demonstrated that appropriate potassium fertilization can promote fruit enlargement and enhance sugar accumulation. For example, Wu et al. (2024) reported that maintaining fruit potassium concentration at an appropriate level of approximately 1.5% in Newhall navel orange increased fruit growth rate, enhanced source–sink activity, and promoted sucrose transport from leaves to fruits, thereby improving fruit quality. In Cara Cara navel orange, potassium application at 0.50 kg per plant promoted the accumulation of sucrose, fructose, and glucose, which was closely associated with the regulation of sucrose metabolism-related enzyme activities (Wu et al., 2021). Foliar application of K_2SO_4 has also been shown to increase fruit weight, total soluble solids, soluble sugar content, and the TSS:TA ratio while reducing titratable acidity (Thu et al., 2024). Furthermore, Xu et al. (2024) found that optimized nutrient management in citrus orchards increased yield by 11.9%, single fruit weight by 2.8%, TSS by 5.9%, and total sugar content by 8.6%, indicating that balanced nutrient regulation plays an important role in improving fruit quality.

Although the importance of potassium in citrus quality formation has been widely recognized, the optimal potassium application rate, fertilizer type, and application timing remain variable under different production conditions. Citrus responses to potassium are influenced by multiple factors, including cultivar, rootstock, climatic conditions, and soil nutrient status. Moreover, excessive potassium input may lead to nutrient competition and inefficient resource utilization (Kuzin and Solovchenko, 2021; Sardans and Peñuelas, 2021). Therefore, clarifying the regulatory effects of potassium management on citrus fruit development and quality formation is important for improving fertilizer use efficiency and achieving high-quality and sustainable citrus production.

This study focuses on the effects of potassium fertilization on citrus fruit size, sugar accumulation, and quality formation, with particular emphasis on the roles of potassium in promoting fruit enlargement, regulating carbon assimilate transport, and improving sugar–acid balance. The aim is to clarify the relationship between potassium nutrition and citrus fruit quality development, thereby providing theoretical references for precision potassium management and the production of high-quality citrus fruits in modern orchards.

2 Physiological Functions of Potassium in Citrus Growth

2.1 Potassium uptake, transport, and distribution in citrus plants

Potassium in citrus is mainly absorbed by the root system and subsequently transported over long distances through the xylem and phloem to meet the physiological demands of metabolically active tissues (Wen et al., 2021; Wegner et al., 2025). Previous botanical studies have shown that after potassium is taken up from the soil, it is transported through the xylem to aboveground tissues along with the transpiration stream. Source tissues can then reload potassium into the phloem, allowing its redistribution to sink organs and partial recycling back to the root system (Dreyer et al., 2017). This recycling process has important physiological significance because potassium concentration gradients facilitate vascular transport processes, including sucrose reloading, while helping coordinate the balance between aboveground demand and root supply (Dreyer et al., 2017; Raddatz et al., 2020). Citrus plants also possess a relatively well-developed potassium transport system. Öz (2024) reported that 25 *CsHAK* genes have been identified in sweet orange (*Citrus sinensis*), and these HAK/KUP/KT transporter proteins are involved in potassium transport across the plasma membrane and within organelles.

Potassium is generally preferentially accumulated in organs with high metabolic activity, particularly leaves, where strong osmotic regulation and transport control are required. However, during citrus fruit development, fruits also function as important potassium sink organs (Sardans and Peñuelas, 2021; Jiao et al., 2022). In citrus orchards, the amount of potassium absorbed and exported by fruits is higher than that of other mineral nutrients, which explains why potassium deficiency can rapidly affect fruit quality and final yield in the current growing season.

Fertilization studies have further demonstrated that potassium supply can modify nutrient allocation patterns between vegetative organs and fruits. For example, Wen et al. (2021) showed that combined application of potassium fertilizer and organic fertilizer increased dry matter accumulation in spring flush leaves and shoots, while enhancing mineral nutrient uptake by both vegetative tissues and fruits. Root-zone potassium application