Bangladesh J. Bot. **53**(3): 665-672, 2024 (September) Special DOI: https://doi.org/10.3329/bjb.v53i30.76672

EFFECTS OF LONG-TERM REED PLANTATION ON SALINE HABITAT

Zhe Pang[1,2], Juan Li[1,2*], Dongwen Hua[3] and Jinbin Li[1,2]

Shaanxi Provincial Land Engineering Construction Group Co., Ltd, Xi'an 710075, China;

Keywords: Reed, Saline–alkaline land improvement, Soil salinity, Soil structure improvement, Fertility improvement

Abstract

In recent years, the improvement and utilization of saline-alkaline soil has gradually shifted from engineering measures to biological measures. As a salt-tolerant plant, the reed has been preliminarily proven to have a role in improving saline-alkaline land. In order to explore the long-term effect of planting unharvested reeds on the improvement of saline-alkaline land, a pilot plot was set up in Fuping Pilot Test Base (34° 42'180"E; 109°11'49" N) near Lubo Beach, Fuping, Shaanxi, in 2012 to ascertain the improvement effect of long-term reed cultivation on saline–alkaline land. The objective was to study the long-term changes in soil pH, electrical conductivity, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-, and CO_3^{2-} contents, soil particle size and soil fertility. Results showed that (i) reed cultivation could effectively reduce soil salinization in the long term. From 2012 to 2022, the average pH of saline soil decreased from 9.42 to 8.86, and the electrical conductivity decreased from 1.20 μS/cm to 0.70 μS/cm. (ii) Reed cultivation considerably reduced the contents of Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-, and CO_3^{2-} in the soil in the long term, and the reduction in each index was 5.9, 41.7, 63.5, 90.6, 81.7, 90.6, 77.9 and 90.3%, respectively. (iii) Reed cultivation changed the soil structure. The soil texture of the 0–60 cm soil layer changed from silty sandy loam to silty loam from 2018 to 2022. (iv) Long-term reed planting without harvesting effectively improved soil fertility. In 2012, the content of soil organic matter was only 2.74 g/kg, but in 2022, the value reached 12.8 g/kg. Reed planting improved the physical and chemical properties of saline soil. Therefore, biological restoration of reed can be considered in low-lying saline–alkaline areas with high water volumes.

Introduction

The global area of saline–alkaline land has reached 950 million ha (Malcolm and Sumner 1998). China has approximately 27 million ha of saline–alkaline land, including 6 million ha of arable land and 21 million ha of saline–alkaline wasteland, which are mainly distributed in the in-land areas of Northeast China, North China, Northwest China and coastal areas north of the Yangtze River. Soil salinization has become an important issue that restricts agricultural development.

Climate effects, unreasonable cultivation techniques and elevated groundwater levels can lead to soil salinization (Xie 1993). Although many technological achievements have been made in the improvement of saline–alkaline soil, no fundamental breakthroughs have been achieved in controlling the secondary salinization of soil and improving the utilization of primary saline–alkaline soil (Xu 2004). In recent years, the improvement and utilization of saline–alkaline soil have gradually shifted from using engineering measures to adopting biological ones 4 (Gao 2022, National Technical Committee for Standardization of Fertilizers and Soil Conditioners 2023). Plants in severely saline–alkaline soil areas are nearly unable to survive because of the high alkalinity. Therefore, further research on plant salt tolerance and the cultivation of new salt-resistant varieties as biological measures is needed.

*Author for correspondence: <lijuan8136@163.com>. [1]Institute of Land Engineering and Technology Shaanxi Provincial Land Engineering Construction Group Co., Ltd., Xi'an 710075, China. [2]Key Laboratory of Degraded and Unused Land Consolidation Engineering the Ministry of Natural Resources, Xi'an 710075, China. [3]School of Human Settlements and Civil Engineering, Xi'an Jiaotong University, Xi'an 710075, China.

Crops, such as red bean grass, alfalfa, aggregate grass, small crown flower, reed sheep, white stem salt grass, star grass and reed, exert certain improvement and desalination effects on saline–alkaline soil (Zhang 2005, Sidiguli 2010, Pei 2016) The improvement effect of reed, a salt-tolerant plant, on saline–alkaline land has been preliminarily confirmed (Pei 2016). Reeds have massive potential for use as a biological species source for saline–alkaline land improvement due to their high vitality and wide distribution. Zhang (2005) and Wu and Sun (2017) studied the dynamic changes in ion content in saline–alkaline soil at different reed growth stages. They found that soil pH, conductivity and various salt ion contents decrease when reeds are planted. Reeds can accumulate salt. Li (1995) analyzed the effectiveness of planting star grass in improving saline–alkaline soil. Results showed that the overall pattern of crop soil desalination rate in different planting years is perennial > three years > biennial > one year, that is, the desalination rate gradually increases with the increase of planting time. However, extant research focused on the short-term effects of reeds on surface soil pH, conductivity, salt ions, and other aspects (Sidiguli 2010, Sun *et al*. 2012, Zhang *et al*. 2016, Wu and Sun 2017). Systematic research on the improvement effect of saline soil layers at different depths under a long-term scale and soil profile is not sufficient. Similarly, limited research has been conducted on the differences in desalination effects caused by seasonal salt return and different years of rainfall evaporation. This study used the method of planting reeds for desalination and conducted 10 years experimental monitoring to study the improvement effect of long-term reed planting on saline–alkaline land. The feasibility of using reed cultivation to improve saline–alkaline land was analyzed to provide a theoretical basis for the bioremediation of saline–alkaline land.

Materials and Methods

The experimental community is located in the Fuping Pilot Base of the Key Laboratory of Degradation and Unused Land Remediation of the Ministry of Natural Resources (34°42'180"E, 109°11'49" N). It has a warm-temperate, continental-rainy, hot seasonal monsoon arid climate, with characteristics such as large temperature difference, minimal precipitation, strong evaporation and dry climate. The annual average temperature is 13°C and the annual average precipitation is 587.4 mm.

The experimental device was a cylindrical, hollow cement column with a height of 98 cm, an inner diameter of 80 cm and a wall thickness of 8 cm. The bottom of the device was treated with an anti-leakage agent to prevent salt leakage inside the device. Ten parallel simulation devices were used. Saline–alkaline soil was dug from heavily saline-alkaline land, filled and compacted in accordance with the profile characteristics. We dug as close to the actual location of the saline–alkaline land as possible. The soil layer thickness was 60 cm. In 2012, in the first year after the installation of the device, planting was performed with a density of 300 plants per simulated device. When withered or yellow reeds were found, they were promptly removed and replanted. Every year, the reeds naturally withered and decayed, and no manual harvesting was conducted.

After the experimental device was completed and planted in 2012, samples were collected in October 2012, 2013, 2015, 2018 and 2022 for the analysis of pH, conductivity, Ca^{2+}, Mg^{2+}, Cl^{-}, SO_4^{2-}, HCO_3^{-} and CO_3^{2-}contents; and other indicators to study the improvement effect of long-term reed planting on saline-alkaline land. Sampling was conducted on the cultivation layer (0-30 cm) of non-harvested reed potted plants in different periods in 2012, 2015, 2018 and 2022. Samples from 0-30 cm soil layer were collected in October each year and their organic matter content was measured and used as the organic matter content of potted plants for that year. It was also used to determine the overall trend of long-term changes in organic matter and soil fertility. Soil samples were collected at depths of 0–20, 20–40, and 40–60 cm in 2018 and 2022 for a soil mechanical composition analysis to determine the improvement effect of reed planting on the soil structure. The research methods and testing instruments used for all the indicators in this study were showed in Table 1.

Table 1. Detection methods and testing instruments of related indicators.

Testing index	Testing method	Instrumentation
pH	NY/T 1377-2007	Acidometer (S220)
Organic Matter	LY/T 1237-1999	Oil bath pot (DU-30G)
Conductivity	HJ 802-2016	Conductivity meter (EC215)
Granularity	GB/T 19077-2016	Laser particle analyzer (Mastersizer 3000)
Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-, CO_3^{2-}	LY/T 1251-1999	Digital bottle mouth titrator (Brand）

Results and Discussion

A high or low pH of soil can decrease the effectiveness of water-soluble nutrients in the soil, seriously hindering the normal growth and development of crops and affecting yield (Li 1995). Fig. 1 shows the effect of reed cultivation on soil pH in saline–alkaline soil from 2012 to 2022. Analysis revealed that planting reeds effectively reduced soil pH. The average pH of saline–alkaline soil decreased by 0.56 from 9.42 to 8.86 during 2012 to 2022. The difference in pH reduction between 2012 and 2022 was highly significant ($P < 0.01$). Although the saline–alkaline soil still did not meet the requirements for crop growth, the reduced pH of the saline–alkaline soil had a substantial effect.

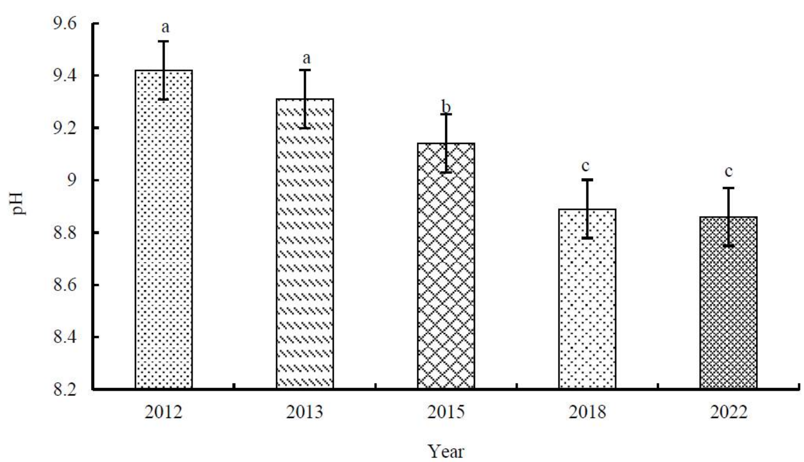

Fig. 1. Effect of reed planting on the pH of saline–alkaline land from 2012 to 2022.

High soil salinity affects the photosynthesis and respiration of crops and hinders the synthesis of crop proteins (Yang *et al.* 2011, Pei 2016). Soil conductivity is an indicator that measures soil water-soluble salts, which is an important attribute of soil and a factor in determining if salt ions in the soil limit crop growth. Fig. 2 shows the effect of reed cultivation on soil conductivity in saline–alkaline soil from 2012 to 2022. The soil conductivity content increased from 1.20 to 0.55

μS/cm from 2012 and 2015, and the decrease was statistically significant. During 2015–2022, the soil conductivity slightly increased from 0.55 μS/cm in 2015 to 0.77 μS/cm in 2018, followed by a decrease, which may be related to factors, such as climate and rainfall in that year. Overall, the decrements in electrical conductivity in 2012 and 2022 showed a significant difference ($P < 0.01$). Planting reeds over a long period reduced soil electrical conductivity and improved saline–alkaline soil.

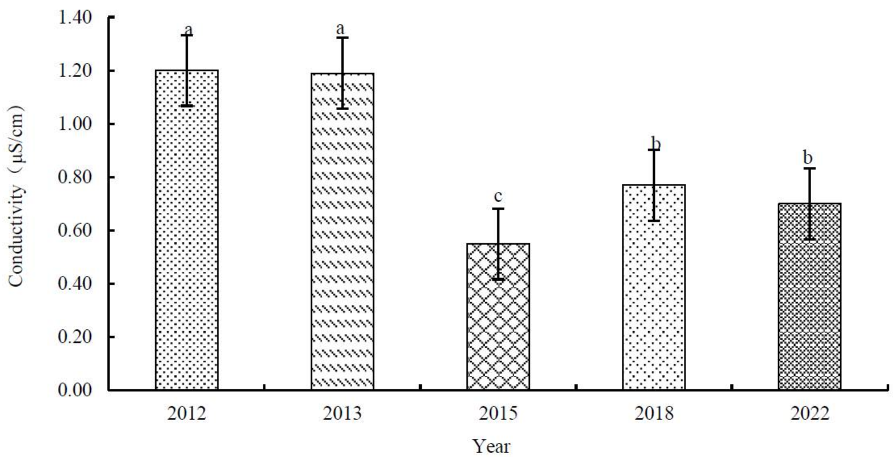

Fig. 2. Effect of reed planting on the conductivity of saline land from 2012 to 2022.

The composition and content of various ions in saline–alkaline soil are important indicators for judging the degree of soil salinization. They considerably affect the supply, migration, and transformation of soil nutrients and the absorption of nutrient ions by plants (Qin *et al.* 2012). Fig. 3 shows the effects of long-term reed cultivation on soil Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-, and CO_3^{2-} contents. From a long-term perspective, the various indicators decreased considerably from 2012 to 2018 and gradually stabilized from 2018 to 2022. The contents of Mg^{2+}, SO_4^{2-}, and CO_3^{2-} form the six ions decreased substantially from 2012 to 2022, with an overall decrease of over 90% (90.55, 90.57 and 90.29%, respectively). The decrease in Cl^-, Ca^{2+}, and HCO_3^- was small (81.75, 63.48 and 77.93%, respectively). In addition, the changes in the above mentioned salt ions indicated that the enrichment of the salt ions by reeds exhibited certain differences. The order of enrichment of the salt ions from strong to weak was as follows: $Mg^{2+} > SO_4^{2-} > Cl^-$. The possible reasons for the decrease in soluble salt ions may include the covering effect of reeds that reduces soil water evaporation and effectively inhibits the surface aggregation of Cl^- in saline soil, which is beneficial for soil desalination. Another possible reason is the low density of the reeds planted in the indoor simulation experimental equipment. Moreover, the growth process of reeds enriches salt and can remove a considerable amount of salt, thereby effectively reducing the content of major salt ions, which is the main reason for the decrease in soluble salt ions.

At the initial stage of the experiment, due to the limitations of research at that time, changes in the soil structure were not considered, and basic data on soil particle size at the initial stage were lacking. In 2018, a study on the particle transport patterns of saline soil at different growth stages of reeds in a single growth season showed that the particle composition of the surface soil changes (Sun *et al.* 2012). Afterward, research on the soil structure was added to the study of the improvement effect of reeds on saline–alkaline land. Table 2 shows the distribution pattern of soil particle composition at different depths under long-term non-harvesting reed planting from 2018 to 2022. No significant difference in soil particle size was found between the different soil depths. However, from 2018 to 2022, the soil clay content decreased by 11%, the powder content increased by 18.37%, and the sand content decreased by 95.42%. In accordance with the international soil particle size classification standard, the soil texture of the 0-60 cm soil layer changed from Silty sandy loam to Silty loam.

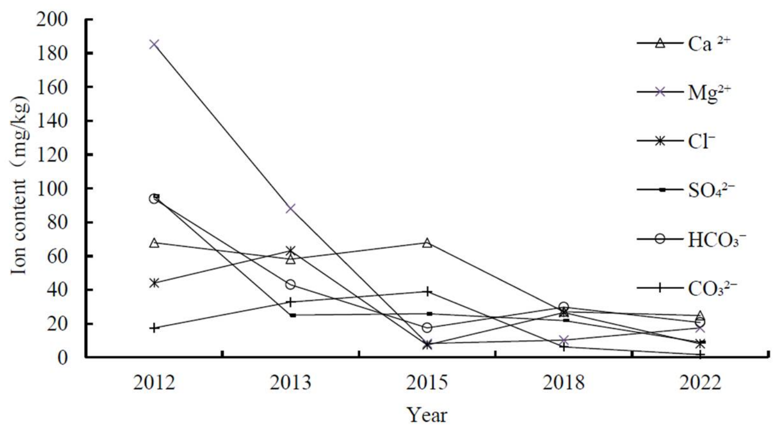

Fig. 3. Effects of reed planting on the content of various salt ions in saline land from 2012 to 2022.

Table 2. Regularity of soil particle size distribution from 2018 to 2022.

Time	Sampling depth (cm)	Particle size composition (%)			Soil texture USDA
		Clay	Silt	Sand	
2018	0–20	24.58	65.70	9.72	Silty sandy loam
	20–40	24.91	66.50	8.59	Silty sandy loam
	40–60	24.05	64.80	11.15	Silty sandy loam
	Average	24.51	65.67	9.82	Silty sandy loam
2022	0–20	21.11	78.63	0.27	Silty loam
	20–40	22.17	76.88	0.95	Silty loam
	40–60	22.17	77.69	0.13	Silty loam
	Average	21.82	77.73	0.45	Silty loam
Change rate	/	−11.00%	18.37%	−95.42%	/

Soil organic matter is an important indicator for measuring soil fertility and determining soil nutrient storage and supply levels (Alan *et al*. 2024). Analysis of Fig. 4 indicates that after the experimental setup in 2012, due to the soil being raw, the soil fertility was low, and the organic matter content was only 2.74 g/kg. After long-term reed cultivation, the overall fertility of the soil exhibited steady growth. The difference in the increase in soil organic matter content from 2012 to 2022 was highly significant ($P < 0.01$). In 2022, the soil organic matter content reached 12.8 g/kg, and the annual average growth from 2012 to 2022 was 36.7%.

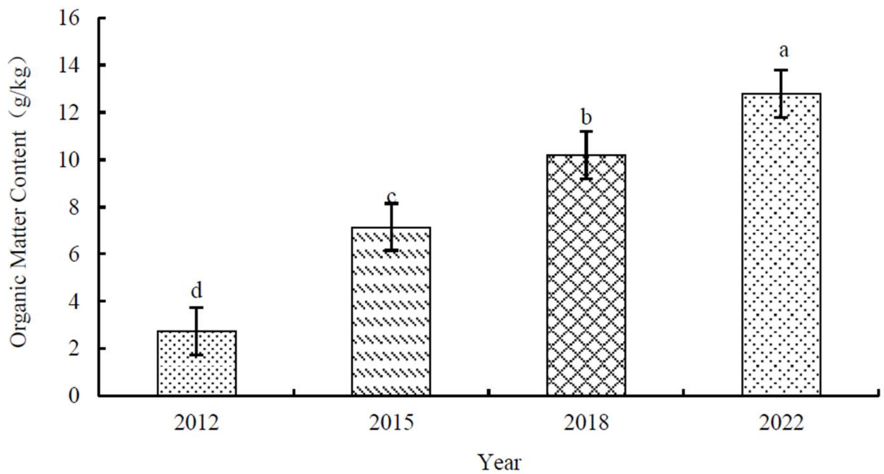

Fig. 4. Effects of long-term non-harvesting reed planting on organic matter in saline–alkaline soil.

During the experiment, the pH and electrical conductivity of the soil after reed cultivation showed an overall decrease trend from 2012 to 2022. The use of reed cultivation to improve the degree of salinization in the saline–alkaline land has produced valuable results. For example, Li and Zhu, 2006 found in their study on the management of saline–alkaline land in the low-lying, closed-flow areas of the western Songnen Plain that reeds have salt tolerance functions. Their developed root systems can absorb a large amount of salt during their growth process. Each kirogram of reeds can absorb approximately 6.45 g of salt while effectively reducing the pH of saline soil. Sun *et al*. (2012) conducted a study on the salt enrichment ability of reeds at different growth stages under indoor simulation conditions and found that reeds have a considerable effect on reducing the salt content in saline–alkaline soil during the growth stage. After the growth stage, reeds wither and decay into humus, which also has a certain effect on reducing the salt content and increasing the organic matter content of saline–alkaline soil, a finding that is consistent with the results of the current experiment. During the growth process, the creeping rhizomes of reeds criss-cross the soil and penetrate to deeper than 70 cm. In saline–alkaline soil, reed roots produce soil macropores and improve the soil micro-ecological environment (Li 2014, Ji *et al*. 2002). The decrease in soil salinity may be due to the growth of the massive root system that improves the soil structure and permeability, thereby considerably reducing the rate of soil salt accumulation and return (Cui *et al*. 2014). In addition, the rotting of reed straw into humus plays a certain role in reducing the pH and salinity of saline–alkaline soil. After reed rotting, large amounts of acidic substances, such as humic acid and fulvic acid (Sidiguli 2010; Mi *et al*. 2016), are produced, and these processes comprehensively reduce the pH and conductivity of surface soil.

The presence of reed root holes greatly increases soil hydraulic conductivity (Mi *et al*. 2016), thereby improving the soil structure of saline–alkaline soil. However, studies on this soil structure have a short time frame, and long-term research on soil structure is needed in the future. From 2012 to 2022, the overall fertility of soil exhibited a steady growth trend in the current study. The planting of reeds considerably improves the soil fertility of saline–alkaline land. Reed litter on the surface of saline–alkaline soil decays and transforms into humus, increasing the organic matter content of the surface soil. At the same time, as the soil salinity decreases, the number of soil microorganisms increase, thereby improving the enzyme content of the soil and further enhancing soil fertility.

It can be concluded that: After long-term reed cultivation, the overall pH and conductivity of the soil decreased. From 2012 to 2022, the average pH of the saline–alkaline soil decreased from 9.42 to 8.86, and the conductivity decreased from 1.20 to 0.70 µS/cm. Reed cultivation had a considerable effect on improving saline soil. Over a long period, reed cultivation remarkably reduced the contents of Ca^{2+}, Mg^{2+}, Cl^{-}, SO_4^{2-}, HCO_3^{-}, and CO_3^{2-} in the soil. The contents of Mg^{2+}, SO_4^{2-}, and CO_3^{2-} decreased considerably from 2012 to 2022, with the overall decline exceeding 90% (90.55, 90.57, and 90.29%, respectively). The decrease in Mg^{2+}, SO_4^{2-}, and CO_3^{2-} contents was small, with reductions of 81.75, 63.48and 77.93%, respectively. Over a long period, reed cultivation led to changes in the soil structure. From 2018 to 2022, the soil texture in the 0–60 cm soil layer changed from Silty sandy loam to Silty loam. Planting reeds without harvesting for a long period effectively improved soil fertility. The organic matter content in the soil was only 2.74 g/kg in 2012, but it increased to 12.8 g/kg in 2022, indicating an average annual growth rate of 36.7% from 2012 to 2022.

Acknowledgements

This research ware supported by Shaanxi Province Key Research and Development Plan - Key Industrial Chain Project (Research and Development and Demonstration of Key Technologies for Soil Improvement and Restoration in Salinized Grain Fields, 2022ZDLNY02-04) and application of earthworm manure in improving the quality of new cultivated land (DJNY2024-27).

References

Alam MA, Yeasin M and Ahmed A 2024. Carbon pool and respiration of rhizosphere soils of different mangrove plant species in Bangladesh Sundarbans. Bangladesh J. Bot. **53**(1): 131-140.

Cui TT, Dou S and Yang YN 2014. Effect of deep applied corn stalks on composition of soil humus and structure of humic acid. J. Soil Sci. **51**(4): 718-725.

Gao S 2022. Effects of comprehensive agronomic improvement measures on salinity characteristics of saline-alkali land in Northern Yinchuan. J. Agricul Sci. **43**(03): 40-44.

Ji GD, Sun TH and Sui X 2002. Impact of ground crude oil on the ecological engineering purifi-cation system of reed wetland. Acta Ecol. **2002**(5): 31-36.

Li CY 1995. Analysis of the effect of planting star grass on improving saline alkali soil. J. Natural Sci. Harbin Normal Univ. **11**(4): 100-104.

Li F 2014. Study on removal efficiency and absorption of and of salinity and nitrogen and phosphorus by reed saline-alkali wetland in the west of Jilin Province. Shenyang: Graduate School of Chinese Academy of Sciences (Northeast Institute of Geography and Agroecology).

Li XY and Zhu B 2006. A preliminary study on the countermeasures of salinized land management in Daqing City. J. Mudanjiang Normal Coll.: Natural Sci. Edit. **3**: 3.

Malcolm E and Sumner RN 1998. Sodic soils - distribution, properties, management, and environmental consequences. New York: Oxford University Press.

Mi YB, Yang JS, Yao RJ and Yu SP 2016. Effects of farming practice on soil respiration, ECE and organic carbon in coastal saline soil. Acta Pedol Sin. **53**(3): 612-620.

National Technical Committee for Standardization of Fertilizers and Soil Conditioners (SAC/TC 105) 2023. General techniques for improving saline alkali land Part 3: Biological improvement. GB/T 42828.3-2023.

Pei Y 2016. The impact of coastal saline soil on the growth of reeds and improvement measures. Jiangxi Agricult. **2016**(14): 19.

Qin ZL, Lu JH, Lu S, Tian ZP, Yan P and Bao F 2012. The effect of drip-irrigation cultivated glycyrrhiza on soil microorganism and salinity content. Xinjiang Agril. Sci. **49**(10): 1920-1925.

Sidiguli H 2010. Spatial variability of soil characteristics and its effects on the growth of phragmites australis in keriya oasis. Xinjiang University.

Sun B, Jie JC, Wang N , Li SQ and Li CJ 2012. Effect of reeds on salt enrichment and improvement of saline alkali land. J. Soil Water Conserv. **2012**(03): 94-98+103.

Wu LC, Sun YY 2017. Effect of reeds on salt improvement and distribution in saline-alkali soil. western development (land development engineering research) **2017**(09): 46-52.

Xie CT 1993. The Principle of Saline Soil Improvement and Crop Resistance. Beijing: China Agricultural Science and Technology Press.

Xu HG 2004. China's Halophytic Vegetation and Salinization Ecological Management. Beijing: China Agricultural Science and Technology Press.

Yang XG, Song NP, Liu BR, An H and He XP 2011. Summer salinization characteristics of irrigated corn cropland during oasisization of desert steppe. J. Soil Water Conserv. **25**(4): 69-101.

Zhang L, Han JC, Ma ZH, Chan TQ and Shi CD 2016. Study on dynamic change of ion contents of saline-alkali soil during different reed growth stages. Res Soil Water Conserv. **23**(4): 38-42.

Zhang YH 2005. Desalination effects of salt tolerant plants growing in alkali-saline soil in Ningxia. Gansu Agril. Sci. Tech. **2005**(3): 48-49.

(Manuscript received on 21 June, 2024; revised on 31 August, 2024)