

The relationship between temperature conditions and tomato growth and yield formation is therefore both physiological and developmental. Temperature alters metabolic efficiency, respiration, membrane stability, photosynthesis, and carbon use, and these whole-plant effects interact with stronger reproductive sensitivity during flowering and fruiting (Alsamir et al., 2020; Elazazi et al., 2024). Experimental and modeling studies show that yield losses under heat stress are driven mainly by reductions in fruit number, fruit set, seed set, and individual fruit mass rather than by a simple decline in total biomass. In South Florida simulations, yield decreased as air temperature increased, with losses of 52°C-85% above current conditions, primarily because fruit production declined, even though biomass accumulation and leaf area index increased with temperature (Ayankoji and Morgan, 2020). Likewise, controlled studies of fruit development found that both low (14°C) and high (26°C) temperature regimes tended to produce small parthenocarpic fruits and low fruit yields, while newer modeling work showed that 30-34°C reduces pollen viability, germination, seed set, and fruit mass, and that 14°C lowers yield by reducing both fruit set and fruit size (Zepeda et al., 2026). Together, these findings indicate that tomato yield formation is shaped not only by mean temperature but by the timing, duration, and amplitude of thermal stress, especially during sensitive reproductive stages.

Against this background, the objective of this review is to synthesize current knowledge on how temperature regulation affects tomato growth, reproductive development, and final yield, and to identify practical and biological factors that can improve resilience under fluctuating thermal environments. Recent work has shown that even within commercial greenhouses, local canopy microclimates can vary by up to 3°C in daily average temperature and can measurably influence stem growth, fruit growth, and truss mass, indicating that “temperature regulation” must be understood at the crop-canopy scale rather than only at the level of a central climate setting (Šalagovič et al., 2024). At the same time, advances in genetics and molecular physiology show that thermotolerance can be improved through targeted trait selection and mechanistic understanding: quantitative trait loci linked to fruit set, yield, and soluble solids have been identified under high temperature, and heat-responsive reproductive regulators such as the TSP4a/TSP4b module have been shown to help maintain fruit set and fruit sugar levels under warming conditions (Elazazi et al., 2024; Lu et al., 2025). Accordingly, this review focuses on three linked themes: the importance of temperature regulation in tomato production systems, the mechanisms by which temperature shapes growth and yield formation, and the emerging management, breeding, and monitoring strategies that can support high yield and fruit quality under climate warming.

2 Temperature Requirements and Environmental Regulation in Tomato Production

2.1 Optimal temperature ranges during different growth stages

Tomato temperature requirements vary by developmental stage, and reproductive performance is generally more temperature-sensitive than vegetative growth. Broadly, optimal growth has been placed between 18°C and 32°C, but fruit set and yield respond best within a narrower mean temperature window, with daily average temperatures of 21°C-24°C, 22°C-25°C, or 22°C-26°C repeatedly identified as favorable for reproductive success (Luo et al., 2023). Night temperature is also important during flowering and fruit set, because night temperatures of 15°C-20°C increase marketable yield, while a night temperature of 13°C can still maintain good fruit set under some conditions (Alsamir et al., 2020; Lee et al., 2022).

Stage-specific thresholds further show that tomato should not be managed with a single thermal target throughout the crop cycle. Seedling emergence can already be damaged at 30°C, whereas temperatures above 35°C significantly inhibit germination, vegetative growth, flowering, fruit set, and ripening; by contrast, lower developmental thresholds for tomato are often placed near 15°C, below which growth and development largely cease (Lee et al., 2022). During fruit development, increasing temperature accelerates ripening, with fruits ripening 95, 65, 46, and 42 days after flower opening at 14°C, 18°C, 22°C, and 26°C, respectively, but both high and low temperature regimes also tend to produce small parthenocarpic fruits and lower yields when flower number or fruit set is impaired.

2.2 Effects of temperature fluctuations on plant development

Temperature fluctuations affect tomato development not only through mean temperature but also through the timing, duration, and amplitude of thermal stress. Sub-optimal temperatures reduce leaf and truss initiation rates