Agricultural Water Management 164 (2016) 223–234

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Response of a salt-sensitive plant to processes of soil reclamation in two saline–sodic, coastal soils using drip irrigation with saline water

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ARTICLE INFO

Article history:
Received 19 July 2015
Received in revised form 21 October 2015
Accepted 29 October 2015
Available online 11 November 2015

Keywords:
Saline soil
Soil properties
Irrigation water salinity
Chinese rose
Management

ABSTRACT

The aim of this study was to evaluate the impact of soil types and properties on coastal saline soil reclamation and the response of plant growth to the reclamation processes in two soils. Two very heavy coastal saline soils were reclaimed in a three-year trial using drip irrigation with saline water. Chinese roses (*Rosa chinensis*) were planted, and soil indexes, growth characters, ion absorption and dry matter production were determined. Our results showed that significant salt leaching occurred in both soils, and the effect during the early period of reclamation was better in sandy loam than silt soil. There were higher emergence and survival rates of plants in sandy loam soil due to the rapid reclamation process, while plant growth and dry mass were greater in silt soil due to good fertilizer and water conservation. Most roots were present in the 0–20-cm profile in both soils, but the fine root length value in silt soil was relatively high. These results indicate that water and nutrient management differed in the two soils. During soil reclamation, more attention should be paid to nutrient supply and maintaining soil moisture in sandy loam and to rapidly establishing suitable soil root-zone environments for plant emergence in silt soil.

1. Introduction

Saline soils are an important soil resource in the world, and coastal saline soil is one of the main types. In China, there is a large region of coastal saline land bordering the Pacific Ocean, including 10,000 km^2 along the 6000 km of coastline extending from Jiangsu Province to Liaoning Province (Yu and Chen, 1999). Sandy loam and silt soils are the main soil types in this coastal saline region. The soils in these coastal areas are strongly affected by salinisation and sodification. They are characterized by high EC_e (electrical conductivity of saturated paste extracts), SAR (sodium adsorption rate of saturated paste extracts) and chloride (Cl^-) content, often related to their heavy texture. Plant growth is significantly affected via several mechanisms including sodium (Na^+) or chloride toxicity, competition for uptake of other cations and osmotic effects on water uptake or interference with uptake of nutrients (Grewal, 2010; Naidu and Rengasamy, 1993; Rengasamy et al., 2003). Especially in fine-textured soils (silt), high SAR and the salinity problem have a marked detrimental effect on soil structure; and saline–sodic soils can slake, disperse and swell and further result in a decrease in water and air movement, plant-available water, root penetration, seedling growth and plant establishment (Akhter et al., 2004; Oster et al., 1999; Sumner, 1993). With the rapid industrialization and urbanization in coastal regions, there is an urgent need for reclamation of saline soils to meet the increasing demand for ecological construction.

The limited fresh water is one major factor restricting ecological construction in coastal regions. Many approaches including engineering, chemical and biological methods to reclaim saline soils have not yielded desirable results due to water limitations (Li et al., 2015). Non-conventional water resources such as saline water, brackish groundwater and treated wastewater are alternatives to fresh water (Rhoades et al., 1988). Saline water has been successfully used for irrigating crops and other plants (Crescimanno and Garofalo, 2006; Darvishi and Dadnia, 2012; Hadi and Raijadhav, 2007; Niu et al., 2011, 2012, 2013; Ozrad et al., 1972; Sa et al., 2013). However, most previous research on saline water irrigation has been based either on non-saline soils or using crops and salt-tolerant plants – there is a dearth of information on very heavy

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http://dx.doi.org/10.1016/j.agwat.2015.10.031
0378-3774/

Table 1
Grain-size composition, bulk density, EC_e (electrical conductivity of saturated paste extracts), pH_e (pH of saturated paste) and SAR (sodium adsorption rate of saturated paste extracts) in both initial soils.

Site	Soil depth (cm)	Grain-size composition (%)			Soil texture class (USDA)	Bulk density (g/cm^3)	EC_e (dS/m)	pH_e	SAR (mmol/L)$^{0.5}$
		<0.002 mm	0.002–0.05 mm	0.05–2 mm					
Eco-city	0–120	0.70	80.14	19.16	Silt	1.60	29.71	8.02	57.50
Industrial area	0–120	0.42	42.85	56.73	Sandy loam	1.56	26.33	7.84	50.17

saline soils with high EC_e and SAR and landscape plants sensitive to salt – thus this is a problem that ecological construction must confront during reclamation of saline soils using saline water irrigation. Our group has developed a rapid and sustainable approach for vegetation landscape construction in coastal saline soils and this approach has proved effective in reclamation of very heavy saline soil (Li et al., 2015). The method relies on soil treatment and drip irrigation. Soils are tilled and treated with a gravel–sand layer and saline water is used to irrigate salt-sensitive plants.

However, the soil reclamation processes differ with soil hydraulic conductivities and can produce different soil physical and chemical properties during the reclamation processes in different soils, further affecting plant growth. The effects of soil properties on plants may be proportionally greater and result in different threshold values for saline water irrigation. In the present study, Chinese rose (*Rosa chinensis*), a conventional landscape flower plant and confirmed as sensitive to soil salinity, were planted in coastal regions with two very heavy saline soils (sandy loam and silt soils), and received water at five levels of salinity using drip irrigation. The primary objective of the work was to determine the effects of different soil types and properties on the soil reclamation processes using the proposed method and the response of plant growth to the reclamation processes in the two soils. The results will be useful in improving the method of reclamation of different saline soils for sensitive plants using drip irrigation with saline water.

2. Materials and methods

2.1. Site description

Field experiments were conducted in the International Eco-City (39°20′N, 118°54′E) and the Industrial Zone (39°03′N, 118°48′E), respectively, during 2012–2014. Both areas were located in Caofeidian District in the south of Tangshan city, east China, and north of Bohai Gulf which borders the Pacific Ocean (Fig. 1). The study areas are characterized by a temperate semi-humid monsoon climate with annual precipitation of approximately 550 mm, with most rainfall during June–September.

According to Wang et al. (1993), the saline soils of the study areas are two typical coastal saline soils developed from beach mud, with the main ions being chloride and Na^+. The EC_e and SAR of the non-reclaimed saline soils at a depth of 100 cm were 26.0–30.0 dS m^{-1} and 50.0–59.0 (mmol L^{-1})$^{0.5}$, respectively. The bulk density was in the range of 1.70–1.85 g cm^{-3}, and reduced to 1.50–1.65 g cm^{-3} after soil tillage, excavation and backfilling (Table 1). The soils were silt in the International Eco-City and sandy loam in the Industrial Zone based on soil classification standard of USDA. In particular, the saline silt had characteristics of sticky texture structure and poor ventilation and permeability. The soil texture, soil bulk density, EC_e, pH_e and SAR in the two experiment sites are shown in Table 1.

The surroundings of the both experimental sites are all wasteland due to the high salt content in soil and there are no factory buildings and residential areas, so no external environment factors from people exist which may influence the experiment.

2.2. Plot layout and management

In order to extend the application of the proposed reclamation method and display its popularization, a salt-sensitive plant (Chinese rose, *R. chinensis*) was selected. The successful survival of the salt-sensitive plant could confirm that the reclamation method is more effective in salt tolerant plants survival due to their higher salt tolerance. In addition, Chinese rose (*R. chinensis*), as an important shrubs flower in the coastal ecology landscape construction, has been widely applied in garden and road greening. Its successful application in reclamation of coastal saline lands could enhance the landscape reconstruction of the area.

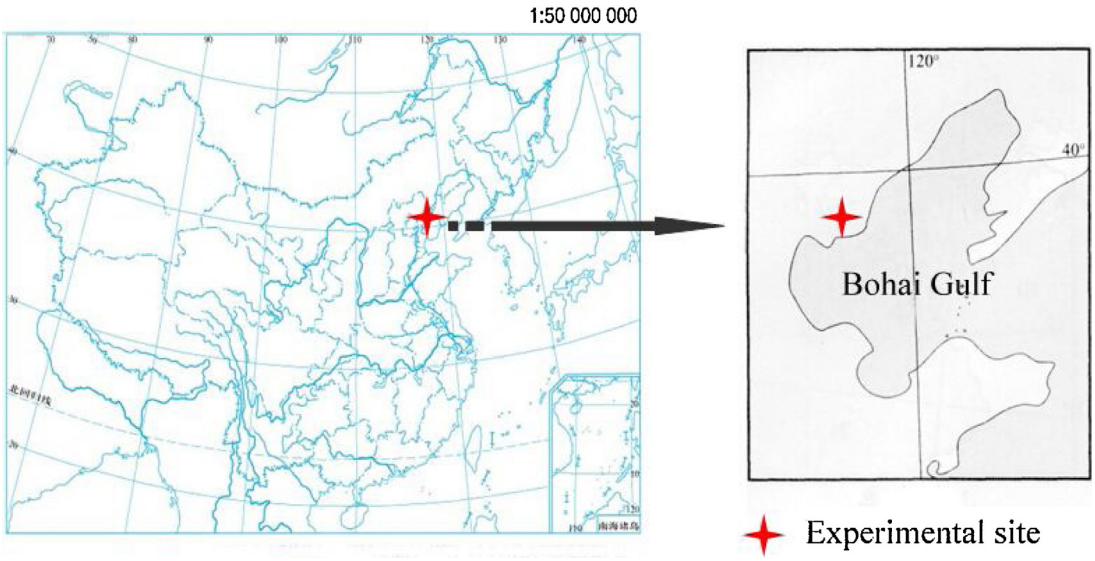

Fig. 1. The location of experimental site.