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Review

Soil salinity management with drip irrigation and its effects on soil hydraulic properties in north China coastal saline soils

Jiaxia Sun[a,b], Yaohu Kang[a,*], Shuqin Wan[a], Wei Hu[a], Shufang Jiang[a], Tibin Zhang[a,b]

[a] Key Laboratory of Water Cycle and Related Land Surface Processes, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China
[b] Graduate University of Chinese Academy of Sciences, Beijing 100049, China

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ABSTRACT

A field experiment with five soil matric potential (SMP) treatments (−5, −10, −15, −20 and −25 kPa) was used to study the effects of drip irrigation on soil salinity, soil hydraulic properties and vegetation growth in coastal saline soils of north China. Irrigation water came from local groundwater with electrical conductivity of 1.7–2.1 dS m^{-1}. The experiment was conducted over three years: 2009–2011. Soil hydraulic properties (hydraulic conductivities, Gardner α and the contribution of pore classes to water flow) were measured three times, i.e. the baseline value (CK) before experiment in 2009, and after one and two years of soil salinity leaching in 2010 and 2011, respectively. Results indicated that low salinity zones existed in the experimental treatments and had expanded during drip irrigation when SMP was controlled at higher than −25 kPa, the average electrical conductivity of the saturation paste extract (ECe) in root zones was below 8 dS m^{-1} for −5, −10, −15, −20 and −25 kPa treatments, and the highest ratio of desalinization (the removal of salt content accounted for the percentage of initial salt content by leaching) in the whole soil profile for the −5 kPa treatment was 64.4%. Meanwhile, the pH of saturated soil extracts concomitantly increased with drip irrigation in the soil profile, whereas it was slightly affected by SMP under drip irrigation. In addition, the hydraulic conductivities, Gardner α and the contribution of macropores (>0.5 mm) and mesopores (0.5–0.25 mm) to water flow in the surface layer in all five SMP treatments were greater than those in the CK treatment, which indicated that the soil structure had improved. The native vegetation was reed [*Phragmites australis* (Cav.) Trin. ex Steud.] and suaeda (*Suaeda glauca Bge*) community. After treatment, the average survival rate of low salt-tolerant plants (*Hibiscus syriacus*, *Prunus cerasifera* Ehrh., *Ilex buxoides* S.Y. Hu and *Ligustrum lucidum*) was 48.9% at the end of the third year of treatment. Overall, based on salt ratio of desalinization, the SMP above −5 kPa at a depth of 20 cm immediately under a drip emitter could be used as an indicator of irrigation scheduling for vegetation rehabilitation in north China coastal saline soils.

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* Corresponding author. Tel.: +86 10 64856516; fax: +86 10 64856516.
E-mail addresses: sunjiaxia@gmail.com (J. Sun), kangyh@igsnrr.ac.cn (Y. Kang).

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1. Introduction

There is 2270 km^2 of coastal saline land in north China (Li et al., 1995), and most is low yield fields and wasteland. The native vegetation is reed [*Phragmites australis* (Cav.) Trin. ex Steud.] and suaeda (*Suaeda glauca Bge*) community, interspersed with bare land. With the rapid development of industrialization and urbanization in coastal saline regions there is an urgent need for reclamation and vegetation rehabilitation in coastal saline areas.

The salinity of coastal saline soil is high, and with the same ion composition as sea water (Khan et al., 1996). Moreover, the groundwater table is shallow and the soil salinity changes seasonally (Shi et al., 2005), which makes the soils unsuitable for sustainable use. The traditional methods of saline soil utilization were biological, chemical and salt-tolerant species. However, presently the main method of vegetation rehabilitation is to replace saline with non-saline soil for depths of 0–100 cm, and this has been widely used in coastal saline areas. This method is expensive and is not sustainable due to the shallow and saline groundwater; therefore, a cheap, simple and sustainable method is needed.

Drip irrigation is considered the most efficient irrigation method because it applies water precisely and uniformly at high frequencies, maintaining high soil matric potential (SMP) in the root zone and thus compensating for the decreased osmotic potential caused by irrigation with saline water, and constant high total water potential can be maintained for crop growth (Goldberg et al., 1976; Kang, 1998). Additionally, well-aerated conditions can be maintained under drip irrigation (Keller and Bliesner, 1990). However, most studies have concentrated on crops such as tomato (Wan et al., 2007), oleic sunflower (Chen et al., 2009) and waxy maize (Kang et al., 2010), and few studies have considered vegetation rehabilitation under drip irrigation in coastal saline soils.

Many studies have investigated irrigation scheduling for a wide variety of crops in different saline soils (Kang, 2005; Wang et al., 2011) based on SMP. Moreover, irrigation by controlling the SMP at a depth of 20 cm immediately under the emitter throughout the growing season has been accomplished in saline soils with arid and semi-arid climates in the Ningxia Plain, China (Tan and Kang, 2009), and was applied in saline wasteland with an inland arid climate in Xinjiang, northwest China (Wang et al., 2011), and also in saline-sodic soils of the Songnen Plain, China (Liu et al., 2011). These studies developed appropriate treatments, but appropriate irrigation scheduling for plants varies according to different soils and regions. However, the natural conditions of coastal saline soils in north China are quite different to Ningxia and Xinjiang, and so further studies are needed in these coastal saline soils.

In a given soil, the changes of soil structure tend to affect hydraulic properties, such as (near-saturated) hydraulic conductivity and the pore size distribution parameter, Gardner α, which are important parameters for understanding aspects of unsaturated soil water flow (Bagarello et al., 2005, 2007; Hu et al., 2009).

The objectives of this study were: (1) to investigate the effects of SMP treatment under drip irrigation on soil salinity during and between planting years; (2) to identify the possible concomitant change of relevant soil hydraulic properties in response to salinity regulation; (3) to examine the effects of different SMP treatments on vegetation growth; and (4) to determine the criteria for irrigation scheduling for vegetation rehabilitation under coastal saline land conditions in northeast China.

Table 1
Initial soil ECe and pHe of the experiment site.

Depth (cm)	ECe (dS m^{-1})	pHe
0–5	20.5	8.00
5–10	26.5	7.92
10–20	25.7	8.00
20–30	24.1	8.06
30–40	28.7	8.02
40–50	23.0	8.07
50–60	17.0	8.16
60–70	13.5	8.21
70–80	13.8	8.17
80–90	11.6	8.22
90–100	10.6	8.23

2. Materials and methods

2.1. Experimental site and natural conditions

Field experiments were conducted in Lianmeng village, Dagang District, Tianjin (38°41′58′N, 117°26′09′E) during 2009–2011, located in the southeast of Tianjin city, west of Bohai Gulf. The study area is characterized by a temperate semi-humid monsoon climate with mean annual precipitation of 593.6 mm. Most rainfall is received during June–September (Fig. 1). The groundwater table varies within depths of 45–138 cm (Fig. 2) depending on precipitation. The irrigation water was the local groundwater with an electrical conductivity (EC) of 1.7–2.1 dS m^{-1}.

The soil texture was silt loam, with 0.6% of particles less than 0.002 mm, 51.8% of particles between 0.002 and 0.02 mm, and 47.6% of particles larger than 0.02 mm. The electrical conductivity and pH of saturated soil extract (ECe and pHe) of the initial soil profile are shown in Table 1.

2.2. Experimental design and arrangements

Five SMP treatments were set up for determining the optimal SMP treatment for vegetation rehabilitation in coastal saline soil. The SMP was controlled at levels higher than −5 kPa (C5), −10 kPa (C10), −15 kPa (C15), −20 kPa (C20) and −25 kPa (C25), respectively. The SMP was measured by a tensiometer buried at a depth of 20 cm immediately under the dripper. The soil was deep plowed to a depth of 60 cm, and then the soil bed (25 cm in height) was raised in the center of each plot. The hibiscus (*Hibiscus syriacus*), redleaf cherry plum (*Prunus cerasifera* Ehrh.), boxwood (*Ilex buxoides* S.Y. Hu), and Chinese glossy privet (*Ligustrum lucidum*) were planted in each plot (Fig. 3).

To avoid the effect of saline soil on tensiometer accuracy, the saline soil was replaced by non-saline soil and compacted in an area of diameter 10 cm and 25 cm depth. Then a hole was made by removing soil to a depth of 23 cm with an auger in the center of the non-saline soil area – in which was placed the tensiometer – and mud was filled into the gap between the tensiometer and the hole.

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