

Experimental Study on the Effects of Drip Irrigation Amount and Soil Temperature on Soil Profile CO₂ Concentration in Potted Cotton (Postprint)

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Abstract

This study investigated the effects of irrigation amount and soil temperature on soil CO₂ concentration at different depths in Xinjiang under mulched drip irrigation conditions. Using pot experiments and gas chromatography monitoring, the variation patterns of soil CO₂ concentration in the 10-50 cm soil layer were studied under different drip irrigation amounts [full irrigation (CK, 100%); mild water deficit (W1, 80%); severe water deficit (W2, 60%)] for both cotton-planted and bare soil conditions. Results showed that irrigation amount had a significant effect on soil profile CO₂ concentration. Under both cotton-planted and bare soil conditions, soil CO₂ concentration at different depths increased with increasing irrigation amount, and soil profile CO₂ concentration exhibited a distribution characteristic of lower in the upper layer and higher in the lower layer, with CO₂ concentration at 50 cm being approximately twice that at the surface 10 cm layer, and CO₂ concentration in cotton-planted soil being approximately twice that in bare soil. Soil profile CO₂ concentration exhibited distinct diurnal and seasonal variation patterns. Within a day, soil temperature and soil profile CO₂ concentration increased with air temperature, showing a “single-peak” curve variation pattern with the peak occurring at 16:00; during the cotton growth period, soil profile CO₂ concentration reached its maximum value at the flowering and boll-forming stage. Both irrigation amount and soil temperature showed significant positive correlations with soil profile CO₂ concentration ($P < 0.01$). These results can provide theoretical reference for water-saving and emission reduction in cotton cultivation in arid regions.

Full Text

Effects of Irrigation Volume and Soil Temperature on Soil CO₂ Concentration under Drip Irrigation in Xinjiang

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Abstract

This study aimed to explore the effects of irrigation volume and soil temperature on soil CO₂ concentrations at different depths under drip irrigation in Xinjiang. The barrel test was used with different amounts of drip irrigation: full irrigation (CK) at 100% irrigation, mild water deficit (W1) at 80% irrigation, and severe water deficit (W2) at 60% irrigation. The variation in CO₂ concentrations in the 10–50 cm soil layer was monitored and studied using gas chromatography in planted cotton and bare soil. The results showed that the amount of irrigation had a significant effect on the soil profile CO₂ concentration. Under the condition of cotton planting or bare soil, with an increase in the amount of irrigation, the soil CO₂ concentration increased at different depths, and the soil profile CO₂ concentration was characterized by an upper, lower, and higher distribution. The CO₂ concentration at a depth of 50 cm was about twice that at a depth of 10 cm in the surface layer, and the concentration of CO₂ in the cotton-planted soil was about twice the concentration of CO₂ in bare soil. The change in CO₂ concentration in the soil profile showed evident diurnal and seasonal variation. In one day, the soil temperature and soil profile CO₂ concentration increased with the increase in temperature, showing a “single peak” curve, with the peak appearing at 16:00. The soil profile CO₂ concentration during the cotton growth period reached a maximum during the flowering period. Irrigation quantity and soil temperature were positively correlated with the soil profile CO₂ concentration ($P < 0.01$). This result provides a theoretical reference for water saving and emission reduction in cotton planting in arid areas.

Keywords: drip irrigation water volume; soil temperature; drip irrigation under film; CO₂ concentration in soil profile; Xinjiang

Introduction

Xinjiang is one of the three largest cotton-producing regions in China, with its cotton planting area and output accounting for significant proportions of the national total. In 2018, the cotton planting area in Xinjiang reached 2.49×10^6 hm², representing 74.31% of the national total, while cotton output reached

5.11×10^6 t, accounting for 83.84% of the national total. Drip irrigation under mulch film has been widely adopted in Xinjiang cotton production, fundamentally changing traditional surface irrigation methods and representing a major water-saving irrigation technology. However, drip irrigation affects soil moisture and temperature regimes, which in turn influence soil CO₂ emissions.

Previous studies have shown that irrigation significantly affects soil CO₂ emissions. Research indicates that from 1990 to 2014, global soil CO₂ emissions increased by 9% due to climate warming. Soil moisture content and temperature are key factors regulating soil CO₂ emissions, with soil CO₂ concentration showing significant positive correlations with both factors ($P < 0.01$). Under drip irrigation, soil moisture distribution patterns differ from traditional irrigation methods, creating unique soil CO₂ emission characteristics. Studies have demonstrated that soil CO₂ concentration exhibits vertical stratification, with higher concentrations in deeper layers, and shows clear diurnal and seasonal variations correlated with temperature changes.

Materials and Methods

The experiment employed a barrel test system with three irrigation treatments: CK (full irrigation at 100% of standard), W1 (mild water deficit at 80% of standard), and W2 (severe water deficit at 60% of standard). Soil CO₂ concentrations were monitored at depths of 10–50 cm using gas chromatography in both cotton-planted and bare soil conditions. The experimental site was located at 44°18' 25" N, 86°03' 27" E. Each treatment was replicated three times.

Results

2.1 Dynamic Changes in Soil Profile CO₂ Concentration Figure 1 shows the dynamic changes in soil CO₂ concentration under different treatments during the entire cotton growth period. The CO₂ concentration in the soil profile displayed a consistent pattern across treatments: CK > W1 > W2. Compared with CK, the W1 and W2 treatments reduced soil CO₂ concentration by 18.56% and 29.87%, respectively. The vertical distribution showed that CO₂ concentration increased with depth, with concentrations at 50 cm being approximately 1.82–1.86 times those at 10 cm.

The diurnal variation in soil CO₂ concentration followed a single-peak curve, reaching its maximum at 16:00 and minimum in the early morning hours. Seasonally, CO₂ concentration peaked during the cotton flowering period, corresponding with maximum root activity and soil microbial respiration.

2.2 Effects of Soil Moisture and Temperature on CO₂ Concentration

Soil moisture content showed a significant positive correlation with soil CO₂ concentration ($P < 0.01$). Under mulched drip irrigation (MBS), the coefficient of determination (R^2) between soil moisture and CO₂ concentration was 0.603, 0.494, and 0.384 for CK, W1, and W2 treatments, respectively. Soil temperature

also exhibited a strong positive relationship with CO₂ concentration, with R² values of 0.531 and 0.630 for different measurement periods ($P < 0.01$). The combined effect of soil moisture and temperature explained 58.1%-77.8% of the variation in soil CO₂ concentration.

During the cotton growth period, soil CO₂ concentration ranged from 1,042.49 to 24,064.6 mol · mol⁻¹ under planted conditions and 880.55 to 12,460.51 mol · mol⁻¹ in bare soil. The presence of cotton plants increased soil CO₂ concentration by approximately 78.5%-89.1% compared to bare soil, highlighting the significant contribution of root respiration.

2.3 Vertical Distribution Characteristics The vertical distribution of CO₂ concentration showed a distinct pattern: lower in the surface 10 cm layer, decreasing further in the 10-20 cm layer, then gradually increasing below 20 cm. This pattern reflects the combined effects of gas diffusion, root distribution, and microbial activity. At 20-50 cm depths, CO₂ concentration showed strong correlations with both soil moisture and temperature, indicating that environmental factors regulate subsurface CO₂ accumulation.

Discussion

The significant positive correlation between irrigation amount and soil CO₂ concentration confirms that water availability enhances root and microbial respiration. Similar results have been reported in maize fields and other cropping systems. The vertical stratification of CO₂ concentration, with higher values at 50 cm depth, aligns with findings from loess profile studies showing that subsurface layers act as CO₂ accumulation zones.

Soil temperature emerged as a critical factor, with CO₂ emissions increasing exponentially within the 10-42°C range. The diurnal pattern, peaking at 16:00, reflects the lag between temperature increase and biological response. The seasonal maximum during the flowering period corresponds to peak plant metabolic activity and root biomass.

The mulched drip irrigation system creates a unique microenvironment where soil moisture and temperature interact to regulate CO₂ production and transport. The plastic mulch increases soil temperature while reducing evaporation, thereby intensifying CO₂ emissions compared to bare soil. However, the water-saving benefits of drip irrigation may offset some of the enhanced emissions per unit of crop yield.

Conclusion

Irrigation volume and soil temperature significantly affect soil profile CO₂ concentration under drip irrigation in Xinjiang cotton fields. CO₂ concentration increases with irrigation amount and soil depth, showing clear diurnal (peak at 16:00) and seasonal (peak during flowering) patterns. The presence of cotton plants substantially increases soil CO₂ concentration through root respiration.

These findings provide theoretical guidance for optimizing irrigation strategies to balance water conservation and greenhouse gas emissions in arid region agriculture.

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