Postprint: Effects of Brackish Water Drip Irrigation Under Plastic Mulch on Soil Salinity and Cotton Yield

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Abstract

Rational utilization of brackish water resources for irrigation is of crucial significance in alleviating freshwater resource shortages in southern Xinjiang. This study utilized the cotton field of the 31st Regiment in Korla as the experimental subject, with freshwater serving as the control. By mixing saline water from alkali drainage ditches with freshwater at different ratios, six gradient treatments were established to investigate the effects of brackish and saline water on soil salt distribution and cotton yield in cotton fields. The results demonstrated: With increasing mineralization, soil salinity in each treatment exhibited varying degrees of increase, with Treatment 5 (full saline) showing the greatest increase and a salt accumulation rate of 131.03%. In the vertical direction, soil salinity in each treatment peaked at the 20∼40 cm depth as soil depth increased; in the horizontal direction, the degree of salt accumulation followed the order: between films > wide row > narrow row. With increasing mineralization, cotton yield gradually decreased, with the primary factor for yield reduction being the number of bolls per plant, while single boll weight had no significant effect on cotton yield. Based on the influence of soil salinity under mulched drip irrigation on cotton growth and yield, when the mineralization of irrigation water corresponded to a fresh to saline water ratio of 4 1 (mineralization 2.36 ∼3.39 g · L-1), the inhibitory effect on cotton growth was relatively minor, with yield decreasing by 11.85% compared to the control treatment.

Full Text

Effects of Drip Irrigation with Brackish Water on Soil Salinity and Cotton Yield

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Abstract

Water scarcity is a major factor affecting sustainable agricultural development in Xinjiang. However, brackish water contains abundant natural resources in Xinjiang, and reasonable utilization of brackish water in agriculture is of considerable significance to cope with water scarcity problems, increase crop yield, and conserve freshwater resources in southern Xinjiang. The objective of this study is to investigate the effects of utilizing brackish water exhibiting different degrees of mineralization on soil salt distribution, yield components, and seed cotton yield. A field experiment was conducted at the 31st Regiment of Yuli County in Korla City, Xinjiang Province, Northwest China. Six different volume ratios of freshwater to saltwater—freshwater (CK), 4:1 (treatment 1), 3:2 (treatment 2), 2:3 (treatment 3), 1:4 (treatment 4), and saltwater (treatment 5)—were verified via a field experiment. The results indicate that soil salinity significantly increased for treatments 1-5 when compared with CK. The highest soil salinity was obtained using treatment 5, where the relative growth rate of soil salinity reached 131.03%. In the vertical direction, soil salinity initially increased and subsequently decreased with increasing soil depth; soil salinity under all treatments was observed to primarily accumulate in the 20–40 cm soil layer. In the horizontal direction, the order of soil salinity at different locations was no-mulch zone > wide row > narrow row. In addition, the boll number per plant significantly decreased with increasing mineralization degree. However, there were no significant differences in weight per boll for different treatments. The seed cotton yield significantly decreased with increasing mineralization degree. Compared with CK, the seed cotton yield decreased by 11.85%, 22.37%, 28.66%, 37.78%, and 59.69% in treatments 1-5, respectively. The reduction in seed cotton yield under treatment 1 was minimal. This study suggests that the optimal volume ratio of freshwater to saltwater is treatment 1 (4:1). Accordingly, the usage of treatment 1 (4:1) is recommended to deal with water scarcity and ensure sustainable agricultural development in southern Xinjiang.

Keywords: under-mulched drip irrigation; brackish water; soil salt; cotton yield; Korla; Xinjiang

1 Materials and Methods

1.1 Experimental Design

The field experiment was conducted using a randomized complete block design with three replications. Six irrigation treatments were established with different freshwater to brackish water ratios as described in the abstract. Each plot measured 5 m × 6 m (30 m^2) with three replicate plots per treatment.

1.2 Soil Sampling and Analysis

1.2.1 Soil Salinity Measurement Soil samples were collected from different depths using a soil auger. The samples were air-dried, passed through a 1 mm sieve, and mixed with deionized water at a 1:5 soil-water ratio. After shaking for 10 minutes, the electrical conductivity was measured using a DDS-307A conductivity meter to determine soil salinity.

1.2.2 Sampling Layout Soil samples were collected from three horizontal positions: narrow row, wide row, and no-mulch zone. Vertically, samples were taken from 0-20 cm, 20-40 cm, 40-60 cm, 60-80 cm, and 80-100 cm depth intervals. The sampling was conducted both before irrigation and after harvest to characterize salt distribution patterns.

1.3 Data Analysis

Experimental data were processed using Excel for initial calculations. Statistical analysis was performed using SPSS software, and figures were generated using SigmaPlot 10.0. Analysis of variance (ANOVA) was conducted to determine significant differences among treatments at $P < 0.05$ level.

2 Results and Discussion

2.1 Soil Salinity Distribution Characteristics

2.1.1 Vertical Distribution Prior to irrigation, soil salinity in the 0-40 cm layer exhibited surface accumulation patterns, with higher salinity in the surface layer compared to deeper layers. Following irrigation, soil salinity increased significantly across all treatments compared to the control. The most pronounced salt accumulation occurred in the 20-40 cm soil layer, where the salt content reached its maximum value. Below this depth, salinity gradually decreased with increasing depth. The vertical distribution pattern followed the order: 20-40 cm > 0-20 cm > 40-60 cm > 60-80 cm > 80-100 cm.

The significant accumulation in the 20-40 cm layer can be attributed to the combined effects of evaporation and transpiration, which draw water upward from deeper layers while leaving salts behind. The mulching material reduced surface evaporation, preventing excessive salt accumulation at the soil surface and promoting salt accumulation in the subsurface layer.

2.1.2 Horizontal Distribution Soil salinity exhibited distinct horizontal distribution patterns across the different zones of the planting configuration. The salinity levels followed a consistent gradient: no-mulch zone > wide row > narrow row. This pattern was observed across all treatments and sampling depths.

The highest salinity in the no-mulch zone resulted from direct evaporation from the bare soil surface, which concentrated salts in the surface layer. The narrow row zone, being directly beneath the drip emitters, received the most frequent leaching effect from irrigation water, resulting in the lowest salinity levels. The wide row zone represented an intermediate condition with moderate salinity levels.

2.2 Effects on Cotton Growth and Yield Components

2.2.1 Yield Components The effects of different irrigation treatments on cotton yield components are presented in Table 4. Boll number per plant showed a significant decreasing trend with increasing brackish water proportion. However, no statistically significant differences were observed in individual boll weight among treatments, indicating that salinity primarily affected fruit retention rather than boll development.

Seed cotton yield decreased significantly with increasing mineralization degree. Compared with the freshwater control, yield reductions of 11.85%, 22.37%, 28.66%, 37.78%, and 59.69% were recorded for treatments 1 through 5, respectively. Treatment 1 (4:1 freshwater to brackish water ratio) showed the smallest yield reduction while still providing substantial freshwater savings.

2.2.2 Optimal Irrigation Ratio Based on the comprehensive evaluation of soil salinity dynamics and cotton yield performance, treatment 1 (freshwater to brackish water ratio of 4:1) is recommended as the optimal practice. This treatment maintained soil salinity at manageable levels while minimizing yield loss. The brackish water salinity in this treatment ranged from 2.36 to 3.39 g · L ^{1}, which is within the tolerance threshold for cotton under drip irrigation with plastic film mulching.

The results demonstrate that moderate use of brackish water (up to 20% of total irrigation volume) can be a viable strategy for addressing water scarcity in southern Xinjiang. However, continuous monitoring of soil salinity and periodic leaching with freshwater may be necessary to prevent long-term soil degradation.

[Figure 1: see original paper]

[Figure 2: see original paper]

[Figure 4: see original paper]

3 Conclusions

This study investigated the effects of drip irrigation with brackish water on soil salinity distribution and cotton yield in Xinjiang. The key findings are:

1. Soil salinity increased significantly with increasing proportions of brackish water, with the highest accumulation occurring in the 20–40 cm soil layer.
2. Horizontal distribution of salts followed the pattern: no-mulch zone > wide row > narrow row.

3. Cotton yield decreased with increasing brackish water proportion, but treatment 1 (4:1 ratio) showed only an 11.85% yield reduction compared to freshwater irrigation.
4. The optimal freshwater to brackish water ratio is 4:1, which balances water conservation with acceptable yield levels.

These results provide practical guidance for farmers in water-scarce regions of Xinjiang to utilize brackish water resources sustainably while maintaining agricultural productivity.

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