Effects of Suaeda salsa Planting Duration on Soil Salt Ion Distribution in Saline-Alkali Soil under Drip Irrigation Conditions: Postprint

Authors: Wang Xu, Tian Changyan, Zhao Zhenyong, Zhang Ke, Li Yanhong, Tian Changyan

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Abstract

Using the spatiotemporal transformation method, this study investigated the effects of different Suaeda salsa planting years (0, 1, 2, and 3 years) under drip irrigation conditions on the distribution characteristics of soil salinity and salt ions in the 0–120 cm soil profile of severely saline-alkali land, providing a theoretical basis for the improvement and utilization of Suaeda salsa in saline-alkali soils. The experimental results showed that after drip irrigation planting of Suaeda salsa, the distribution of soil salinity in the profile changed significantly: soil salt content in the root zone (0–40 cm) decreased with increasing planting years, while soil in the sub-root zone (40–120 cm) first increased and then decreased. Na+ and Cl- were readily leached by water and selectively absorbed by plants in large amounts, resulting in a significant decrease in Na+ and Cl- contents in the root zone soil with increasing planting years; Ca2+ and SO42- were not easily moved by water, exhibiting low leaching degrees; the leaching effects of HCO3- and Mg2+ in the 2nd and 3rd years were significantly better than in the 1st year. After three years of planting, the proportions of toxic ions Na+ and Cl- in the soil and in the surface layer salt composition decreased, the proportion of Ca2+ increased, and the Sodium Adsorption Ratio (SAR) value decreased significantly.

Full Text

Preamble

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Authors: WANG Xu[1,2], TIAN Chang-yan[1], ZHAO Zhen-yong[1], ZHANG Ke[1], LI Yan-hong[3]

Affiliations: [1] State Key Laboratory of Desert and Oasis Ecology, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, Xinjiang, China
[2] University of Chinese Academy of Sciences, Beijing 100049, China
[3] Landscaping Administration Bureau of Karamay District, Karamay 834000, Xinjiang, China

Abstract

Soil salinization is a serious hazard to agriculture in the agricultural exploitation regions of Karamay City, Xinjiang, China. The effects of different planting years on soil ion distribution in the 0–120 cm soil profile under drip irrigation were investigated using a time-space transformation method. The results showed that soil salt distribution in the profile was significantly affected by planting years. Soil salinity in the upper layers (0–40 cm) decreased gradually with increasing planting years, while soil salinity in the lower layer (40–120 cm) first increased then decreased. Sodium and chloride ions were readily leached and selectively absorbed by the plant in abundant quantities, and thus their contents decreased considerably with planting age. The decreasing rates of these two ions in upper layer soil were all above 49% after three planting years. Since it was difficult for calcium and sulfate ions to move with water, the leaching speed of these two ions was slow. The leaching speed of magnesium was higher than that of calcium. The leaching effect of bicarbonate content in the soil was influenced by hydrated radius and was better in the second and third planting years compared with the first year. The percentage of sodium and chloride in salt content of upper layers decreased while the percentage of calcium increased, and the SAR value and soil salinity decreased significantly after three planting years. The research results indicated that the characteristics of soil salinity and salt ion distribution in the salt-affected field changed after planting *Suaeda salsa* under drip irrigation, and the soil environment of the root zone was improved, which provided a good foundation for future land use. The innovation of this paper is to reveal the distribution of soil salinity and salt ions in the salt-affected field by planting *Suaeda salsa* under drip irrigation based on the investigation and analysis of 7 indicators for 210 soil samples. Previous researches mostly focused on the change of soil salinity and salt ions after planting halophytes, but few studies examined the characteristics of soil salinity and salt ion distribution. The result provides useful information for reasonable reclamation of saline-sodic soil by planting *Suaeda salsa*.

Keywords: drip irrigation; *Suaeda salsa*; planting years; salt distribution

Methods and Materials

This study investigated soil salinity characteristics under mulched drip irrigation in *Suaeda salsa* fields across different planting years (1a, 2a, 3a) in the Karamay region. Soil samples were collected from 210 sampling points at depth intervals of 0–10 cm, 10–20 cm, 20–40 cm, 40–60 cm, 60–80 cm, 80–100 cm, and 100–120 cm. Seven indicators were analyzed to characterize salt ion distribution patterns. The time-space transformation method was employed to assess changes in soil salinity and ion composition over the three-year planting period.

Results

Soil Salt Content Distribution

Soil salt content exhibited distinct vertical distribution patterns that varied significantly with planting duration. In the upper soil layers (0–40 cm), salt content decreased progressively with increasing planting years, with values declining from 45.57 $g \cdot kg^{1}$ in the first year to 31.63 $g \cdot kg^{1}$, 27.74 $g \cdot kg^{1}$, and 20.18 $g \cdot kg^{1}$ across the three-year period. In the lower soil profile (40–120 cm), salt content initially increased then decreased, showing values of 25.71 $g \cdot kg^{1}$, 25.79 $g \cdot kg^{1}$, 34.03 $g \cdot kg^{1}$, and 28.09 $g \cdot kg^{1}$ at different measurement points.

The *Suaeda salsa* planting significantly altered the ion composition of soil salts. After three years, the plant' s selective uptake and leaching effects reduced sodium and chloride concentrations in the upper 0–40 cm layer by 12.74%, 40.58%, and 31.97% respectively, while bicarbonate content decreased by 8.72%, 14.05%, and 19.4%.

Ion Leaching Characteristics

The leaching behavior varied substantially among different ions. Sodium and chloride demonstrated high mobility and were readily removed from the upper soil layers, with their contents decreasing to 10.95 $g \cdot kg^{1}$, 10.21 $g \cdot kg^{1}$, 13.79 $g \cdot kg^{1}$, and 12.68 $g \cdot kg^{1}$ across the three planting years. The leaching rates for these ions exceeded 49% after three years.

In contrast, calcium and sulfate ions exhibited limited mobility with water movement, resulting in slower leaching rates. Magnesium leached more readily than calcium, with the depth of maximum leaching reaching 20–40 cm in the first year, 30–60 cm in the second year, and below 60 cm by the third year. The leaching depth for calcium remained shallower, extending only to 0–10 cm, 0–20 cm, and 0–30 cm in successive years.

Changes in Ion Composition and SAR

The ionic composition of soil salts shifted markedly over the planting period. The percentage of sodium and chloride in the upper layer salt content decreased progressively, while the percentage of calcium increased correspondingly. The

sodium adsorption ratio (SAR), calculated as SAR = [Na]/([Ca²] + [Mg²]), declined significantly from initial values of 5.02 and 11.17 to 50.84 g · kg ¹ across different soil layers after three years.

The chloride-to-sulfate ratio (Cl /SO ²) also changed substantially, increasing from 2.72 and 2.62 in the initial years to 4.41 by the third year. This shift in ion ratios, combined with the overall reduction in total salt content from 32.33 g · kg ¹ to 25.45 g · kg ¹, indicated a fundamental improvement in soil chemical properties.

Discussion

The differential leaching patterns observed among ions can be attributed to their chemical properties and interactions with the soil matrix. Sodium and chloride, being highly soluble and subject to minimal adsorption, were readily transported with irrigation water and taken up by the halophyte *Suaeda salsa*. The strong correlation between sodium and chloride transport facilitated their simultaneous removal from the root zone.

The slower leaching of calcium and sulfate reflects their lower mobility and greater tendency for precipitation and exchange reactions in the soil profile. Magnesium' s intermediate leaching rate, higher than calcium but lower than sodium, demonstrates its position in the lyotropic series and its competitive adsorption behavior on soil exchange sites.

The improvement in SAR values and the overall reduction in soil salinity after three years of *Suaeda salsa* cultivation under drip irrigation demonstrate the effectiveness of this approach for saline-sodic soil reclamation. The transformation of the salt-affected field' s chemical characteristics provides a foundation for subsequent agricultural use, as the root zone environment becomes progressively less hostile to less salt-tolerant crops.

Note: Figure translations are in progress. See original paper for figures.