and DeVetter (2017) demonstrated in blueberry that conventional foliar calcium and boron applications do not necessarily improve fruit quality when plant nutritional status, cultivar differences, and nutrient transport efficiency are not considered, because treatments may only increase leaf boron concentration without improving fruit calcium levels, firmness, shelf life, fruit set, or yield.

6 Integrated Calcium and Boron Management for Blueberry Production

6.1 Optimization of calcium and boron application strategies

During the period from flowering to fruit maturity, plant nutrient requirements and nutrient transport capacity undergo significant changes. Therefore, integrated calcium and boron management in blueberry should be regulated according to phenological stages. During flowering and early fruit set stages, calcium and boron are closely associated with reproductive success. Insufficient nutrient supply during flowering, ovule fertilization, and young fruit development may reduce fruit set, with boron being particularly important for pollen germination and cell elongation (Álvarez-Herrera et al., 2025). During the early fruit expansion stage, before extensive cuticle formation occurs, calcium absorption and transport into fruits are relatively efficient. Therefore, the first few weeks after flowering are generally considered the optimal period for targeted calcium supplementation to fruits (Lopes et al., 2026). As fruits enter the ripening stage, reduced fruit transpiration and increased wax deposition on the cuticle restrict nutrient entry, resulting in gradually reduced calcium uptake capacity. Meanwhile, under high-temperature and high vapor pressure deficit stress conditions, calcium and boron uptake may also become stabilized or even decline (Arrington and DeVetter, 2017; Lopes et al., 2026). This developmental pattern explains why early calcium spraying in ‘Liberty’ blueberry improved fruit firmness and reduced weight loss, whereas later applications showed relatively weaker effects (Lobos et al., 2021a).

Current studies indicate that the focus of calcium and boron management in blueberry should be maintaining appropriate nutrient supply and optimizing application timing rather than simply increasing fertilizer inputs. In ‘Draper’ and ‘Bluecrop’ blueberry, Arrington and DeVetter (2017) found that continuous calcium and boron spraying from the early pink bud stage to the end of flowering increased leaf boron concentration but did not improve fruit calcium concentration, fruit set, yield, single fruit weight, or firmness, indicating that routine annual applications do not necessarily result in quality improvements. Similarly, foliar calcium application at recommended concentrations during the green fruit stage in multiple blueberry cultivars did not increase fruit calcium levels, firmness, or shelf life, suggesting that nutrient delivery efficiency into fruits remains a limiting factor (Vance et al., 2017). In contrast, preharvest application of 400-800 g Ca/ha improved postharvest quality in ‘Liberty’ blueberry, while high-frequency calcium spraying beginning at mid-full bloom in ‘Draper’ blueberry alleviated green fruit drop. These results indicate that cultivar differences, nutrient deficiency status, and application timing are more decisive factors determining final outcomes than simply supplying nutrients.

For boron management, current recommendations suggest supplementing 0.4-2.5 kg/ha boron when summer leaf boron concentrations in blueberry are ≤30 ppm, while foliar spraying concentrations exceeding approximately 500 ppm may increase the risk of phytotoxicity (Arrington and DeVetter, 2017; Leon-Chang and Bryla, 2024). Controlled environment studies further demonstrated that a foliar boron concentration of approximately 400 mg/L was safer and more effective than 800 mg/L, as excessive boron reduced photosynthetic performance and increased lipid peroxidation levels (Hirzel et al., 2025; Lopes et al., 2026). Currently, direct studies on the optimal Ca:B ratio in blueberry remain insufficient. However, studies in tomato, mango, strawberry, and Asian pear have consistently shown that, under appropriate nutrient ratios, combined Ca+B application generally improves fruit firmness, soluble solids content, and yield more effectively than single nutrient treatments, whereas excessive nutrient supply does not further enhance fruit quality (Mohamed et al., 2021; Gholamnejad et al., 2023; El-Motaium et al., 2025).

6.2 Integration of nutrient management with orchard practices

Irrigation strategy is an important component of the blueberry calcium and boron management system, as the uptake and transport of both elements are highly dependent on xylem transport and water movement in the