Effects of rhus typhina and robinia pseudoacacia on physicochemical properties of saline soil in Dagang Area, Tianjin

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Abstract. In order to explore the effect of using two different afforestation tree species to improve soil in coastal saline-alkali land, the method of combining field sampling and indoor analysis and test was adopted. The physical and chemical properties of soils planted with Rhus typhina and Robinia pseudoacacia forest were determined. The results showed that afforestation could improve soil structure, decrease soil bulk density and increase soil fertility. To reduce soil salinization, the soil physical and chemical indexes of Robinia pseudoacacia plantation were better than those of growing Rhus typhina forest, so the planting area of Robinia pseudoacacia plantation in Dagang area could be increased. Planting Rhus typhina forest could also improve the soil in this area, but its effect was lower than planting Robinia pseudoacacia plantation.

1. Introduction

Soil salinization is a global problem, especially in developing countries, which affects the environment and agricultural productivity [1,2]. The total area of salinized land in the world is about 10 million km², and the total area of salinized land in China is about 1 million km². It is mainly distributed in the northeast, northwest, inland areas of north China and coastal areas north of the Yangtze river [3]. The area of salinized land in Tianjin is about 7800 km², accounting for 65.8% of the total soil area in Tianjin. The land with greater than 0.2% soil salinity is about 4700 km², accounting for 39.3% of the total soil area. The salinized land in Tianjin Binhai new area is about 1958.9 km², accounting for 86.3% of the total area of Binhai area. As a coastal city, the coastal area of Tianjin contains 25% of the total area of salinized land, among which the area of salinized soil accounts for 79.9% of the total area of salinized land, and the severely salinized land accounts for 32.1% of the total area of severely salinized land [4-8]. Soil salinization in Dagang area of Tianjin is serious, with high salt content, low organic matter content, poor soil fertility and alkaline soil [9,10].

Rhus typhina is a small deciduous tree belonging to the sumac family. It is native to Europe and the United States, often in the open sand or gravel soil growth, and more cultivated in the provinces north of the Yellow River basin to use mainly for barren hills greening as well as saline landscape forest species.

Robinia pseudoacacia is a deciduous leguminous tree, which require higher water condition, for example the growth was slower in places with high water table, was extremely easy to induce diseases, and had certain drought resistance [11].

At present, Wang, Li and Hou et al have deployed 6 representative soil salinization profiles in coastal
areas of Tianjin, and studies had shown that soil surface vegetation was an important factor affecting soil salinization [12]. Land salinization was one of the major obstacles to the utilization of land resources. Wang, Sun, Li et al discussed the effects of different salt isolation measures on soil water and salt dynamics and photosynthetic characteristics of *Robinia pseudoacacia* in coastal saline-alkali land [13]. In the development of coastal new urbanization, soil quality problems were mainly concentrated on soil salinization, soil salinization and other problems. Ma studied the relationship between the physical and chemical characteristics of coastal soil and soil quality [14]. Y H Gao conducted research on soil water and salt transport and salt-tolerant plants' improvement of saline soil in the saline and alkaline land of Bohai bay [15]. Wang et al made various studies on soil physicochemical properties from soil depth, soil organic carbon, planting methods of different plants, microbial effects and other aspects [16,17]. Cao, Li, Qin et al studied the growth rules of *Robinia pseudoacacia* in pure and mixed forests of 2-3 years in coastal saline and alkaline lands [18]. Lu, Liu, Yang et al studied the physicochemical properties of soil in the artificial pure forest of Chinese scholar tree and *Robinia pseudoacacia* planted in the coastal saline and alkaline land for six years and three years of seedling age [19]. In the past five years, there had been few studies on the effects of *Rhus typhina* on saline soil. Because of the harsh soil conditions of saline-alkali land, there were few plant species that could grow, and it greatly restricted the local economic development, so the research on saline-alkali land improvement technology had become urgent. Test materials mainly were artificial pure forest planting acacia and torch for two sample, and physical and chemical properties of soil were tested to explore the acacia and torch influence on soil physical and chemical properties so as to provide theoretical basis for soil salinization, governance, and improvement and for the popularization and application of saline-alkali land improvement and landscaping.

2. Materials and methods

2.1. Test materials
The test soil was taken from the north of Dagang district of Tianjin in spring 2018. The soil was planted with *Robinia pseudoacacia* forest and torch forest respectively. The plant spacing of *Robinia pseudoacacia* was 2 m×2 m, and the plant spacing of the torch was 3 m×3 m. Take the wasteland soil of the same plot as the reference.

2.2. Sampling method
Select a square sample plot and draw two intersecting diagonals on each sample plot. Take 4 vertices of 2 diagonals and a center point as sampling points. Take 5 soil samples from each sample plot and repeat them for 3 times. A ring knife was used for sampling physical traits, and a shovel was used for sampling chemical traits.

2.3. Determination of soil physical properties
Soil bulk density using ring knife method; Soil porosity and soil moisture content were determined by drying method.

The percentage of pores in the soil per unit volume is called the total porosity of the soil. Can be calculated by the following formula:

\[ \text{Total porosity } \% = \left(1 - \frac{\text{bulk density}}{\text{specific gravity}}\right) \times 100 \]

Single factor randomized block design was adopted in the experiment.

Data were analyzed using anova and significance test.

2.4. Determination method of soil chemical properties
Cations in soil water-soluble salts include Ca\(^{2+}\), Mg\(^{2+}\), K\(^{+}\) and Na\(^{+}\). Among them, Ca\(^{2+}\) and Mg\(^{2+}\) were commonly determined by EDTA titration. K\(^{+}\) and Na\(^{+}\) were determined by flame photometry. Carbonate ion and bicarbonate ion were determined by double indicator -- neutralization titration method, chloride
ion by silver nitrate titration method, soluble salt by conductance method, organic matter content by potassium dichromate capacity method -- external heating method, and soil pH value by pH-3B type acidity meter [20,21].

Single factor randomized block design was adopted in the experiment. Data were analyzed using anova and significance test.

- Flame spectrophotometer Model: FP640 Manufacturer: Shanghai Hongji Instrument Equipment Co., LTD
- pH-3B pH Meter Model: pH-3B Manufacturer: Xi’an Yunyi Analytical Instrument Co., LTD
- Conductivity Meter Model: HI2316 Manufacturer: Beijing Zhongke Dilian Technology Development Co., LTD

3. Results and analysis

3.1. Physical properties of soil

The physical properties of soil planted with *Rhus typhina* forest and *Robinia pseudoacacia* forest were analyzed, and the results were shown in table 1: Soil physical properties of *Robinia pseudoacacia* plantation were significantly better than that of the soil planted with *Rhus typhina*, but there was no significant difference from the control.

|          | water content (%) | Bulk density(g/cm³) | Porosity (%) |
|----------|-------------------|---------------------|--------------|
| CK       | 27.478 a          | A 1.982 a A         | 51.232 a AB  |
| Robinia pseudoacacia | 25.712 ab         | A 1.656 a AB        | 53.319 a A   |
| Rhus typhina | 22.766 b         | A 1.293 b B        | 43.432 b B   |

3.2. Soil chemical properties

3.2.1. Content analysis of K⁺, Ca²⁺ and Mg²⁺ in soil of planting *Rhus typhina* forest and *Robinia pseudoacacia* forest. The results of the determination of K⁺, Ca²⁺ and Mg²⁺ in the soil planted with *Rhus typhina* forest and *Robinia pseudoacacia* forest and the soil used as the control were shown in table 2: In the K⁺ content determination, there was no significant difference between the soil planted with plants and the control, while there was significant difference between the soil planted with *Robinia pseudoacacia* forest and the soil planted with *Rhus typhina* forest. In the content determination of Ca²⁺ and Mg²⁺, the soil planted with *Robinia pseudoacacia* forest and *Rhus typhina* forest was significantly different from that of the control group, while there was no significant difference in the content of Ca²⁺ and Mg²⁺ between the two plants.

|          | K⁺(mg/L) | Ca²⁺(mg/L) | Mg²⁺(mg/L) |
|----------|----------|------------|------------|
| CK       | 0.0328   | ab A       | 0.0713 a A | 0.269 a A |
| Robinia pseudoacacia | 0.0410     | a A        | 0.0458 b B | 0.0363 b B |
| Rhus typhina | 0.0305   | b A        | 0.0365 b B | 0.0420 b B |

3.2.2. Content analysis of Cl⁻, Na⁻ and HCO₃⁻ in the soil of planting *Rhus typhina* forest and *Robinia pseudoacacia* forest. The results of the determination of Cl⁻, Na⁻ and HCO₃⁻ in the soil planted with *Rhus typhina* forest and *Robinia pseudoacacia* forest and the soil used as the control were shown in table 3: The content of Cl⁻ in the soil of *Robinia pseudoacacia* was significantly different from that of the control, and the difference was significant between the soil of planting *Robinia pseudoacacia* and the soil of
planting *Rhus typhina*. However, there was a significant difference between the soil planted with the *Rhus typhina* and the control.

**Table 3.** Content Analysis of Cl\(^-\), Na\(^+\) and HCO\(_3\)^- in soil of planting *Rhus typhina* forest and *Robinia pseudoacacia* forest.

|                | Cl\(^-\) (mg/L) | Na\(^+\) (mg/L) | HCO\(_3\)^- (mg/L) |
|----------------|-----------------|-----------------|--------------------|
| *Robinia pseudoacacia* | 0.0413 a AB | 0.0400 a A | 0.0375 a A |
| CK             | 0.0315 b A | 0.0335 a A | 0.0478 a A |
| *Rhus typhina*    | 0.0205 c B | 0.0440 a A | 0.0384 a A |

There was no significant difference in Na\(^+\) and HCO\(_3\)^- contents between the soil planted with *Robinia pseudoacacia* forest and *Rhus typhina* forest and the control soil.

3.2.3. Content analysis of pH, organic matter and electrical conductivity of soil in planting *Rhus typhina* forest and *Robinia pseudoacacia* forest. The results of pH, conductivity and organic matter content of the soil planted with *Rhus typhina* forest and *Robinia pseudoacacia* forest and the control soil are shown in table 4: The pH differences of the three soils were not significant. In the determination of soil organic matter content, the difference of organic matter content between the soil planted with *Robinia pseudoacacia* and the other two kinds of soil was extremely significant, while the difference of organic matter content between the control soil and the soil planted with *Rhus typhina* was not significant. There was no significant difference between the electrical conductivity of the soil planted with *Robinia pseudoacacia* and the control soil. The electrical conductivity of the soil planted with *Robinia pseudoacacia* and the control soil was significantly higher than that of the soil planted with *Rhus typhina*.

**Table 4.** Content analysis of pH, organic matter and electrical conductivity in soil of planting *Rhus typhina* forest and *Robinia pseudoacacia* forest.

|                | pH | organic matter (g/kg) | Electrical conductivity (us/cm) |
|----------------|----|-----------------------|--------------------------------|
| *Robinia pseudoacacia* | 6.80 a A | 0.508aA | 0.173 a A |
| CK             | 7.20 a A | 0.315bB | 0.156 a A |
| *Rhus typhina*    | 6.98 a A | 0.380bB | 0.148 b B |

4. **Discussions**

4.1. Discussions on the physical properties of soil for growing *Rhus typhina* forest and *Robinia pseudoacacia* forest

Soil bulk density refers to the dry soil weight per unit volume of soil in the natural state of undamaged soil structure. Soil porosity was related to soil bulk density and water content. Bulk density was also an important index of soil porosity. The decrease of soil bulk density leads to the increase of soil porosity and water content. In this experiment, soil bulk density decreased, water content and total porosity increased after planting *Rhus typhina* forest and *Robinia pseudoacacia* forest, effectively improving soil physical properties, which was consistent with the research results of Liu *et al* [22]. The physical properties of soil planted with *Robinia pseudoacacia* forest were better than those of soil planted with *Rhus typhina*.

4.2. Effects of planting *Rhus typhina* forest and *Robinia pseudoacacia* forest on the content and electrical conductivity of soil ions

The conductivity of soil reflects the content of main ions in soil, and the higher the conductivity, the higher the content of ions [22]. The results showed that the content of water-soluble ions in the soil of different tree species was different in the same season, which might be the difference between different tree species or related to the growth and development characteristics of plants themselves. This was
consistent with the research of Bi and Zhang [23]. In the experiment, the content of Cl⁻ and K⁺ in the soil planted with *Robinia pseudoacacia* forest was significantly higher than that in the soil planted with *Rhus typhina*, and there was no significant difference in the content of HCO₃⁻, Na⁺, Mg²⁺ and Ca²⁺ between them.

4.3. *Effects of planting Rhus typhina forest and Robinia pseudoacacia forest on soil pH and organic matter*

A comprehensive evaluation was conducted on salinized soil by pH and organic matter. A high pH index value indicated that the higher salinization degree of soil, the greater the harm to plants. The higher the organic matter content was, the better the soil nutrients were. In the pH measurement, there was no significant change in the soil pH value of the two plants. In the determination of organic matter content, the organic matter content in the soil planted with *Robinia pseudoacacia* forest was higher than that in the soil planted with *Rhus typhina* forest, which was consistent with the study of Wang, Li, Dong *et al* [24,25].

5. Conclusion

In this experiment, according to the analysis of physical and chemical properties, the soil planted with *Robinia pseudoacacia* forest was superior to the soil planted with *Rhus typhina* forest in terms of soil moisture content, bulk density and porosity. In the determination of K⁺ content and electrical conductivity of the soil planted with *Robinia pseudoacacia* forest, the soil was higher than that planted with *Rhus typhina* forest, and there was no difference between the two in the determination of pH, Na⁺, Cl⁻, HCO₃⁻, Ca²⁺ and Mg²⁺. The soil organic matter content of *Robinia pseudoacacia* plantation was higher than that of *Rhus typhina* plantation. The soil physical and chemical properties of *Robinia pseudoacacia* plantation were better than that of *Rhus typhina* plantation. Therefore, in Dagang district of Tianjin city, the proportion of planting *Robinia pseudoacacia* forest should be increased and the planting scale of *Rhus typhina* forest should be reduced.

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