

Organic matter improvement promotes root activity by enhancing moisture retention, nutrient availability, and the physical environment of the rhizosphere. Soil organic matter is a major driver of soil quality because it affects pH, moisture retention, and nutrient concentrations (Xie et al., 2024). More generally, organic amendments provide a slow-release bank of macro- and micronutrients while improving physical and biological soil properties (Singh et al., 2024). In orchard systems, amendments and biologically active carriers increased root length density and shoot growth in apple, indicating that improved soil conditions can translate into stronger root systems and higher nutrient capture capacity (Ding et al., 2024).

Microbial amendments improve nutrient availability mainly by reshaping rhizosphere communities and strengthening nutrient cycling. Soil amendments increased fungal diversity, increased microbial network complexity, and enhanced bacterial–fungal synergy linked to nutrient cycling functions (Ding et al., 2024). In pear, bio-organic fertilizers increased yield by up to 20%, and adding beneficial bacteria tripled the yield increase achieved by organic fertilizer alone, largely through altered soil chemistry and a more plant-beneficial microbiome (Wang et al., 2022). Integrated fruit-tree intercropping systems likewise increased organic matter, available phosphorus, and available potassium while increasing beneficial microbial groups related to disease prevention and nutrient cycling, although they also carried risks such as soil acidification that require corrective management (Xie et al., 2024).

7 Challenges and Future Development of Cherry Nutrient Management

7.1 Current problems in nutrient management

A central problem is that nutrients are not distributed uniformly among fruits, leaves, peduncles, prunings, and perennial organs. In sweet cherry orchards, N was more evenly distributed across fruits, peduncles, and prunings, whereas K was concentrated in fruits and peduncles and Ca and Mg were retained mainly in fallen leaves, showing that fruit demand does not mirror whole-tree nutrient status (Karampatzakis et al., 2025). Under high yields, K was redistributed from leaves to fruits, further indicating that internal remobilization can intensify organ-to-organ imbalance. Uneven distribution also occurs within the fruit itself: calcium concentration was two- to three-fold higher at the stem end than at the stylar end, and fruit-to-fruit variation in calcium mass was wide even within cultivars (Winkler et al., 2020). Source–sink imbalance compounds this heterogeneity because sweet cherry fruit develop rapidly, compete strongly with vegetative sinks, and depend on adequate leaf area per fruit for uniform quality formation (Matteo et al., 2022).

A second persistent problem is the tendency toward excessive or poorly balanced fertilization. Precision-nutrition reviews note that conventional nutrient management often leads to over-fertilization, uneven nutrient supply, environmental pollution, and economic inefficiency (Singh et al., 2024). Cherry-specific studies likewise emphasize the lack of site-specific fertilization guidelines and the need to account for nutrient removal and recycling rather than replacing nutrients generically (Karampatzakis et al., 2025). Antagonistic interactions make this problem more serious: high K levels can reduce Ca and Mg status, and high nitrogen can depress leaf P and K while also lowering leaf Ca and Mg at excessive rates (Rutkowski and Łysiak, 2023). In sweet cherry fruit, increasing K or N can therefore improve some growth traits while simultaneously worsening the mineral balance associated with firmness and storage potential (Santos et al., 2024).

7.2 Technical limitations in improving firmness and shelf life

The main technical limitation is the difficulty of delivering calcium into cherry fruit at the right place and time. Calcium influx is positively related to transpiration and declines as xylem functionality is progressively lost during fruit development, making late-season correction inherently difficult (Winkler et al., 2020). Natural fruit calcium concentrations also decline during development because import slows while continued growth dilutes accumulated calcium (Matteo et al., 2022). Reviews conclude that preharvest sprays and postharvest dips sometimes increase fruit calcium and improve firmness, cracking, or rot resistance, but at other times they are ineffective because calcium movement through the cuticle is erratic and the uptake pathways remain poorly understood (Winkler and Knoche, 2019). Even when calcium enters tissues, responses are spatially selective: