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Effects of Irrigation Strategies on Growth, Yield, and Fruit Quality of Greenhouse Tomato

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Abstract Greenhouse tomato production relies heavily on effective water management, and irrigation strategies and water supply levels directly influence plant growth, yield formation, and fruit quality. This study reviewed the effects of different irrigation strategies on physiological responses, root development, yield components, and quality formation in greenhouse tomatoes, and further discussed the development trends of precision irrigation technologies and sustainable management practices. The results indicate that appropriate water supply promotes root growth, photosynthesis, and dry matter accumulation, thereby improving plant growth and yield performance. Excessive irrigation enhances vegetative growth but reduces water-use efficiency and may negatively affect fruit quality. Moderate deficit irrigation improves resource-use efficiency while maintaining relatively high yield by regulating root-shoot balance and promoting the accumulation of quality-related compounds, including sugars, vitamin C, and lycopene. Tomato water requirements vary among growth stages, and precise regulation based on evapotranspiration (ET), growth stage, and root-zone moisture status is more effective for balancing yield and quality. Future greenhouse tomato production should strengthen the integration of irrigation, fertilization, environmental regulation, and smart monitoring technologies to establish efficient, water-saving, and sustainable production systems.

Keywords Greenhouse tomato; Irrigation strategy; Water-use efficiency; Deficit irrigation; Fruit quality; Precision irrigation

1 Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most important economic vegetable crops worldwide, with high nutritional value and extensive applications in fresh consumption and food processing (Sagar and Singh, 2023). Tomato fruits are rich in various functional compounds, including vitamin C, lycopene, phenolics, organic acids, and carbohydrates, which collectively determine fruit quality and market value (Lu et al., 2021; Zhang et al., 2025). With increasing consumer demand, tomato production has continued to expand, and protected cultivation has become an important production system for improving yield stability and supply capacity. According to He et al. (2024), global tomato production reached 2.54×10^{12} kg in 2022, with China contributing 1.37×10^{12} kg, accounting for 53.72% of the global production. Greenhouse and other protected cultivation systems can improve land-use efficiency, support year-round production, and reduce the impacts of climatic fluctuations on yield and quality (Amankwaa-Yeboah et al., 2023). However, protected production relies heavily on water and nutrient management, and resource-use efficiency remains a key factor limiting its sustainable development.

Greenhouse environments receive limited natural rainfall, making irrigation the primary source of water supply. Improper irrigation management can result in resource waste and reduced production efficiency. Previous studies have shown that excessive irrigation decreases water and nitrogen use efficiency and may negatively affect fruit quality and economic returns, whereas insufficient water supply restricts cell expansion, plant growth, and yield formation (Wu et al., 2022; Zhang et al., 2025). In arid and semi-arid regions, water scarcity further increases the uncertainty of greenhouse tomato production (Amankwaa-Yeboah et al., 2023; Liu et al., 2024). Therefore, precise irrigation management based on crop growth stages and environmental conditions is essential for improving resource-use efficiency.