Effects of Drip Irrigation Duration on Soil Physicochemical Properties and Crop Yield in the Ili River Basin (postprint)

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Abstract

To elucidate the distribution of soil moisture, total nitrogen, and organic matter in newly reclaimed cropland under varying years of drip irrigation application in the Southern Bank Irrigation District of the Ili River, Xinjiang, and to further understand soil nutrient dynamics during water diversion irrigation and reclamation of wasteland in arid regions, this study was conducted in a continuously newly reclaimed area of the Ili River Basin—the Management Office of the Southern Bank Irrigation District of the Ili River—with winter wheat (Triticum aestivum L.) as the research object. By monitoring soil moisture, total nitrogen content, and soil organic matter content in the 0–60 cm profile across different drip irrigation application years (1 yr, 2 yr, 3 yr, 4 yr) and uncultivated wasteland (CK), the effects of drip irrigation duration on soil physicochemical properties and winter wheat yield under drip irrigation conditions were investigated. The results demonstrated that: soil water content in newly reclaimed land increased with prolonged drip irrigation application; planting and irrigation improved soil water infiltration conditions in newly reclaimed land, facilitating water regulation and storage in the tillage layer; total nitrogen in each soil layer of newly reclaimed land increased with drip irrigation application years, with the depth distribution pattern shifting from a decrease-then-increase trend before reclamation to an increase-then-decrease trend after reclamation, exhibiting surface accumulation in the 0–30 cm soil layer; soil organic matter content in the 0–60 cm profile under different drip irrigation application years increased with application duration, with reclamation and planting enhancing soil organic matter content in the 0–40 cm layer and showing significant enrichment in the 0–20 cm soil layer; according to the nutrient classification standards of the Second National Soil Survey, both total nitrogen and organic matter improved by one grade following wasteland reclamation in the study area; winter wheat yield in newly reclaimed cropland irrigated for 1–4 yr increased with drip irrigation

application years. The primary drivers of nutrient and yield increases were the local irrigation regime and crop straw residue.

Full Text

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Abstract

This study aimed to clarify the soil moisture distribution and the distribution of total nitrogen and organic matter in newly cultivated arable land under different durations of drip irrigation in the Ili River South Irrigation Area of Xinjiang' s Yili River Basin, and to further understand the changes in soil nutrients during the process of diversion irrigation and wasteland reclamation in arid regions. This was achieved by monitoring the effects of different numbers of years of drip irrigation (1a, 2a, 3a, 4a) on winter wheat (*Triticum aestivum* L.) and uncultivated wasteland (CK) soil moisture, total nitrogen content, and soil organic matter content in a 0–60 cm soil profile in the New Reclamation Area, Ili River South Bank Irrigation Area. The effects of years of drip irrigation on soil physical and chemical properties and winter wheat yield under drip irrigation were analyzed. The research results showed that the soil moisture content of newly cultivated land increased with the extension of the application of drip irrigation. Planting and irrigation improved the soil water infiltration conditions of the newly opened land, which is conducive to water storage and storage of the cultivated layer. This increased the application life of drip irrigation, and with an increase in depth, the distribution trend changed from decreasing before increasing to increasing to increasing and then decreasing. Surface aggregation occurred in the 0–30 cm soil layer during different application years to the 0–60 cm soil layer. The organic matter content increased with the increase in the number of years. Reclamation increased the soil organic matter content of the 0–40 cm soil layer and the soil was significantly enriched in the 0–20 cm soil layer. According to the relevant national soil grading standards for the second soil census, after the reclamation of wasteland in the research area, the soil nutrient total nitrogen and organic matter concentrations were all improved by one level. The newly cultivated arable land was irrigated for 1–4 years, and the winter wheat yield increased with the increase in the number of years of drip irrigation. The main reasons for the increase in nutrients and yields are the current local irrigation system and crop residues.

Keywords: drip irrigation; application period; soil moisture; soil total nitrogen;

soil organic matter; winter wheat; south irrigation area of Ili River

1. Introduction

The Yili River Basin represents a critical agricultural region in Xinjiang, where wasteland reclamation through drip irrigation has become increasingly important for food security. Previous studies have demonstrated that approximately 50% of arable land in this region depends on irrigation systems [13]. The process of converting wasteland to cultivated land fundamentally alters soil physicochemical properties and water infiltration characteristics [1]. With the expansion of drip irrigation applications, understanding the temporal changes in soil quality parameters becomes essential for sustainable land management.

2. Materials and Methods

2.1 Study Area and Experimental Design The study was conducted in the New Reclamation Area of the Ili River South Bank Irrigation Region. Soil samples were collected from plots subjected to different drip irrigation durations: 1 year (A1), 2 years (A2), 3 years (A3), and 4 years (A4), with uncultivated wasteland serving as control (CK). Winter wheat (*Triticum aestivum* L.) was cultivated under consistent management practices across all treatment plots.

2.2 Soil Sampling and Analysis Soil samples were collected from 0–60 cm depth profiles, stratified into 10 cm intervals. The 0–30 cm layer exhibited a bulk density of 1.53 $g \cdot cm^{-3}$, with porosity of 35.47% and field capacity of 31.22%. Soil moisture content, total nitrogen, and organic matter were measured using standard analytical methods. The sampling was conducted in September 2018, with five replicate plots per treatment.

3. Results

3.1 Soil Moisture Distribution Soil moisture content in the 0–60 cm profile increased progressively with irrigation duration. The infiltration capacity of newly reclaimed land improved significantly, enhancing water storage in the cultivated layer and extending the effective application life of drip irrigation systems. With increasing depth, the moisture distribution pattern transitioned from an initial decreasing trend to an increase-then-decrease pattern. Surface aggregation was observed in the 0–30 cm layer across all irrigation durations, with notable improvements in the 0–60 cm profile.

3.2 Total Nitrogen Content Total nitrogen (TN) content exhibited significant vertical stratification, with concentrations of 2.17 $g \cdot kg^{-1}$ in the 0–20 cm layer, representing a 15–20% increase compared to deeper horizons. After 4 years of irrigation (A4), the 0–30 cm layer showed TN enrichment of 49% relative to control, while the 20–30 cm layer in A4 plots demonstrated a 108.1%

increase (0.13 $g \cdot kg^{-1}$). The 0–60 cm profile showed consistent TN improvement, particularly in the 30–40 cm zone where content reached 0.48 $g \cdot kg^{-1}$.

3.3 Soil Organic Matter Dynamics Soil organic matter (SOM) content increased significantly with reclamation duration. Figure 4 illustrates SOM distribution across different soil layers and reclamation years. The 0–40 cm layer showed substantial enrichment, with the 0–20 cm surface layer reaching 2.17 $g \cdot kg^{-1}$. After 3–4 years of cultivation, SOM content in the 0–10 cm layer increased by 28.8–49% compared to initial conditions. The correlation between reclamation years and SOM content was highly significant ($r = 0.983$, $p < 0.01$).

3.4 Crop Yield Response Winter wheat yield demonstrated a strong positive correlation with irrigation duration. Grain yield increased from 54.73 $kg \cdot hm^{-2}$ in year 1 to 66.63 $kg \cdot hm^{-2}$ in year 4, representing a 21.7% cumulative increase. The correlation coefficient between yield and reclamation years was 0.828 ($p < 0.01$). Yield showed significant positive correlations with soil TN ($r = 0.950$, $p < 0.05$) and SOM ($r = 0.983$, $p < 0.01$) in the 0–30 cm layer.

4. Discussion

The observed improvements in soil quality parameters can be attributed to two primary factors: the efficient water delivery of the drip irrigation system and the incorporation of crop residues. Irrigation enhanced water infiltration and reduced surface evaporation, while root biomass and stubble decomposition contributed to nutrient accumulation. The significant enrichment of TN and SOM in surface layers (0–20 cm) aligns with patterns typical of conservation agriculture in arid regions.

Correlation analysis revealed that soil physicochemical properties in the 0–30 cm layer were the strongest predictors of crop yield (Table 3). Total nitrogen and organic matter showed correlation coefficients of 0.983 and 0.963 ($p < 0.01$), respectively, with yield. The 0–60 cm profile also showed significant correlations, with the 0–10 cm layer exhibiting the strongest relationships: TN ($r = 0.943$), SOM ($r = 0.897$), and moisture content ($r = 0.883$).

According to China's Second National Soil Survey classification standards, reclamation elevated soil nutrient status by one complete grade level. The combination of improved moisture retention and nutrient enrichment created favorable conditions for sustained yield increases. The 4-year irrigation treatment (A4) produced optimal results, with yield increases directly proportional to the accumulation of soil organic matter and nitrogen.

5. Conclusion

Drip irrigation duration significantly influences soil physicochemical properties and crop productivity in newly reclaimed lands of the Yili River Basin. Soil moisture, total nitrogen, and organic matter contents all increased progressively

with irrigation years, with the most pronounced changes occurring in the 0–30 cm surface layer. Winter wheat yield showed a direct positive response to these soil improvements. The integration of efficient irrigation management and crop residue retention represents an effective strategy for sustainable intensification of agriculture in this arid region.

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