

2.3 Regulation of canopy microenvironment and fruit quality formation

Canopy management also affects fruit development by altering the berry microenvironment, including temperature, humidity, airflow, evaporation, and solar exposure. Reviews emphasize that canopy manipulation changes not only sunlight but also temperature and humidity around clusters, thereby influencing disease incidence, berry thermal relations, and ripening conditions (Lan, 2025). This mechanism is especially important in humid or rainy regions, where vigorous shoot growth, high air humidity, and poor ventilation accelerate fungal spread and depress fruit quality (Du et al., 2023). It is also increasingly important in warm climates, where excessive cluster exposure and heat accumulation can impair color development and composition rather than improve them (Hunter et al., 2021; Petoumenou and Patris, 2021; Dou et al., 2024).

Berry-quality responses show that the effect of exposure is nonlinear. In warm-climate Cabernet Sauvignon, shoot thinning hastened maturity, increased soluble solids by about 2.5 °Brix, and reduced methoxypyrazines, but it did not improve anthocyanins at harvest and reduced yield substantially, indicating that more exposure does not necessarily improve all quality traits (Torres et al., 2020). Row-orientation work showed that morning-exposed berries with cooler afternoon profiles had slightly advanced sugar ripening and generally higher anthocyanins and phenols, whereas bunches reaching late-afternoon heat peaks had poorer composition (Hunter et al., 2021). Controlled-environment studies confirm the mechanism: high temperature and low light both impaired coloring, high temperature promoted sugar accumulation but caused softening, and high heat downregulated anthocyanin-pathway genes while reducing total anthocyanin accumulation in sensitive cultivars (Dou et al., 2024; Zha et al., 2024). At the molecular level, high-light berry microclimates increased expression of genes linked to photosynthesis, carbohydrate metabolism, photoprotection, and flavonol synthesis, supporting a direct connection between canopy-regulated microclimate and fruit metabolic composition. In table grapes specifically, improving canopy-associated preharvest conditions enhanced red color and consumer acceptability in ‘Crimson Seedless’, with Sunred® increasing anthocyanin accumulation and overall market acceptance (Petoumenou and Patris, 2021).

3 Case Background: Canopy Optimization Management Practice in ‘Shine Muscat’ Grapes

3.1 Cultivar characteristics and problems in production

A major practical problem in ‘Shine Muscat’ is that basic cultivation standards remain incompletely standardized despite fast acreage expansion. Korean studies note that growers lack cultivar-specific protocols for seedlessness induction and cluster thinning, and leaving inflorescences longer than 5 cm increases later berry-thinning labor and often produces clusters exceeding 1 000 g (Figure 1) (Shin et al., 2019). Related work showed that natural berries can be relatively small and clusters sparse, while rust spot near maturity can reduce appearance quality and commodity value.



Figure 1 Shape of ‘Shine Muscat’ clusters at harvest time following floral cluster thinning to 3 cm (A), 4 cm (B), and 5 cm (C) (Adopted from Shin et al., 2019)

Fruit-load and uniformity problems are central because heavier or less-regulated clusters tend to dilute quality. Floral cluster thinning is used to improve cluster uniformity and regulate fruit quality, and in ‘Shine Muscat’ larger cluster load is associated with poorer within-cluster consistency and lower sugar-acid balance (Shin et al.,