

and increase the time from anthesis to ripening, while high temperatures above the optimum alter vegetative and reproductive growth, including flower and pollen development, and thereby reduce fruit set and final yield (Graci and Barone, 2024). Experimental evidence also shows that tomato can integrate day-night temperature variation only within limits: early- and late-summer regimes with average day/night temperatures of 28.1°C/24.3°C and 30.1°C/26.5°C supported more clusters, flowers, fruits, and better quality than the hotter 32.4°C/28.5°C mid-summer regime (Talukder et al., 2025).

Short periods of temperature extremes during reproductive stages can be especially damaging because they directly impair pollen quality, seed set, fruit set, and fruit mass. In a controlled modelling study, 30°C and 34°C reduced pollen viability and germination, lowering seed set and fruit mass, while 14°C and 34°C reduced fruit set; the predicted yield loss at 14°C came from both fewer fruits and smaller fruits, whereas at 30°C it came mainly from smaller fruits (Zepeda et al., 2026). Field and greenhouse comparisons likewise showed that yield losses near 70% under high temperature were linked to poorer fruit set, and that maximum or minimum temperature during sensitive reproductive periods can matter more than season-long mean temperature because even short exposure above the optimum can sharply reduce reproductive success (Ro et al., 2021).

2.3 Temperature management strategies in greenhouse tomato production

Greenhouse temperature management should aim to maintain stable crop-level conditions rather than relying only on compartment-wide averages. Commercial greenhouse monitoring has shown spatial temperature gradients of up to 3°C and vapour pressure deficit differences of up to 0.6 kPa within the same canopy, and these local microclimate differences measurably altered stem growth, fruit growth, and truss mass at harvest (Šalagovič et al., 2024). This supports the use of denser sensor networks, because local microclimate effects on plant growth were larger than bulk climate variation recorded by a single central sensor, making whole-greenhouse sensor grids more suitable for climate control than one-point monitoring (Šalagovič et al., 2024).

In hot-season protected cultivation, cooling strategies should be adjusted to reproductive thermal thresholds rather than fixed to a single seasonal set point. Mean daily temperatures of 25°C-26°C appear to be the upper limit for proper fruit set and fruit yield in protected tomato during Mediterranean summer, and reducing mean daily temperature by only 1°C-1.5°C with fogging, together with increasing daytime relative humidity from 50% to 70%, improved pollen viability. Evidence from passive solar greenhouse systems also suggests that low-cost protection can buffer unfavorable field conditions and raise marketable yield, but shading must be used cautiously because although greenhouse production increased yield 1.8-fold over open field, added shading delayed flowering and reduced marketable yield by 48% (Angmo et al., 2021).

3 Effects of Temperature Regulation on Tomato Vegetative Growth

3.1 Effects on seed germination and seedling establishment

Temperature regulation strongly determines the success of tomato seed germination and early seedling establishment because these stages are among the most temperature-sensitive phases of the crop life cycle. Controlled experiments showed that the most suitable germination temperatures were 24°C-28°C, whereas germination rate and seedling vigor declined above 28.5°C, only about half of the seeds germinated at 31.5°C, and no germination occurred at 36°C (Tokić et al., 2023). Classic thermal analysis similarly found that germination occurred between 6.0°C and 37.5°C, with the optimum range for germination kinetics centered around 25.9°C-29.5°C, indicating that both excessively low and excessively high temperatures constrain rapid and uniform emergence.

High temperature not only suppresses germination percentage but can also trigger physiological inhibition that compromises subsequent establishment. In one genetic study, prolonged exposure of imbibed seeds to elevated temperature induced thermo-dormancy in the cultivar 'Moneymaker', with induction beginning after about 33 h and germination falling to 0% after roughly 100 h of exposure. Variety comparisons also showed that 33°C significantly reduced germination rate, vigor, germination index, and vitality index, and that early seedling roots were inhibited more strongly than shoots, with larger effects in less thermotolerant genotypes.