increasingly viewed as interdependent ripening regulators, but the kiwifruit-specific auxin network remains less resolved than the ethylene and ABA pathways (Durán-Soria et al., 2020; Bai et al., 2021).

6 Environmental and Cultivation Factors Affecting Sugar–Acid Balance

6.1 Light and temperature effects

Canopy light conditions influence carbohydrate accumulation mainly by regulating photosynthesis, leaf sugar metabolism, and carbon export to the fruit. In kiwifruit, carbohydrate supply varies with leaf area, leaf position, light exposure, and leaf age, so canopy structure directly affects the amount of photosynthate reaching fruit sinks (Patiyal et al., 2024). Light quality also changes sugar metabolism at the source level: red or red–blue light increased leaf sucrose, glucose, and fructose compared with blue-dominant treatments, and the red–blue 3:1 treatment gave the highest sucrose content and SPS activity (Zhang et al., 2026). Promoter analysis of the AdSPS family further showed that light-responsive elements are abundant, supporting direct light regulation of sucrose metabolism genes in kiwifruit. Field management that improves light interception can therefore strengthen sugar accumulation indirectly through enhanced source activity, although excessive solar irradiance can become harmful rather than beneficial (Patiyal et al., 2024).

Temperature has equally strong effects on respiration and organic acid metabolism. High summer temperatures and heat load reduce dry matter, soluble solids, and starch-to-sugar conversion, while increasing acidity and delaying commercial ripening (Denaxa et al., 2023). Elevated temperature during starch accumulation also diverts carbohydrates toward vegetative growth and away from fruit sinks, weakening final sugar accumulation. By contrast, Mitalo et al. (2019) found that low-temperature storage can accelerate sugar accumulation and softening even without detectable ethylene production, and these changes occur faster at 5 °C than at 22 °C. Postharvest blue light has the opposite effect, reducing respiration, ethylene production, total soluble solids accumulation, and starch degradation, thereby delaying ripening (Xu et al., 2024). Organic acid behavior during ripening is closely tied to respiratory metabolism, with citrate decline being the main cause of titratable acidity (Mao et al., 2023).

6.2 Water and nutrient regulation

Water management affects both yield and flavor-related composition, but the response depends on irrigation intensity and growth stage. A recent meta-analysis by Ding et al (2025) showed that optimized water and fertilizer management increased soluble sugar by 6.35% and reduced titratable acidity by 4.35%, improving overall fruit quality. The same analysis found that excessive irrigation had a greater negative effect on yield and water-use efficiency, whereas reducing super-optimal water input increased yield by 16.24% and water-use efficiency by 20.06%. Stage-specific fertigation studies in ‘Jinyan’ further showed that moderate water deficit combined with potassium regulation can maintain yield while improving TSS and sugar/acid ratio, with late-stage HWHK treatment raising TSS by 30.58% and sugar/acid ratio by 24.91% (Cui et al., 2023).

Among nutrients, potassium has the clearest effect on flavor development because it regulates osmotic balance, carbon transport, and sugar–acid composition. Excess potassium can raise soluble solids and pH enough to disrupt acid balance and impair flavor, while overapplication also competes with Ca, Mg, and NH^{4+} uptake (Ding et al., 2025). In ‘Hayward’, increasing potassium generally reduced SSC and titratable acidity, and intermediate rates were more appropriate overall than the highest doses (Tarakçıoğlu and Öztürk, 2022). Potassium source also matters: basal K_2SO_4 followed by KCl topdressing improved fruit weight and vitamin C relative to single-source treatments (Ma et al., 2025). Nitrogen effects appear more conditional. Moderate nitrogen can increase fruit weight without large changes in sugars or acids, but excess N can disrupt nutrient balance and reduce fruit K and Ca status. Calcium mainly improves firmness and storability rather than sugar–acid composition: foliar Ca sprays increased fruit Ca and firmness, but did not significantly alter soluble solids or acidity (Sotiropoulos et al., 2021). In calcareous soils, Baldi et al. (2025) pointed out that soil-applied Ca was largely ineffective for improving fruit quality, whereas reflective films increased soluble solids at harvest and during storage.