mango yield, while also improving fruit firmness, total soluble solids content, and reducing acidity. In strawberry, Ca+B treatment increased fruit firmness, soluble solids, sugar content, vitamin C, anthocyanin content, and marketable fruit yield (Mohamed et al., 2021). However, research results in blueberry are not entirely consistent. In the southern highbush blueberry cultivar 'Sharpblue', preharvest boric acid + $CaCl_2$ foliar application increased yield and extended storage duration, while combined nutrient treatment reduced physiological weight loss and decay rate under cold storage conditions (Negi and Upadhyay, 2024). However, in northern highbush blueberry, repeated foliar applications of calcium and boron did not increase fruit firmness, single fruit weight, fruit set rate, or yield. Although calcium concentrations in plant tissues changed after treatment, fruit calcium concentration did not increase significantly (Arrington and DeVetter, 2017). These differences indicate that the effects of calcium-boron synergism on blueberry fruit size and firmness largely depend on cultivar characteristics, initial nutritional status, and the efficiency of nutrient transport into developing fruits.

Currently, the most convincing evidence for calcium–boron synergistic effects is mainly focused on postharvest quality maintenance. In blueberry, Lobos et al. (2021a) reported that early calcium application increased fruit firmness of 'Liberty' blueberry by approximately 10%, reduced water loss, increased the proportion of healthy fruits, and decreased decay and dehydration after storage, indicating that calcium application timing plays an important role in storage performance. Reviews related to blueberry also indicate that storage losses mainly result from water loss, fungal infection, and continuous weakening of cell wall structures. When preharvest nutrient management effectively enhances fruit structural stability, it has the potential to improve storage performance (Lopes et al., 2026). However, not all calcium-based nutritional programs can extend shelf life. Vance et al. (2017) evaluated $CaCl_2$, $CaCl_2$+B, calcium silicate, chelated calcium, and calcium acetate in strawberry, raspberry, blackberry, and four blueberry cultivars, including Spartan, Liberty, Draper, and Legacy, with calcium concentrations ranging from 0.05% to 0.30%. Treatments were applied three to four times continuously from the immature green fruit stage, and fruit quality was evaluated at 5, 10, 15, and 20 days after harvest. The results showed that none of the treatments significantly altered calcium concentrations in leaves or fruits, nor did they improve fruit firmness, skin toughness, weight loss rate, collapse rate, or shelf life. Electrostatic spraying also did not outperform conventional spraying. These findings indicate that simply increasing spray coverage does not necessarily mean that calcium can effectively enter fruit tissues or cell wall structures.

5.3 Nutrient balance and optimization strategies

Improvement of fruit quality depends more on the balance between calcium and boron supply rather than simply increasing the input of a single element. For example, in tomato, higher calcium levels combined with higher boron supply resulted in better quality and yield performance. Meanwhile, boron was able to modify calcium distribution within plants and fruits, increase symplastic Ca content, and slightly enhance the transfer index from apoplast to symplast (Gholamnejad et al., 2023). Haleema et al. (2024) also found in tomato that Ca+B treatment had a significantly greater effect on improving fruit firmness than calcium or boron application alone. Moreover, boron increased fruit calcium content, indicating that boron may promote calcium binding and utilization within cell wall structures. El-Motaium et al. (2025) reported that in mango, the optimal treatment was not the highest nano-calcium application rate, but rather 250 mg/L boron combined with 50% of the recommended nano-calcium level, further demonstrating that appropriate nutrient ratios and balanced supply are more beneficial for quality formation than simply increasing nutrient inputs. This principle is also applicable to blueberry because fruit firmness is closely associated with pectin structure and cell wall-bound calcium, while boron may participate in cell wall maintenance and reproductive development processes. However, direct studies on the optimal Ca:B ratio in blueberry remain limited.

Optimization of calcium and boron nutrition also requires avoiding nutrient imbalance, inappropriate application timing, and low nutrient utilization efficiency. Calcium is mainly transported through the xylem, while fruit transpiration is relatively low; therefore, calcium delivery to fruits is often restricted. Meanwhile, both calcium and boron have certain limitations in their transport and distribution within plants. Compared with non-targeted fertilization, multiple foliar applications during critical developmental stages are often more effective. Arrington