Geoderma 335 (2019) 104–111

Contents lists available at ScienceDirect

Geoderma

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

Effects of planting *Tamarix chinensis* on shallow soil water and salt content under different groundwater depths in the Yellow River Delta

Xiaoqian Li[a,b], Jiangbao Xia[a,*], Ximei Zhao[a,b], Yinping Chen[a,b]

[a] Shandong Provincial Key Laboratory of Eco-Environmental Science for the Yellow River Delta, Binzhou University, Binzhou 256603, PR China
[b] Shandong Agricultural University, Shandong Provincial Key Laboratory of Soil Erosion and Ecological Restoration, Taian 271018, PR China

ARTICLE INFO

Handling Editor: Junhong Bai

Keywords:
Groundwater depth
Soil moisture
Soil salinity
Soil salt ions
Yellow River Delta

ABSTRACT

Groundwater is the main limiting factor that affects the growth and spatial distribution of vegetation in the Yellow River Delta, China. We carried out an experiment to investigate the effects of a *Tamarix* group and control group (bare soil, 0–20 cm) on shallow soil moisture, salt and salt ion distribution at various groundwater depths under brackish water salinity, and we simulated six different phreatic water depths (0.3–1.8 m). The results show that deeper groundwater depths decreased the soil water content, and the soil water content of the control group declined dramatically when the depth exceeded 1.2 m. However, when the phreatic depth exceeded 1.2 m, *Tamarix* presence mitigated the reduction in soil water content. A turning point in the water depth was also observed, and *Tamarix* exhibited water retention effects. The soil salt content presented converse S type as the phreatic water depth increased; *Tamarix* presence mitigated the reduction in soil salt content better than that in the control group. *T. chinensis* exhibited its maximum salt reduction range at a groundwater depth of 1.2 m. In the soil of the *Tamarix* group, the cations consisted mostly of Na^+ and Ca^{2+}, while the anions consisted mostly of Cl^- and SO_4^{2-}. The soil Cl^-/SO_4^{2-} ratio tended to decline along with the rise in the phreatic water depth. *T. chinensis* plantings resulted in easier leaching of shallow saline soils, which remained in a stable desalting state when the phreatic water depth was shallow (0.3–1.2 m); the shallow layers of the saline soil were converted to chloride saline soil. When the phreatic water depth was > 1.2 m, the shallow soil was in a balanced state, and the main salt in the shallow soil consisted of sulfate salt; the soil salt content decreased, and the soil environmental quality improved. Therefore, when seedlings of *T. chinensis* are planted in coastal saline-alkali soil under brackish water salinity, the local phreatic water level should not be < 1.2 m, as *T. chinensis* can effectively improve saline-alkali soils.

1. Introduction

Soil salinization constitutes a widespread and serious soil degradation phenomenon in China. The occurrence of soil salinization is increasing worldwide due to the poor management of water and soil resources, which has severely impacted the sustainable development of the environment and agricultural economy (Cetin and Kirda, 2003; Zhang, 2010). The saline soil area of the Yellow River Delta is approximately 240,000 hm^2, accounting for approximately 1/2 of the area. Restricted by the saline-alkali soil conditions, the vegetation structure in this area is simple and biodiversity is low; these phenomena severely restrict the sustainable development of agriculture and the safety of the ecosystem (Luo et al., 2016). Moreover, salinity is an important driver of land degradation and poses a threat to both soil microbes and plants (Q.Q. Zhao et al., 2017; X.M. Zhao et al., 2017). Therefore, scientific and effective improvements to saline-alkali land have important practical significance for the protection of ecological environments and the improvement of the land use ratio in this area (G.L. Zhang et al., 2016; L.H. Zhang et al., 2016).

The improvement of saline-alkali land should follow the salt distribution laws in soil, and soil salt movements are closely related to groundwater depth (Jin et al., 2012; Wang et al., 2013). Salt dissolves in groundwater and accumulates in the surface layer via capillary rise. Therefore, groundwater depth directly affects the total salt contents of soils, and the total salt content of soil decreases as the groundwater depth increases (Mohamed et al., 2014; Gong et al., 2015). Studies on soil water and salt in the Yellow River Delta have mostly focused on the spatial variability of soil water and salt (Yang and Yao, 2007; Z.R. Wang et al., 2015; J.J. Wang et al., 2015), the effects of groundwater on vegetation type or plant community distribution (He et al., 2007; Laversa

* Corresponding author.
E-mail address: xiajb@163.com (J. Xia).

https://doi.org/10.1016/j.geoderma.2018.08.017
Received 23 December 2017; Received in revised form 30 July 2018; Accepted 10 August 2018
0016-7061/

et al., 2015), and dynamic changes in soil water and salt (Dong et al., 2013; Chang et al., 2014; Chen et al., 2015). Few studies have investigated the distributions of water, salt and major salt ions in shallow soil. Shallow soil is the main location of the growth and development of plant seedlings. The content and distribution of water and salt in shallow soil directly affect seedling survival and greatly influence plant productivity and water-use efficiency. The increases and decreases in groundwater depths and evaporation are the key factors that affect the entry of salt into shallow soil (Uma, 2013; Tian et al., 2015).

Tamarix chinensis Lour. is a shrub species with strong saline-alkali soil and water conservation ability that is widely distributed in the Yellow River Delta. This species plays an important role in improving the regional ecological environment and maintaining the stability of the coastal ecosystem (Xia et al., 2016a, 2016b). Given the development of national ecological construction and the improvements to urban and rural greening levels, the value of *T. chinensis* has been recognized (Han and Zhou, 2010). Studies have investigated the interaction between *T. chinensis* and soil water and salt in the Yellow River Delta; these studies mainly focused on the distribution of ions in the soil around *T. chinensis* (G.L. Zhang et al., 2016; L.H. Zhang et al., 2016; Lu et al., 2016), the effects of "salt islands" and "fertilizer islands" on *T. chinensis* in coastal saline-alkali soil (Zhang and Chen, 2015), and the application of *T. chinensis* in coastal saline-alkali soil greening (Xie, 2006). The influence of *T. chinensis* on the distributions of water and salt in shallow soil and the relationship between water depth and soil water-salt distribution are not clear, which has somewhat restricted soil improvement efforts and the effective use of saline-alkali soil.

Investigations of field vegetation have shown that the growth status of *T. chinensis* differs throughout the coastal saline-alkali soil of the Yellow River Delta, and the major cause of these differences is the phreatic water depth. Therefore, this study hypothesized that *T. chinensis* differentially influences the water and salt contents in shallow soil (0–20 cm) at different phreatic water depths and that *T. chinensis* has a certain water level threshold for shallow soil salinity accumulations. To test the above hypotheses, this study simulated 6 groundwater depths under brackish water (3 g/L) conditions in a research greenhouse. The soil column, which was planted with 3-year-old *T. chinensis* plants, served as the research object. The water content, salt content and main salt ion content of the shallow soil (0–20 cm) at different phreatic water depths were then measured and analyzed. We expected to reveal the distribution of water and salt in the soil profile under *T. chinensis* planting conditions and explore the effects of *T. chinensis* on the accumulation of major salt ions in the soil. Finally, our results should provide a theoretical basis and technical reference for both the prevention and control of secondary soil salinization and the management of *T. chinensis* planting in the Yellow River Delta.

2. Materials and methods

2.1. Experimental materials

To maintain the accuracy of the phreatic water depth and the maneuverability of the experiment, the experimental site was located in the research greenhouse of Binzhou University, Shandong Province, China. The light intensity in the greenhouse was approximately 85–90% of that of the natural light in the area. The temperature was between 22 °C and 30 °C, and the relative humidity was between 41% and 65%. The soil samples used in this study were obtained from the lower reaches of the Yellow River in the Yellow River Delta. The soil particle size distribution was as follows: 8.14% coarse sand, 22.95% fine sand, and 68.91% silt and clay. The field soils had an initial soil pH of 7.54, an average soil salinity of 1‰, a field moisture capacity of 37.86%, and a soil bulk density of 1.32 g/cm^3. The soil was carefully added to the soil column with attempts to maintain its original physical properties. Salt from the muddy coastal zone of the Yellow River Delta was used to configure the test groundwater; the groundwater had a pH value of 8.77, conductivity of 6.16 DS/cm, salinity of 0.32%, and salinity of 3 g/L.

2.2. Experimental design

The Yellow River Delta groundwater is generally shallow (average depth is 1.14 m) (Fan et al., 2010), and investigations of adjacent *T. chinensis* forest farms revealed that the phreatic water depth is 1.2 ± 0.6 m (Xia et al., 2016a, 2016b), the shallow groundwater salinity ranges from 1.5 to 2.0 g/L, and the water quality is alkaline (Xia et al., 2013). The saline groundwater in the Yellow River Delta is dominated by brackish water. Therefore, in accordance with the premise of brackish water salinity, six depths—0.3 m, 0.6 m, 0.9 m, 1.2 m, 1.5 m and 1.8 m—were simulated, and 3 repetitions were included at each water level.

The specific experimental design was as follows: polyvinyl chloride (PVC) pipes of different heights were used as experimental materials for planting *T. chinensis* and simulating groundwater depths in a research greenhouse. The PVC pipes had an inner diameter of 0.30 m, and the height was adjusted in accordance with the simulated groundwater depth. The exact height of the PVC pipes = the simulated groundwater depth + the actual flooding depth (0.55 m) + the top gap layer above the soil surface (0.03 m). The heights of the PVC pipes were 0.88, 1.18, 1.48, 1.78, 2.08 and 2.38 m (Fig. 1). An inverted layer of quartz sand and a permeable cloth were placed at the bottom of each PVC pipe to prevent soil leakage from the bottom. Each PVC pipe was placed in an outer bucket that contained brackish water, and the water depth was maintained at 0.55 m. Four 1.0 cm water inlet holes were drilled into the PVC pipes in a row at 10 cm intervals from the 0.55 m flooded area; after which, the holes were covered with the permeable cloth. This design allowed water to enter the soil column from the bottom flooded area and the surrounding inlet holes. The undisturbed soil samples were added to the circular PVC pipes in accordance with the phreatic water level, and care was taken to avoid large disturbances as much as possible. Three-year-old seedlings of *T. chinensis* were planted in the PVC pipes and irrigated in the early stage (40 days) of seedling cultivation with 4.0 L of fresh water during each application for a total volume of 12.0 L. No seedlings were planted in the PVC pipes of the control group. The other conditions were identical.

2.3. Experimental method and index determination

2.3.1. Transplantation and management of T. chinensis

The experiment started on March 3, 2014. Healthy, three-year-old *T. chinensis* seedlings of uniform sizes were selected. The seedlings were cut at the stem and kept at 60 cm in height, the average length of their rhizomes was 1.3 cm, and the root length was 12–16 cm. The seedlings were planted in the PVC pipes; each PVC pipe received 2–3 plants. Routine management and monitoring of *T. chinensis* were carried out, and the seedlings that grew poorly were replanted. After approximately one month, the *T. chinensis* seedlings had adapted to their environment, and at this time, each container was thinned to only 1 vigorously growing seedling.

2.3.2. Sampling and index measurements

The study took the soil with planted *T. chinensis* and bare soil without plants as the research objects. The determination of soil water and salt parameters began in June 2014. Soil samples with pore diameters of 2.0 cm were removed by drilling from the shallow soil at a depth of 0–20 cm. Five samples were randomly selected from each PVC pipe and mixed into a composite sample, and three soil columns served as three replications. The soil salt content was determined by the residue drying method, and the soil moisture content was determined by the drying method. A 5:1 soil:water mixture was extracted by the residue drying method and was used to determine the major salt ions in the soil. Na^+, K^+, Ca^{2+}, and Mg^{2+} cations were determined by atomic