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Salt leaching and *Iris germanica* L. growth in two coastal saline soils under drip irrigation with saline water

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ABSTRACT

Soil salinity and freshwater shortage are two major limiting factors for vegetation construction in coastal saline regions. A field experiment using water-salt regulation method of drip-irrigation with different irrigation water salinity (EC_{iw}; 0.8, 3.1, 4.7, 6.3, and 7.8 dS/m) to plant *Iris germanica* L., was imposed in two coastal saline soils (sandy loam and silt) during 2013–2015. The regulatory method was scheduled of drip irrigation to control the soil matric potential (SMP). The results showed that soil salinity (EC_e, electrical conductivity of the saturation paste extract) decreased from 27 to 30 dS/m to 1.91 and 3.61 dS/m in the 0-95 cm soil profile after 30 months in sandy loam and silt soil, respectively. Soil salinity decreased with times and increased with EC_{iw} increasing, but no significant difference obtained in salt leaching. Survival rates decreased both with times and EC_{iw}, and significant difference occurred in treatments. Survival rate decreased by 2.33% and 2.88% for each unit of EC increasing in the irrigation water in sandy loam saline soil in 2014 and 2015, respectively, and corresponding values were 2.74% and 11.53% in silt saline soil. It was concluded that higher values of SMP should be continuously controlled in both soils in the third year for *Iris germanica* L., especially in silt soils with low soil infiltration, to maintain a suitable soil salinity environment for root growth and compensate for the decreased osmotic potential caused by irrigation with saline water, and constant high total water potential can be maintained for plant growth.

1. Introduction

Soil salinity is a major obstacle for the utilization of saline land resources (Oo et al., 2015). Leaching method as a common practice has been widely applied in reclaiming salt-affected soils around the world. As an advanced irrigation technique with water-saving advantage, drip irrigation is applied as a water-salt regulation technology, and is increasingly used for salt-affected soils worldwide. This technology is highly effective in utilization and reclamation of salt-affected soils (Chen et al., 2015; Kang et al., 2010; Li et al., 2015a). In addition, high SMP could be maintaining in the root zone under high frequencies, which is better in compensating for the decreased osmotic potential when saline water irrigating (Meiri et al., 1992), thus constant high total water potential can be maintained for plant growth (Goldberg et al., 1976). In recent years, a method of water-salt regulation using drip irrigation with saline water has been successfully applied in reclamation of saline soils on crop and some landscape plants (Chen et al., 2015; Kang et al., 2010; Sun et al., 2013; Li et al., 2015a,b,2016).

Re-vegetation is an important approach for mitigating salinization and land degradation, it improves biodiversity and conservation values provides income to land holders through forest resources, carbon credits and offset schemes, and successfully remediates and reclaims land that is otherwise unproductive (Drake et al., 2016). Re-vegetation of salt-affected soils is an approach that has been successfully applied internationally (Drake et al., 2016). In addition, leaf litters and root growth on phytoremediation practices have also been reported affected physical, chemical and microbial properties of saline soil during its reclamation and improves soil quality (Singh et al., 2016). In China, a large region of coastal saline wasteland located in the coastal area bordering the Pacific Ocean from Jiangsu Province to Liaoning Province. Most of these wasteland is not being used due to soil salinity and freshwater shortage, especially for silt soil (Li et al., 2015a). In recent years, rational reclamation and suitable utilization of coastal saline soils has become a major issue and attracted increasing awareness from both government administrators and scientists in China. There is an urgent need to improve the landscape through re-vegetation to meet the increasing demand of living environments for cities and districts (Chen et al. 2015; Li et al., 2015a,b).

The method of water-salt regulation using drip-irrigation combined with plants growing for re-vegetation of coastal saline soils, has been

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applied in coastal regions around Bohai Gulf. More than 30 species of landscape plants have been planted successfully with survival rate > 80% in saline soils under freshwater irrigation, but less species for saline water irrigation. In order to extend the variety of plant types and the application of the reclamation method using drip irrigation with saline water, further studies are needed concerning drip irrigation with saline water in reclamation of saline soils on more landscape plants, especially the common plants in landscape.

I. germanica L. as kind of cover plant, has been widely applied in landscape construction in coastal regions. Unfortunately, there is a dearth of information on the suitable irrigation water salinity for *I. germanica* L. subjected to salinity in saline land. In this study, *I. germanica* L. was planted in two coastal saline soils (sandy loam and silt), and received irrigation water at five levels of salinity using drip-irrigation. The aim of this study was to develop an approach for re-vegetation with *I. germanica* L. under saline water drip irrigation in coastal saline soils.

2. Materials and methods

2.1. Site description

The study station located in the Industrial Zone (39°03′N, 118°48′E) and the International Eco-City (39°20′N, 118°54′E) of Caofeidian District in the south of Tangshan city, east China, and north of Bohai Gulf which borders the Pacific Ocean. The study area has a typical semi-humid monsoon climate, and rainfall is concentrated in the June-September with annual precipitation of approximately 550–580 mm. There are large areas of coastal saline land which has not been utilized. Field experiments were carried out in 2013–2015 on these coastal saline lands. The initial average soil EC_e and sodium adsorption rate (SAR) values were 27–30 dS/m and 50-59 $(mmol/L)^{0.5}$ in the 0–95 cm soil profile, respectively. According to the soil classification standard of USDA, the soils were silt in the in the Eco-City and sandy loam in the Industrial Zone. The part of soil property parameters are shown in Table 1. Reed [*Phragmites australis* (Cav.) Trin. Ex Steud] and suaeda (Suaeda glauca Bge.) are often the only native plants in the landscape (Fig.1).

2.2. Plot layout and irrigation

I. germanica L. was selected as test plant in this study. The soil was treated before planted, that is soil was removed to a depth of 100 cm and a 20 cm gravel-sand layer (15-cm thick gravel layer and 5-cm thick sand layer) was laid aiming of reducing capillarity of the soil to prevention of salt, and then the soil was backfilled. The soil treatment process was detailed in Li et al., (2015a,b).

Five levels of irrigation water salinity (EC_{iw}) (0.8, 3.1, 4.7, 6.3 and 7.8 dS/m) were designed in this study. *I. germanica* L. was directly planted in 2013, and 72 *I. germanica* L. plants were planted at a spacing of 0.3 m × 0.3 m in each 3.0 m × 3.0 m experimental plot. Each treatment in one plot consisted of four raised (15 cm) beds as replications, and each bed was 3.0 m long and 0.3 m wide with 0.8 m between bed centers (Fig. 2). Two rows of plants were grew in each bed.

Gravity drip-irrigation system was used in each treatment of this experiment, which consisting of a tank (200 L) and 4 drip tubes. The tank was installed at 0.8 m above the ground to contain irrigation water. Drip tubes with 0.2-m (in sandy loam soil) and 0.3-m (in silt soil) emitter intervals were placed in the center of the beds. One vacuum gauge tensiometer was installed 0.2 m directly underneath one emitter located in the center of the plot for each treatment. The tensiometers were observed twice daily (at 8:00 and 18:00h), and irrigation water with amount of 6 mm was applied when the reading value of tensiometers exceeded the target SMP value, which considering the ability of the soil to retain water and the maximum daily evapotranspiration of the planted area. Based on the experimental results of Sun et al. (2012, 2013), we set the SMP threshold at −5 kPa when the herbaceous plants were transplanted to the end of the first year, and −10 kPa in the second year and −13 kPa in the third year combining with saving-water and soil salinity environment. On 21–24 November and 6–8 April, 24 mm of freshwater irrigation was applied to each treatment due to the onset of winter and plant sprouting in spring, respectively.

2.3. Observation and measurements

An auger (2.0 cm diameter, 15 cm high) was used in this study to obtain soil cores before transplanting and on November 2014 and 2015. The samples were obtained at 0, 10, 20, 30 and 40 cm from the emitters. Soil samplings distribution was shown in Fig. 2. All soil samples were air-dried and passed through a 1-mm sieve. Soluble salt, soluble cations and soil pH were measured in extracts of saturated soil pastes. EC_e was determined by use of a conductivity meter (DDS-11A, REX, Shanghai). Soluble cations-calcium (Ca^{2+}), magnesium (Mg^{2+}) and Na^+ were measured with ICP-OES (Optima 5300DV, USA). The SAR was calculated using the follow eqation (Rhoades et al., 1992):

$$SAR = \frac{[Na^+]}{([Ca^{2+}] + [Mg^{2+}])^{0.5}} \quad (1)$$

where the concentration of each cation is in mmol/L.

In this study, average EC_e values within the whole soil profile were integrated to account for both spatial and temporal variations and were determined as follows (Dou et al., 2011):

$$EC_e(t) = \frac{\sum_{j,k}^{n,m} EC_e(t, j, k) \times S(j, k)}{\sum_{j,k}^{n,m} S(j, k)} \quad (2)$$

where t represents the time at which soil samples were obtained; j represents the distances from the emitter where soil samples were attained; k represents the depths of soil samples and $S(j, k)$ represents the depth interval of the soil samples.

The survival rates were counted in 2013–2015. The shoot biomass of plants (three plants per treatment) was measured at the end of 2014.

Table 1

Soil mechanical composition, bulk density, EC_e (electrical conductivity of saturated paste extracts), pHs (pH of saturated paste) and SAR (sodium adsorption rate of saturated paste extracts) in initial soil.

Site	Soil depth (cm)	Soil mechanical composition (%)			Soil texture	Bulk density (g/cm^3)	EC_e (dS/m)	pHs	SAR $(mmol/L)^{0.5}$
		< 0.002 mm	0.002–0.05 mm	0.05–2 mm					
Eco-City	0-25	0.48	42.89	56.63	Sandy loam	1.35	27.73	7.97	54.38
	25-45	0.52	41.66	57.83		1.57	28.03	8.06	55.28
	45-95	0.55	45.36	54.09		1.69	27.31	7.88	50.28
Industrial area	0-25	0.94	80.71	18.35	Silt	1.48	29.30	7.91	56.45
	25-45	0.90	82.80	16.30		1.66	27.66	8.08	57.43
	45-95	1.16	82.64	16.20		1.68	27.08	8.03	58.30