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Effect of irrigation with sea water on soil salinity and yield of oleic sunflower

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ABSTRACT

A field trial was carried out in 2013 and 2014 in a research field near Sari (Iran), to study the effect of irrigation with Caspian Sea water on soil salinity, growth parameters and yield components of oleic sunflower. The experiment was conducted with 4 levels of blending viz. 0% (S_0) (fresh water), 15% (S_{15}), 30% (S_{30}) and 45% (S_{45}) mix of sea and fresh water. Soil salinity in the soil profile up to 0–1.0 m increased from 1.1 dS m^{-1} (before sowing) to 1.4, 2.1, 2.8 and 3.6 dS m^{-1} for S_0, S_{15}, S_{30} and S_{45}, respectively. In the off-season, soil salinity decreased again to its original level in the control (S_0) and to 1.3, 1.8 and 2.7 dS m^{-1} respectively in S_{15}, S_{30} and S_{45}, due to rainfall. The corresponding oil yield decreased from 2.6 t ha^{-1} (S_0) to 2.4, 2.0 and 1.5 t ha^{-1} respectively for S_{15}, S_{30} and S_{45}. This corresponds to a yield reduction of 10–14% for every 1 dS m^{-1} increase in soil salinity. The results also indicate that salinity threshold value for oleic sunflower in Sari region is about 1.6 dS m^{-1}. Compared to the control (S_0), irrigation with 15% and 30% of sea water had no significant effect on seed yield and irrigation water productivity based on oil yield (IWP_{oil}). For S_{45}, however, seed yield and IWP_{oil} were significantly reduced by 32 and 39% in 2013, and 26 and 34% in 2014. It is concluded that, to irrigate oleic sunflower, 30% Caspian Sea water can be applied for mixing into the irrigating water in the area which has an annual rainfall of 540 mm.

1. Introduction

Iran is the largest consumer of irrigation water in the Middle East (Ghadiri et al., 2006). Most croplands in the north of Iran must be irrigated because rainfall is insufficient during the growing season, so irrigation plays an important role in crop production in the region. In Iran, irrigated agriculture consumes more than 90% of the fresh water abstractions (Tarafdar, 2015). Therefore, the use of alternative sources of water for irrigation can reduce future water scarcity problems. One alternative water source in the region is Caspian Sea water. Iran has more than 700 km coastlines along the Caspian Sea. Caspian Sea water has a salinity of between 5 and 13 g L^{-1} (8–20 dS m^{-1}) (Peeters et al., 2000), which is roughly 33% of the salinity of the open oceans. Caspian Sea water has lower Cl^- and Na^+ and higher Ca^{2+} and SO_4^{2-} contents compared to the water from open oceans. This is less harmful for the soils' physical and chemical properties (Ghadiri et al., 2006). One common way to increase irrigation water supply is to mix saline water with fresh water (Grattan et al., 2011). Irrigation with mixed Caspian Sea water and fresh water has been successfully used to irrigate field-grown barley in the north of Iran (Ghadiri et al., 2006). The suitability of the mixed water depends on the crop salt tolerance and the long-term management plan for irrigation and crop production (Grattan et al., 2011). Sunflower is one of the most widely cultivated oil crops in the world (Flagella et al., 2002). It is moderately tolerant to salinity with no significant yield reduction by soil salinity up to 4.8 dS m^{-1} (Francois, 1996). Drip irrigation, gives the greatest advantages in using saline water (Shalhevet, 1994) by maintaining high matric potential and low salt accumulation in the root zone (Malash et al., 2005). Di Baccio et al. (2004) reported that irrigation with 10% of sea water did not reduce growth parameters of sunflower. Ghadiri et al. (2006) found that 50% sea water can be applied for mixing into the irrigating water without a significant reduction in grain yield of barley. In tomato, sea water significantly reduced plant growth and berry yield (D'Amico et al., 2003). Sgherri et al. (2007) stated that irrigation with sea water reduced fruit yield and fruit weight of tomato. Wan et al. (2007) investigated the effects of saline water on tomato under drip irrigation. They found that

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irrigation with saline water reduced tomato yield, but irrigation water use efficiency increased with increasing salinity of water. They also found that the soil salinity in the soil layer 0–90 cm did not increase after three years of irrigating with saline water. Kang et al. (2010) reported that applying saline water reduced plant height, leaf area index, seed weight and yield of fresh cobs. Jiang et al. (2012) reported that wheat yield and irrigation water productivity decreased when the salinity of irrigation water was higher than 3.2 dS m^{-1}. Amer (2010) evaluated the effect of saline water irrigation on corn crop and reported that leaf area index and corn yield decreased by increasing salinity level of irrigation water, while soil salinity increased by increasing salinity of irrigation water. Wan et al. (2010) examined cucumber response to the irrigation water salinity. They reported that cucumber yield decreased by increasing salinity of irrigation water. They also found that soil salinity in the soil layer 0–90 cm did not change after 3 years irrigation with saline water due to rainfall with an average 260 mm during growing season. Izzo et al. (2008) examined the effects of irrigation with diluted sea water on sunflower. Their results showed that plant height and leaf area decreased with increasing proportion of sea water. Francois (1996) investigated the effect of saline water on sunflower and concluded that it is moderately tolerant to salinity. Applying saline water three weeks after sowing, reduced height, the number of seeds per head, seed yield and seed weight of four sunflower hybrids. Vieira Santos (2004) reported that salt stress significantly reduced chlorophyll content of sunflower leaves. Di Caterina et al. (2007) and Cucci et al. (2007) examined the effect of saline irrigation water on seed yield of sunflower, finding that seed yield, seed weight, the number of seeds per plant and oil content of sunflower seed decreased with increasing salinity of irrigation water. Flagella et al. (2004) investigated the effect of saline water on sunflower. Their results showed that oil content of sunflower seed decreased from 52% to 21% on increasing salt stress. They also reported that oil yield reduction was 27, 52, 80 and 88% at the salinity level of 3, 6, 9 and 12 dS m^{-1}, respectively. Chen et al. (2009) studied the effect of drip irrigation with saline water on sunflower. They found that plant height, head diameter, yield and seed weight decreased with increasing salinity of irrigation water, while the irrigation water use efficiency was increased by increasing salinity of irrigation water. They also reported that soil salinity in soil profile could be maintained in the subsequent year after saline water drip irrigation. Verma et al. (2012) reported that saline water can be used in an area with about 600 mm rain without long-term increase in the soil salinity. Yarami and Sepaskhah (2015) studied saffron response to the saline water. They found that yield of saffron decreased with increasing salinity of irrigation water. They also reported that soil salinity increased after using saline water, but the rainfall above 400 mm prevented salt accumulation in the root zone. Feng et al. (2015) investigated crop response to the long-term irrigation with saline water and reported that the rainfall with an average 500 mm can leach salts accumulation from the top soil layer to the deeper layers. Wang et al. (2015) investigated the effects of saline water on winter wheat and soil salinity. They found that soil salinity increased at harvest time, especially in the top 0–40 cm of soil layer. They also reported that these impacts were eliminated by precipitation (364 mm) during off-season period. Tedeschi and Dell'Aquila (2005) examined long-term effects of saline water irrigation on crops and soil. They reported off-season rainfall with an average of 608 mm caused leaching of salts from the top 0–40 cm layer of soil and accumulation of salt in the deeper layers. Additionally, in the north of Iran, mean annual rainfall is more than 600 mm and about 85% of annual precipitation occurs during off-season period. This can probably remove the accumulated salt in the root zone. In Northern Iran, due to lack of fresh water, especially during the period of peak plant water requirement, the feasibility of using other sources of water such as sea water should be studied.

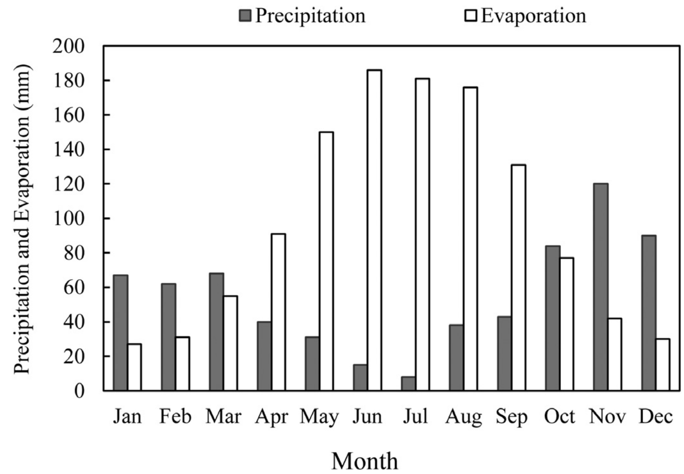

Fig. 1. Average monthly precipitation and evaporation (15 year period).

Irrigation with sea water, if feasible, can reduce the demand of fresh water for irrigation. The effect of drip irrigation with sea water on oleic sunflower, however, has not been studied sufficiently. Therefore, the objective of the present study was to evaluate the effects of irrigation with blending of sea water on soil salinity and growth parameters, yield components and irrigation water productivity of sunflower plant.

2. Materials and methods

2.1. Site description

The experiment was carried out in the research field of Sari Agriculture Science and Natural Resources University (36°39′41″ N, 53°03′57″ E) in 2013 and 2014, to study the effects of irrigation with different concentrations of Caspian Sea water on oleic sunflower. The site elevation is −15 m (MSL). The average annual temperature is 17.5 °C and the annual rainfall and evaporation are 666 and 1177 mm, respectively (Fig. 1).

2.2. Experimental design and treatments

The experiment was conducted with 4 levels of blending viz. 0% (S_0) (fresh water), 15% (S_{15}), 30% (S_{30}) and 45% (S_{45}) mix of sea and fresh water. The treatments were replicated three times in 12 plots and laid out in a randomized complete block design. The soil's main physical and chemical properties are presented in Table 1. The compositions of sea water and fresh water used in this study are given in Table 2. Well water was used as the fresh water source.

Sunflower (*Helianthus annuus* L.) cv Azargol was sown on 22 May 2013 and 17 May 2014 in five rows. The rows were 75 cm apart, with the seeds placed 20 cm apart within the row. Plot size was 12 m^2 (3.75 m × 3.2 m). The plants were irrigated by using drip tape with 20 cm emitter spacing. Before applying the treatments, all plots were irrigated with well water. To minimize the adverse effect of saline water, treatments started 38 days after sowing in both years. The saline water mixture for each treatment was prepared in tanks and distributed in plots using thin-walled drip tubing (tape). Soil water content was measured with a Time Domain Reflectometer (TDR, Decagon Devices, United States). TDR probes were installed in row, at a depth of 6.5 cm, 19 cm, 31.5 cm and 44 cm, representing the soil moisture variations at 12.5 cm intervals. The estimated water requirement was calculated based on S_0 treatment before each irrigation event. Two plots of S_0 treatment were equipped to monitor the water content of the soil. All plots were irrigated every