

Research Progress on Water-Salt Dynamics in Coastal Saline-Alkali Land

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Abstract: Saline-alkali land is a widely distributed soil type on the Earth's land, and its special physicochemical properties restrict plant growth and agricultural production. As the largest developing country in the world, China has extensive saline-alkali land, accounting for nearly 10% of the total global saline-alkali land area. With population growth and economic development, how to effectively utilize and improve saline-alkali land to enhance its agricultural productivity has become an important topic in current agricultural sustainable development. This paper synthesizes recent research progress on water-salt dynamics and improvement and utilization of coastal saline-alkali land, providing a systematic review of water-salt movement patterns, soil improvement technologies, crop salt tolerance mechanisms, and planting patterns. The aim is to provide a scientific basis for the rational development and utilization of coastal saline-alkali land.

Keywords: Coastal Saline-Alkali Land, Water-Salt Dynamics, Improvement and Utilization of Saline-Alkali Land.

1. Water-Salt Dynamics in Coastal Saline-Alkali Land

1.1. Water-Salt Movement Patterns

The water-salt dynamics in coastal saline-alkali land are influenced by various factors, including climate, topography, soil properties, vegetation cover, and human activities. Among these, rainfall and evaporation are the main driving forces for water-salt movement. Rainfall replenishes soil moisture and promotes salt leaching, while evaporation leads to soil moisture loss and salt accumulation on the surface. Liu Feng (20XX) studied the seasonal changes in soil physicochemical properties in saline-alkali land in the Songnen Grassland and found that as soil salinity increased, soil moisture content gradually decreased, while electrical conductivity and pH values gradually increased. Dong Hezhong et al. (2006) also observed in their research on coastal saline cotton fields in Dongying, Shandong, that soil salt content exhibited seasonal variations, with higher levels in spring and autumn and lower levels in summer.

Furthermore, factors such as soil texture, structure, and groundwater level also have significant impacts on water-salt movement. Fu Ying et al. (2015) discovered in their study of *Robinia pseudoacacia* plantations in coastal saline-alkali land in Tianjin that there were significant differences in soil moisture content and salinity among different soil layers, with notable seasonal variations. The topsoil layer (0-20cm) was significantly affected by rainfall and evaporation, resulting in large fluctuations in moisture content and salinity, while the deeper soil layers (20-80cm) were relatively stable. These studies indicate that water-salt dynamics in coastal saline-alkali land are a complex process influenced by multiple factors.

1.2. Effects of Salt on Soil and Crops

Excessive soil salinity can negatively impact crop growth, mainly manifesting as osmotic stress and ion toxicity. High

salt concentrations reduce soil water potential, affecting crop water absorption and utilization. Additionally, certain ions in the salt, such as Na^+ and Cl^- , can be toxic to crops, inhibiting their growth and development. Furthermore, salinity can also affect soil physical properties, such as reducing soil aeration and permeability, thereby impacting root growth and nutrient absorption.

In saline-alkali land, different types of salt ions have varying effects on crops. For example, Na^+ and Cl^- are common salt ions in saline-alkali land and have obvious toxic effects on crops. In contrast, ions such as K^+ , Ca^{2+} , and Mg^{2+} have certain promotional effects on crop growth. Therefore, in the process of improving saline-alkali land, it is necessary to comprehensively consider the impacts of different salt ions and take corresponding measures for regulation and control.

2. Improvement Technologies for Coastal Saline-Alkali Land

2.1. Engineering Measures

Engineering measures are one of the important means for improving saline-alkali land, primarily including drainage, irrigation, land leveling, and covering with isolation layers. Drainage is a key measure for improving saline-alkali land, as it lowers the groundwater level, reducing the opportunity for salt to rise to the surface with capillary water, thereby decreasing soil salinity. Irrigation can wash away salt in the soil while supplementing the water needed for crop growth.

Land leveling can improve soil drainage conditions, reducing salt accumulation caused by localized waterlogging. Covering with isolation layers can block the pathway for salt to rise with capillary water, lowering soil salinity. Furthermore, some studies have explored the use of new drainage technologies such as subsurface drainage pipes and vertical drainage wells to improve saline-alkali land.

2.2. Chemical Amendments

Chemical amendments are methods that involve adding chemical substances to alter soil physicochemical properties, thereby reducing soil salinity. Common chemical amendments include gypsum, phosphogypsum, and desulfurized gypsum. These amendments can react chemically with salt in the soil to form insoluble salt precipitates, thus lowering the salt concentration in the soil solution.

Additionally, some organic materials such as farm manure and straw can also be used as amendments. They can indirectly reduce the harm of soil salinity to crops by improving soil structure and enhancing soil fertility. However, the use of chemical amendments requires caution, as excessive application may have negative impacts on the soil environment.

2.3. Biological Improvement Measures

Biological improvement measures utilize the life activities of plants, microorganisms, and other biological entities to improve the soil properties of saline-alkali land. Salt-tolerant plants can reduce soil salinity by absorbing salt from the soil and secreting organic matter. At the same time, their root activities can improve soil structure and enhance soil fertility.

Microorganisms also play an important role in the improvement of saline-alkali land. Some salt-tolerant microorganisms can improve the soil environment by decomposing organic matter and fixing nitrogen. Furthermore, microorganisms can form symbiotic relationships with plants, promoting plant growth and development.

In biological improvement measures, selecting appropriate salt-tolerant plant and microorganism species is crucial. Additionally, it is necessary to consider the interactions between plants and microorganisms and their impacts on the soil environment.

3. Crop Salt Tolerance Mechanisms and Cultivation Patterns

3.1. Crop Salt Tolerance Mechanisms

The study of crop salt tolerance mechanisms is crucial for understanding how crops grow and develop in saline-alkali environments. Currently, research on crop salt tolerance mechanisms mainly focuses on osmotic adjustment, ion balance, and antioxidant defense.

Osmotic adjustment is one of the important ways for crops to adapt to salt stress. When soil salinity increases, crop cells accumulate small molecular organic compounds (such as proline, betaine, etc.) to reduce the intracellular osmotic potential, thereby maintaining normal physiological functions of the cells. Ion balance is also a key mechanism for crop salt tolerance. Crops mitigate the toxic effects of salt on cells by regulating the concentration and ratio of ions inside and outside the cells. For example, some crops can maintain intracellular ion balance by increasing K^+ absorption and reducing Na^+ absorption.

Antioxidant defense is an important way for crops to cope with oxidative damage caused by salt stress. Salt stress leads to the generation of a large number of reactive oxygen species in crops, causing damage to cell structure and function. Crops synthesize antioxidant enzymes (such as superoxide dismutase, peroxidase, etc.) to scavenge these free radicals and protect cells from oxidative damage.

3.2. Selection and Cultivation of Salt-Tolerant Crop Varieties and Cultivation Patterns

The selection and cultivation of salt-tolerant crop varieties is an effective way to improve agricultural productivity in saline-alkali lands. Currently, a number of salt-tolerant crop varieties, such as salt-tolerant rice, salt-tolerant wheat, and salt-tolerant cotton, have been selected through conventional breeding and genetic engineering methods. These varieties exhibit good growth and developmental performance in saline-alkali environments, providing strong support for the agricultural utilization of saline-alkali lands.

In addition to selecting salt-tolerant crop varieties, reasonable cultivation patterns are also important measures to improve agricultural productivity in saline-alkali lands. For example, adopting crop rotation, intercropping, and relay cropping patterns can fully utilize resources such as light, temperature, water, and soil, improving crop yield and quality. At the same time, reasonable planting density and fertilization management can also improve the crop growth environment and enhance their salt tolerance.

Furthermore, some studies have explored the use of new fertilizers such as biochar and seaweed fertilizer to improve soil properties of saline-alkali lands and enhance crop salt tolerance. These fertilizers can reduce the harm of soil salinity to crops by improving soil structure and enhancing soil fertility.

4. Case Analysis and Discussion

4.1. Case Study on Management and Utilization of Coastal Saline-Alkali Lands

Taking Dongying City, Shandong Province as an example, located near the entrance of the Yellow River, the city possesses abundant resources of coastal saline-alkali lands. To reasonably develop and utilize these resources, Dongying City has adopted a series of measures for saline-alkali land improvement and agricultural utilization. For instance, engineering measures such as constructing drainage canals and leveling the land have been implemented to lower the groundwater level and improve soil drainage conditions. Chemical ameliorants like gypsum and organic fertilizers have been applied to reduce soil salinity and enhance soil fertility. Additionally, salt-tolerant crop varieties have been selected and cultivated, and salt-tolerant cultivation techniques have been promoted to improve agricultural productivity in saline-alkali lands.

After years of efforts, Dongying City has achieved remarkable results in saline-alkali land improvement and utilization. Currently, the city has established a number of salt-tolerant crop cultivation bases and ecological agriculture demonstration zones in saline-alkali lands, making significant contributions to local agricultural development and ecological construction.

4.2. Discussion and Prospects

Despite some progress made in the improvement and utilization of coastal saline-alkali lands, many challenges and issues remain. For example, how to further improve the effectiveness of saline-alkali land improvement and reduce the costs; how to select and cultivate more excellent salt-tolerant crop varieties and promote more efficient salt-tolerant cultivation techniques; and how to balance the relationship between saline-alkali land improvement and

ecological protection.

Looking ahead, with the continuous advancement of technology and the enhancement of innovation capabilities, it is believed that these issues will gradually be resolved. At the same time, we should also recognize that the improvement and utilization of saline-alkali lands is a long-term and complex process that requires the joint efforts and cooperation of governments, research institutions, enterprises, and farmers. Only through such collaboration can we achieve sustainable utilization of saline-alkali lands and sustainable development of agricultural production.

5. Conclusion

As a special type of soil, coastal saline-alkali lands have always been a research hotspot in agriculture and environmental fields due to their water-salt dynamics and improvement and utilization. This paper synthesizes recent research progress on the water-salt dynamics and improvement and utilization of coastal saline-alkali lands, providing a systematic review from aspects such as water-salt movement patterns, soil improvement techniques, crop salt tolerance mechanisms, and cultivation patterns. Through case analysis, this paper demonstrates the practical achievements and challenges faced in the management and utilization of coastal saline-alkali lands. In the future, we need to further strengthen the research and promotion of saline-alkali land improvement techniques, enhance agricultural productivity and ecological environment quality in saline-alkali lands, and make greater contributions to the realization of sustainable agricultural development and ecological civilization construction.

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