

softening by reducing cell wall enzyme activities and limiting the transfer of wall-bound boron away from structural compartments, thereby helping maintain firmness during postharvest life (Álvarez-Herrera et al., 2025).

Zinc and manganese are less directly studied in cherry firmness than calcium or boron, but the available evidence supports roles in enzyme activity, photosynthesis, and fruit development. Boron-centered reviews identify both Zn and Mn among the essential micronutrients that interact with boron in plant nutritional networks, with the cell wall acting as an important intermediary of these interactions (Long and Peng, 2023). Zn homeostasis is linked to transporter regulation, root development, and optimized uptake, while Mn homeostasis is linked to transporter regulation and chlorophyll production, which is essential for photosynthesis (Usmani et al., 2025). In sweet cherry fruit, Zn and Mn are consistently present at low but measurable concentrations, typically within the broader 0.45–19 mg/kg range reported for Zn, Mn, B, Fe, Cu, and Na, which indicates that they are regular components of the fruit mineral matrix rather than incidental contaminants (Zhang et al., 2025). Practical evidence from fruit crops further suggests that combined micronutrient programs can improve fruit growth and quality traits, and cherry-focused work has cited positive effects of adding microelements such as B, Fe, and Zn to calcium-based spray programs for cracking management (Matteo et al., 2022; Sandilya et al., 2023).

Calcium remains the primary nutrient for direct firmness retention in cherry, while potassium, magnesium, boron, zinc, and manganese influence firmness and shelf life through growth, assimilate supply, and mineral balance. The most effective orchard strategy appears to be balanced, stage-specific nutrient management that increases fruit calcium while avoiding antagonistic nutrient ratios and supporting overall fruit development.

4 Nutrient Management Strategies During Cherry Fruit Development

4.1 Pre-bloom and bloom-stage nutrition

Early-season nutrition determines reproductive success because flower viability, fruit set, and the initial sink strength of young fruit are established around bloom, when cherry is highly sensitive to environmental and nutritional constraints (Xu et al., 2023). Pre-bloom nutrient programs should therefore prioritize adequate reserves and timely supply of nutrients linked to reproductive development, especially boron and calcium, while maintaining sufficient leaf support for carbohydrate supply to developing flowers and fruitlets (Figure 2) (Matteo et al., 2022; Bons and Sharma, 2023).

Fruit set depends on both reproductive nutrition and source–sink balance. In sweet cherry, high crop load is negatively associated with fruit quality, while regulation of fruit set alters leaf:fruit ratio and assimilate availability to the remaining fruitlets (Parveze et al., 2024). Boron is especially important at this stage because deficiency reduces fruit set in sweet cherry, and preflowering boron supply increases endogenous boron during early growth, improves fruit set, and promotes mesocarp cell enlargement (Michailidis et al., 2023; Arredondo et al., 2024). Not all bloom-stage B interventions are beneficial under all conditions, however, since a 0.01% boric acid spray reduced fruit set in one frost-prone field study, indicating that bloom applications require careful context-specific management rather than routine use (Xu et al., 2023).

Early calcium supply is physiologically justified because mineral influx into cherry fruit is fastest during early development, when xylem flow still dominates, whereas xylem functionality declines later toward maturity (Winkler et al., 2020; Michailidis et al., 2021). Calcium applied during dormancy can enter dormant flower buds and phloem, and high-dose dormant applications improved later fruit calcium status, cracking incidence, and fruit set (Michailidis et al., 2021). Boron supplementation is also effective when targeted early: soil-applied ^{10}B at full bloom was absorbed more strongly than pre-senescence application, whereas boron applied directly to flowers remained largely in the fruit, making floral boron a useful complementary method to support current-season fruit demand (Arredondo et al., 2024). Evidence from other fruit systems also supports combined B + Ca programs for firmer tissues and longer shelf life, consistent with their complementary roles in cell-wall structure and fruit integrity (Islam et al., 2016).