

2 Mechanisms of Canopy Management Affecting Growth and Development of Fresh Table Grapes

2.1 Regulation of canopy structure and balance of vegetative growth

Canopy structure determines whether grapevines allocate resources to productive fruit growth or to excessive vegetative expansion. Foundational reviews describe canopy management as the manipulation of shoot number, shoot spacing, leaf area, fruit-zone exposure, and vigor so that the canopy is neither overly dense nor overly sparse, with the goal of maintaining an appropriate balance between shoot growth and fruit load (Lan, 2025). Dense, vigorous canopies promote long shoots, active laterals, and shading, which divert photosynthates into superfluous leaf area and create imbalance, while excessively short or thinned canopies can leave insufficient leaf area to ripen fruit adequately. In vigorous vineyards, lateral shoots often worsen crowding, humidity, and disease pressure, but in moderate-vigor systems lateral leaves can support sugar accumulation during ripening and increase starch reserves, showing that the value of vegetative growth depends on canopy context rather than on leaf area alone.

Experimental evidence shows that structural interventions affect fruit set, bunch architecture, and yield components by changing sink competition and carbohydrate partitioning. Removing active vegetative sinks at bloom increased fruit set, berries per cluster, and cluster weight in Pinot noir, whereas promoting vegetative growth during that period reduced reproductive allocation. Early canopy practices also altered berry number, berry fresh weight, and bunch compactness determinants in cultivar-dependent ways, indicating that the position and timing of leaf or shoot removal matter physiologically (Mataffo et al., 2023). In pre-flowering leaf-removal trials, intensive removal of main leaves and lateral shoots reduced yield potential by 47% on average, while even partial removal lowered yield potential and shifted must composition, supporting cautious use of severe early defoliation (Verdenal et al., 2024). Multi-season work in Montepulciano further showed that shoot thinning alone reduced canopy density without reliably improving composition, whereas shoot thinning plus pre-flowering defoliation reduced yield, lowered *Botrytis* incidence, improved fruit composition, and produced a carry-over reduction in the following year's yield (Silvestroni et al., 2019).

2.2 Optimization of canopy light environment and improvement of leaf photosynthetic efficiency

The most consistent mechanism linking canopy management to grapevine performance is the regulation of the internal light environment. Canopy architecture directly controls light quantity and quality in leaves, buds, and clusters, and light interception is repeatedly identified as the dominant microclimatic driver of canopy photosynthesis, fruitfulness, and ripening. Practices such as shoot thinning, positioning, leaf removal, and divided or alternative training systems improve light penetration and canopy porosity, but the target is balance rather than maximum openness because excessive gaps waste incident radiation and excessive exposure can cause photoinhibition or quality losses (Lan, 2025). In overhead table grape systems, modeling showed that the most productive leaf layers were those receiving intermittent shade plus sunflecks, whereas the topmost continuously exposed leaves showed some photoinhibition, indicating that moderate internal illumination can support whole-canopy carbon gain efficiently even at relatively high leaf area index.

Training-system and canopy-opening studies show how this mechanism translates into photosynthetic performance. In 'Miguang' grape, the single-curtain system increased photosynthetic photon flux density in the cluster zone, raised chlorophyll content, improved net photosynthetic capacity of basal-to-middle leaves during berry expansion and veraison, and increased assimilate allocation to fruit while reducing vegetative growth (Du et al., 2023). In a desert vineyard, open canopies increased photon flux density, daily light integral, photosynthetic rate, and leaf area during vegetative growth, while berries from open canopies had higher soluble solids and total phenols, although canopy opening also increased temperature (Hernández-Ordoñez et al., 2024). Canopy architecture also modified water-use behavior: a sprawl system in Syrah improved radiation interception efficiency and water-use efficiency relative to vertical shoot positioning under semiarid stress (De La Fuente et al., 2026). Under drought, variation in photosynthesis within canopies was mainly explained by differences in light interception, while severe stress progressively suppressed gas exchange across most canopy positions, showing that light optimization and water status interact rather than acting independently.