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Drip irrigation with saline water for oleic sunflower (*Helianthus annuus* L.)

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ABSTRACT

The field experiments were carried out in 2007 and 2008 to study the effects and strategies of drip irrigation with saline water for oleic sunflower. Five treatments of irrigation water with average salinity levels of 1.6, 3.9, 6.3, 8.6, and 10.9 dS/m were designed. For each treatment, 7 mm water was applied when the soil matric potential (SMP) 0.2 m directly underneath the drip emitters was below −20 kPa, except during the seedling stage. To ensure the seedling survival, 28 mm water was applied after sowing during the seedling stage. Results indicate that amount of applied water decreases as salinity level of irrigation water increases. The emergence will be delayed when the salinity level of irrigation water is higher than 6.3 dS/m, but these differences will be alleviated if there is rainfall during emergence period. The final emergence percentage is not changed when salinity level of irrigation is less than 6.3 dS/m, and the percentage decreases by 2.0% for every 1 dS/m increase when the salinity level of irrigation water is above 6.3 dS/m, but the decreasing rate will be reduced if there is rainfall. The plant height and yield decrease with the increase of salinity of irrigation water. The height of plants decreases by 0.6–1.0% for every 1 dS/m increase in salinity level of irrigation water. The yield decreases by 1.8% for every 1 dS/m increase in salinity level of irrigation water, and irrigation water use efficiency (IWUE) increases with increase in salinity of irrigation water. The soil salinity increases as the salinity of irrigation water increasing after drip irrigation with saline water in the beginning, but the soil salinity in soil profile from 0 to 120 cm depths can be maintained in a stable level in subsequent year irrigation with saline water. From the view points of yield and soil salt balance, it can be recognized even as the salinity level of irrigation water is as high as 10.9 dS/m, saline water can be applied to irrigate oleic sunflower using drip irrigation when the soil matric potential 0.2 m directly under drip emitter is kept above −20 kPa and the beds are mulched in semi-humid area.

1. Introduction

Sunflower, as a major oil seed, is widely cultivated in the world (Flagella et al., 2002). Oleic sunflower is rich in monounsaturated fats, and therefore considered as a useful source of dietary fat in preventing heart disease (Allman-farinelli et al., 2005), which makes oleic sunflower an important breeding objective for sunflower (Flagella et al., 2002). Irrigation is known to boost both growth and yield of sunflower (Katerji et al., 1996; Flagella et al., 2002), and many aspects of the increase in yield following irrigation have been studied, such as full irrigation, irrigation only at certain growth stages or deficit irrigation (Unger, 1983; Rinaldi, 2001; Demir et al., 2006).

However, scarcity of fresh water is becoming a constraint to irrigation throughout the world (Mantell et al., 1985; Beltrán, 1999). Meanwhile, saline water is in plentiful supply in the world (Mantell et al., 1985) such as in the semi-humid area. It would be a feasible way to use saline water as an important substitutable resource for fresh water in irrigating the plants such as oleic sunflower which is moderately tolerant of salinity (Francois, 1996; Mass and Grattan, 1999) if appropriate practices were applied (Oster, 1994; Lei et al., 2003; Wan et al., 2007).

Drip irrigation is able to apply water at low discharge rate and high frequency over a long period of time, resulting in a condition to maintain high soil water content in root zone all the time, and minimize salinity levels in the soil water due to leaching (Keller and Bliesner, 1990). Meanwhile, because of the point-source characteristic of drip irrigation, the salts along with water can be pushed toward the fringes of wetting area, and forming a desalinization zone in the center of wetting area, in close proximity to the dripper (Goldberg et al., 1976; Kang, 1998). Thus, drip irrigation is widely regarded as a suitable system for applying saline water to crops (Malash et al., 2005).

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Kang et al. (2004) and Kang and Wan (2005) studied the effects of soil matric potential (SMP) on field crops with drip irrigation, and reported that the matric potential of soil 0.2-m directly underneath the drip emitter can be used to judge whether it is time to irrigate the crop. Based on this finding, experiments were carried out (Wan et al., 2008a,b) to investigate the effects of saline water, applied with drip irrigation, and soil matric potential on tomato (*Lycopersicon lycoperisicum* (L.)), which is classified as a tolerant to salinity (Francois, 1984). In the experiments, the electrical conductivity of saline water (EC_{iw}) was from 1.1 to 4.9 dS/m when the SMP at 0.2 m depth immediately under drip emitters was controlled from −10 to −50 kPa. Results showed that saline water can be used to irrigate tomato after seedlings survival stage by drip irrigation when EC_{iw} value was less than 5 dS/m, which is consistent with the salt tolerance of the crop that has been reported to have a threshold salinity of 5.7 dS/m and a percent yield reduction per unit increase in salinity above the threshold of 3.4 % (Francois, 1984; Mass and Grattan, 1999). Meanwhile, the soil salinity in the layer of 0–90 cm did not increase obviously after 3-year saline water irrigation. However, the studies did not cover the effect of saline water on seedling emergence or the effect of higher salinity levels of irrigation water on plant growth and yield.

On the other hand, in the semi-humid area in china, mean annual precipitation was more than 500 mm, and the precipitation was mainly concentrated from June to August which was the growing season for crop. The rain occurs during the crop season may mitigate the impact of salinity in the rootzone (Leter and Feng, 2007) in this area.

The objectives of this study were: (1) to investigate the effect of drip irrigation with saline water on emergence, vegetative growth, yield, and IWUE of oleic sunflower when salinity level was up to 10.9 dS/m; (2) to assess the impact on soil salinity by drip irrigation with saline water of different salinity levels; and (3) to approach a management strategy for oleic sunflower when saline water is applied through drip irrigation in the semi-humid area with plentiful saline water.

2. Materials and method

2.1. Experimental site

The field experiments were conducted during 2007 and 2008 at Jinghai Experimental Station for Efficient Water Use of Agriculture in Coast Zone, Institute of Geographic Science and Natural Resource Research, Chinese Academy of Sciences. The station (38°53′N, 116°47′E) is located in south-western of Tianjin, China, and has a temperate semi-humid monsoon climate. Mean annual temperature is 12 °C with an average of 2700 sunshine hours a year. Mean annual precipitation is 570 mm, mainly concentrated from June to August. The soil texture and saturated hydraulic conductivity are shown in Table 1.

2.2. Experimental design

2.2.1. Plot layout, irrigation water salinity and management

The experiment consisted of five treatments according to the salinity level of irrigation water. The salinity of irrigation water was measured as electrical conductivity, and the electrical conductivity of irrigation water (EC_{iw}) for five treatments was 1.6, 3.9, 6.3, 8.6, and 10.9 dS/m, respectively. Irrigation water of different salinity levels for the experiments was obtained by mixing the water from two wells in the station in the required proportion. The salinity level of water in two wells was 1.6 and 11.9 dS/m. The five treatments were replicated three times in 15 plots and laid out in a completely randomized block design.

Each of the 15 plots consisted of three raised (15 cm) beds, with 1.4 m between bed centers. Each bed was 0.6 m wide and 4.4 m long; each plot was therefore 4.2 m × 4.4 m (Fig. 1).

Each treatment had a separate gravity drip irrigation system consisting of a tank and nine drip tubes (three tubes in one plot). The tank (390 L) was 1 m above the ground. Drip tubes with emitters spaced 0.2 m apart were placed at the center of each raised bed. Throughout the growing period of oleic sunflower, only saline water was used for irrigation in the experiment. The study of Wan et al. (2007) showed that soil salinity did not increase after 3-year saline water irrigation when the matric potential of soil 0.2 m underneath the drip emitters was kept at −20 kPa. Because of this result, in the experiments, the matric potential of soil 0.2 m directly underneath the drip emitters was monitored regularly, and irrigation was applied as soon as the potential came close to −20 kPa, except during the seedling stage which required more water. One vacuum gauge tensiometer was installed 0.2 m directly underneath one emitter located in the center of middle bed within the plot for each treatment. The tensiometers were observed three times a day (at 8:00, 14:00, and 17:00 h).

2.2.2. Plant management and measurements

Seeds of the sunflower hybrid G101 were sown on 19 June 2007 and 7 June 2008 in double rows in a zigzag pattern. The rows were 0.3 m apart; within a row, the seeds were sown 23 cm apart. The thinning occurred on the 15th day and 13th day after sowing in 2007 and 2008, respectively.

In 2007, the beds were mulched with black polyethylene sheets after thinning; in 2008, the mulch was in place before sowing. To ensure that the seedlings survived, approximately 28 mm water was applied after sowing.

Emergence rate was recorded daily after sowing, from 19 June to 4 July in 2007 and from 7 to 19 June in 2008. Emergence rates were calculated from the amount sown, however, the final emergence percentage on the thinning day was calculated based on two methods including the amount sown and the number of hills. Six plants of young seedlings per replication were chosen to measure the height and total biomass (fresh weight and dry weight) on the thinning day in 2008.

Table 1
Basic properties and saturated hydraulic conductivity of soil profile.

Soil layers	Soil mechanical composition (%)			Soil texture	Soil bulk density (g/cm^3)	Saturated hydraulic conductivity (cm/day)
	<0.002 mm	0.002–0.05 mm	0.05–2 mm			
0–30	9.13	82.91	7.96	Silt	1.22	67.67
30–45	9.44	88.53	2.03	Silt	1.45	21.95
45–65	10.39	89.19	0.42	Silt	1.36	25.61
65–75	9.32	89.99	0.69	Silt	1.32	32.07
75–160	9.99	89.64	0.37	Silt	1.35	27.04
160–240	9.01	90.22	0.77	Silt	1.27	39.04