Journal of Integrative Agriculture 2015, 14(10): 2077–2089

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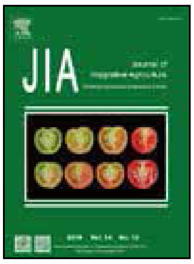

RESEARCH ARTICLE

Effects of water application intensity of microsprinkler irrigation on water and salt environment and crop growth in coastal saline soils

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Abstract

Laboratory and field experiments were conducted to investigate the effects of water application intensity (WAI) on soil salinity management and the growth of *Festuca arundinacea* (festuca) under three stages of water and salt management strategies using microsprinkler irrigation in Hebei Province, North China. The soil water content (è) and salinity of homogeneous coastal saline soils were evaluated under different water application intensities in the laboratory experiment. The results indicated that the WAI of microsprinkler irrigation influenced the è, electrical conductivity (ECe) and pH of saline soils. As the WAI increased, the average values of è and ECe in the 0–40 cm profile also increased, while their average values in the 40–60 cm profile decreased. The pH value also slightly decreased as depth increased, but no significant differences were observed between the different treatments. The time periods of the water redistribution treatments had no obvious effects. Based on the results for è, ECe and pH, a smaller WAI was more desirable. The field experiment was conducted after being considered the results of the technical parameter experiment and evaporation, wind and leaching duration. The field experiment included three stages of water and salt regulation, based on three soil matric potentials (SMP), in which the SMP at a 20-cm depth below the surface was used to trigger irrigation. The results showed that the microsprinkler irrigation created an appropriate environment for festuca growth through the three stages of water and salt regulation. The low-salinity conditions that occurred at 0–10 cm depth during the first stage (−5 kPa) continued to expand through the next two stages. The average pH value was less than 8.5. The tiller number of festuca increased as SMP decreased from the first stage to the third stage. After the three stages of water and salt regulation, the highly saline soil gradually changed to a low-saline soil. Overall, based on the salt desalinization, the microsprinkler irrigation and three stages of water and salt regulation could be successfully used to cultivate plants for the reclamation of coastal saline land in North China.

Keywords: coastal saline soil, microsprinkler irrigation, water application intensity, soil salinity, water and salt regulation, reclamation

1. Introduction

The coastal area surrounding the Bohai Gulf contains the main land resources for expanding agriculture in North China, thereby alleviating increasingly severe conflict with industrialization and urbanization (Shi *et al.* 2005; Wang

Received 12 August, 2014 Accepted 21 April, 2015
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doi: 10.1016/S2095-3119(15)61062-0

et al. 2012). However, the majority of this land suffers from high salinity due to its highly salt content, clayey soil texture and shallow groundwater. For example, a highly saline soil from the region had the same ion composition as sea water (Khan *et al.* 1996) and was classified as a chloride saline soil (Wang *et al.* 1993). Due to its direct development from coastal mud flats, the soil has a heavy clay texture and low permeability. Moreover, the infiltration capacity of the soil tends to decrease greatly with saturation, accompanied by the corruption of soil structure (Wan *et al.* 2012; Wang *et al.* 2012).

Traditional methods used for the reclamation of the coastal saline soils include ponding irrigation, chemical amendments and biological reduction (Khan *et al.* 1996; Singh *et al.* 2001; Shi *et al.* 2003; Wang *et al.* 2012; Datta *et al.* 2013). In recent decades, replacement of the entire soil surface with nonsaline soil has been the main method. This method is costly for developing countries and is a sustainable solution for the amelioration of coastal saline soil. Thus it is an urgent priority to determine usable, low-cost and simple methods for reclaiming salt-affected lands.

Microirrigation, which can provide a constant supply of water to crop zones, has been proven to increase water use efficiency over conventional irrigation methods, and the practice also eliminates percolation to groundwater and surface runoff (Madramootoo and Morrison 2013; Wang *et al.* 2013). Microirrigation applies irrigation water precisely and uniformly at high frequencies, and techniques include drip irrigation, microsprinkler irrigation and surge irrigation (Cao and Zhang 2000). Recently, drip irrigation has been used widely to reclaim salt-affected soils (Burt and Isbell 2005; Rajak *et al.* 2006), and our research group has successfully applied it to reclaim takyric solonetz (Zhang *et al.* 2013), saline-sodic soils (Liu *et al.* 2012; Wan *et al.* 2012) and coastal saline soils (Sun *et al.* 2012, 2013). These studies found that salt displacement is the most efficient under unsaturated flow conditions, which is in agreement with the results of Oster *et al.* (1972).

As another microirrigation technique, microsprinkler irrigation can also maintain soils in an unsaturated condition under reasonable parameters and a convenient irrigation schedule. The technique has gained attention in recent years because it applies water directly to the soil surface, allowing water to dissipate under low pressure in a wetted profile that uniformly meets water demand, and its drops produce little or no rain splash, thereby avoiding much of the destruction of the natural soil structure associated with sprinkler irrigation (Hancock and Willgoose 2003; Marco and Rubens 2003; Reich *et al.* 2009). However, most previous studies of the technique had concentrated on high-value crops in nonsaline soils (Kumar *et al.* 2009; Reich *et al.* 2009; Tripathi *et al.* 2010), while few studies have considered vegetation rehabilitation under microsprinkler irrigation in coastal saline soils. To test the effectiveness of microsprinkler irrigation in the reclamation of coastal saline soils, a laboratory and field experiments were conducted. After evaluation the water application intensity (WAI) of microsprinkler irrigation on soil water content and salinity under laboratory experiment, the field experiment was conducted. Microsprinkler irrigation also provides the means to maintain relatively constant and high soil-water matric potentials in the root zone thereby minimizing the effects of matric stress on festuca growth. Measurement of soil matric potential (SMP) can also be used to trigger irrigation.

Recently, numerous studies have been carried out for evaluating the suitable SMP levels to trigger irrigation in the saline soils. Studies have focused on the effects of different levels of SMP on salt distribution in the soil. They have found that after 2–3 years cultivation the very strongly saline soil gradually changed to a moderately saline soil. The data reported in these studies focused on results obtained after several years of irrigation. This paper focuses on the changes in the depth distributions of salinity that occurred during the first year of irrigation, while festuca was grown, of a native soil that was severely saline-sodic from the soil surface to a depth of 20 cm.

The objectives of this research were: (1) to investigate the effects of different water application intensity (WAI) levels on soil water content (θ), electrical conductivity (ECe), and pH; (2) to determine the soil salt and pH distribution under the different SMP threshold values used to trigger microsprinkler irrigation; (3) to optimize the water application intensities of microsprinkler irrigation and water and salt management strategies based on SMP in coastal saline soils.

2. Results and discussion

2.1. Influence of different WAI values on soil water content and salinity in laboratory experiment

Irrigation The experiments were initiated on 28 March, 2012, and the water application amount of each treatment was 200 mm. Irrigation duration was determined using the WAI values: a higher WAI indicated a shorter necessary irrigation duration (Table 1). Water movement for 1.08, 2.12 and 3.05 mm h^{-1} treatments produced unsaturated flow, while WAI of 5.17 and 7.23 mm h^{-1} produced saturated flow and ponding. Moreover, the vertical wetting front decreased as WAI increased, because no water accumulated in the surface soil when the WAI was smaller than the soil infiltration rate, and the soil water movement was most efficient under unsaturated flow conditions.

Influence of different WAI values on soil water content and salinity Fig. 1 illustrates the spatial distribution of θ,