

Sorghum [*Sorghum bicolor* (L.) Moench.] growth, and soil moisture and salt content as affected by irrigation water salinity

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Abstract

Information on the impact of salinity of irrigation water on soil moisture and salt content is scant in the literature. Therefore, in the present study, growth of sorghum as well as soil moisture and salt content were investigated as affected by irrigation water salinity. In this experiment, the effect of three salinity levels of irrigation water, i.e., 2, 7, and 14 dS m⁻¹ was monitored on sorghum growth, and changes in soil moisture and salinity of soil saturated extract during the growing season. Irrigation water salinity, depending on the intensity of stress, reduced forage yield, so that 7 and 14 dS m⁻¹ salinity decreased the fresh weight by 11% and 45% and the dry weight by 17% and 62%, respectively, compared to those in non-saline conditions. At two soil depths (0-30 cm and 30-60 cm), the lowest moisture content was observed under non-saline conditions and the highest at 14 dS m⁻¹. The salinity of soil saturated extract was also increased with increasing salinity of irrigation water. By applying salinities of 2 and 14 dS m⁻¹, soil salinity decreased and increased by the end of the growing season, respectively. However, soil salinity in 7 dS m⁻¹ treatment was decreased first and then increased until the end of the growing season. At the end of the growing season, the average soil salinity in 7 and 14 dS m⁻¹ treatments was 1.8 and 1.4 times, respectively, higher than that of the irrigation water salinity. In a nutshell, high moisture content in saline soils may help sustain the growth of halophytes to some extent.

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Introduction

Of several stressful environments known in nature, soil salinity causes considerable loss of crop productivity world over (Pirasteh-Anosheh et al., 2017a). Both primary and secondary salinities occur widely on the globe transforming the cultivable lands into derelict ones. Although irrigated lands are less prone to salinity stress compared with non-irrigated lands, about 20% of the irrigated areas of China, Pakistan, India, Iran and Iraq has been appraised to be salt-affected (Cherlet et al., 2018).

Iran is considered as an arid and semi-arid region in terms of climate. One of the characteristics of these areas is high evaporation, and low and scattered rainfall, which ultimately lead to the accumulation of various salts in the surface layer and profile of most of the country's soils. This trend has been exacerbated by improper irrigation management (Cheraghi and Rasouli, 2009; Pirasteh-Anosheh et al., 2017b). The total area of irrigated lands in Iran is 7.3 million ha and the total area of agricultural lands with different degrees of soil salinity and water or both is estimated at 3.5 million ha. It is also estimated that there is about 1.73 billion cubic meters of saline groundwater resources with a salt content of more than 5000 mg L⁻¹ (equal to almost 7 dS m⁻¹) in important river basins of the country (Ranjbar and Pirasteh-Anosheh, 2015; Ranjbar et al., 2018).

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Although salinity of irrigation water has a direct effect on soil salinity and moisture, a few studies have compared the effect of irrigation with non-saline and saline waters on soil properties, especially soil moisture and salinity. Soil salinity in irrigation with saline water significantly increases, while it decreases with increasing soil depth (Alihour et al., 2015). In one study, it was found that with increasing electrical conductivity of irrigation water (EC_{iw}), more moisture remained in the soil, and also the electrical conductivity of soil saturation extract (EC_e) increased significantly. The amount of water consumed by the plants in control plots was greater than those in saline plots (Pirasteh-Anosheh et al., 2017b).

Although the effect of salinity stress on the performance of sorghum as a plant tolerant to salinity has been well studied, changes in soil and water salinity during the growing season of sorghum under the influence of EC_{iw} have received less attention. Sorghum and other plants, on the other hand, respond more to the EC_e rather than to EC_{iw} . Therefore, the aim of this study was to investigate the changes occurring in soil moisture and salinity during the growing season of sorghum under the influence of irrigation with different salinity levels.

Materials and Methods

The present study was conducted on a sorghum farm at the National Salinity Research Center (NSRC) in Yazd Province, Iran during 2016. The treatments were three levels of electrical conductivity of irrigation water (EC_{iw}): 2, 7, and 14 $dS\ m^{-1}$, that were arranged in a randomized complete block design (RCBD) with three replications. The results of physicochemical analysis and contents of cations and anions of soil are given in **Tables 1** and **2**.

Table 1. Physico-chemical properties of field soil before initial leaching

EC	Texture	FC	PWP	pH	K	P	OC
($dS\ m^{-1}$)		(%)	(%)		$mg\ kg^{-1}$		(%)
12.4	Sandy loam	23.5	8.1	7.82	216.1	11.4	0.57

EC: Electrical conductivity, FC: Field capacity, PWP: Permanent wilting point, K: Potassium, P: Phosphorus, OC: Organic matter

Table 2. Amounts of cations and anions of field soil before initial leaching

Cl^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	CO_3^{2-}	HCO_3^-
68.0	20.1	18.8	48.7	0.73	2.67	1.86

Units: $meq\ L^{-1}$

Plowing was done using a garden tractor and the experimental plots were prepared after land leveling. Uniform seeds of sorghum [*Sorghum bicolor* (L.) Moench.] were planted with a distance between rows of 50 cm and a row spacing of 10 cm. Each plot included six 4-meter rows. Sowing was done manually in the month of May. A relatively newly released forage sorghum cultivar, Pegah, was used in this experiment. Pegah is a high yielding forage cultivar with one time cutting, which has high content of protein and acceptable content of sugars (Fouman et al., 2008).

Before planting, the whole field was irrigated twice with fresh water to salt leaching. Saline water treatments were prepared by mixing water from two natural wells with EC of 2 and 16 $dS\ m^{-1}$ in two separate pools. The desired EC_{iw} levels were made in a control room and then entered the plots with a piping system. The distance of each irrigation was done according to the custom of the region as 100% field capacity (FC) plus 25% of the leaching fraction. For this purpose, soil sampling was performed before each irrigation and the amount of water needed to reach the FC was calculated. Salinity treatments were applied after plant establishment.

At the flowering stage, sampling was done for fresh and dry weights. This time was considered to achieve the best quality of sorghum forage (Atis et al., 2012; Hedayati-Firoozabadi et al., 2020). For this purpose, one square meter was taken from each plot, and weighed immediately. The initial weight was considered as fresh weight. The samples were stored in an oven at $70 \pm 3\ ^\circ C$ for 48 h, after which dry weight was measured. Field soil sampling was performed at pre-planting time, planting time, 24, 48, 72 and 96 days after planting and soil salinity and moisture were determined at two depths of 0 to 30 and 30 to 60 cm. After normality testing with Minitab Statistical Software, the means of fresh and dry weights, as well as, soil salinity and moisture were compared based on standard error ($\pm SE$) estimation.

Results and Discussion

Sorghum forage yield was significantly affected by salinity level (**Figure 1**), and more losses in fresh and dry weights were observed as EC_{iw} increased. Salinity stresses of 7 and 14 $dS\ m^{-1}$ were associated

with 11% and 45% reduction in fresh weight (**Figure 1a**) and 17% and 62% in dry weight (**Figure 1b**), respectively. It is now evident that salinity not only reduces the total photosynthetic capacity of plants by reducing the number and area of leaves, but it also reduces the synthesis of assimilates for plant growth by reducing the chlorophyll amount in the leaves, resulting in a decrease in plant biomass (Taiz et al., 2015). Another reason for the loss of biomass can be due to the metabolic energy related to adaptation to stress conditions, reduction of photosynthesis rate of leaf, reduced carbon uptake, tissue damage, and reaching the maximum salt concentration that the plant can tolerate (Pirasteh-Anosheh et al., 2016).

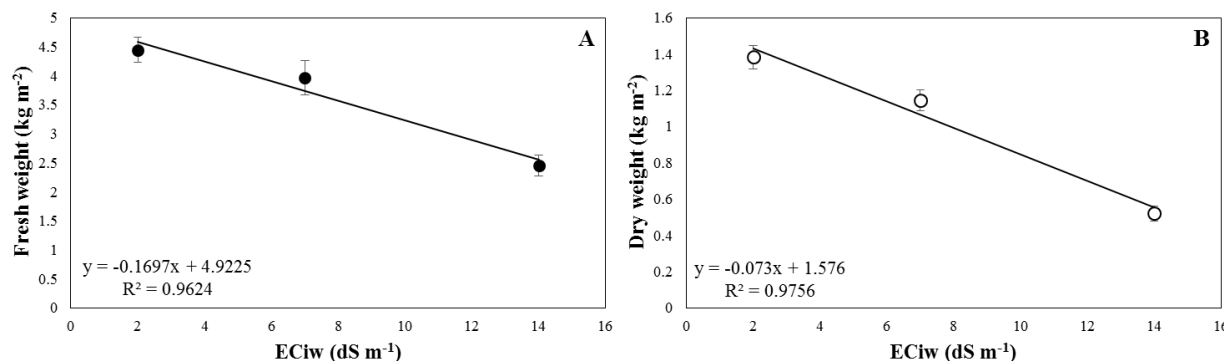


Figure 1. The effect of electrical conductivity of irrigation water (EC_{iw}) on fresh weight (A) and dry weight (B) of sorghum. The means with similar overlaps are not significantly different based on standard error ($\pm SE$).

The results showed that a significant difference was observed between the soil moisture content of different EC_{iw} treatments during the growing season, except before planting (**Figure 2**). At both depths, the lowest moisture content was observed in non-saline treatment and the highest in 14 dS m⁻¹ treatment. The probable reasons for higher soil moisture content in saline plots could have been less plant growth, less evapotranspiration, and also destruction of soil structure in these plots. Under saline conditions, the plant grows less and therefore has less transpiration and uses less water (Pirasteh-Anosheh et al., 2017a,b).

In the present study, it was found that the average soil moisture content during the growing season in EC_{iw} of 7 and 14 dS m⁻¹ was greater than that in non-saline irrigation by 29% and 38% at 0 to 30 cm soil depth and by 13% and 17% at 30 to 60 cm soil depth, respectively (**Figure 2**). This issue has also been shown in the study of Alihour et al. (2015), where it was reported that evapotranspiration from plots irrigated with non-saline water (2.3 dS m⁻¹) was higher by 1.8 times than plots irrigated with saline water (12 dS m⁻¹). El-Boraie (1997) also indicated that when the salinity of irrigation water increases, soil moisture depletion decreases and more water remains in saline conditions. Of course, it should be noted that the increase in water retention in the soil after irrigation with saline water leads to an increase in unusable water at the end of the season. Therefore, although there was more water in the saline conditions, this water is not easily accessible. Furthermore, this water is not usable at least for crops, in terms of quality. In a study of Pirasteh-Anosheh et al. (2017b), it was found that based on soil moisture, the amount of irrigation water required for control plots was significantly higher than that in saline plots.

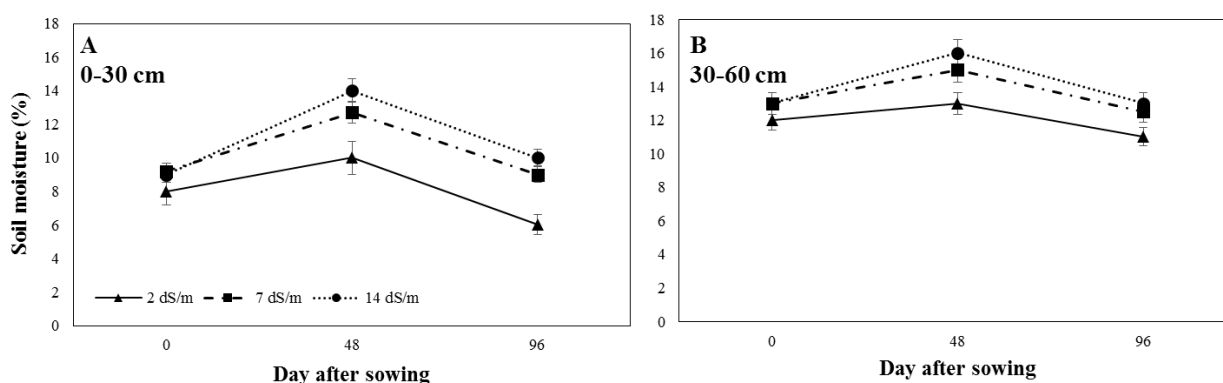


Figure 2. The effect of electrical conductivity of irrigation water (2, 7 & 14 dS m⁻¹) on soil moisture content during the growing season at two soil depths. The means with similar overlaps are not significantly different based on standard error ($\pm SE$).

In all three EC_{iw} treatments, the average salinity of soil saturation extract (EC_e) during the growing season increased with increasing soil depth (Figure 3), so that soil salinity at the depth of 0 to 30 cm was greater than at 30-60 cm by 16%, 28% and 14% in 2, 7, and 14 $dS\ m^{-1}$ treatments, respectively. This could be due to the increase of water-soluble salts in saline water and leaching to deeper layers of soil. The appropriate volume of irrigation water is affected by various management factors. One of these factors is solute leaching by considering leaching fraction. To prevent yield loss, additional salts should be washed outside the root development zone by using an appropriate irrigation volume (Cheraghi and Rasouli, 2009).

The results also showed that the EC_e was increased at both depths with increasing EC_{iw} (Figure 3). Increasing the EC_{iw} from 2 to 7 and 14 $dS\ m^{-1}$ increased the EC_e by 2.20 and 3.69 times at 0 to 30 cm depth and by 2.41 and 3.61 times at 30 to 60 cm depth. These findings agree with the results of some previous studies such as El-Boraie (1997), Alihoury et al. (2015) and Pirasteh-Anosheh et al. (2017b). El-Boraie (1997) reported that soil salinity as well as the amount of sodium, calcium and magnesium ions in the soil were increased with increasing salinity of irrigation water. Alihoury et al. (2015) also showed that the highest soil salinity in all three depths of 0 to 25 cm, 25 to 50 cm and 50 to 75 cm was obtained from plots irrigated with saline water.

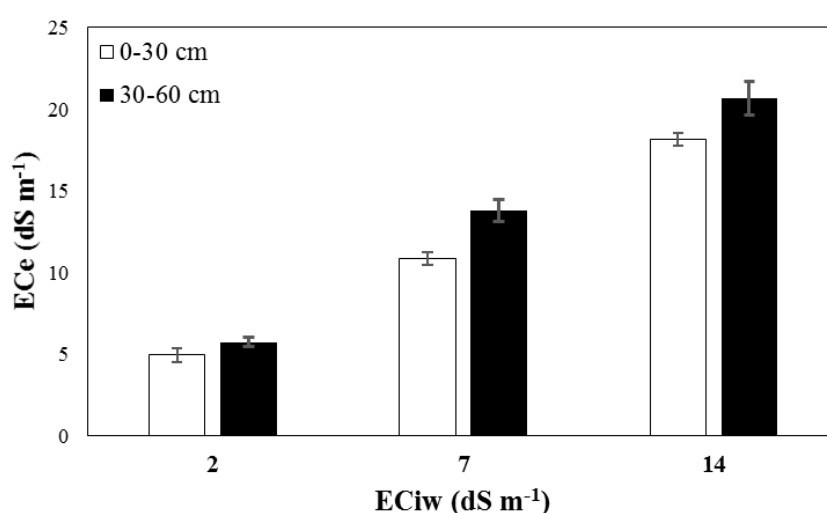


Figure 3. The effect of electrical conductivity of irrigation water (EC_{iw}) on average of electrical conductivity of soil saturation extract (EC_e) at two soil depths. The columns with similar overlaps are not significantly different based on standard error ($\pm SE$).

With the initial pre-sowing leaching, the EC_e was significantly reduced at both depths, especially at 0 to 30 cm (Figure 4). With continued irrigation with fresh water before applying salinity treatments, this decrease in soil salinity was kept at both depths. Applying irrigation water salinity treatments, the trend of soil salinity was changed in different EC_{iw} treatments, so that EC_{iw} treatments of 2 and 14 $dS\ m^{-1}$ caused a decrease and increase, respectively, in soil salinity by the end of the growing season. While, soil salinity in EC_{iw} of 7 $dS\ m^{-1}$ decreased until the 24th day after sowing and then increased until the end of the growing season (Figure 4). This trend was observed at both depths, which was more pronounced at the upper layer of soil. Cheraghi and Rasouli (2009) investigated leaching and salinity in wheat farms under saline conditions and reported that rainfall has an effective role in wheat production in saline lands due to the decrease in solute concentration during the growing season. Under these conditions, salinity profile showed a uniform distribution of salts in the soil, which was due to high water use in the farms. In the study of Alihoury et al. (2015), the EC_e was decreased with increasing soil depth, which was in accordance with the non-saline conditions in the present study.

In the present experiment, the EC_{iw} of 2, 7 and 14 $dS\ m^{-1}$ increased soil salinity at the end of the season compared to that at the beginning of the season by 2.4, 1.6 and 1.3 times at a depth of 0 to 30 cm and by 2.8, 2.0 and 1.5 times at a depth of 30 to 60 cm (Figure 4). Dosoky (1999) observed that increase in EC_{iw} from 0.6 to 3.7 $dS\ m^{-1}$ resulted in an increase in soil salinity from 1.9 $dS\ m^{-1}$ at the beginning of the experiment to 24.8 $dS\ m^{-1}$ at the end of the growing season. Therefore, the accumulation of salts in soil is closely related to the salt concentration in irrigation water and irrigation management, which is closely related to the actual leaching rate.

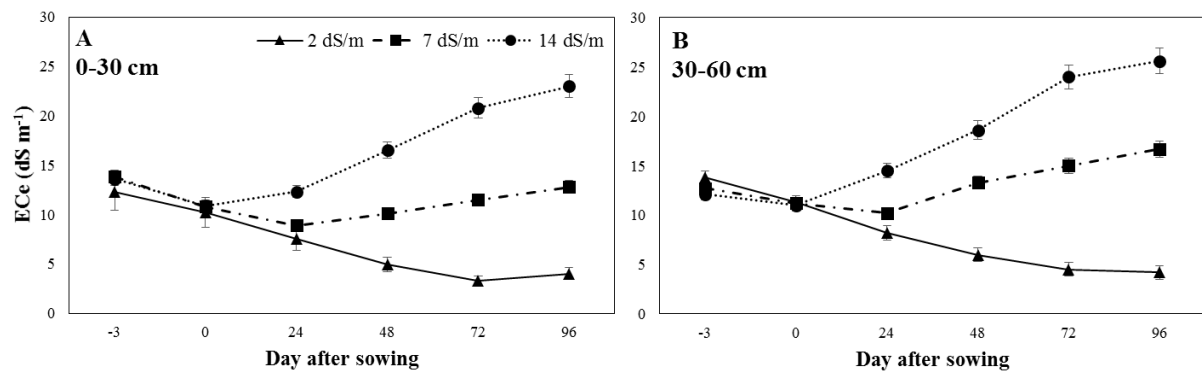


Figure 3. The effect of electrical conductivity of irrigation water (2, 7 & 14 dS m⁻¹) on electrical conductivity of soil saturation extract (ECe) during the growing season at two soil depths. The means with similar overlaps are not significantly different based on standard error (\pm SE).

Conclusions

It can be concluded that there is a direct relationship between irrigation water salinity with soil moisture and salinity, so that in saline conditions, more moisture may remain in the soil. Optimal leaching can significantly reduce soil salinity during the growing season. Therefore, in saline plots, soil moisture is higher at the end of the growing season, but due to its low quality, it can be used only by plants with high salinity tolerance, such as halophytes.

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