



Figure 2 Mechanisms of photosynthate transport and hormonal regulation in grapevines, highlighting phloem function and carbohydrate allocation (Adopted from Li et al., 2021)

Canopy structure shapes P_n , G_s and T_r by modifying light and water status, with open, well-lit canopies generally enhancing photosynthesis but increasing transpirational demand. Strong vertical gradients in radiation and water potential create sharp differences in photosynthesis among canopy layers, so mid-canopy leaves in mixed light often dominate carbon gain. These physiological patterns control carbohydrate accumulation and transport, where adequate, well-distributed active leaf area and effective phloem function are critical for sustaining fruit sugar accumulation and overall vine performance.

5 Effects of Canopy Structure on Fruit Quality

5.1 Influence on sugar accumulation

Canopy structure, through its effects on source-sink balance and microclimate, strongly regulates the rate and extent of sugar accumulation in berries. Shoot thinning, which reduces crop load and increases canopy porosity, consistently hastened ripening and increased total soluble solids (TSS) by about 2.5 Brix in Cabernet Sauvignon, although it reduced yield (Torres et al., 2020). Similarly, early or cluster-zone leaf removal often increases berry sugar and final wine alcohol, indicating that greater light exposure and a higher leaf-to-fruit ratio can accelerate sugar accumulation when temperature is not excessive (Stefanović et al., 2021). These responses show that structural manipulations of the canopy can shift the trajectory of berry sugar dynamics.

Conversely, increasing shading within the canopy tends to slow sugar accumulation and delay maturity. Partial canopy shade that reduced solar radiation by ~75% lowered leaf net assimilation and resulted in berries with reduced TSS and delayed phenological development compared with unshaded vines (Lu et al., 2021). Artificial canopy shading applied at fruit set likewise decreased sugar concentration at harvest and increased must acidity, pointing to a general slowing of ripening under reduced light and temperature (Micciché et al., 2023). Late-season canopy reduction by shoot trimming can also decrease final TSS without major changes in yield, providing a tool to moderate excessive sugar in warm climates (Assefa et al., 2025).

5.2 Regulation of organic acids and flavor compounds

Canopy structure alters berry temperature and light, thereby modifying organic acid degradation and acid-sugar balance. Shading treatments that reduce irradiance and berry temperature generally increase titratable acidity and lower pH at harvest, as shown for partially shaded Cabernet Sauvignon and shaded Nero d'Avola. In contrast,