revealed substantial variations in soil solution nutrient availability and leaf nutrient composition among different fields and phenological stages, highlighting the importance of continuous leaf nutrient diagnosis (Zayani et al., 2024).

Precision potassium management is increasingly moving toward data-driven approaches. For example, unmanned aerial vehicle (UAV)-based multispectral imaging combined with machine learning techniques can accurately estimate major nutrient concentrations, including potassium, in citrus trees and generate spatial nutrient distribution maps for commercial orchards, providing a basis for site-specific fertilization management (Costa et al., 2022). More broadly, intelligent fertilizer recommendation systems integrating artificial intelligence (AI), the Internet of Things (IoT), and interpretable models demonstrate that real-time soil and climate data can support more accurate and explainable fertilization decisions (Venkateswara and Padmanaban, 2025). Studies in other fruit crops have also confirmed the practical value of adjusting potassium fertigation programs according to actual crop load and using machine vision technologies to optimize potassium demand prediction. These approaches may provide useful references for citrus orchards, where fruit load often varies considerably among different production years (Kuzin et al., 2020).

7 Integrated Potassium Management for Citrus Orchards

7.1 Coordination of potassium with other nutrient management

Potassium management should be considered as a component of an integrated nutrient management system because fruit growth and quality formation depend more on the coordinated uptake of nitrogen, phosphorus, and potassium rather than potassium supply alone. Ma et al. (2022) reported that drip fertigation improved fruit total soluble solids (TSS), titratable acidity (TA), and vitamin C content while increasing nitrogen, phosphorus, and potassium accumulation in fruits. The underlying mechanism was mainly attributed to nitrogen promoting sugar synthesis through enhanced photosynthesis, whereas phosphorus and potassium contributed more directly to sugar accumulation and regulation of the sugar-acid ratio. Field monitoring in Clementine mandarin orchards in Morocco similarly showed that optimized fertilization programs required increased nitrogen and potassium inputs compared with conventional local practices; however, monthly leaf nutrient diagnosis indicated that the major limitation was not simply insufficient annual nutrient supply but rather an inappropriate temporal distribution of nitrogen and potassium availability (Zayani et al., 2024). In Washington navel orange, repeated foliar applications of KNO_3 improved leaf nutritional status, productivity, and fruit quality, suggesting that potassium can be combined with nitrogen through a single fertilizer source during periods of high canopy nutrient demand (Al-Sabbagh and El-Gioushy, 2024).

Interactions among potassium, calcium, and magnesium are also highly important, as the balance of cation supply influences peel integrity, root health, and fruit development. For example, in a citrus hybrid susceptible to fruit cracking, potassium application increased calcium, nitrogen, and potassium concentrations in both peel and pulp tissues and improved the peel-to-pulp firmness ratio, which was associated with reduced fruit cracking incidence (Jiao et al., 2022). A field-scale analysis of fruit cracking in Bingtang sweet orange by Shi et al. (2025) further demonstrated that soil calcium, potassium, and magnesium were important factors affecting cracking severity. Fruit cracking rate was negatively correlated with soil calcium and potassium concentrations but positively correlated with soil magnesium content.

However, excessive potassium supply may aggravate cation imbalance. In ‘Salustiana’ orange, high potassium treatments increased potassium accumulation in leaves and flavedo tissues but reduced calcium and magnesium accumulation in fruit tissues (Stagno et al., 2024). Such nutrient imbalance is relatively common in commercial production. A survey in southwestern China found that severe magnesium deficiency was closely associated with excessive nitrogen and potassium fertilization. Optimized management practices involving magnesium supplementation and reduced N-P-K inputs improved yield, fruit quality, nutrient use efficiency, and economic returns (Wang et al., 2022).