water potential of -10 kPa, drip-irrigated tomatoes reached a plant height of 99.2 cm and a leaf area of 16,569 cm², whereas furrow-irrigated plants reached only 73.1 cm and 11,763 cm², respectively (Mukherjee et al., 2023).

Biomass accumulation and dry matter allocation exhibited similar patterns. In greenhouse-grown tomatoes, dry matter accumulation increased with increasing irrigation levels, reaching 90.79, 73.42, and 60.27 g/plant under I1, I2, and I3 treatments, respectively (Lyu et al., 2025). Higher water availability increased leaf dry matter, fruit dry matter, and total water consumption, while dry matter accumulation showed a significant positive correlation with yield. Wei et al. (2021) reported that, compared with non-aerated irrigation, aerated irrigation increased plant height, stem diameter, biomass accumulation, and leaf area index by 10.2%, 7.3%, 12.5%, and 6.2%, respectively. These results indicate that sufficient water supply combined with improved root-zone aeration can further promote vegetative growth. Dynamic growth analysis under aerated drip irrigation also demonstrated higher maximum growth rates of plant height and leaf area index, together with an extended effective vegetative growth period, thereby promoting later reproductive growth and yield formation (Xiao et al., 2022).

3.2 Regulation of plant growth under water-saving irrigation

Water-saving irrigation regulates tomato growth mainly by moderately reducing excessive vegetative growth while maintaining basic physiological activity. Under mild water deficit conditions, plants can maintain relatively stable growth through adaptive regulation. Compared with full irrigation, deficit irrigation generally reduces tomato plant height, stem diameter, leaf area, root length, and aboveground biomass. Turan et al. (2023) reported that under 50% field capacity conditions, the shoot fresh weight, root fresh weight, shoot dry weight, root dry weight, plant height, stem diameter, and leaf area of tomato seedlings decreased by 43%, 19%, 39%, 29%, 20%, 18%, and 50%, respectively. A combined salinity and water stress experiment under greenhouse conditions also showed that 40% irrigation significantly reduced leaf area and stem growth, further confirming that severe water limitation suppresses tomato vegetative development (Alshami et al., 2023).

However, mild water deficit generally causes only limited growth reductions while improving resource-use efficiency. In a soilless cultivation system, compared with full irrigation, the W80N100 treatment showed no substantial reductions in photosynthesis or stomatal conductance, and yield decreased by only 2.90%-8.75%, while irrigation water-use efficiency increased by 21.40% and 14.06%, respectively (Ullah et al., 2021). Similarly, Chand et al. (2020) found that maintaining soil water content at 80% field capacity improved irrigation water-use efficiency with only minor yield losses.

Tomato plants exhibit distinct adaptive responses under water stress. Mild deficit irrigation can increase the root-to-shoot ratio and improve water-use efficiency, indicating a shift toward more conservative water-use strategies (Lyu et al., 2025). When water limitation occurs during the reproductive stage, plants tend to allocate more resources to belowground growth. A study on cherry tomato showed that lower irrigation frequency promoted root development and increased the root-to-shoot ratio (Poomkokrak et al., 2024). Water stress also induces a series of biochemical defense responses. Under drought conditions, tomato plants alleviate stress by increasing proline accumulation, enhancing antioxidant enzyme activity, and improving osmotic adjustment capacity. In addition, salicylic acid and potassium can further regulate stress-responsive gene expression, antioxidant defense, stomatal regulation, and osmotic balance (Patané et al., 2022; Sahoo et al., 2025). These adaptive mechanisms explain why moderate deficit irrigation can maintain relatively stable plant growth and improve water productivity in some cases, whereas prolonged or severe water deficiency ultimately reduces biomass accumulation and marketable production performance.

3.3 Effects of irrigation methods on root-shoot coordination

Different irrigation methods alter water and oxygen distribution in the root zone, thereby affecting coordination between tomato roots and aboveground growth (Figure 2). Drip irrigation generally promotes better plant growth than furrow irrigation because it provides more precise water delivery and reduces deep percolation losses. Mukherjee et al. (2023) reported that under -10 kPa conditions, drip irrigation reduced total irrigation water input by approximately 20%-23% compared with furrow irrigation while increasing yield by 22%-28%. In drip