Light affects not only the supply of photosynthetic assimilates, but also directly participates in the regulation of floral organ retention through specific signaling pathways. Under low-light conditions, the transport of assimilates to inflorescences and young fruits decreases, which can easily lead to failure in floral organ competition and subsequent abscission. Recent studies have found that the small peptide signaling molecule SlIDL6 and its downstream calcium-dependent protein kinase SlCPK10 constitute an important regulatory module in low-light-induced tomato flower abscission; this pathway promotes flower drop by altering Ca^{2+} signaling status in abscission-zone cells (Fu et al., 2024). This suggests that the problem of flower drop under winter-spring protected cultivation or cloudy low-light conditions is not only the result of insufficient carbon supply, but may also involve the active activation of signaling transduction in the abscission zone. Therefore, from cultivation management to molecular breeding, regulation can be directed toward stabilizing flower retention ability under low-light conditions.

In addition to average environmental conditions, spatial microclimate heterogeneity within the greenhouse can further aggravate differences in fruit set among inflorescences. Different inflorescences on the same plant may experience different light, temperature, and humidity conditions, causing some inflorescences to show higher flower number, pollination efficiency, and fruit retention capacity, while others are more prone to flower drop or small fruit formation. This difference is more obvious in continuous-fruiting systems, in large canopies, or under high-density protected cultivation. Therefore, reducing flower and fruit drop in protected tomato production should not be limited to regulating average daily temperature or a single light indicator, but should also emphasize microclimate homogenization within the canopy, improved light exposure around inflorescences, and optimized local ventilation conditions (Jerca et al., 2024).

In addition, humidity and airflow can indirectly influence flower and fruit drop by affecting pollen release, stigma pollination, and disease occurrence. Excessively high humidity may reduce pollen dispersal efficiency, while insufficient airflow weakens anther vibration and canopy heat dissipation, and can easily create a combination of localized high humidity and high temperature, ultimately damaging the fruit set process. Therefore, stable fruit set requires coordinated management of temperature, light, humidity, and airflow. In protected production practice, the risk of flower and fruit drop can be jointly reduced and the temporal stability of fruiting improved through measures such as ventilation, supplemental lighting, regulation of day-night temperature differences, improvement of canopy structure, and the use of mechanical vibration or insect pollination (Fu et al., 2024).

4 Fruit Development and Yield Component Traits in Protected Tomato Production

4.1 Effects of single fruit weight and fruit enlargement rate on yield formation

In greenhouse tomato production, total yield can usually be divided into two major components: fruit number per unit area and average single fruit weight, among which single fruit weight directly affects both per-plant yield and population yield formation. Management practices capable of increasing assimilate supply to fruits or enhancing fruit sink strength often increase single fruit weight and overall yield. For example, supplemental lighting and CO_2 enrichment can significantly enhance plant photosynthesis and dry matter production, while also increasing single fruit weight and per-plant yield, indicating that yield improvement does not rely entirely on increasing fruit number, but to a large extent on strengthening the growth capacity of individual fruits (Figure 2).

At the cultivation management level, single fruit weight is not necessarily better when larger, but should be maintained within an appropriate range coordinated with fruit number, truss load, and late-stage plant vigor. If individual fruits become excessively large while source supply, water transport, or root absorption capacity is insufficient, subsequent trusses may experience intensified competition, leading to uneven fruit enlargement, increased malformed fruits, or reduced yield in later stages. Conversely, under relatively stable fruit set conditions, moderately increasing single fruit weight is often one of the most direct ways to raise yield. Average single fruit weight and aboveground biomass are important positive indicators affecting final yield, and that moderate water deficit treatments can maintain relatively high marketable fruit yield while improving water-use efficiency (Figure 3).