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Modeling the Relationship between Temperature and Tomato Yield in Greenhouse Systems

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Abstract Temperature is one of the most critical environmental factors affecting the growth, development, and productivity of greenhouse tomatoes. This paper systematically reviews and analyzes the relationship between temperature dynamics and tomato yield formation under protected cultivation conditions. The study summarizes the physiological mechanisms through which temperature regulates photosynthesis, respiration, flowering, fruit set, and stress responses during different growth stages. In addition, the characteristics of greenhouse microclimates and the interactions between temperature, humidity, light, and CO_2 are discussed. Various modeling approaches, including statistical regression models, process-based crop models, and machine learning algorithms, are evaluated for their ability to predict tomato yield under variable temperature conditions. The paper also examines methods for model calibration, validation, and performance assessment using multi-season datasets. Several case studies are presented to demonstrate the practical applications of temperature-yield models in greenhouse management and precision agriculture. Finally, the challenges, limitations, and future prospects of intelligent temperature regulation and climate-adaptive modeling are highlighted to support sustainable greenhouse tomato production.
Keywords Greenhouse tomato; Temperature dynamics; Yield prediction; Crop growth model; Precision agriculture

1 Introduction

Greenhouse tomato production has become essential for ensuring stable, year-round supply while making efficient use of land, water, and energy. Within these protected systems, temperature is a primary driver of plant development, resource use, and ultimately yield, and its role is intensifying under climate change and more frequent heat extremes (Kürklü et al., 2025). Elevated temperatures and longer hot seasons already reduce yield, force higher cooling and irrigation demands, and complicate climate control in commercial greenhouses. At the same time, the greenhouse structure creates opportunities to actively manage temperature and to exploit its buffering capacity, provided that quantitative relationships between temperature regimes and tomato yield are well understood (Flores-Velázquez et al., 2022). Developing models that link temperature dynamics to yield is therefore important for climate-resilient design, control, and strategic planning in greenhouse tomato systems.

Over the past decades, numerous experimental and monitoring studies have examined tomato responses to greenhouse temperature. Work in high-tech and plastic houses shows that small but persistent temperature differences within a single compartment (on the order of 3 °C in daily averages) can significantly alter stem growth, fruit growth, and truss mass, even when bulk climate appears uniform (Šalagovič et al., 2024. Experiments manipulating air or soil temperature demonstrate substantial effects on photosynthesis, dry-matter accumulation, quality traits, and yield, with warmer root zones or air generally increasing yield and water productivity up to an optimum, beyond which heat stress causes losses (Efeta et al., 2025). Heat-stress trials further reveal strong genotype-dependent yield declines and quality changes, underscoring the importance of temperature thresholds and exposure duration around flowering and fruit set. Recent climate-change-oriented studies highlight that extreme high temperatures in commercial greenhouses already cause substantial yield losses (often >10%) and sharply increase resource use, confirming temperature as a critical vulnerability factor in modern soilless systems.