Review of vine water deficit. What levers for the vineyard in the short and medium term?

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>>> In the context of climate change, most wine-growing regions are experiencing periods of water deficit, or even water stress, as well as heatwaves. The proven increase in average temperatures has led to a shift in the phenological stages of the vine. In the Mediterranean regions of the south of France, more frequent thunderstorms in the fall and lower rainfall in winter have led to reduced filling of soil water holding capacity before budburst. In addition, rainfall over the growing cycle is decreasing while evapotranspiration is increasing. This combination of climate changes (rainfall × temperature) has an impact on vine cultural practices, berry composition and the aromatic profile of wines. As such, it seems useful to share a bullet-point list of the possible consequences of increased water deficit and heat peaks on the physiology of the vine and its fruit and to point out some potential solutions in the short and medium term, especially when planting young vines. <<<

■ Vines and water: a few reminders

➔ During its growth cycle, grapevine needs 450-550 mm of water (1 mm = 1 liter per m^2 = 10 m^3 per ha).
➔ From budburst to harvest, it takes between 250 and 350 liters of water in the vineyard to produce one liter of must.
➔ The soil water holding capacity depends largely on root depth, soil texture and the proportion of coarse material.
➔ Evaporation from the soil depends on the humidity of the surface layer, its structure and any cover crops. It is difficult to estimate the split between soil evaporation and transpiration in their contribution to overall water loss per hectare (in mm).
➔ The choice of rootstock is a crucial factor in adapting a vine to water deficit.
➔ 98 % of the plant's water needs result from its transpiration.
➔ Water-use efficiency is the plant's ability to fix a given amount of carbon for a given level of water loss through transpiration.
➔ Improved water-use efficiency resulting from increased photosynthetic activity and/or more efficient stomatal regulation can be considered a drought adaptation trait.
➔ Growth of lateral (secondary) shoots decreases as soon as there is a slight water deficit, while growth of primary shoots is impacted by moderate water deficit (Figure 1).
➔ The final berry volume is reduced at water deficit levels lower than those required to reduce the bunch number per vine or the berry number per bunch (Figure 1).
➔ Filling of the soil up to its water holding capacity is important before budburst to ensure even budburst and after the harvest to maintain photosynthesis in the leaves and promote the buildup of carbon reserves.

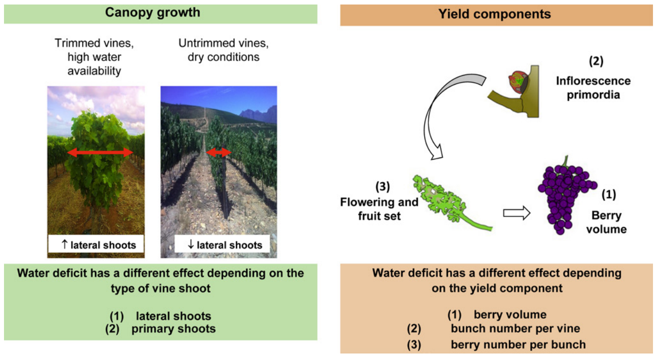

Figure 1. Impact of water deficit on shoot growth and yield components. Secondary (lateral) shoots are impacted by lower water deficit levels than primary shoots, which carry the year's crop[1]. The final berry volume is impacted at lower water deficit levels than the bunch number per vine, which in turn is impacted at lower water deficit levels than the berry number per bunch[2].

■ Potential consequences of drought (severe water deficit) and rising temperatures (heatwaves)

a) Vegetative growth and yield components

➔ Reduction in vegetative growth and hence in the exposed leaf area.
➔ Reduction in the growth of lateral shoots, with positive or negative consequences depending on the climatic conditions (increased exposure of the bunches to sunshine, reduced activity of carbon sinks or sources depending on the stage).
➔ In the case of severe and early water deficit, uneven budburst and a reduction in the fertility of latent buds on the growing primary shoots (Figure 1)[3].
➔ Deterioration in the growth of inflorescences and flowers in year N + 1 (for which the primordia were formed in the latent buds in year N), which may lead to fertilization defects including coulure (poor fruit set) and millerandage (uneven berry development and ripening).
➔ Reduction in berry volume (from the green growth stage of the fruit and post-veraison/ripening), reducing the final yield but possibly favoring quality (less compact bunches, increased concentration of primary and secondary metabolites), the important thing being to avoid blocked ripening[2, 4].
➔ Increased risk of back-flow of water from the fruit to the leaves, especially in the event of water deficit and heat stress after veraison, leading to shriveling of the berries (shriveling is generally irreversible after the plateau of sugar accumulation and at the end of ripening).

Figure 2 summarizes the relationships between soil water availability, total leaf area per vine and/or per hectare and yield per vine and/or per hectare, and possible ways to adapt to them. The leaf area per hectare is a major factor in the water balance, as 70 to 80 % of the water lost through evapotranspiration is due to the transpiration of the vine.

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Figure 2. The adaptation of a vineyard to water deficit is determined from the moment of planting (choice of training system, planting density, leaf/fruit ratio, yield, combination of grape variety and rootstock). The profitability of a wine estate can be endangered by repeated severe water deficits affecting yields and hence the number of bottles produced per hectare.

b) Berry composition and wine quality

➔ Inhibition of the biosynthesis of primary metabolites (organic acids, sugars)[5] leading to disruption of berry ripening dynamics[6].
➔ Increase in wine pH through concentration of potassium and decomposition of malic acid.
➔ Inhibition of the biosynthesis of secondary metabolites (phenols, aroma precursors) pre- and post-veraison in case of severe water deficit. The anthocyanin content in berries is, however, favored at moderate levels of water deficit.
➔ Change in the aromatic profile of the wine when more than 20 % of berries are shriveled[7].
➔ Uneven berry growth[4] which may have an effect on wine style.
➔ An earlier harvest, which is mainly due to the overall sugar concentration in the berries (i.e. the Brix or potential alcohol) being used to determine the harvest date rather than the daily accumulation of sugar per berry resulting in more sugar per berry (mg/berry).

■ Possible solutions: the toolbox

Table 1 presents the goals for reducing the water consumption of a vineyard and the potential solutions in the short, medium and long term.
The vine's water needs extend from before budburst to after the harvest (Figure 3). In a terroir approach (soil × climate), it is the soil water holding capacity and rainfall events that mark out the phenological stages and dictate berry composition. When irrigation is allowed, it makes it possible to compensate for the vagaries of the weather,

Table 1. Reduction in the water consumption of a vineyard and possible solutions.

Goals	Solutions put in place
Increase in the soil storage capacity	-Regeneration of microbial life in soils -Input and increase of organic matter in soils -Irrigation
Reduction of evaporation losses	-Changes to tillage practices and cover crops
Reduction of the leaf area and transpiration losses	-Reduction of the total leaf area per vine (and alignment of the associated yields) -Reduction in planting density -Shading of the vines (shade structures) -Choice of low training systems (Gobelet, Palmette)
Maintenance of production, reduction of transpiration losses	-Choice of drought-tolerant grape varieties and rootstocks considering potential wine styles -Supplementary irrigation
Maintenance of production, Freshness of white and rosé wines	-Regeneration of soil life for better management of the soil water storage capacity -Supplementary and reasoned irrigation of the vine (Figure 2)

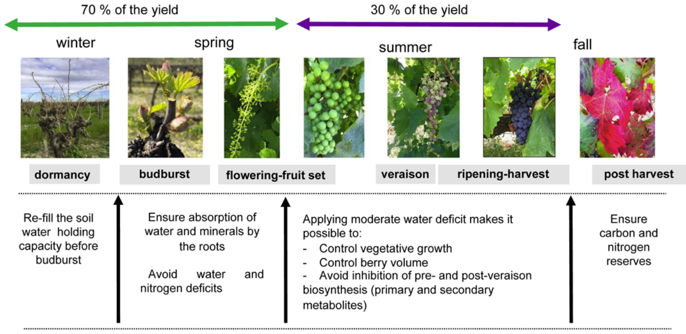

Figure 3. The vine's water needs extend from before budburst to after the harvest.

which may be unfavorable to the yield, berry quality and associated wine styles.

■ Conclusion

Severe water deficit (water stress) should be avoided in the vine from before budburst to after the harvest, and in particular for the production of white and rosé wines. Clearly, the following points must be taken into account when considering the impact of the water status on vine functioning (vegetative growth; vine fertility/yield; growth and composition of fruit; categories and aromatic profiles of wines):
➔ The period of onset of water deficit in relation to the phenological stages
➔ The intensity of water deficit (deficit versus stress)
➔ The duration of water deficit.
The water status of the vine must be considered in relation to temperature and, in particular, the intensity and duration of heatwaves must be taken into account. ■

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