

Despite extensive work, several limitations constrain the current understanding and application of canopy-based strategies. Many studies evaluate single levers (e.g., training system alone or a specific defoliation regime) under narrow climatic and cultivar conditions, making it difficult to generalize results or predict performance under future climates. Systematic reviews emphasize that most adaptation studies lack multi-lever and multi-scale approaches, and rarely quantify economic feasibility, restricting their usefulness for decision-makers in commercial vineyards. There is also incomplete coverage of the diversity of canopy forms and their long-term physiological impacts. Reviews indicate that classical systems such as VSP and goblet, though widely used, may be less aligned with future climate demands, yet empirical comparisons with alternative systems in different regions remain limited. Evaluations often focus on a few compositional traits (sugars, basic phenolics) and short time frames, while long-term effects on carbohydrate reserves, vine longevity, and cumulative yield are less frequently addressed. These gaps hinder precise recommendations on optimal canopy structures across ecologically contrasting regions.

Future research needs to integrate canopy architecture with other adaptation levers, especially under projected climate scenarios. Systematic assessments show that combining changes in training system, irrigation regime, soil and floor management, and canopy manipulation leads to more robust adaptation strategies than any single intervention alone. Modelling tools that couple gas exchange, water status, leaf temperature and radiation load can be expanded to simulate how alternative trellis designs, shading devices and reflective treatments interact with heatwaves and water scarcity. Such approaches could guide site-specific canopy designs that maintain photosynthesis while protecting fruit quality. At the application level, regionally tailored canopy systems offer promising prospects. Reviews of training systems under warming suggest re-evaluating high-wire, divided and non-VSP canopies in warm and semi-arid areas, while using more exposing systems in newly suitable cool regions to accelerate ripening. Recent work also points to using berry skin flavonols as practical indicators of canopy architecture and radiation exposure, supporting precision management of leaf area and porosity in the field. Coupling these physiological indicators with remote sensing and decision tools could enable dynamic canopy management that sustains photosynthetic efficiency and fruit quality across increasingly variable ecological conditions.

Acknowledgments

I extend our sincere gratitude to the anonymous reviewers for their valuable and insightful comments, which have greatly strengthened this paper.

Conflict of Interest Disclosure

The author affirms that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

References

- Abubakar M., Chanzy A., Flamain F., and Courault D., 2023, Characterisation of grapevine canopy leaf area and inter-row management using Sentinel-2 time series, *OENO One*, 57(4): 7703.
<https://doi.org/10.20870/oeno-one.2023.57.4.7703>
- Anić M., Osrečak M., Andabaka Ž., Tomaz I., Večenaj Ž., Jelić D., Kozina B., Kontić J.K., and Karoglan M., 2021, The effect of leaf removal on canopy microclimate, vine performance and grape phenolic composition of Merlot (*Vitis vinifera* L.) grapes in the continental part of Croatia, *Scientia Horticulturae*, 285: 110161.
<https://doi.org/10.1016/j.scienta.2021.110161>
- Assefa M., Creasy G., Hofmann R., and Parker A., 2025, Asynchronous accumulation of sugar and phenolics in grapevines following post-veraison leaf removal, *OENO One*, 59(2): 9314.
<https://doi.org/10.20870/oeno-one.2025.59.2.9314>
- Cataldo E., Salvi L., Paoli F., Fucile M., and Mattii G.B., 2021, Effects of defoliation at fruit set on vine physiology and berry composition in Cabernet Sauvignon grapevines, *Plants*, 10(6): 1183.
<https://doi.org/10.3390/plants10061183>
- Collins C., Wang X., Leseffo S., Bei R., and Fuentes S., 2020, Effects of canopy management practices on grapevine bud fruitfulness, *OENO One*, 54(2): 313-325.
<https://doi.org/10.20870/oeno-one.2020.54.2.3016>