

In addition to root activity, the vertical and horizontal distribution patterns of roots also profoundly affect water and fertilizer uptake efficiency. If roots are excessively concentrated in localized zones, water and nutrients may be depleted too rapidly in those areas, increasing spatial heterogeneity of resources in the soil or substrate and reducing overall use efficiency. In contrast, if roots can form a relatively broad and uniform distribution within the root zone, they are better able to continuously acquire water and nutrients from different spatial locations and buffer short-term fluctuations in supply. In soil-grown greenhouse tomatoes, mulching practices, emitter placement, and irrigation level all significantly alter root length density distribution. For example, under plastic mulch, more roots are concentrated in the top 0-20 cm of soil, whereas without mulch, roots are more often distributed at a depth of about 20 cm, which is related to the more suitable temperature and moisture conditions in the surface soil under mulching (Ge et al., 2025). At the same time, deficit irrigation can cause roots to redistribute either upward or deeper into the soil profile. In potted cherry tomato, increasing the number of emitters per plant can encourage roots to expand more widely, while deficit irrigation promotes deeper root extension. The combination of two emitters + deficit irrigation can create a root distribution that is both wide and deep, thereby increasing root length density, root weight density, yield, and water-use efficiency (Figure 5).

5.2 Fundamental role of root health in plant growth and stress resistance

In addition to root system size and distribution, root health itself is also fundamental to sustained growth and stress resistance in protected tomato production. Root health includes not only intact root structure, high cellular activity, and undamaged absorptive tissues, but also a stable rhizosphere environment, adequate oxygen supply, low pathogen pressure, and a relatively balanced beneficial microbial community. Healthy roots can maintain high water and nutrient uptake capacity and support continuous shoot growth and high photosynthetic assimilation by influencing hormonal signaling, osmotic regulation, and antioxidant systems. Under high-temperature stress, tomato genotypes that maintain higher root dry weight and a higher root-to-shoot ratio usually show higher yield and harvest index, indicating that a larger, healthy root biomass is an important basis for heat tolerance and sustained carbon assimilation (Mohammed et al., 2025).



Figure 5 Spatial distribution of tomato fruits at different maturity stages on plants and management status