

The gas environment created by bagging is equally important because restricted permeability can alter respiration and transpiration around the fruit. Plastic-film bags for table grapes were explicitly described as atmosphere-modifying packages that hinder CO<sub>2</sub> escape and O<sub>2</sub> entry, while perforation-controlled packaging work in other fruits showed that adjusting the number of perforations can stabilize favorable O<sub>2</sub>, CO<sub>2</sub>, and humidity levels by regulating fruit respiration and transpiration (Amorim et al., 2020; Herrera et al., 2024). Although most direct grape evidence here comes from postharvest systems, the same principle applies to preharvest bagging: gas exchange is not simply blocked, but engineered by material permeability and venting, which in turn influences water loss, condensation risk, and fruit metabolic activity.

### 2.3 Regulation of light environment by different bagging materials

The most consistent microenvironmental effect of fruit bagging in grapes is the modification of the light regime reaching the berry surface. Cluster bagging in Cabernet Sauvignon markedly reduced both photosynthetically active radiation and solar radiation throughout berry development, and work in Muscat-flavored table grapes likewise showed that bags of different materials and colors have different light transmittances that alter the fruit microenvironment and ultimately fruit quality (Wang et al., 2022). Light regulation is therefore the main mechanism by which bagging materials differ biologically, because variation in transmittance changes not only exposure intensity but also the spectral composition of light perceived by berry tissues.

Differences among bag colors and materials produce distinct quality outcomes because high- and low-transmittance bags do not regulate berry development in the same way. In 'Kyoho' grapes, light transmittance ranked white > yellow > blue, and higher transmittance increased soluble solids and anthocyanin content, whereas lower transmittance reduced berry cracking and increased sub-epidermal thickness; similarly, in multi-bag trials on Muscat-flavored grapes, transparent and white bags promoted phenolics and monoterpenes, while pink and blue bags showed inhibitory effects (Wang et al., 2022). These findings show that bagging materials should not be treated as interchangeable coverings, since their optical properties directly shape the balance between visual protection, ripening progress, skin integrity, and the accumulation of flavor- and color-related metabolites.

## 3 Effects of Fruit Bagging on Grape Growth and Development

### 3.1 Effects on fruit expansion and morphological development

Fruit bagging can promote berry expansion and improve commercial morphology, but the effect depends strongly on bag material, timing, and cultivar. In Mediterranean table grapes, bagged bunches were heavier than unbagged controls across cultivars, mainly because of higher berry number and berry weight in some seedless varieties, while parchment bags in another study increased berry length, width, and weight more clearly than paper or non-woven materials (Pisciotta et al., 2020; Luca et al., 2023). These results indicate that bagging can support fruit enlargement, but the benefit is not universal across all bag types.

Color-specific and stage-specific bagging studies reach a similar conclusion. In 'Muscat Hamburg', white non-woven polypropylene bags produced the highest bunch weight, berry diameter, berry weight, and yield per vine in both evaluated seasons, whereas in 'Kyoho' grape the highest berry weight was obtained when bagging was applied late, at 7 to 9 weeks after full bloom, rather than throughout the whole development period (Kiran et al., 2020). Together, these findings suggest that moderate microclimate modification during key expansion phases is more favorable for berry growth than prolonged or poorly timed enclosure.

Bagging also affects berry texture and skin-related morphology, which are important components of market quality. In Sicily-grown table grapes, bagging altered mechanical traits, increasing berry hardness in seedless cultivars while lowering skin break force in all varieties, which indicates a softer and easier-to-chew skin; broader reviews similarly note that bagging often improves size uniformity and reduces deformities caused by environmental stress (Pisciotta et al., 2020; K et al., 2025). This combination of improved external uniformity and modified skin mechanics helps explain why bagged grapes often meet fresh-market standards even when compositional effects are mixed.