

alter fruit set, berry number per bunch, and berry fresh weight in cultivar-dependent ways, so stable marketable yield requires moderate and cultivar-specific regulation rather than severe canopy reduction (Mataffo et al., 2023).



Figure 3 Effects of different floral cluster thinning intensities on the cluster shape of ‘Shine Muscat’ grapes at harvest (Adopted from Choi et al., 2023).

Image caption: Floral cluster thinning was performed to 3 cm, 4 cm, and 5 cm, respectively, seven days before full bloom (Adopted from Choi et al., 2023)

5.2 Effects on source-sink balance and nutrient allocation

The second mechanism is the regulation of source-sink balance, because canopy optimization determines how much assimilating leaf area is available per unit fruit mass and how dry matter is partitioned among shoots, berries, and reserve organs. Grapevines are managed around the ratio of leaf area to fruit mass, and imbalance can appear as delayed ripening, fruit abortion, or alternate bearing (Martínez-Lüscher and Kurtural, 2021). Modeling work supports the same framework by showing that weather and source-sink ratio at critical stages determine bunch number, berry number, and berry fresh weight, while carbohydrate allocation must account for both sink strength and sink priority, including reserve storage (Zhu et al., 2021). In practice, this means canopy optimization in ‘Shine Muscat’ should aim to preserve enough functional leaf area to support ripening while preventing excessive vegetative demand from competing with clusters.

Evidence across grape systems shows that nutrient and assimilate allocation shifts strongly with canopy structure and crop load. In source-sink manipulation studies, moderate to high leaf or cane density increased berry weight, bunch weight, bunch volume, and yield in some cultivars, while the lowest cane density combined with the highest leaf density improved assimilate accumulation efficiency per gram of berry. By contrast, severe defoliation had major negative effects on berry size, berries per cluster, soluble solids, root starch, root mass, and ripening date, and these effects carried over into the following season as reduced leaf area, clusters per vine, berries per cluster, and yield (Martínez-Lüscher and Kurtural, 2021). Related experiments showed that under shade, vegetative development was maintained at the expense of berries, whereas under water deficit and high crop load, berry growth became the priority sink, confirming that carbon and nutrient allocation are plastic and environment-dependent (Poupard et al., 2025). For ‘Shine Muscat’, this supports using moderate vigor control, cluster thinning, and light optimization to direct assimilates toward fruit without triggering carbon starvation of the vine (Cheng et al., 2025; Lan, 2025).

5.3 Effects on yield stability under different environmental conditions

Yield stability in ‘Shine Muscat’ also depends on whether canopy optimization can buffer environmental stress, especially low light in protected cultivation and high temperature during ripening. Supplemental LED lighting under rain-shelter conditions increased ‘Shine Muscat’ yield, and the 300 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ night treatment raised yield by 45.1% relative to the unsupplemented control while also giving the highest economic return (Yuan et al.,