

al., 2023). Recent foliar nutrient trials also suggest that nitrogen-containing formulations can accelerate cell expansion and softening, which may compromise cell-wall integrity even when fruit growth is improved (Varaldo et al., 2023). For firmness-oriented orchard management, the target should therefore be moderate vegetative vigor, adequate leaf area, and nutrient ratios that avoid excessive N:Ca and K:Ca imbalance (Matteo et al., 2022; He et al., 2025).

4.3 Foliar and soil application strategies

Both foliar and soil nutrient delivery can contribute to firmness and shelf life, but they serve different purposes: foliar sprays are faster and more target-oriented for short-term correction, whereas soil fertilization and fertigation are better suited to maintaining seasonal nutrient availability and root-zone balance (Bons and Sharma, 2023). The most effective programs integrate both approaches according to phenological stage and nutrient mobility (Santos et al., 2024).

Foliar calcium sprays can improve firmness, reduce cracking, and enhance storage performance, but their effects are often inconsistent because calcium penetration into cherry fruit is erratic and declines with fruit age (Winkler and Knoche, 2019). Timing is therefore critical. In unthinned trees, a Stage I CaCl_2 spray produced higher firmness than sprays at Stages II or III, while early sprays improved fruit textural properties even under high crop load (Matteo et al., 2022). Later sprays can still be useful for cracking reduction, since applications at 39 or 62 days after full bloom reduced cracking in thinned trees (Matteo et al., 2022). Cultivar response remains variable, with calcium improving firmness in Sweetheart and Regina but not Bing in one study, so spray programs should be adjusted by cultivar and local conditions.

Soil fertilization and fertigation remain the foundation for sustaining nutrient supply across the season, particularly for potassium, magnesium, nitrogen, and background calcium and boron nutrition (Arredondo et al., 2024; Santos et al., 2024). Soil K fertilization applied under the canopy before bloom improved several fruit quality traits, showing that root-zone supply can effectively influence later firmness and soluble solids (Ateş et al., 2022). Boron management through the soil is also stage-sensitive: application at full bloom enhances absorption and whole-tree distribution more than application before leaf senescence, while late-season soil B may still help build reserves for the following year (Arredondo et al., 2024). More broadly, root-zone nutrient management should avoid indiscriminate fertilizer use, because excess input can impair mineral balance and create environmental costs, whereas stage-specific nutrient modulation and synchronized fertigation improve both nutrient-use efficiency and fruit quality outcomes (He et al., 2025).

5 Effects of Nutrient Management on Cherry Shelf Life

5.1 Reduction of postharvest softening

Postharvest softening is a primary limit on cherry shelf life, and mineral nutrition can slow this process by preserving wall structure and reducing physiological deterioration. The strongest evidence supports calcium, including both preharvest sprays and postharvest dips, although some newer work suggests calcium source and combination treatments also matter (Belge et al., 2017; Wu et al., 2023).

Calcium delays softening by reducing the activity of enzymes that degrade pectin and other wall polysaccharides during storage (Çelik et al., 2022). In Chinese cherry, preharvest calcium treatments reduced PME, PG, Cx, and β -Gal activities and down-regulated key softening-related genes, indicating direct suppression of cell wall disassembly (Wu et al., 2023). In ‘Celeste’ sweet cherry, calcium treatment increased firmness and was associated with changes in cell wall metabolism, while cold storage itself inhibited Pa β Gal and PaEXP1 transcript accumulation before expression partly recovered during shelf life (Belge et al., 2017). These findings are consistent with the broader interpretation that calcium helps maintain the middle lamella and slows the resolution of pectic structure that normally accompanies ripening and storage (Erbaş and Koyuncu, 2023).

Calcium also prolongs shelf life by maintaining membrane stability and lowering oxidative deterioration during storage. Postharvest calcium application in hydro-cooling water increased fruit tissue calcium by 29%–85% in