fertigation systems, shorter irrigation intervals can enhance root growth, nitrogen uptake, stem diameter development, and leaf area index, indicating that both irrigation frequency and irrigation amount regulate the balance between belowground water acquisition and canopy expansion (Zhang et al., 2025).

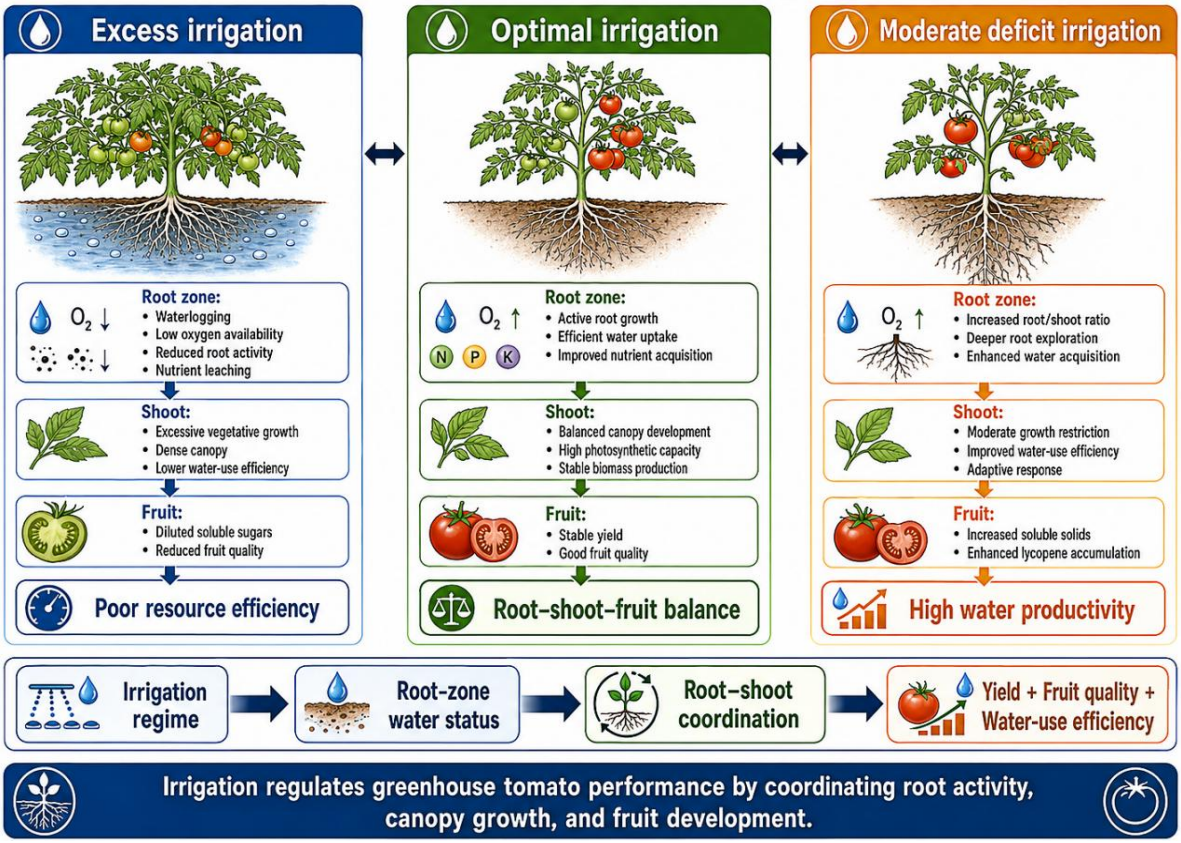


Figure 2 Integrated regulation of root-shoot-fruit coordination under different irrigation regimes in greenhouse tomato

Image caption: Different irrigation regimes regulate greenhouse tomato performance through coordinated effects on root-zone conditions, shoot growth, and fruit development. Excess irrigation may cause waterlogging, reduced oxygen availability, nutrient leaching, and excessive vegetative growth, resulting in lower water-use efficiency and reduced fruit quality. Optimal irrigation maintains active root growth, efficient nutrient uptake, balanced canopy development, and stable fruit production by achieving root-shoot-fruit coordination. Moderate deficit irrigation promotes deeper root exploration, increases the root-to-shoot ratio, improves water-use efficiency, and enhances fruit quality through increased soluble solids and lycopene accumulation

Mulched drip irrigation modifies soil moisture and temperature distribution and influences spatial root development. Under mulching conditions, tomato roots are mainly concentrated in the 0-20 cm soil layer, while low-water mulched treatments exhibit a wider distribution range of root length density compared with high-water mulched treatments (Ge et al., 2025). Model simulations by Sun et al. (2023) showed that 83%-90% of total roots under mulched drip irrigation were distributed within the 0-20 cm soil layer. However, as surface soil water deficit increased, the contribution of deeper roots to water uptake gradually increased.

Studies on substrate cultivation and localized irrigation systems further demonstrate that root-shoot balance depends strongly on water supply patterns. Ullah et al. (2021) found that mild water deficit under soilless cultivation increased average root diameter, total root length, and root surface area, suggesting that moderate water limitation can stimulate root development while maintaining canopy function. In potted cherry tomato production, increasing the number of emitters improved root length, root dry weight, leaf area index, photosynthetic rate, and biomass accumulation. The study recommended using two emitters per plant under deficit irrigation conditions to alleviate root-zone drought stress while simultaneously improving root architecture and canopy growth (Shabbir et al., 2020). Optimization of root-shoot coordination in greenhouse tomatoes depends on irrigation strategies that maintain suitable root-zone moisture and aeration conditions, promoting root expansion