prolonged heat exposure and warm nights in yield reduction. Yet higher maximum temperatures earlier in the growth period were associated with improved productivity, and cumulative heat intensity above 30 °C around harvest showed a negative association with low yield, highlighting complex, stage-dependent responses to heat events.

Controlled-environment experiments reveal physiological mechanisms through which excessive heat depresses fruit yield and size. For the low-chill cultivar ‘KU-PP2’, growth at 30 °C accelerated early fruit expansion and shortened the development period by up to 18 days but substantially reduced final fruit weight and soluble solids compared with 20 °C, effects attributed to diminished photosynthetic capacity under sustained high temperature. Related work on ‘Mihong’ shows that moderate warming (+3.4 °C) can increase photosynthesis, stomatal density, and tree yield, while stronger warming (+5.7 °C) reduces photosynthetic rates and floral bud differentiation, thereby lowering current yield and compromising yield potential in the following year, illustrating how heatwaves that push temperatures beyond optimal thresholds can damage both current and subsequent crops (Lee et al., 2020).

3.3 Seasonal temperature variability and yield stability

Interannual variability in seasonal temperatures modulates both phenology and yield stability in peach orchards. In Moroccan Sais Valley conditions, years with higher temperatures during flowering and fruit growth showed earlier bloom and maturity but significantly lower fruit weight, suggesting that warmer seasons may compress developmental periods and reduce assimilate accumulation per fruit. Long-term observations in a warm Tunisian production area similarly indicate that exceptionally warm winters with low chill accumulation delay and desynchronize flowering, increase bud abscission, and reduce yield and fruit quality when chilling falls below cultivar-specific thresholds, demonstrating that warm-winter anomalies destabilize reproductive success and commercial output.

At broader spatial scales, process-based phenology models that couple chilling, forcing, frost risk, and growing degree days show that climate warming will shift the thermal niche of peach cultivation, with earlier bloom and easier ripening but increasing risk of insufficient winter chill in traditional warm regions. Analysis of historical low-yield events in the U.S. Midwest and Southeast further identifies “false spring” patterns-early GDD accumulation followed by hard freezes-as major drivers of regional peach crop failures, and uses surface temperature thresholds and GDD tracking to build a decision-support tool capable of predicting major yield reductions, emphasizing how seasonal temperature sequences rather than single extremes determine yield stability.

4 Temperature Regulation of Peach Fruit Quality Attributes

4.1 Temperature effects on sugar and acid metabolism

Storage and handling temperature strongly shape sweetness-acidity balance in peach by altering sugar and organic acid metabolism. Non-chilling storage around 12 °C allows normal ripening, maintaining flavor development and preventing chilling injury, whereas storage at 4 °C, although effective at slowing softening, induces off-flavors and increased bitterness linked to the accumulation of specific bitter flavonoids and related metabolites (Muto et al., 2022). Low-temperature stress can also trigger metabolic reprogramming of carbohydrates: during cold storage, sucrose and other soluble sugars often change in parallel with chilling symptoms, reflecting their dual roles as flavor components and stress protectants.

Regulation of sucrose metabolism under cold and temperature-related treatments is central for both flavor and chilling tolerance. Hot-air and methyl jasmonate treatments before storage at 5 °C increased sucrose and sorbitol contents compared with controls, associated with higher sucrose phosphate synthase activity and lower acid invertase activity, suggesting that moderate temperature stress combined with elicitors can maintain sweetness while enhancing chilling resistance (Figure 1). Similarly, salicylic acid pretreatment prior to 4 °C storage raised total soluble sugars, largely via sucrose accumulation, and modified expression of sucrose-related genes, while simultaneously activating cold-response transcription factors and reducing internal browning, indicating that temperature-driven sugar metabolism is tightly coupled to stress signaling and quality preservation.