Effects of Garden Waste Compost and Bentonite on Muddy Coastal Saline Soil

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Abstract: In order to effectively utilize resources and improve the amelioration effect of coastal saline soil, we studied the effects of applying garden waste compost and bentonite on highly saline coastal soil. Four treatments were established: a nonamended control; application of 68 kg·m\(^{-3}\) of garden waste compost; application of 15 kg·m\(^{-3}\) of bentonite; and mixed application of 68 kg·m\(^{-3}\) of garden waste compost and 15 kg·m\(^{-3}\) of bentonite. The results showed that the soil salinity of the three treatments was significantly lower than that of the nonamended control. The desalination effect of the mixed application was the best, and the salinity in the 0–20 and 20–40 cm soil layers decreased to 3.95 g·kg\(^{-1}\) and 3.82 g·kg\(^{-1}\), respectively. Application of both the garden waste compost alone and the mixed application significantly improved the physical and chemical properties of the soil. However, the mixed application had the best effect because of its ability to increase the total porosity, saturated hydraulic conductivity, and soil nutrient levels. The growth of *Robinia pseudoacacia* cv. Idaho in the mixed application treatment was also better than other treatments. Principal component analysis and comprehensive scores indicated that the addition of 68 kg·m\(^{-3}\) of garden waste compost and 15 kg·m\(^{-3}\) of bentonite was the optimal application.

Keywords: garden waste; coastal saline soil; soil nutrients

1. Introduction

The muddy coast is composed mainly of mud or clay and occupies a major part of the eastern coast of China [1,2]. The coastal zone is the most frequent and active zone of interaction between the hydrosphere, lithosphere, atmosphere and biosphere. The unique location of the coastal zone and global climate change cause this zone to be a frequent zone location for natural disasters and a fragile zone for ecosystems [3–7]. The soil in the coastal zone is mainly coastal saline soil, which is rich in soluble salts. The salt content within one meter of the soil layer is generally greater than 4 g·kg\(^{-1}\), and can reach up to 20–30 g·kg\(^{-1}\). Soil desalination is difficult when there is a shallow terrain and slow internal drainage [8–12]. Under these conditions, the growth of plants is limited, and under severe stress, plant death occurs. Underground pipe drainage has been implemented in the coastal area, but due to spatial nutrient limitations, plants are threatened by secondary salinization over long periods of time, and plants are prone to degradation, aging and death [13–16]. Therefore, how to develop ecologically green land scientifically and effectively is an important issue that needs to be solved in coastal areas.

In China, with the rapid development of cities, garden areas have increased rapidly. Moreover, the amounts of garden waste, such as dead branches, fallen leaves, grass clippings and flowers, has also increased as a result of landscape maintenance. For example, from 2006 to 2016, the area of green land in Beijing increased from 39,392 ha to 82,113 ha, and more than 2.37 million tons of garden waste are produced annually [17]. Traditional garden waste disposal methods mainly involve incineration and
landfill deposition, which likely cause environmental problems such as air pollution, land occupation and water pollution. Therefore, garden waste disposal has become a major environmental problem in urban construction [18–20]. According to domestic and international studies, composting represents a significant way to utilize resources [21–24]. Through the composting of garden waste, fresh organic carbon is decomposed and converted into humus [25]. Garden waste compost can be reused as a soil amendment or as an organic fertilizer to maintain soil moisture, improve soil fertility, and improve the soil structure [26–28]. However, the improvement effect of garden waste on salt leaching in saline soil has yet to be verified. Some studies have shown that compost containing a high proportion of humified organic matter can decrease the bioavailability of metals in soil by absorption and by the formation of stable complexes with humic substances. This is due to the great capacity of humic acids to retain or to bind metals. Moreover, their molecular size is usually larger than the soil pore size, resulting in low mobility and little leaching through the soil profile [29]. Therefore, the application of garden waste compost in saline soil will require new methods to improve the desalination effect.

Bentonite exists as a 2:1-type crystal structure composed of two silicon-oxygen tetrahedrons sandwiched between a layer of aluminum-oxygen octahedrons [30]. Owing to the presence of Cu, Mg, Ca and other cations in the layered structure formed by the crystal, the interaction with the crystal is very unstable. In addition, it is easily exchanged with other cations, so it has better ion exchange. Bentonite can absorb hydrated cations (e.g., K⁺, Na⁺, Mg²⁺), and its ion exchange capacity can reach 60~150 meq·100 g⁻¹ [31]. The world is rich in bentonite resources, most of which are distributed in China, the United States, Germany, Italy and Greece. The exchangeable Ca²⁺ ion of calcium bentonite acts mainly on Na⁺ in the soil, which improves the desalination effect [32].

Even though there are many studies concerning garden waste or bentonite as soil conditioners, very little is known about their effects on coastal saline soil. Thus, the question of which amendments are the most effective for saline soil remediation remains unanswered. Our study is a new attempt to investigate the application of garden waste compost and bentonite to coastal saline soil. Two materials were used, and four treatments were applied: no materials, garden waste compost alone, bentonite alone and a mixture of garden waste compost and bentonite. Through analysis of soil salinity, physicochemical properties and plant growth among the different treatments, this study aimed to evaluate the effects of different amendments and provide basic data for rational application of these materials in coastal areas.

2. Materials and Methods

2.1. Experimental Site and Material

The study was carried out in July 2016 at the Future Technology City (N39°7′ N, 117°32′ E), Binhai New Area, Tianjin, China, where a wide-ranging coastal saline land greening project was being undertaken (Figure 1). The research site has a warm temperate coastal semi-humid continental and maritime transitional monsoon climate with four distinct seasons. The annual average precipitation is 516 mm, concentrated mainly from July to September, with precipitation during this period accounting for more than 73% of total annual precipitation. The long-term average surface water evaporation is 1625 mm, and the evaporation is approximately three times higher than precipitation. The research soil is a silt-filled soil that has been deposited for 5 years, and the soil type is clay. The general properties of soil (0–40 cm depth) collected from the research site are shown in Table 1.

Bentonite was purchased from Jianping Huiying Chemical Co., Ltd. Liaoning Province, China. The relative chemical composition of the main elements (wt./wt.) in the bentonite was: 61% SiO₂, 16% Al₂O₃, 5.01% CaO, 3.19%Fe₂O₃, 0.27%FeO, 0.15%TiO₂, 3.19%MgO, 0.29%MnO, 1.00%K₂O, 0.22% Na₂O and 0.03%P₂O₅.
Garden waste comprises fallen leaves, grass clippings and branches collected during greening-related maintenance. The properties of green waste are listed in Table 2. The composting experiment was conducted at Tianjin Beilin Xinyuan Greening Engineering Co., Ltd. (Tianjin, China). The waste was broken down by a brush chipper (BC700XL, Vermeer) to a particle size of approximately 0.5–2 cm. The moisture content of these raw materials was adjusted to approximately 50–60%, and urea was added to adjust the initial C:N ratio of the compost material to 25–30 to optimize the microbial activity. A commercial microbial inoculant, Effective Microorganisms (EM, from Zhengzhou Nongfukang Biotechnology Co., Ltd.) was added to the compost material to accelerate microbial activity. A commercial microbial inoculant, Effective Microorganisms (EM, from Zhengzhou Nongfukang Biotechnology Co., Ltd.) was added to the compost material to accelerate microbial activity. A commercial microbial inoculant, Effective Microorganisms (EM, from Zhengzhou Nongfukang Biotechnology Co., Ltd.) was added to the compost material to accelerate microbial activity. A commercial microbial inoculant, Effective Microorganisms (EM, from Zhengzhou Nongfukang Biotechnology Co., Ltd.) was added to the compost material to accelerate microbial activity. A commercial microbial inoculant, Effective Microorganisms (EM, from Zhengzhou Nongfukang Biotechnology Co., Ltd.) was added to the compost material to accelerate microbial activity. A commercial microbial inoculant, Effective Microorganisms (EM, from Zhengzhou Nongfukang Biotechnology Co., Ltd.) was added to the compost material to accelerate microbial activity.

Figure 1. Location of experiment site.

Table 1. Properties of the saline soil.

| Index                              | Value ± standard deviation (n = 5) |
|------------------------------------|-----------------------------------|
| pH                                 | 7.69 ± 0.42                       |
| EC (mS·cm⁻¹)                       | 4.89 ± 0.35                       |
| Bulk density (g·cm⁻³)              | 1.53 ± 0.08                       |
| Total porosity (%)                 | 39.37 ± 2.41                      |
| Hydraulic conductivity (cm·s⁻¹)    | 0.63 × 10⁻⁵ ± 0.10⁻⁵               |
| Organic matter (g·kg⁻¹)            | 1.73 ± 0.01                       |
| Available nitrogen (mg·kg⁻¹)       | 41.21 ± 1.22                      |
| Available phosphorus (mg·kg⁻¹)     | 4.53 ± 0.39                       |
| Available potassium (mg·kg⁻¹)      | 58.2 ± 2.41                       |
| CO₃²⁻ (g·kg⁻¹) b                   | 0.03 ± 0.01                       |
| HCO₃⁻ (g·kg⁻¹) b                   | 0.17 ± 0.01                       |
| Cl⁻ (g·kg⁻¹) b                     | 4.75 ± 0.02                       |
| Ca²⁺ (g·kg⁻¹) b                    | 0.83 ± 0.01                       |
| Mg²⁺ (g·kg⁻¹) b                    | 0.68 ± 0.01                       |
| K⁺ (g·kg⁻¹) b                      | 0.37 ± 0.01                       |
| Na⁺ (g·kg⁻¹) b                     | 6.48 ± 0.15                       |
| SO₄²⁻ (g·kg⁻¹) b                   | 2.86 ± 0.18                       |

a Mean value ± standard deviation (n = 5). The properties of the saline soil were determined according to the methods described by Wang [26]. b Soluble salt ions.
Table 2. Main characteristics of raw materials.

| Index                | Value a               |
|----------------------|-----------------------|
| pH                   | 7.17 ± 0.31           |
| EC (mS·cm⁻¹)         | 1.21 ± 0.05           |
| Bulk density (g·cm⁻³) | 0.15 ± 0.01           |
| Total carbon (%)     | 42.93 ± 3.72          |
| Total nitrogen (%)   | 0.82 ± 0.04           |
| C:N ratio            | 52.34 ± 3.21          |
| Water content        | 40.17 ± 2.55          |

a Mean value ± standard deviation (n = 5). The properties of the raw materials were determined according to the methods described by Tong [18].

Table 3. Physiochemical properties of the final garden waste compost.

| Index                                    | Value a               |
|------------------------------------------|-----------------------|
| pH                                       | 6.65 ± 0.22           |
| EC (mS·cm⁻¹)                             | 1.62 ± 0.14           |
| Bulk density (g·cm⁻³)                    | 0.34 ± 0.02           |
| Total carbon (%)                         | 68 ± 2.71             |
| Total nitrogen (%)                       | 2.57 ± 0.18           |
| Available phosphorus (mg·kg⁻¹)           | 498 ± 9.46            |
| Available potassium (mg·kg⁻¹)            | 1079 ± 8.08           |
| Germination index (%)                    | 99 ± 1.31             |
| Humic acid carbon: Fulvic acid carbon ratio (C_{HA}/C_{FA}) | 1.71 ± 0.1 |

a Mean value ± standard deviation (n = 5).

2.2. Experiment

The experiment involved four treatments: (1) a nonamended control (CK), (2) addition of 68 kg·m⁻³ of garden waste compost (T1), (3) addition of 15 kg·m⁻³ of bentonite (T2), and (4) addition of 68 kg·m⁻³ of garden waste compost plus 15 kg·m⁻³ of bentonite (T3). The amount of bentonite and garden waste compost added in the field experiment was based on that used in the studies by Zhou [32] and Tong [18].

Each treatment was repeated three times and was randomly arranged in 12 blocks. Each block was 54 m² (6 m × 9 m), surrounded by 50-cm-wide protection lines. A drainage desalination system with a depth of 1 m and a spacing of 5 m was installed underground (Figure 2). All the blocks were separated by plastic sheets to a depth of 1 m. The drainage pipe consisted of a perforated polyvinyl chloride (PVC) pipe with a diameter of 0.06 m and a slope of decrease of 2‰. To prevent soil particles from entering the pipe and causing blockage, crushed stones were laid on top of the pipe as a filter material, the thickness of which was 20 cm. Considering the engineering cost and the depth of the plant roots, the amendments and soil within the 0–40 cm layer were thoroughly mixed together. The salt in the soil was removed by leaching; micro spray irrigation was applied 5 times from July to October for rinsing. Three-year-old Robinia pseudoacacia cv. Idaho trees were planted at a spacing of 3 m in August. Trees displaying similar height, basal diameter, and growth potential were obtained from the saline-alkali-tolerant botanical garden. The tree is shallow rooted, and most of its roots are found in the top 30–40 cm layer of the soil. Because of its tolerance to salt stress, the tree is planted in coastal saline soil [33].
2.3. Measurement and Analysis

One year after planting, the physicochemical properties of the soil were determined and the growth of the plants was measured. Each tree in the sample area was surveyed, and the growth indexes, such as diameter at breast height (DBH) and tree height were measured every two months. Five samples were randomly collected from the 0–20 cm and 20–40 cm soil layers, and all soil samples were dried and ground through a 1-mm sieve. Soil samples were prepared as soil leachate extracted from a 1:5 (w/v) soil-distilled water solution to measure pH and the concentration of Ca$^{2+}$, Mg$^{2+}$, Cl$^{-}$, SO$_{4}^{2-}$, Na$^{+}$ and K$^{+}$. Soil bulk density and total porosity were measured according to the cutting-ring method. Saturated hydraulic conductivity was determined by a Guelph permeameter (Model 2800K, United States) [34]. Soil pH and salinity were measured via a multiparameter water quality meter (Model DZS-706, China). The concentration of Ca$^{2+}$, Mg$^{2+}$, Cl$^{-}$ and SO$_{4}^{2-}$ were measured via ion chromatography (Dionex ICS-1100, United States) [35], and the concentrations of Na$^{+}$ and K$^{+}$ were measured with a flame photometer (Model AP1500, China). The organic matter was determined using the dry combustion method [36]. Alkali solution diffusion was used to measure the available nitrogen content [37], and available phosphorus content was measured using the Olsen method [38]. The available potassium content was subsequently measured via ammonium acetate digestion-flame photometry [39]. Survival rate was calculated by counting the number of plants in each treatment that survived. Tree height (H) was measured with a Vertex IV altimeter, and the diameter at breast height (DBH) was measured with a Vernier caliper.

Duncan’s test was performed using SPSS 22.0 software to verify the differences among the treatments. In order to eliminate the reweighting among original indices and assign principal component weights to evaluation indices, principal component analysis was used to perform dimensionality reduction, standardization and decorrelation processing on the physical and chemical properties of the four treatments. Finally, according to He and Lin [40,41] (Formulas (1) and (2)), the quantitative analysis was performed by a comprehensive principal component evaluation function, and transverse comparison of four treatments was carried out to provide a helpful reference to evaluate the improvement effect.

\[
F_j = \sum_{i=1}^{9} (x_i \times f_{vi}) \quad (i = 1, 2, \ldots, 9) \tag{1}
\]

\[
Q = \frac{\sum_{j=1}^{3} (F_j \times v_{ij})}{ac} \quad (j = 1, 2, 3) \tag{2}
\]

$x_i$: The value of the i-th indicator
$f_{vi}$: The eigenvector value of the i-th indicator
$F_j$: The jth principal component score
Q: The soil improvement effect comprehensive evaluation score
vcj: The variance contribution rate of the j-th principal component
ac: The cumulative contribution rate of all principal components

3. Results

3.1. Effect of Garden Waste and Bentonite on the Soil pH and Electric Conductivity (EC)

The salt within coastal saline soil originates mainly from seawater. Because the geological salt accumulation process started before the soil-forming process, the salt-alkali soil contains a large amount of soluble salt. The EC of the experimental soil before the improvement was 4.89 dS·m$^{-1}$, which seriously exceeds the range that a plant can tolerate. Figure 3 shows that after leaching, the salinity of the CK group was still higher than 3 dS·m$^{-1}$, and the desalting effect was weak. The addition of garden waste compost or bentonite alone (T1, T2) resulted in significant differences in EC compared with that of the CK ($P < 0.05$), and the salt rejection rate exceeded 50%; however, the soil was still heavily salinized. The addition of garden waste compost and bentonite (T3) had the best desalination effect, which was significantly better than that of the other treatments ($P < 0.05$). The EC in the 0–20 cm layer and the 20–40 cm layer was 1.2 dS·m$^{-1}$ and 1.16 dS·m$^{-1}$, respectively. The soil pH of the experimental soil was 7.69, and the pH in the T1, T2 and T3 treatment groups increased slightly in the surface layer after the addition of the soil amendments, but the difference was not significant.

![Figure 3](image-url)

**Figure 3.** Effect of amendments on the soil pH (a) and electric conductivity (EC) (b). CK, nonamended control; T1, green waste compost; T2, bentonite; T3, green waste compost plus bentonite. Mean value ± standard deviation ($n = 15$). Significant differences were analyzed via Duncan’s test, with different letters indicating significant differences between treatments ($P < 0.05$).

3.2. Effect of Garden Waste and Bentonite on Soil Permeability

Table 4 shows the analysis results of the soil porosity and permeability in each treatment. The soil bulk density, total porosity and saturated hydraulic conductivity in the CK treatment were 1.53 g·cm$^{-3}$, 43.35%, and $0.74 \times 10^{-5}$ cm·s$^{-1}$, respectively; these values are not favorable for soil water and salt transport and leaching improvement. The bulk density of the T1 and T3 treatments (which were amended with garden waste compost) was significantly lower than that in CK, and the total porosity and saturated hydraulic conductivity in the first two treatments were significantly greater than those in the CK. The physical properties of the soil in T1 were the best; the total porosity and hydraulic conductivity were $51.13\%$ and $8.67 \times 10^{-4}$ (cm·s$^{-1}$), respectively, which were significantly greater than those of the other treatments. The addition of bentonite alone did not significantly improve the soil bulk density, porosity or permeability, suggesting that bentonite has hygroscopic swelling which have an adverse effect on soil permeability [27].
Table 4. Effect of amendments on soil bulk density, total porosity and saturated hydraulic conductivity.

| Treatment | Soil Bulk Density (g cm\(^{-3}\)) | Total Porosity (%) | Saturated Hydraulic Conductivity (cm s\(^{-1}\)) |
|-----------|-----------------------------------|--------------------|-----------------------------------------------|
| CK        | 1.53 ± 0.02a                      | 43.35 ± 0.91a      | 0.74 × 10\(^{-5}\) ± 0.30 × 10\(^{-5}\)a |
| T1        | 1.31 ± 0.04bc                     | 51.13 ± 1.14c      | 8.67 × 10\(^{-4}\) ± 0.29 × 10\(^{-4}\)b |
| T2        | 1.49 ± 0.03ab                     | 44.38 ± 1.65ab     | 1.18 × 10\(^{-5}\) ± 0.10 × 10\(^{-5}\)a |
| T3        | 1.37 ± 0.01c                      | 49.3 ± 1.06c       | 6.63 × 10\(^{-4}\) ± 0.13 × 10\(^{-4}\)c |

Significant differences were analyzed via Duncan’s test, with the different letters indicating significant differences between treatments (\(P < 0.05\)). Mean value ± standard deviation (\(n = 15\)).

3.3. Effect of Garden Waste and Bentonite on Soil Nutrients

On the basis of the information shown in Figure 4, the available potassium and organic matter in the 20–40 cm layer was significantly greater in the T2 treatment than that in the CK treatment, revealing that the addition of bentonite alone helped to prevent the loss of potassium and organic matter in the 20–40 cm layer.

![Figure 4](image_url)

**Figure 4.** Effects of amendments on organic matter (a), available nitrogen (b), available phosphorus (c) and available potassium (d). Significant differences were analyzed via Duncan’s test, with different letters indicating significant differences between treatments (\(P < 0.05\)). Mean value ± standard deviation (\(n = 15\)).
The use of garden waste compost alone significantly increased the soil nutrient content; all indicators increased by 22% to 55%. The indexes of T3 were the greatest across all treatments and were significantly different from those of other treatments. The organic matter content of the 0–20 cm and 20–40 cm soil layers was 2.11 times that of the CK, indicating that the combination of garden waste compost and bentonite significantly increased the soil nutrient content, and this improvement effect was obviously better than that of the other treatment groups.

3.4. Effect of Garden Waste and Bentonite on Tree Growth

Figure 5 shows the results of the investigation on the growth of Robinia pseudoacacia cv. Idaho in the experimental plot. At one year after planting, the survival in the four treatments were 39% (CK), 75% (T1), 42% (T2) and 91% (T3). The CK and T2 treatment had the highest tree mortality rate, with survival lower than 50%. Owing to the slow growth during the sapling stage and the adaptation process, the growth in the four treatments in the same year was not extensive, and the increases in plant height and DBH tended to be relatively flat. In the following year, compared with those in the CK, the plant height and DBH in the other treatments tended to increase rapidly, and there was no death in T3. The plant growth was also greater in the T3 treatment than in the other treatments, indicating that the T3 treatment was more suitable for improving site conditions.

3.5. Comprehensive Evaluation of Soil Improvement Effects under Different Treatments

Principal component analysis (PCA) was used to determine the interaction and relationships between the physical and chemical properties of the soils. The obtained eigenvalues and eigenvectors are shown in Figure 6. The first principal component (PC1) contributed to 61.5% of the variance; the second principal component (PC2), 12.3%; and the first two principal components combined, 73.8%. Together, this accounted for most of the variation of the original data. The data of the different treatments were independent, indicating that there was a significant difference between the treatments. Table 5 shows that the eigenvector value of soil nutrition (AN, AP, AK) was the largest (i.e., it was the first principal component). The eigenvector value of pH was the largest (i.e., it was the second principal component). Soil bulk density and total porosity constituted the third principal component. Therefore, available nitrogen, pH, soil bulk density and total porosity were the four main environmental factors. The variance contribution rate of each principal component was used as the weight, and the result of the linear weighted sum of each principal component was taken as the comprehensive evaluation value (Q). From the comprehensive evaluation scores and rankings in Table 6, it can be seen that T3 was
one of the best treatments. Although the comprehensive evaluation will change with different indexes systems, data and evaluation methods [42], the scoring results of this study are highly consistent with the observed growth of plants in different treatment groups. On the whole, the mixed application of garden waste compost and bentonite had the greatest influence on coastal saline soil and the best improvement effect.

Figure 6. The principal component analysis (PCA) plot of soil physical and chemical properties.

Table 5. Principal component eigenvectors.

| Variable                        | PC1  | PC2  | PC3  |
|---------------------------------|------|------|------|
| Available nitrogen (AN)         | 0.885| −0.202| 0.069|
| Available phosphorus (AP)       | 0.876| −0.101| 0.287|
| Available potassium (AK)        | 0.86 | −0.173| −0.067|
| Saturated hydraulic conductivity (Ks) | 0.83 | 0.105 | −0.146|
| Bulk density (BD)               | −0.819| −0.403| 0.359|
| Total porosity (TP)             | 0.819| 0.403 | −0.359|
| Organic matter (OM)             | 0.789| −0.332| 0.307|
| Salt                            | −0.78 | 0.186 | −0.196|
| pH                              | 0.096| 0.778 | 0.61 |

Table 6. Comprehensive evaluation of principal component analysis.

| Treatment | F1    | F2    | F3    | Q     |
|-----------|-------|-------|-------|-------|
| CK        | 106.27| −15.00| 20.48 | 77.78 |
| T1        | 156.08| −24.10| 29.36 | 113.84|
| T2        | 120.55| −18.17| 22.37 | 87.96 |
| T3        | 194.00| −31.24| 36.91 | 141.35|

The comprehensive evaluation scores (Q) were calculated by Formulas (1) and (2).

4. Discussion

According to this study, the coastal saline soil of Tianjin is a typical NaCl-type saline soil that is highly saline and has an extremely poor structure. The soil permeability was only $0.63 \times 10^{-5}$ cm·s$^{-1}$,
which can lead to a very long natural desalination process. The EC of the 0–20 cm soil layer in the CK treatment (without a soil amendment) remained as high as 3.21 dS·m⁻¹. Therefore, effective measures must be taken to improve soil structure and increase the nutrient content and water conductivity to accelerate soil leaching and salt removal.

The exchangeable Ca²⁺ ions of calcium bentonite act mainly on Na⁺ ions in the soil, which improves the desalination effect. Studies have shown that bentonite reduces the hydraulic conductivity in the soil and increases the accessibility of the exchange surface, thus enhancing the cation exchange rate, which leads to the rapid release of cations from the soil colloid [43].

According to our study, the soil salinity after the garden waste compost and bentonite were mixed together and applied was significantly lower than that in response to garden waste compost applied alone, which indicates that adding bentonite may help in leaching Na⁺.

During the second year after planting Robinia pseudoacacia cv. Idaho, the mortality rate of the trees without any amendment (CK) and with the addition of bentonite alone (T2) was very high. Analysis of the soil physical and chemical properties of these two treatments revealed that the soil salinity in the bentonite treatment and the CK treatment was not reduced. The average annual precipitation in Tianjin is 516 mm, and the average surface water evaporation across many years is 1625 mm, which is three times the precipitation [44]. The movement of soil salt depends mainly on the evaporation/deposition of surface water. The amount of water that is evaporated is much greater than the amount that falls as precipitation, which drives the rapid accumulation of soil salt near the surface. Even if the underground drainage desalination system could control the groundwater level effectively, salt will still accumulate in the soil because of the low soil desalination rate. The results of Zhang’s study showed that the high temperature in the coastal area in the summer aggravated the back-salt effect of the surface soil, and that it is necessary to apply suitable soil amendments to drainage desalination systems to improve them further [45]. In addition to being involved in ion exchange, bentonite also undergoes strong hygroscopic expansion. Under the repeated evaporation and precipitation cycles in nature, hygroscopic expansion is greater than the ion exchange effect. The salt rises faster because of capillary action, and the soil is more likely to return to being saline. Eilenbrod’s research found that the application of bentonite greater than 20% will reduce the hydraulic conductivity of the soil due to the swelling effect, which in turn reduces the leaching efficiency [46].

The mixed application of garden waste compost and bentonite can significantly increase the total porosity and saturated hydraulic conductivity. At the same time, the ion exchange of bentonite was promoted to prevent its hygroscopic swelling and salt accumulation. Studies have shown that the combination of organic and inorganic modifiers can produce interactions, thereby enhancing the effects of soil amendments [47]. In the present study, the soil nutrient contents in the T3 treatment was greater than that in the T1 and T2 treatments. The microorganisms produced during the fermentation process also play a role in activating soil nutrients. The presence of bentonite improves the physical structure of the soil as well as the water and fertilizer retention abilities. Therefore, the addition of garden waste compost and bentonite helped to establish a self-sustaining ecosystem in saline soils [48], ensuring the sustainability of green land in the Tianjin coastal area.

5. Conclusions

The mixing of garden waste compost in the coastal saline soil drainage project accelerated soil leaching and salt removal, reduced the salt content and improved the physical and chemical properties of the soil, which created suitable environment for the growth of Robinia pseudoacacia cv. Idaho. According to the results of a PCA and a comprehensive evaluation of soil improvements, the application of garden waste compost together with bentonite presented the best effects in terms of improving the total porosity, permeability, nutrient content, and physical and chemical properties of the soil. The results of this study will directly provide technical and theoretical support for the improvement of saline land and afforestation in coastal areas.
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