Effect of Phragmites communis on Salt Modification in Saline-alkaline Soil

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Abstract. In order to study the influence of reed on the salinity improvement and distribution in saline soils, the distribution characteristics of pH, conductivity, organic matter and salinity of different soil layers before and after reed planting and single growing season were measured. The results showed that after six years of improvement, the reed on the 6 kinds of salts in the improvement of the effect more than 60%. The change of soil pH and conductivity was consistent. With the growth and development of reed, the pH value and conductivity of the surface soil decreased significantly, while the middle layer has no changed. The content of soil organic matter in saline soil was significantly higher than that in middle and bottom layers, and the content of soil organic matter increased significantly with the initial 8.95 g·kg⁻¹ to 11.80 g·kg⁻¹, while the soil organic matter changed in the middle and bottom soil was small. The salt the saline soil was significantly higher than that in the middle and bottom layers. The effect on the salt improvement of the surface soil was the best during the reed whole growth period.

1. Introduction
Soil salinization has become one of the most difficult land deterioration problems. According to data, the area of salty soil all over the world has been increasing at a speed of 100*10⁴ hm²~150*10⁴ hm² per year. In the world, salty soil lands spread widely in more than 100 countries, mainly in arid-semiarid regions in every continent. At present, the total area of salty soil lands in China is about 3600*10⁴ hm², covering 4.88% of available lands in China [1]. Soil salinization will seriously do harm to plant growth and ecological environment. Currently, the ways to improve salty soil lands mainly include building irrigation and drainage works[18], raising salt-tolerant plants[2], improving soil fertility through artificial measures and adding chemical substances, etc. [17] Among them, irrigation and drainage works take effect rapidly, and have good effects, but have large amount of engineering, and a high cost adding such chemical improvers as phosphogypsum[6], fly ash and furfural residue can...
reduce the degree of soil salinization but is likely to cause such potential risks as heavy metal pollution in soil. While biological measures are receiving more and more attention in the academic circle due to its low costs and small negative influence. Raising halophytes of a good salt-tolerant ability, such as Puccinellia tenuiflora, Casuarina equisetifolia, Populus euphratica, and Populus euphratica, etc. can absorb and transfer salt in soil, to solve the salinization [9,10]. Certainly, parting out germs of a good salt-tolerant ability through cultivating to improve efficient utilization of salty soil nutrients can also solve the salinization [7].

The reed, as a salt-tolerant plant, has a function of improving salty soil lands which has been affirmed preliminarily [19]. Due to its tenacious vitality and wide spreading, there is a huge possibility that it is used as a biological species improving salty soil lands. However, there are only reed influence researches in such aspects as PH values, conductivity and salt ions of topsoil, in a short time, and there lack systematical researches on improvement effects of salty soil layers of different depths at a long-term size and a soil profile [21]. This thesis, through analyzing the improving effect of seven years of reed planting on salty soil lands, as well as dynamic changes of salinity regularities of distribution of soil in different depths in salty soil lands within different bearing periods, in purpose of studying reed influence on distribution rules of of salty soil profile salt, of further analyzing reed possibility of improving salty soil lands, provides theory evidence for biology repair methods of salty soil lands [11,12].

2. Research method and material

2.1. General situation of research area

For this experiment, an analogy method is adopted for studying reed influence on salinity distribution rules of salty soil in Lupo Shoal, with the analogy device set in a key lab for degraded and unused lands of Shaanxi Fuping County Ministry of Land and Resources, established in 2009 and has been filled with salty soil in Lupo Shoal. That area has the same natural conditions as the the Lupo Shoal. Lupo Shoal is located in Fuping County of Shaanxi Province, whose total area is 109km², height is 377~380m and the amount of evaporation from lands for the whole year is 1000~1300mm which is 2~2.3 times more than the rainfall, having a semi-arid continental climate. Due to its terrain features, plus using water irrigation and flood diversion projects in Luoxi irrigated area, sedimentation is caused in drainage channels within the shoal area, and watertable rise is also caused within it, so the soil salinization becomes more and more serious gradually. Soil in the Lupo Shoal consists of moderate salty soil and severe salinized fluvio-aquic soil.

2.2. Experiment material and device

Analogy Device: That is a cylindrical hollow cement pillar of a height of 0.98m, whose internal diameter is 80cm and wall thickness is 8cm, also for whose bottom, seepage prevention has been adopted to prevent salt in the device from seepage. There are totally 10 analogy devices. Soil for the Experiment: Salty soil is taken from the Lupo Shoal. Soil filling as well as compaction shall be done according to profile features to ensure getting near to the actual situations of Lupo Shoal. Thickness of soil layers in the analogy devices is 60cm.

Reed Planting: Seeding shall be done according to the density of 300 reeds in every device, with regular checks. If a reed is found withered and yellow or dead, in time remove it and fill the gap with seedlings. Every year reeds shall not be harvested artificially but shall be withered and yellow and then shall decompose naturally.

2.3. Experiment design and method

In 2009, such 6 ions as Ca²⁺, Mg²⁺, Cl⁻, SO₄²⁻, HCO₃⁻ and CO₃²⁻ as well as background values of pH and conductivity of soil in devices were measured before planting reeds; the whole reed growth season in 2016 was set as the main research period, also 3 devices will be selected at random for collecting soil samples respectively in the period of emergence, leaf spreading, flowering, maturation and withering,
with soil collected for every analogy device according to the surface (0-20 cm), the middle layer (20-40 cm), the bottom layer(40-60 cm) in order to mensurate pH, conductivity, organic matters, contents of such ions as Ca$^{2+}$, Mg$^{2+}$, Cl$^{-}$, SO$_4^{2-}$, HCO$_3^-$ and CO$_3^{2-}$ of soil.

For the soil, whose pH shall be mensurated by a pH meter; conductivity a conductivity meter; Ca$^{2+}$ and Mg$^{2+}$ an EDTA titrimetry; Cl$^{-}$ a silver nitrate titrimetry; SO$_4^{2-}$ an EDTA indirect complexometric titration; CO$_3^{2-}$ and HCO$_3^-$ a neutralizational process of double reagents. Data shall be handled with Excel 2016, and statistical analysis for data shall be conducted by SPSS 19 software.

### 3. Results and analysis

#### 3.1. Reed planting effect on improving salty soil

Through comparing background values in 2009 with average values of such 6 ions as Ca$^{2+}$, Mg$^{2+}$, Cl$^{-}$, SO$_4^{2-}$, HCO$_3^-$ and CO$_3^{2-}$, pH and conductivity of soil of 0-60cm in withering reed period in 2016, improvement effects of long-term planting of reed on salinity of salty soil in Lupo Shoal has been studied (Table 1). Results show that from 2009 when reeds are planted in established analogy devices to 2016 when pH in salty soil in devices has decreased by 0.53 unit, and conductivity of the soil has decreased by 35.8%, and six salinity ions contents have all decreased by more than 60%, reeds have improved effectively the salty soil in Lupo Shoal. Among them, reed improvement effect is the best on Mg$^{2+}$ decreasing by 94%; the second-best on SO$_4^{2-}$ whose contents have decreased by 77%.

| Year | pH   | Conductivity(mS·cm$^{-1}$) | Ca$^{2+}$ (mg·kg$^{-1}$) | Mg$^{2+}$ (mg·kg$^{-1}$) | Cl$^{-}$ (mg·kg$^{-1}$) | SO$_4^{2-}$ (mg·kg$^{-1}$) | HCO$_3^-$ (mg·kg$^{-1}$) | CO$_3^{2-}$ (mg·kg$^{-1}$) |
|------|------|---------------------------|---------------------------|--------------------------|-------------------------|---------------------------|---------------------------|---------------------------|
| 2009 | 9.42 | 1.20                      | 67.9                      | 185.2                    | 44.1                    | 95.4                      | 93.8                      | 17.5                      |
| 2016 | 8.89 | 0.77                      | 27.0                      | 10.2                     | 26.5                    | 21.9                      | 29.8                      | 6.3                       |

#### 3.2. Dynamic changes of pH and conductivity of salty soil in different reed bearing period within single growth season

![Figure 1. Soil pH at different depths of each reed growth stage](image)

From an emergence period to a withering period of reeds (Figure 1), pH of 0-20cm surface soil has decreased continuously, 8.22 from the former 9.16, with the decreasing range being 17%, among which changes from the maturation period to the withering period of reeds are the most obvious. 20-40cm middle layer soil pH values are also in a decreasing trend from an emergence period to a withering period, but are the lowest during the maturation period, 8.31. 40-60cm bottom layer soil pH
values have risen slowly and then tended to be steady from the emergence period to the flowering period, with the soil pH value rising up to 9.46 during the withering period from 8.92 during the emergence period. On the whole, during the reed bearing period, pH value changes of soil are in a trend of decreasing upper soil and increasing lower soil.

From an emergence period to a leaf spreading period of reeds, conductivity of surface soil is in a trend of increasing (Figure 2), and then during a withering period, the conductivity has decreased gradually, so during the whole bearing period, the conductivity decreases from 0.93 mS·cm⁻¹ to 0.36 mS·cm⁻¹; middle-layer soil has no obvious changes during every bearing period of reeds; bottom-layer soil has conductivity obviously lower than that of surface soil and middle-layer soil before a heading period, also with the growth of reeds, the conductivity has risen gradually and been at a record level during the maturation period. Thus, reeds have a good improvement effect on conductivity of 0-20cm surface soil of salty soil in Lupo Shoal.

![Figure 2. Soil conductivity at different depths of each reed growth stage](image)

3.3. Dynamic changes of organic content of salty soil in different reed bearing period within single growth season

Through analyzing organic matters in every soil layer within different reed bearing periods (Figure 3), it can be known that within every reed bearing period, organic contents of surface soil are all obviously higher than those of the middle-layer and bottom-layer soil. With the growth of reeds, organic contents of surface soil have increased gradually to 11.80 g·kg⁻¹ during the withering period from 8.95 g·kg⁻¹ during the emergence period, rising by 31.8%. Thus, planting reeds in salty soil of Lupo Shoal can obviously raise the organic content of soil, especially of surface soil.
3.4. Dynamic changes of salinity distribution rule of salty soil in different reed bearing period within single growth season

Through analyzing content distribution rules of such ions as $\text{Ca}^{2+}$, $\text{Mg}^{2+}$, $\text{Cl}^-$, $\text{SO}_{4}^{2-}$, $\text{HCO}_{3}^-$, $\text{CO}_{3}^{2-}$ in salty soil within different reed bearing periods (Figure 4), it can be acquired that reeds have an obvious improvement effect on 0-20cm surface salty soil salinity, and with getting near to the reed bearing period, contents of every salinity ion in surface soil have decreased gradually. 20-40cm middle-layer soil salinity content has no obvious changes with the growth of reeds. While bottom-layer soil salinity ions are in a trend of rising.

The $\text{Ca}^{2+}$ content in 0-20cm surface salty soil has decreased obviously from a emergence period to a leaf spreading period of reeds, to 52.38 mg·kg$^{-1}$ from 110.72 mg·kg$^{-1}$, with the decreasing amplitude reaching 52.7%, but tended to be steady from a leaf spreading period to a withering period, with the decreasing amount being only 20.28 mg·kg$^{-1}$. The $\text{Mg}^{2+}$ content in the middle-layer and bottom-layer soil basically has no change during reed growing periods.

Changing rules of the $\text{Mg}^{2+}$ content is basically the same as those of the $\text{Ca}^{2+}$ content. During the whole reed bearing period, the $\text{Mg}^{2+}$ content of surface soil has decreased by 59.1%, with the middle-layer and the bottom-layer soil having no obvious changes. Such salt base anions of 0-20cm surface salty soil as $\text{Cl}^-$, $\text{SO}_{4}^{2-}$, $\text{HCO}_{3}^-$, $\text{CO}_{3}^{2-}$, have decreased gradually with the growth of reeds, among which there is a relatively big change in the $\text{Cl}^-$ content from the emergence period to the flowering period, which has decreased by 49.94 mg·kg$^{-1}$, whose decreasing amplitude has been relatively small from the flowering period to the maturation period.

$\text{Cl}^-$ contents of middle-layer and bottom-layer soil from the emergence period to the leaf spreading period have not changed basically. And from the leaf spreading period to the withering period the $\text{Cl}^-$ content of middle-layer soil has decreased gradually, while the $\text{Cl}^-$ content of bottom-layer soil has risen gradually. That may be due to soil colloid ions with negative charges having a repulsive interaction toward $\text{Cl}^-$ and leading to a downward leaching loss of $\text{Cl}^-$. Reeds have had obvious adsorption and improvement functions on such ions as $\text{SO}_{4}^{2-}$, $\text{HCO}_{3}^-$ in surface and middle-layer soil, with their mean values of reduction ranges higher than 60% from the emergence period to the maturation period.

$\text{CO}_{3}^{2-}$ content of surface soil has decreased gradually, by 19.33 mg·kg$^{-1}$ from the emergence period to the withering period. Reed improvement on the enrichment of $\text{CO}_{3}^{2-}$ in middle-layer soil has mainly concentrated on the period between the emergence period and the flowering period, has not obvious function on the enrichment of $\text{CO}_{3}^{2-}$ in the bottom-layer soil. By aiming at the research of Dingbian saline and alkaline lands, scholars have concluded that during the whole growing period of reeds, $\text{Ca}^{2+}$, $\text{Mg}^{2+}$, $\text{Cl}^-$, $\text{SO}_{4}^{2-}$, $\text{HCO}_{3}^-$, $\text{CO}_{3}^{2-}$ in soil have decreased by 138.7 mg·kg$^{-1}$, 26.93 mg·kg$^{-1}$, 57.76 mg·kg$^{-1}$,
115.35 mg·kg⁻¹, 57.76 mg·kg⁻¹, 31.66 mg·kg⁻¹, and this experiment has acquired the similar research results [22].

Besides, analyzing results in Figure 1 can indicate that the decreasing amount of 0~60cm soil salt ions from the emergence period to the withering period of reeds is higher than the annual average decreasing amount from planting reeds in 2009 to the withering period in 2016, and namely between the soil salt ion decreasing amount many years after planting reeds and the soil salt ion decreasing amount during a single growth season of reeds, there not only is a simple superposition relation, but also may be a repetitive process of salt ion migration.

![Figure 4. Soil salt at different depths of each reed growth stage](image_url)

4. Discussion
Soil pH, conductivity, salt ion content of soil has all decreased obviously before and after the reed planting. Lan Wenhui etc [8]. have researched the Xinjiang Bositeng Lake basin and found that reeds have adsorption and improvement ability for soil salinity as 10 t·hm⁻²·a⁻¹, which are able to decrease obviously soil salinity content. Zhang Yonghong [20], etc. have found by studying that reeds can prevent and cure the salinization of swampland, also reduce pH and the soil salinity content of surface swampland, which is the same as results of this experiment.
In this research, the amount of decreasing salinity during a single growth season of reeds is relatively high and is of no obvious linear relation with planting time of reeds. That may be because experimental devices are relatively closed environments, and reeds naturally decompose in devices from being withered and yellow to the emergence in the next year, and plenty of salinity go back to the soil; besides, irrigation and rainfall have been reduced in autumn and winter, and surface soil of devices has lacked water for a long time, also water evaporation on the soil surface has made the water in bottom-layer soil rise through capillarity, so salinity has been brought to the surface, which leads to salt accumulation process higher than desalination process on the surface, so during the emergence period, a salinity surface accumulation phenomenon is obvious[3,4].

Since the emergence period, irrigation and rainfall have increased, plus reed growth’s increasing the salt enrichment, so the soil salinity content has decreased obviously. Thus, during a single growth season, the salt migration is quick, and salt content in every layer of soil would change greatly. But according to planting results of many years, reed planting is still able to reduce the salinity content of salty soil to some extent.

In this experiment, pH values of surface soil in the emergence period of reeds are relatively high, and the soil is of strong basicity, and the soil conductivity is relatively high. Reasons for those are salt ions of Lupo Shoal have migration leaching loss properties of big differences in soil, also Na⁺ and Cl⁻ have a relatively high migration speed and move to the bottom-layer soil with the salt elution, while SO₄²⁻ is likely to be of a rotational adsorption [16], with such basicity ions as HCO₃⁻ and CO₃²⁻ having a relatively low moving speed and mainly spreading on the soil surface, so the basicity is strengthened.

The soil conductivity has risen gradually from the emergence period to the leaf spreading period of reeds and been at a record level before and after the leaf spreading period. Reasons are that the leaf spreading period is from the last ten-day period of June to the the first ten-day period of July, with the experiment site of relatively high temperature, with the soil water evaporation capacity increasing, and salts have been brought to the surface with the soil water evaporation, which leads to increased soil conductivity. That is basically consistent with the former research results [15].

With the reed growth, soil pH changes are in a trend of decreasing in the upper soil and increasing in the bottom-layer soil. That is because water irrigation has a “salt washing” function on surface soil and has led to a downward salt leaching loss [22], also may be because from the maturation period to the withering period, plenty of reed stems and leaves wither, drop down and decompose on soil surface to form a mould cover, with the organic content of surface rising to 11.80 g·kg⁻¹ from 8.95 g·kg⁻¹, while there are plenty of humic acid and fulvic acid in the mould cover [20,1].

Moreover, with the reed growth, organic content of surface soil will increase, which has raised the microbial activity. Such acid matters as humic acid and fulvic acid increase and combine themselves with such basic salt ions as HCO₃⁻ and CO₃²⁻, etc., which can strengthen soil respiration function [23]. All of those procedures have a comprehensive function of decreasing pH value and conductivity of surface soil, so as to improve soil.

5. Conclusion
Reed improvement to salty soil is a result of comprehensive functions. During the single growth season, with the reed growth, with comprehensive functions of irrigation, reed root interlude and organic matter decomposition, so organic content of surface soil has risen obviously, with the pH and conductivity decreasing obviously, with the content of such ions as Ca²⁺, Mg²⁺, CI⁻, SO₄²⁻, HCO₃⁻, CO₃²⁻ decreasing obviously, but pH and conductivity of the middle-layer and the deep soil are in a trend of increasing, with the clay content increasing, so the salt ions rising. Namely reeds have the best improvement effect on salty surface soil during a single growth season [14].

From the withering period to the emergence period in the next year, because after reed decomposition plenty of salts go back to soil, plus irrigation and rainfall reductions, the capillarity function will be strengthened, so during the emergence period, surface accumulation of soil salts is obvious, with the surface contents of six ions all higher than those in the middle-layer and bottom-layer soil. On the one hand, irrigation and rainfall will influence soil salt migration and spreading. On
the other hand, irrigation water quality and rainfall will influence soil salt content to some extent. So, considering that is suggested for future researches [13,5].

From the long-term time scale, through seven years of reed improvement to salty soil, such six ions as Ca^{2+}, Mg^{2+}, Cl^{-}, SO_{4}^{2-}, HCO_{3}^{-}, CO_{3}^{2-} have been decreased obviously, and the best improvement effect is toward Mg^{2+}. However, due to relatively closed devices, its improvement effect has been limited. In this research, there lacks a contrast test of harvesting and removing reeds from the devices after reeds are ripe, also analyzing mechanism of improving saline and alkaline lands by reeds remains to be discussed further, which need to be studied systematically further in the future.

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