Tomato yield formation under different irrigation regimes generally follows a consistent pattern: full irrigation usually achieves the highest total yield, moderate deficit irrigation can maintain or even improve marketable yield, while severe water deficit reduces both fruit size and fruit number (Lyu et al., 2025; Song et al., 2025). This pattern has been observed under conventional drip irrigation, subsurface irrigation, and salinity stress conditions, where moderate irrigation levels generally outperform both insufficient and excessive water supply treatments (Zhang et al., 2022; Alshami et al., 2023).

4.3 Water use efficiency and yield optimization

The relationship between irrigation amount and tomato yield generally follows an asymptotic response pattern. In a three-year drip irrigation experiment, both tomato yield and water-use efficiency increased gradually with increasing irrigation amount. Yield approached a stable level at approximately 90% pan evaporation replacement, whereas water-use efficiency reached a plateau near 70% irrigation level (Liu et al., 2019). Wu et al. (2021) found that tomato yield increased with increasing irrigation amount in greenhouse production; however, the 100% ETc treatment resulted in the highest total water consumption and the lowest water-use efficiency for both total yield and marketable yield. Similarly, in drip fertigation tomato production, increased irrigation levels enhanced evapotranspiration but reduced water and nitrogen use efficiencies (Zhang et al., 2025). Excessive irrigation may further reduce yield performance by decreasing soil aeration, increasing nitrogen losses, and promoting excessive vegetative growth.

Achieving high yield under water-saving conditions generally depends on moderate deficit irrigation, precise water regulation, and coordinated optimization of irrigation with fertilization or root-zone management practices. Multiple studies have indicated that moderate irrigation targets are more suitable for balancing productivity and resource efficiency. In greenhouse drip irrigation systems, 75% ETc maintained both marketable yield and water-use efficiency at favorable levels (Wu et al., 2021). In greenhouse cherry tomato production, 80% ET_0 combined with appropriate nitrogen supply achieved the highest average fruit yield and economic returns, while maintaining soil moisture at 72%-80% of field capacity improved water-use efficiency and root-to-shoot ratio without substantial yield reduction (Lyu et al., 2025). Irrigation interval also affects yield formation. Liu et al. (2019) reported that, under the same seasonal irrigation amount, increasing irrigation frequency improved yield and water-use efficiency, with the W2D1 treatment increasing yield by 8.0%-26.1% compared with treatments with longer irrigation intervals.

5 Effects of Irrigation Strategies on Tomato Fruit Quality

5.1 Regulation of sugar and organic acid characteristics

Water deficit generally increases soluble solids and soluble sugar contents in tomato fruits, and this response has been widely reported in greenhouse tomatoes, processing tomatoes, and cherry tomato production systems (Wang et al., 2015; Li et al., 2021; He et al., 2024). In greenhouse tomatoes under drip fertigation, Zhang et al. (2025) found that decreasing irrigation levels increased soluble solids, soluble sugars, organic acids, vitamin C content, and sugar-acid ratio, while shorter irrigation intervals further improved most quality parameters. A three-year greenhouse experiment showed that irrigation at 70% pan evaporation, compared with 90% pan evaporation, improved water productivity, vitamin C, soluble solids, soluble sugars, and organic acid contents, while causing only minor yield reductions (Li et al., 2021). Moderate water deficit during fruit ripening can also promote glucose and fructose accumulation, increasing total soluble sugar content by 48.69% and sugar-acid ratio by 43.09% (He et al., 2024). Similar results were observed in processing tomato production under regulated deficit irrigation, where glucose content increased by 17.78%, soluble solids increased by 10.17%, and the soluble solids-to-titratable acidity ratio increased by 15.47% (Burato et al., 2024). Although the magnitude of sugar accumulation varies among studies, water deficit generally enhances sweetness perception by increasing soluble solids, as also demonstrated in low-frequency irrigation treatments of cherry tomato (Poomkokrak et al., 2024).

The physiological basis of water deficit-induced sugar accumulation mainly involves concentration effects and metabolic regulation. Reduced water supply decreases water dilution within fruits while maintaining or enhancing