at high $Na^+$ concentration, of the external solution, may be involved in reducing the damage associated with excessive Na+ concentration in plant tissue. Besides, the presence of N in the form of $KNO_3$ at this saline condition had improved the growth of corn and barley plants. Table (3) revealed that the foliar application of proline increased significantly the dry weight of plant shoots, with or without leaching treatment. This showed that foliar application of proline at (200 mg/L) significantly decreased the harmful effects of salinity with or without leaching treatment.

**Chemical Composition of Corn and Barely Plants**

The sodium concentration in the shoot of corn and barely plants increased significantly from 0.61 and 0.59 % with irrigation of 3.36 dS/m to 1.02 and 0.98% with irrigation of 7.95 dS/m respectively, with or without leaching treatment (Table 4). On the other hand, $K^+$ concentration in plant shoot (corn and barley) decreased from 3.21 and 3.1 % to 1.62 and 2.22%, with the same treatment respectively. These results are associated with increasing Na/K ratio in the plant from 0.12 and 0.15 to 0.53 and 0.54, respectively. Santos et al. (1999) obtained similar results that salinity decreased $K^+$ content in plants. On the other hand, applying $KNO_3$ fertilizer significantly decreased $Na^+$ and significantly increased $K^+$ concentrations in the shoot of corn and barely plant, with or without leaching treatment. This increase of $K^+$ content had improved the Na – K balance in plant tissue, which facilities plant growth as indicated in Table 3. Foliar application of proline decreased the concentration of $Na^+$ in plant shoot. At the same time, $K^+$ contents in the shoot were increased. Similar results were obtained by (Shaddad, 1990), with *Raphanus sativus* grown under salinity stress. Irrigation with 7.95 dS/m saline water produced the highest Na/K ratio with or without leaching (0.53, 0.54 and 0.73, 0.76 respectively). Similar results found by Badr and Shafei (2002) confirmed that decreasing the value of the Na/K ratio may be involved in reducing the damage associated with excessive $Na^+$ levels in the plant. It is clear from Table 4 that the Na/K ratio, with or without leaching, was decreased significantly with increasing $KNO_3$ fertilization. This relation was associated with increasing the dry weight of the plant shoot. This points out the beneficial effect of $K^+$ to overcome the adverse effects of salinity. The occurrence of high $K^+$ in the plant had involved in reducing the damage caused by high $Na^+$ concentration. Results showed that foliar application of proline decreased the Na/K ratio in plant shoot with or without leaching and this ratio was higher in plant grown without leaching than with leaching treatment (Table 4).

The increasing salinity of irrigation water significantly increased $Cl^-$ content and decreased $NO^-_3$ contents in the shoot of corn and barley plants (Table 5). This decrease in $NO^-_3$ content can be attributed to $Cl^-$ competition with $NO^-_3$ for binding sites on the plasma membrane, which suppressed the influx of $NO^-_3$ from the external solution (Al-Uqaili, 2003). The ratio of $Cl^-/NO^-_3$ in plant tissue increased with increasing salinity of irrigation water and was higher with leaching than without leaching treatment. This is due to the low level of $NO^-_3$ in plant tissue, with leaching treatment as compared without leaching. At the same time, proline contents in shoots significantly increased with increasing irrigation water salinity and were higher in plants grown without leaching than with leaching treatment (Table 5). There were positive relations between proline contents in plant tissue and both $Cl^-$ contents and $Cl^-/NO^-_3$ ratio. It is also clear from Table (5) that chloride content decreased significantly with increasing $KNO_3$ application while $NO^-_3$ content increased significantly with or without leaching. Foliar application of corn and barley plants with proline significantly decreased $Cl^-$ contents and increased $NO^-_3$ contents in the shoot with or without leaching treatment (Table 5). This could be due to the role of proline in minimizing the adverse effect of salinity which is associated with the decrease of both $Na^+$ (Table 4) and $Cl^-$ content (Table 5) and increase of both $K^+$ (Table 4) and $NO^-_3$ content (Table 5) in shoots.

**Table 4.** Effect of irrigation water salinity and potassium nitrate and proline with or without leaching, on the mean value of Na, K concentrations (%), and Na/K ratio in the shoot of corn and barley plants.

| Treatment | with leaching | | | without leaching | | | with leaching | | | without leaching | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $Na^+$ | $K^+$ | Na/K | $Na^+$ | $K^+$ | Na/K | $Na^+$ | $K^+$ | Na/K | $Na^+$ | $K^+$ | Na/K |
| | Corn | | | | | | Barley | | | | | |
| The salinity of irrigation water (S), dS/m | | | | | | | | | | | | |
| 3.36 | 0.61 | 3.21 | 0.12 | 0.80 | 3.04 | 0.25 | 0.59 | 3.1 | 0.15 | 0.80 | 3.12 | 0.25 |
| 5.88 | 0.83 | 2.19 | 0.35 | 1.04 | 2.09 | 0.49 | 0.76 | 2.63 | 0.34 | 1.02 | 2.08 | 0.49 |
| 7.95 | 1.02 | 1.62 | 0.53 | 1.29 | 1.69 | 0.75 | 0.98 | 2.22 | 0.54 | 1.27 | 1.67 | 0.76 |
| L.S.D $_{0.05}$ | 0.03 | 0.21 | 0.01 | 0.049 | 0. 4 | 0.01 | 0.029 | 0.22 | 0.01 | 0.05 | 0.39 | 0.01 |
| Potassium nitrate (K), g/pot | | | | | | | | | | | | |
| 0 | 0.79 | 2.13 | 0.34 | 1.01 | 2.21 | 0.50 | 0.80 | 2.31 | 0.35 | 1.0 | 2.23 | 0.50 |
| 4 | 0.70 | 3.02 | 0.30 | 0.89 | 2.71 | 0.39 | 0.71 | 2.97 | 0.27 | 0.9 | 2.88 | 0.39 |
| 8 | 0.61 | 3.57 | 0.211.0 | 0.81 | 3.17 | 0.30 | 0.62 | 3.51 | 0.20 | 0.8 | 3.31 | 0.30 |
| L.S.D $_{0.05}$ | 0.03 | 0.14 | 0.01 | 0.04 | 0.39 | 0.01 | 0.03 | 0.13 | 0.01 | 0.03 | 0.44 | 0.01 |
| Proline (P), mg/L | | | | | | | | | | | | |
| 0 | 0.74 | 2.93 | 0.32 | 0.94 | 2.74 | 0.72 | 2.89 | 0.31 | 0.94 | 2.72 | 0.42 | 0.41 |
| 100 | 0.72 | 3.01 | 0.30 | 0.91 | 2.77 | 0.69 | 2.99 | 0.29 | 0.91 | 2.84 | 0.39 | 0.38 |
| 200 | 0.70 | 3.09 | 0.31 | 0.89 | 2.87 | 0.66 | 3.03 | 0.28 | 0.88 | 2.90 | 0.37 | 0.36 |
| L.S.D $_{0.05}$ | 0.02 | 0.11 | 0.01 | 0.02 | .0.14 | 0.01 | 0.01 | 0.15 | 0.01 | 0.02 | 0.13 | 0.01 |

This effect was more pronounced with leaching than without leaching treatment. On the other hand, the proline foliar application significantly increased $NO^-_3$ contents in shoots and consequently decreased the $Cl^-/NO^-_3$ ratio in both corn and barley. Table (5) showed that proline content in plants significantly increased with increasing salinity of irrigation water and significantly decreased with increasing potassium nitrate, with or without leaching (Table 5). Proline plays an adaptive role in the tolerance of plant cells to salinity by increasing the concentration of osmotic active components to equalize the osmotic potential of the cytoplasm. Arshi et al. (2005), also found that proline accumulation in the leaves of plants grown on salt-affected soil was 8 times higher than in the control.

Increasing levels of foliar application with proline significantly increased proline contents in the shoot of corn and barley plants. It can be pointed out that exogenous proline application might counteract the negative effects of high salinity on carbohydrate and nitrogen metabolism, which consequently could promote the whole plant growth.

### Soil Salinity

The salinity of soil increased significantly with increasing salinity of irrigation water, with or without leaching (Table 6). This is due to the accumulation of salt in the soil from the water of irrigation (Hussan, 1981). Similar results were obtained by Tomar and Yadov (1992), who found significant increases in soil EC when the soil was irrigated with highly saline water. Besides, EC values in soil were increased significantly with increasing application of $KNO_3$ fertilizer, with or without leaching (Table 6). Table 6 showed significant interaction effects between irrigation water salinity and potassium nitrate on the EC of soil, with or without leaching. It is clear, that the leaching fraction was effective in reducing the accumulation of salts in the soil.

**Table 5.** Effect of irrigation water salinity, potassium nitrate, and proline on $Cl^-$, $NO^-_3$ contents, $Cl/NO_3$ ratio, and proline contents of corn and barley plants with or without leaching.

| Treatment | with leaching | | | With Proline | without leaching | | | with leaching | | | Without Proline | without leaching | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $Cl^-$ | $NO^-_3$ | $Cl/NO_3$ | | $Cl^-$ | $NO^-_3$ | $Cl/NO_3$ | $Cl^-$ | $NO^-_3$ | $Cl/NO_3$ | | $Cl^-$ | $NO^-_3$ | $Cl/NO_3$ |
| | Corn | | | | | | | Barley | | | | | | |
| | (mg $g^{-1}$) | | | | | | | | | | | | | |
| the salinity of irrigation water (S), dS/m | | | | | | | | | | | | | | |
| 3.36 | 13.66 | 1.29 | 10.74 | 1.40 | 15.56 | 1.99 | 8.40 | 13.55 | 1.32 | 10.48 | 1.94 | 15.31 | 2.00 | 8.20 |
| 5.88 | 16.45 | 0.91 | 19.81 | 1.81 | 19.11 | 1.64 | 11.74 | 16.28 | 0.87 | 19.51 | 2.18 | 18.90 | 1.75 | 11.36 |
| 7.95 | 19.47 | 0.64 | 39.73 | 1.77 | 22.59 | 1.18 | 19.43 | 19.36 | 0.61 | 39.40 | 2.33 | 22.37 | 1.17 | 19.12 |
| L.S.D $_{0.05}$ | 0.50 | 0.01 | 0.14 | 0.049 | 2.76 | 0.03 | 0.17 | 0.50 | 0.01 | 0.01 | 0.03 | 0.52 | 0.01 | 0.16 |
| Potassium nitrate (K), g/pot | | | | | | | | | | | | | | |
| 0 | 14.32 | 0.71 | 28.8 | 1.57 | 16.79 | 1.11 | 15.00 | 14.10 | 0.70 | 29.34 | 2.34 | 16.44 | 1.20 | 15.00 |
| 4 | 13.22 | 1.01 | 15.32 | 1.31 | 15.49 | 2.01 | 9.34 | 13.32 | 1.00 | 15.51 | 1.96 | 15.32 | 1.99 | 9.39 |
| 8 | 12.12 | 1.49 | 9.43 | 1.49 | 14.09 | 2.79 | 7.09 | 12.00 | 1.48 | 9.54 | 2.01 | 14.00 | 2.00 | 7.15 |
| L.S.D $_{0.05}$ | 0.14 | 0.01 | 0.07 | | 1.49 | 0.04 | 0.09 | 0.12 | 0.01 | 0.07 | 0.03 | 1.44 | 0.44 | 0.09 |
| Proline (P), mg/L | | | | | | | | | | | | | | |
| 0 | 13.56 | 1.00 | 20.76 | 0.92 | 16.00 | 1.89 | 11.31 | 15.99 | 1.86 | 10.99 | 1.41 | 15.77 | 1.79 | 11.00 |
| 100 | 13.32 | 1.10 | 18.10 | 1.54 | 15.51 | 2.02 | 10.49 | 15.44 | 1.87 | 10.23 | 2.20 | 15.53 | 1.99 | 10.44 |
| 200 | 13.02 | 1.09 | 16.22 | 1.87 | 15.16 | 2.10 | 9.68 | 15.14 | 2.09 | 9.55 | 2.48 | 15.21 | 2.03 | 9.55 |
| L.S.D $_{0.05}$ | 0.03 | 0.01 | 0.03 | 0.01 | 0.70 | 0.03 | 0.08 | 0.69 | 0.03 | 0.077 | 0.03 | 0.70 | 0.03 | 0.088 |

**Table 6.** Effect of irrigation water salinity, potassium nitrate, and proline with or without leaching, on the *EC (dS/m) of soil, collected after harvesting of corn and barley plants.

| Treatment | with leaching | without leaching | with leaching | without leaching |
|---|---|---|---|---|
| | Corn | | Barley | |
| The salinity of irrigation water (S), dS/m | | | | |
| 3.36 | 1.26 | 1.78 | 1.24 | 1.79 |
| 5.88 | 4.39 | 5.21 | 4.41 | 5.29 |
| 7.95 | 6.19 | 8.52 | 6.24 | 8.63 |
| L.S.D $_{0.05}$ | 0.42 | 0.42 | 0.45 | 0.45 |
| Potassium nitrate (K), g/pot | | | | |
| 0 | 2.09 | 2.48 | 2.12 | 2.00 |
| 4 | 3.29 | 4.10 | 3.22 | 3.11 |
| 8 | 4.47 | 5.89 | 4.54 | 4.48 |
| L.S.D $_{0.05}$ | 0.26 | 0.29 | 0.26 | 0.29 |
| Proline (P), mg/L | | | | |
| 0 | 3.29 | 4.25 | 3.30 | 4.26 |
| 100 | 3.15 | 4.22 | 3.26 | 4.21 |
| 200 | 3.04 | 4.20 | 3.21 | 4.19 |
| L.S.D $_{0.05}$ | 0.18 | 0.22 | 0.18 | 0.22 |

## CONCLUSION

The present study confirms the potential of foliar application with proline, soil application with potassium nitrate, and leaching fraction treatment for improving the growth of corn and barley under irrigation with saline water, especially at water salinity of 3.36 dS/m, which is less than the marginal value (3.6 dS/m) for corn and barley production. Besides, potassium nitrate fertilizer as a source for K and N had more adverse effects, due to salinity, on both plant and soil.

## ACKNOWLEDGMENT

The authors wish to express their gratitude to American Institute for Yemeni Studies (AIYS) for supporting scientific research and thanks to the Faculty of Science Department of Chemistry, the University of Sana'a for facilitating work in the labs.

## CONFLICT OF INTEREST

There is no conflict of interest.

## REFERENCES

Abou Hussien, E.A., El-Shafei, F.S., Rizk, N.S., 1994. Effect of salinity and root-knot nematode on growth and nutrients uptake by broad bean plant. Minufiya J. Agric. Res., 19: 3375-3396.

Al-Jobory, H.J., Mahmoud, A.L.E., Al-Mahdi, A.Y., 2017. Natural Occurrence of *Fusarium* Mycotoxins (Fumonisins, Zearalenone and T-2 toxin) in Corn for Human Consumption in Yemen. PSM Microbiol., 2(2): 41-46.

Al-Uqaili, J.K., 2003. Potential of using drainage water for wheat production in Iraq. Emirates-J. Agric. Sci., 15: 36-43.

Arshi, A., Abdin M.Z., Iqbal, M., 2005. Ameliorative effects of $CaCl_2$ on growth, ionic relations and proline content of Senna under salinity stress. J. Plant Nutr., 28: 101-125.

Badr, M.A., Shafei, A.M., 2002. Salt tolerance in two wheat varieties and its relation to potassium nutrition. J. Agric. Res., 35: 115-128.

Bates, L.R., Waldren, R.P., Teare, I., 1973. Rapid determination of free proline for water stress studies. Plant and Soil., 39: 205-207.

Benzyl, M.L., Reuveni, M., 1994. Cellular mechanisms of salt tolerance in plant cells. Hort. Rev., 16: 33-69.

Berteli, F., Corrales, E., Guerrero, C., Ariza, M., Pilego, F., Valpuesta, V., 1995. Salt stress increases ferrodoxin-dependent glutamate synthase activity and protein level in the leaves of tomato. Physiologia Plantarum., 93: 259-264.

Black, C.A., (ed) 1965. Methods of Soils Analysis. Parts 1 and 2. Am. Soc. Agron. Madison, Wisconson USA.

Bray, E.A., Bailey-Serres, Weretilnyk, E., 2000. Responses to abiotic stress. In: Buchanan B, Gruissem W and Jones R (eds.), Biochemistry and Molecular Biology of Plants. American Society of Plant Physiology, Rockville, pp: 1158-1203.

Cataldo, D.A., Maroon, M., Schrader, L.E., Youngs, V.L., 1975. Rapid colorimetric determination of nitrate and nitrite in plant tissue by nitration of salicylic acid. Commun. Soil Sci. Plant Anal., 6: 71-80.

Chapman, H.D., Pratt, P.F., 1978. Methods of Analysis for Soils, Plants and Waters. University of California, Division of Agricultural Sciences.

FAO, 2020. AQUASTAT - FAO's Global Information System on Water and Agriculture.http://www.fao.org/nr/water/aquastat (accessed on 1 June 2020).

Gendy, A.A., Hammad, A.A., 1993. The response of soybean to different levels of salinity. Zagazig J. Agric. Res., 20(6): 1751-1768.

Ghassemi, F., Jakeman, A.J., Nix, H.A., 1995. Salinisation of Land and Water Resources: Human Causes, Extent, Management and Case Studies; CAB International: Wallingford, UK.

Gupta, A.S., Borkowitz, G.A., Pier, P.A., 1989. Maintenance of photosynthesis at low leaf water potential in wheat role of potassium status and irrigation history. Plant Physiol., 89: 1358- 1365.

Haider, Z.M., Hossain, Z.M., 2013. Impact of salinity on livelihood strategies of farmers. J. Soil Sci. Plant Nutr., 13: 417-431.

Hussan, Z., 1981. Using highly saline irrigation water for feeder barley crop. J. Agric. Sci., UK., 96: 515-520.

Hussain, M.I., Farooq, M., Muscolo, A., Rehman, A., 2020. Crop diversification and saline water irrigation as potential strategies to save freshwater resources and reclamation of marginal soils—a review. Environ. Sci. Pollut. Res. Int., 27(23): 28695-28729.

Jalilian, J., Razieh, K., Edris, K., 2014. Improving of Barley Seedling Growth by Seed Priming Under Water Deficit Stress. J. Stress Physiol. Biochem., 10(2): 125-134.

Lingle, S.E., Wiedenfeld, R.P., Irvine, J.E., 2000. Sugarcane response to saline irrigation water. J. Plant Nutr., 23(4): 469-486.

Liu, J., Zhu, J.K., 1997. Proline accumulation and salt-stress-induced gene expression in a salt hypersensitive mutant of Arabidopsis. Plant Physiol., 114: 591-596.

Nadeem, M.K., Qaswar, M., Ahmed, N., Rabnawaz, Rasool, S.J., 2017. Effect of Seed Soaking Time on Germination of Maize (*Zea mays* L.). PSM Biol. Res., 02(1): 46-50.

Nessim, M.G., Hussein, M.A., Moussa, A.A., 2008. The effects of irrigation water salinity, Potassium Nitrate Fertilization, Proline spraying and leaching fraction on the growth and chemical composition of corn grown in calcareous soil. Int. Meeting on Soil Fertility Land Manag. Agroclimatol. Turkey. p: 787-803.

Qadir, M., Noble, A.D., Schubert, S., Thomas, R.J., Arslan, A., 2006. Sodicity-induced land degradation and its sustainable management: Problems and prospects. Land Degrad. Dev., 17: 661–676.

Rengasamy, P., 2006. World salinization with emphasis on Australia. J. Exp. Bot., 57(5): 1017-1023.

Saied, M.M., El-Yamani, M.S., Ghazy, M.A., Amer, A.A., 1996. Influence of different irrigation regimes on barley yield and irrigation efficiencies in salt affected soil. J. Agric. Su. Mansoura Univ., 21: 2727.

Santos, C.V., Caldeira, dos-Santos, C.L.V., 1999. Comparative responses of *Helianthus annuus* plants and Calli exposed to NaCl. I. Growth rate and osmotic regulation in intact plants and Calli. J. Plant Physiol., 155: 769-777.

Shahin, M., 2007. Water Resources and Hydrometeorology of the Arab Region. Water Science and Technology Library.

Shaddad, M.A., 1990. The effect of proline application on the physiology of *Raphanus* *sativus* plants grown under salinity stress. Biol. Plant., 32: 104-112.

Solomon, A., Beer, S., Waisel, Y., Jones, G.P., Paleg, L.G., 1994. Effects of NaCl on the carboxylating activity of Rubisco from *Tamarix jordanis* in the presence and absence of proline-related compatible solutes. Physiol. Plant., 90(1): 198-204.

Tomar, O.S., Yadov, S.P., 1992. Effect of irrigation with saline and sodic waters on the growth of Alibzia lebbeck and soil properties. Indian J. For., 5: 292-297.

Wichelns, D., Qadir, M., 2014. Achieving sustainable irrigation requires elective management of salts, soil salinity, and shallow groundwater. Agric. Water Manag., 157: 31–38.

Zörb, C., Geilfus, C.M., Dietz, K.J., 2019. Salinity and crop yield. Plant Biol., 21(S1): 31-38.