on this, targeted fertilizer types, application rates, and methods should be developed to improve fruit quality and tree health.

In waxberry orchards affected by decline disease, exchangeable calcium, magnesium, and available phosphorus are key factors influencing the structure of rhizosphere microbial communities. Regulating these nutrients through compound fertilizers and bio-organic fertilizers can significantly alter microbial communities and soil metabolite composition.

Specialized waxberry fertilizers and foliar nutrient products, when applied at appropriate rates and frequencies, can increase soil organic matter, leaf chlorophyll content, and fruit sugar and soluble solids content (Guo et al., 2009).

From a broader perspective, soil testing should be used as the basis to guide the partial replacement of mineral NPK fertilizers with organic and bio-fertilizers. This helps maintain soil nutrient balance, enhance carbon sequestration capacity, and achieve long-term sustainability of crop production (Selim, 2020; Urmi et al., 2022).

5 Water Management and Drainage Control

5.1 Critical water demand periods (flowering stage and fruit expansion stage)

Effective water management in waxberry orchards needs to balance avoiding drought, maintaining root aeration, and improving fruit quality. Water shortage and improper irrigation are among the main limiting factors in global fruit production, especially when water stress coincides with key phenological stages, which can significantly reduce tree growth, yield, and fruit size (Devin et al., 2023; Ru et al., 2025). The flowering-fruit set stage and the fruit expansion stage are critical water-demand periods. Water deficit during flowering usually reduces fruit number, while water shortage during fruit expansion has the most significant impact on final fruit size and marketable yield (Berríos et al., 2023).

5.2 Irrigation methods under orchard conditions

The choice of irrigation method should consider local water resource conditions, orchard terrain, and soil type, with a focus on covering the active root zone. Drip irrigation, widely used in orchards in China, can deliver water directly to the root system, reduce evaporation loss, decrease leaf wetness and disease occurrence, and maintain a good soil water-air balance throughout the growing season. Compared with surface irrigation and sprinkler irrigation, drip irrigation can significantly improve yield and water use efficiency, especially under water-limited conditions, and can also reduce fertilizer leaching and soil salinization (Yang et al., 2023; Fareed et al., 2024; Long et al., 2025).

Micro-sprinkler irrigation systems also perform well in orchards. When irrigation timing is optimized, they can improve the uniformity of soil moisture distribution and water storage efficiency. Reducing irrigation time from 24 hours to 19 hours can significantly increase water storage efficiency (from 72% to 89%) and reduce deep percolation losses (Ortega-Farías et al., 2022).

In hilly or semi-arid orchards, constructing rainwater collection systems and infiltration-enhancing measures to guide runoff into the main root zone can increase soil moisture in the 0-60 cm layer by 24%-44%, while also increasing fine root density and yield. This shows good potential under water-scarce conditions (Guo et al., 2021).

5.3 Drainage in rainy seasons and root protection

In regions with concentrated rainfall and high humidity, rapid drainage and root protection are as important as supplemental irrigation. Excess rainfall can raise the groundwater level and cause excessive soil saturation in the root zone, leading to root hypoxia, diseases, and tree decline. Subsurface drainage systems such as buried pipes or blind ditches can significantly reduce soil moisture and groundwater levels, shorten the duration of waterlogging, and increase yield by 6%-8% compared with surface drainage alone (Qi et al., 2025).

Optimizing subsurface drainage spacing can also increase crop yield by promoting root biomass and adjusting aboveground growth allocation, indicating that proper drainage can effectively reduce the negative physiological