Flowering and early fruit set are especially vulnerable to exceedance of these thresholds. Controlled and field experiments consistently show that prolonged daytime or nighttime temperatures above about 32 °C/20 °C (day/night) during the reproductive phase reduce fruit set and fruit weight, leading to significant yield losses (Miller et al., 2021). Studies of pollen performance under episodes of 30 °C-34 °C or short heat shocks around anthesis report sharp declines in pollen viability, germination, and tube growth, which then translate into lower seed set and smaller fruit mass (Zepeda et al., 2026). Conversely, work on optimal ranges and growth-stage specific limits indicates that night temperatures above roughly 21 °C can already discriminate heat-tolerant from heat-sensitive cultivars, emphasizing that even moderate nocturnal warming beyond cultivar-specific thresholds during flowering can markedly depress yield formation.

4.3 Relationship between temperature accumulation and yield stability

Beyond instantaneous thresholds, tomato yield stability in greenhouses reflects the cumulative exposure to supra-optimal or sub-optimal temperatures over the season. Long-term heat stress experiments under greenhouse conditions show that yield loss increases with the duration of exposure: cherry tomato accessions subjected to elevated day set-points for more than 50 days exhibited progressive reductions in harvest index and fruit yield, with some genotypes losing over 40% of yield relative to controls (Park et al., 2023). Recent modeling work combining greenhouse climate projections with morphological yield models similarly demonstrates that future scenarios with 1-8 °C warming and longer hot seasons can decrease yield in heat-sensitive accessions while slightly increasing or stabilizing yield in more heat-resilient ones, highlighting the role of accumulated heat load in determining long-term yield trajectories (Kim et al., 2025).

Temperature accumulation interacts with developmental timing to shape yield stability. A mechanistic model of seed set and fruit mass that incorporates short periods of low (14 °C) and high (30 °C-34 °C) temperature shows that both the level and duration of deviation from the optimum critically affect pollen quality, seed set, and resulting fruit mass, with repeated or longer stress episodes causing cumulative reductions in fruit number and size on a truss (Zepeda et al., 2026). Multi-environment trials comparing performance under optimal field, high-temperature field, and high-temperature greenhouse conditions further confirm that yield stability differs strongly among genotypes: some maintain relatively constant fruit set and yield across environments, while others exhibit steep declines under repeated high-temperature episodes (Ro et al., 2021). Together, these findings support the use of temperature sums or heat-stress indices over sensitive stages as key predictors of yield stability in greenhouse tomato production.

5 Data Acquisition and Experimental Design

5.1 Experimental materials, greenhouse conditions, and cultivation management

Greenhouse tomato studies typically specify cultivar choice, planting density, and structural characteristics to ensure reproducibility and to contextualize yield responses. Experiments on cherry tomato ‘Cheramy F1’ in winter greenhouses used a randomized complete block design with split plots, three rows and three replications, with three plants sampled per row, capturing variability over two consecutive seasons (Arshad et al., 2024). Within this structure, the internal climate ranged from about 8-41 °C across vegetative and fruiting stages, with CO_2 between roughly 386-510 ppm and light intensity from about 95-240 W m^{-2}, providing a broad envelope of temperature regimes for modeling. Other greenhouse trials with large-fruited cultivars have similarly defined plot structure through factorial or split-split plot designs, for example combining cultivar, grafting and plant density (3.5 vs. 5.5 plants m^{-2}) in hydroponic organic systems to test management interactions under hot, humid conditions (Dash et al., 2023).

Representative experimental work also reports greenhouse size, location, and baseline climate. A Ghanaian study used a 270 m^2 greenhouse at a defined latitude, planting tomato ‘Anna F1’ in a 3×3 factorial of spacing and topping treatments, with temperature and relative humidity maintained between 24 °C-32 °C and 63%-80% during the experiment. Orientation and row spacing have been explicitly treated as design variables in Chinese solar greenhouses, where north-south versus east-west orientations and 1.4-1.8 m row spacings were compared to analyze effects on canopy light interception, growth, and yield (Li et al., 2024). Fertilization and soil or substrate