Catena 150 (2017) 24–31

Contents lists available at ScienceDirect

Catena

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

Effect of ridge planting on reclamation of coastal saline soil using drip-irrigation with saline water

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ARTICLE INFO

Article history:
Received 3 February 2016
Received in revised form 6 August 2016
Accepted 2 November 2016
Available online 10 November 2016

Keywords:
Salt-sensitive plant
Ecological landscapes
Salt leaching
Survival rate
Dry mass

ABSTRACT

The ridge planting (RP) system has been widely used in agricultural production and demonstrated as an effective agronomic practice. However, it is not known if it can be used to reclaim saline soil for landscape construction. Our objective was to analyze the soil characteristics and Chinese rose (*Rosa chinensis*) performance at five irrigation water salinity levels of 0.8, 3.1, 4.7, 6.3 and 7.8 dS/m under RP and flat planting (FP) systems in the process of reclamation of coastal saline soils using drip-irrigation. The experiment started in 2012 using two soils (silt and sandy loam) in the coastal saline regions, north of the Bohai Gulf, China. The RP system significantly enhanced salt leaching in total soil profiles, especially the deep soil profile, and improved emergence and survival of Chinese rose compared with FP. The RP system also improved the salt tolerance of Chinese rose to the irrigation water salinity level. Thus, the RP system (ridge height < 15 cm and ridge width < 50 cm) was effective in reclamation of coastal saline soils by planting small shrubs and herbaceous plants under drip-irrigation with saline water. In this respect, it is expected that RP will be more sustainable and effective than FP for reclamation of saline soils using saline water drip-irrigation in construction of ecological landscapes in coastal regions.

1. Introduction

Coastal saline wastelands in north China are potential land resources for agriculture and ecological landscape construction. However, most of them have not been utilized, especially the severely saline soils, due to high soil salinity, fresh water shortage and high sodium adsorption ratio (SAR). In addition, wind erosion, cold damage and flooding are limiting factors in these regions with abundant rainfall (mostly in June–September) and windy conditions.

Reclamation under an unsaturated soil moisture flow can save water and be more effective in leaching salt than saturated moisture flow (Selassie et al., 1992). Drip-irrigation has been shown useful for the reclamation of saline soils (Kang et al., 2010; Liu et al., 2012; Sun et al., 2013; Wan et al., 2012; Wang et al., 2012), and is regarded as the most promising irrigation system for utilization with saline water (Malash et al., 2008; Meiri et al., 1992). In recent years, the authors' group developed some new methods of soil water and salt management for agricultural utilization and plant construction in very severely saline soils based on the drip-irrigation. These methods mainly relay on soil matric potential (SMP) control, using tensiometers buried at 20 cm depth immediately under drip emitters, to apply the irrigation (Chen et al., 2009; Kang et al., 2010; Liu et al., 2012; Sun et al., 2013; Wan et al., 2012; Wang et al., 2012).

The ridge planting (RP) system is a cultural practice widely used throughout the world with many different modifications but with the same goal – to prepare a seedbed elevated above the mean land surface of the field. The most typical application is ridge tillage, which has the advantages of enhanced soil fertility, better water management, facilitated multiple cropping, enhanced rooting depth and improved pest management compared with reported conventional tillage methods (Hatfield et al., 1998). Studies have shown that RP can influence both biotic and abiotic processes of soil, and affect soil aeration, temperature, moisture and nutrients (Benjamin et al., 1990; Burton et al., 2006; Fan et al., 2014; Hatfield et al., 1998; Kane et al., 2015; Zheng et al., 2014; Zhou et al., 2012). These changes in soil environments have an ultimate effect on crop growth and production. Ridge tillage has been successfully applied in reclamation of saline lands in many regions of China, such as Karamay (chloride-sulfate-type saline-sodic soil, northwest China), Yinchuan Plain (takyric solonetz, northwest China) and Songnen Plain (soda alkali-saline soil, northeast China), based on drip-irrigation. Results indicated that soil salinity decreased rapidly and crop yields ranged from slightly less to higher than those in non-saline soils, and coverage of vegetation dominated by *Leymus chinensis* was up to 80% for rapid reconstruction of salinized grassland (Chen et al., 2009; Kang et al., 2010; Liu et al., 2012; Sun et al., 2013; Wan et al., 2012; Wang et al., 2012).

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http://dx.doi.org/10.1016/j.catena.2016.11.003
0341-8162/

With the rapid industrialization and urbanization in coastal saline regions, there is an urgent need to improve the landscape to meet the demand of living environments for cities and districts. The author's team developed a method for reclaiming very severely saline soils to improve the ecological landscape of coastal saline regions (Chen et al., 2015; Li et al., 2015a, 2015b; Sun et al., 2013). This method mainly relies on soil treatment and drip irrigation. Saline soils are tilled and treated with a gravel–sand layer installed under native saline soils as drain layer (Fig. 1), and then drip-irrigation scheduling of an SMP higher above −5 kPa at 20 cm depth under the emitter in the first year and higher than −10 kPa in the second year is used to reclaim soils. Considering the effects of the ridges on the landscapes, flat planting (FP) was applied for ecological landscape construction of coastal saline soils. Chinese rose (*Rosa chinensis*), a plant sensitive to salinity, has been planted using this method (Li et al., 2015a). Due to low survival rates for drip irrigation with higher salinity water, an improved method is required to enhance the tolerance of plants to saline irrigation water.

RP combined with drip-irrigation has proved effective in salt leaching and improving crop response to salinity (Liu et al., 2012; Wang et al., 2012; Wang et al., 2011; Zhang et al., 2013). However, little is known about the effects of RP on reclamation of saline soils for construction of ecological landscapes under drip-irrigation with saline water, and how this system influences the soil environment and plant performance during the process of saline soil reclamation. Chinese rose was examined in the present study to test the possibility of applying RP in landscape construction during reclamation of saline soils. The objectives were to analyze the effects of RP and FP systems on salt leaching and plant performance at five irrigation water salinity levels, and improve the method of reclamation of coastal saline soils with saline water irrigation by adopting agronomic measures.

2. Materials and methods

2.1. Site, soil and experimental design

Field experiments were carried out in 2012–2014 on a coastal saline wasteland at International Eco-City (39°20′N, 118°54′E) and Industrial area (39°03′N, 118°48′E), respectively. Both sites are located in the Caofeidian District in the south of Tangshan city, east China, and north of the Bohai Gulf bordering the Pacific Ocean. The study areas are characterized by a temperate semi-humid monsoon climate with annual precipitation of approximately 550 mm, with most rainfall occurring during June–September. The mean soil texture, bulk density, electrical conductivity of saturated paste extracts (EC_e), pH and SAR at the two sites for different planting types are shown in Table 1. The soils in our field trials were silt soil in the International Eco-City and sandy loam soil in the Industrial area. The EC_e and SAR of the soils at a depth of 100 cm were 27–30 dS/m and 52–60 $(mmol/L)^{0.5}$, respectively.

In June 2012, Chinese roses were planted in a FP system at both sites (Fig. 1A and Table 2). Four treatments with EC of irrigation water (EC_{iw}) of 3.1, 4.7, 6.3 and 7.8 dS/m were designed, with saline water composed by mixing fresh well-water and highly saline shallow-groundwater in different proportions, and fresh well-water with 0.8 dS/m was used as control (Table 3). Each treatment was replicated three times in 15 plots and laid out permanently following a random complete block design. There were 30 and 56 roses planted at a spacing of 0.5 m × 0.6 m in each plot in International Eco-City and the Industrial area, respectively.

In order to determine the effective application of RP on reclamation of saline soils, in June 2013, Chinese roses were planted in a RP system at the both sites with the same saline water irrigation treatments. There were 36 and 24 roses planted at a ridge spacing of 1.1 and 0.8 m in each plot in International Eco-City (Fig. 1B and Table 2) and the Industrial area (Fig. 1C and Table 2), respectively. In silt soil, each of the 15 plots consisted of three raised beds (height 15 cm), with two rows of Chinese roses in each bed and 1.1 m between bed centers (Fig. 1B). Each bed was 0.5 m wide and 3.0 m long. In sandy loam soil, each of the 15 plots consisted of four raised beds (height 15 cm), with one row of Chinese roses in each bed and 0.8 m between bed centers (Fig. 1C). Each bed was 0.3 m wide and 3.0 m long.

2.2. Experimental management

In this experiment, soil was prepared with a gravel–sand layer as described in Li et al. (2015a) (Fig. 1). Each treatment had a separate gravity drip-irrigation system consisting of a tank and drip tubes. The tank was installed at 0.8 m above the ground to contain irrigation water. Drip tubes were placed in position at 0.05 m from roses. One vacuum gauge tensiometer was installed 0.2 m directly underneath one emitter

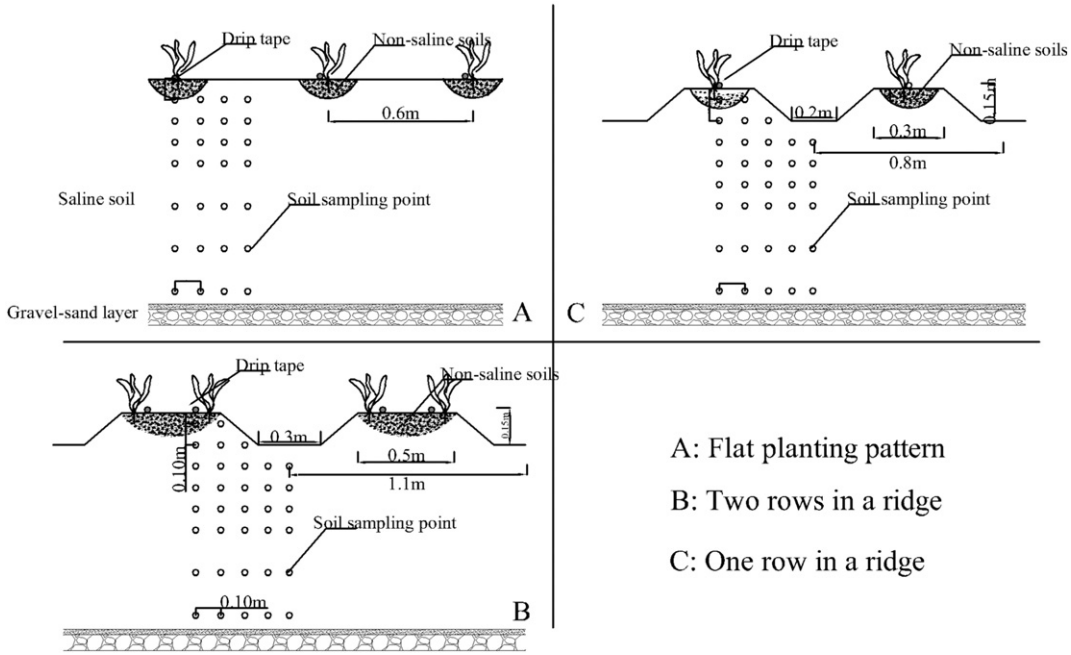

Fig. 1. Planting pattern and soil sampling distribution.