

Berry primary and secondary metabolites in response to sunlight and temperature in the grapevine fruit zone

>>> The chemical composition of berries at harvest, which will affect wine styles, is determined by complex physiological processes occurring from set through the fruit's lifetime to maturity, and this is closely intertwined with environmental and crop management factors. Among those factors, climatic conditions within the fruit zone (*i.e.* microclimate), such as light and temperature, are well-known to affect the physiology of the fruit at the skin, pulp and seed levels. This article will present the potential of leaf thinning in the bunch zone to modify cluster microclimate and berry composition. <<<

■ Vine microclimate relies on vineyard physical and management properties

Vineyards can face significant variation of abiotic factors such as sunlight, temperature, water, wind and air humidity depending on:

- topography
- row orientation
- planting density
- training x pruning systems
- canopy size/volume: height and density

Spatial variability in soil characteristics (depth, structure, composition and texture) should also be considered as it determines root architecture and the water and nutrient assimilation by the plant.

■ What are the aims of grapevine leaf and/or lateral removal in the fruit zone?

The literature is often controversial about the effect of sunlight (exposed versus shaded berries) on fruit primary and secondary metabolite accumulation or degradation. When studying sunlight effects on berry composition, the external and internal faces of the cluster (*i.e.*, facing the inter-row or the canopy) should be considered. Indeed, fruit composition is expected to rely on the spatial distribution of the berries within a cluster specifically related to the extent of exposure, as opposed to the top to bottom position of a fruit on the bunch¹.

Grapevine berry primary and secondary metabolites change drastically over development and thus phenological studies (berry green growth stage, veraison, maturation and senescence) are highly informative (figure 1). In addition, working on a per berry basis, Shahood *et al.*, (2015)² demonstrated that after veraison, the water, sugar and organic acids content vary highly among clusters and also between berries within a given cluster. Part of this heterogeneity originates well before berry maturation, as early as flowering and berry setting. When to apply leaf thinning?

■ Berry green growth stage: effect of sun light and temperature

Leaf removal at berry pea size (after flowering and berry set) is interesting because important compounds are

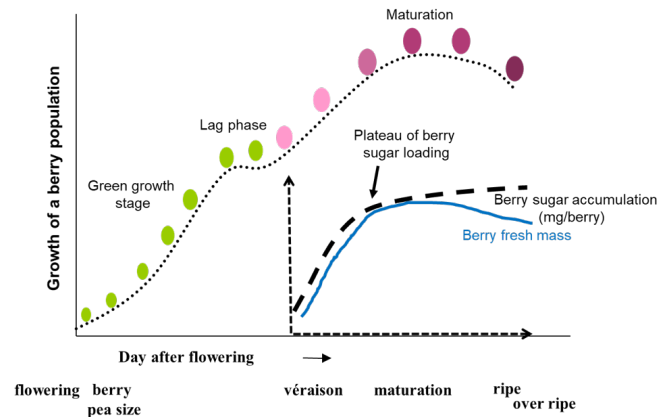


Figure 1. From the onset of veraison (*i.e.* berry softening), the ripening period is divided into two phases: pre- and post-plateau of berry sugar accumulation (in mg/berry) (adapted from Carbonneau *et al.*, 2020)³.

accumulated only during the berry green growth stage and the intensity of sunlight (SL) could impact on their accumulation/degradation (figure 2). The response of leaf removal on grape composition is highly dependent on other biotic (varieties, clones) and abiotic (water, nitrogen) factors, but some general trends can be highlighted. The information below is extracted from the literature and from our own research and experimentation^{4, 5, 6}:

• Potential effects of sunlight (SL)

- Organic acids: no effect of SL
- Tannins: no effect of SL
- Flavonols: SL stimulates biosynthesis
- Pyrazines: SL reduces IBMP accumulation
- Rotundone: no clear trend of SL effect
- Carotenoids and Norisoprenoids (NI): SL stimulates carotenoids and in turn NI accumulation like TDN and B-ionone at harvest, results less clear for Beta-Damascenone
- Monoterpenes: SL stimulates accumulation
- Volatile thiols: SL favours accumulation of volatile thiols precursors
- C6-compounds: no clear effect of SL
- Esters are yeast-derived compounds but early leaf removal can increase their level in white wine by modifying the yeast nutritional source present in grape must at harvest
- Berry fresh mass: no effect of SL except sunburn

• Potential effect of temperature (T)

Increasing sunlight at the cluster level could lead to an increase in berry temperature, the extent of which will depend on the cultivar, topography of the site (mesoclimate) and row orientation. Therefore, the interaction of light and temperature should be considered. The potential effects of temperature are summarised below considering mainly the berry's green growth phenological stage^{4, 5, 6}:

- Organic acids: negative effect of high T > 35°C
- Tannins: no effect of T except extreme heat, which causes a decrease in skin tannins
- Flavonols: no effect of T

- Pyrazines: high T > 35°C reduce IBMP accumulation
- Rotundone: lower accumulation under high T
- Carotenoids: no effect of T
- Volatile thiols: High T tends to lower thiols
- Berry fresh mass: High T > 40°C may exacerbate berry water loss/shrivelling, depending on vine water status. That said, berry water loss can occur at low temperature.
- Exacerbating effect of high (T)/heat waves on cell death within the central region of the berry during ripening

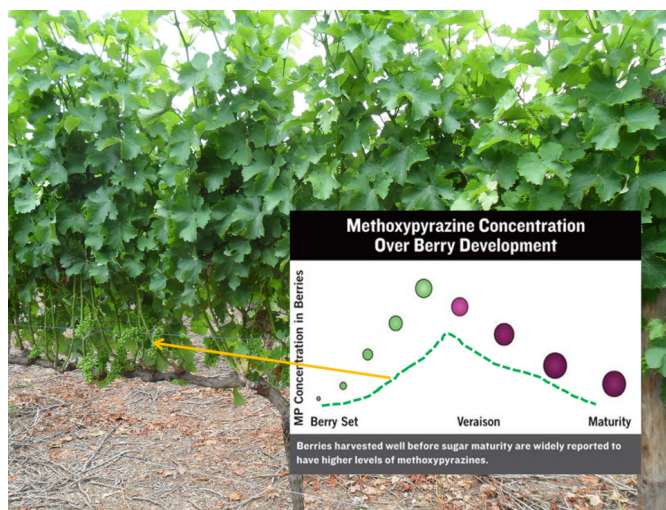


Figure 2. Illustration of early leaf and lateral removal at pea size in the fruit zone (Sauvignon blanc). Increasing sunlight at the bunch level allows to reduce IBMP berry skin concentration pre and post veraison (inspired by the work of Roujón de Boubee D.).

■ Veraison and maturation: effect of sunlight and temperature

From veraison onwards (around 6 °Brix) the fruit accumulates sugar on a daily basis. This is concomitant with an increase in berry volume due to water import².

A berry loads up to 0.8 to 1.2 moles of sugar (equivalent to an average of 10.5-11% in probable alcohol), and stops loading sugar once maturity is reached². This means that from the plateau of berry sugar accumulation, the increase in sugar concentration is due to berry water loss (transpiration and water flow back to the plant). Therefore, when studying the effect of sunlight on berry metabolite evolution, two phases should be considered during maturation (figure 1): before and after the plateau of berry sugar accumulation⁷.

Late leaf removal (LLR) (during veraison) can stimulate the biosynthesis or the degradation of major metabolites in berries through its impacts on berry exposure to light and T. However, LLR should be carefully executed and weighed up against the risk of sunburn and shrivelling, as berries are more sensitive to dehydration at that stage.

→ Anthocyanins: high SL stimulates biosynthesis and berry colour development while low SL leads to red wine with lower colour intensity. Obviously, anthocyanin extraction/diffusion during the process of wine making should be considered.

→ Methoxy pyrazine: although LLR favour their degradation, early leaf removal effect on IBMP accumulation is more intense

→ Other grape aromatic metabolites: effect of LLR is not well understood as most studies have limited their investigation to the impact of leaf removal prior to veraison and maintaining the defoliation after veraison. Late season berry dehydration (LSD) influences the pool of grape and wine aromatic compounds by significantly

decreasing the level of Beta-Damascenone (NI) and esters (via yeast during fermentation). In contrast, LSD favours the accumulation of C6-compounds and metabolites involved in the perception of jammy character such as furanones and lactones.

■ Take home message

Leaf and/or lateral removal in the fruit zone is a powerful tool/cultural practice to improve/change fruit and wine composition and wine styles. This means that from a specific vineyard it is possible to produce different wine styles/typicalities by increasing sunlight at the bunch level. When applying leaf removal to manipulate fruit composition, the berry phenological stage should be considered. In this regard, the appropriate phenological stage to increase sunlight at the cluster level is pea size. Leaf removal applied pre-flowering could help reduce bunch compactness by reducing the number of flowers and increase bunch aeration to improve bunch sanitary conditions and help reduce rot (*Botrytis cinerea*). Applying leaf removal at veraison may also curtail bunch rots and increase berry colour (i.e. stimulating the biosynthesis of anthocyanins for red varieties).

The interactions between abiotic factors, fruit and wine composition, including wine aromatic profiles are complex and aside from some compounds such as IBMP (Sauvignon blanc, Merlot, Cabernet Sauvignon), terpenols (white varieties...), TDN (Riesling...) for which SL and T will affect wine aromatic profiles, it is difficult to predict the impact of fruit zone microclimate on wine styles. ■

Alain Deloire¹, Suzy Rogiers², Guillaume Antalick³, Anne Pellegrino¹,

¹ Montpellier University, L'Institut Agro (SupAgro-IHEV), France

² NWGIC, Department of Primary Industries-NSW, Australia

³ University of Nova Gorica, Vipava, Slovenia

1 Reshef N., Walbaum N., Agam N., and Fait A., 2017. Sunlight Modulates Fruit Metabolic Profile and Shapes the Spatial Pattern of Compound Accumulation within the Grape Cluster, *Front. Plant Sci.*, <https://doi.org/10.3389/fpls.2017.00070>

2 Shahood R., Rienth M., Torregrosa L., Romieu C. (2015) Evolution of grapevine (*Vitis vinifera* L.) berry heterogeneity during ripening. 19th Int. Symp. GIESCO, 1-5 June, Gruissan, France.

3 Carbonneau A., Torregrosa L., Deloire A., Pellegrino A., Pantin F., Romieu C., Ojeda H., Jaillard B., Métay A., Abbal P., 2020. Traité de la Vigne, Physiologie-Terroir-Culture, *Dunod Editeur*, Paris, France, ISBN 978-2-10-079857-5, 689 p.

4 Gouot J.C., Smith J.P., Holzapfel B.P., Barril C., 2019. Grape Berry Flavonoid Responses to High Bunch Temperatures Post Veraison: Effect of Intensity and Duration of Exposure, *Molecules*, 24, 4341; doi:10.3390/molecules2423434

5 Blancquaert E. H., Oberholster A., Ricardo-da-Silva J.M., Deloire A.J., 2019. Effects of Abiotic Factors on Phenolic Compounds in the Grape Berry – A Review, *S. Afr. J. Enol. Vitic.*, Vol. 40, No. 1.

6 Šuklje K., Lisjak, K., BašaCesnik H., Janež L., Du Toit W., Coetzee Z., Vanzo A., Deloire A., 2012. Classification of Grape Berries According to Diameter and Total Soluble Solids To Study the Effect of Light and Temperature on Methoxy pyrazine, Glutathione, and Hydroxycinnamate Evolution during Ripening of Sauvignon blanc (*Vitis vinifera* L.), *J. Agric. Food Chem.*, 60, 9454–9461/9456

7 Šuklje, K., Antalick, G., Meeks, C., Blackman, J. W., Deloire, A. & Schmidke, L. M., 2017. Grapes to wine: the nexus between berry ripening, composition and wine style, *International Society for Horticultural Science (ISHS)*, Leuven, Belgium, pp. 43-50, <https://doi.org/10.17660/ActaHortic.2017.1188.6>