IVES Technical Reviews
vine & wine

https://doi.org/10.20870/IVES-TR.2020.4029

Does water deficit negatively impact wine grape yield over the long term?

>>> Like many other woody perennial crops, grapevine reproductive development occurs over a two-year cycle. Given that water deficits are commonplace in viticulture, especially for red wine grape production, this raises questions about how water deficit in the current season could potentially impact yields the following year. This article will focus on the long-term effects of water deficits on grapevine yield. <<<

■ Grapevine yield formation

Grapevine yield is the product of individual berry size and the total number of berries per vine. Each of these two yield components are themselves made up of different components. The total number of berries per vine is the product of the number of clusters per vine and the number of berries per cluster. The latter is itself a product of flowers per cluster (inflorescence) and percent berry set. Accordingly, water deficit can negatively affect yield via reductions of any of these components.

■ The effects of water deficits in the current season

Current season water deficits slow vegetative growth, ultimately limiting photosynthesis and canopy development. These impacts are more pronounced if the water deficit occurs preveraison, particularly around bloom, when shoot growth rates are at their maximum. At the onset of mild water deficit, vines reallocate energy (i.e. carbohydrates) from supporting shoot growth to supporting root growth, presumably to extract more soil water. Photosynthesis is reduced due to a smaller canopy with less leaf surface area.

If the water deficit continues and intensifies, leaves reduce water loss by closing stomata and changing their leaf orientation to the sun. These responses reduce photosynthesis at the leaf level by limiting gas exchange and reducing light interception. Less sugar production means less sugar export to sinks such as berries, root tips, and also developing buds and storage reserves. Thus, negative impacts on vegetative growth and development in the current season will negatively affect whole-vine carbohydrate production that ultimately supports perennial productivity and survival.

Current season water deficits can reduce yield through several yield components (Fig. 1). Both pre- and postveraison water deficits reduce berry size. Even when preveraison water deficits are released at veraison – as is often the case in many regulated deficit irrigation strategies – they have lasting effects on growth such that berry size will not "catch up" if vines are well-watered postveraison[1]. Severe water deficits just prior to and during flowering may reduce berries cluster indirectly by reducing photosynthesis, thus limiting the amount of carbohydrates available to the developing inflorescence[2]. However, it is important to note that severe water deficits before flowering may be rare except for arid and semi-arid regions (i.e. where annual rainfall is < 500 mm).

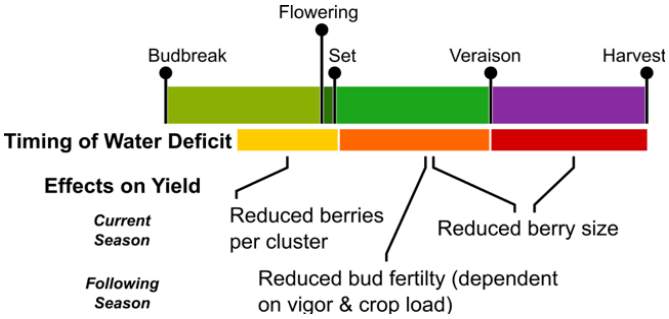


Figure 1. The timing of water deficits dictates the exact effect on yield in the current and following season.

■ Seasonal dynamics of carbohydrate reserve storage

Woody perennials store energy in permanent structures (e.g. woody roots, trunk, cordons, etc.) to survive winter and support vegetative growth prior to the development of mature leaves[3]. Furthermore, carbohydrate reserves are critical to sustain vine productivity over many seasons. Conventional wisdom says that most carbohydrates are stored post-harvest because prior to that time the ripening clusters consume all the carbohydrates produced by photosynthesis. However, this is not correct – grapevines can store carbohydrates beginning much earlier in the growing season. The vine's carbohydrate reserves (mostly starch) are lowest just prior to veraison and then increase steadily to the end of the growing season, depending on the vigor of the vineyard and mainly when the fruits have reached the plateau of sugar accumulation[4].

■ Water deficit effects on bud fruitfulness and long-term productivity

Bud fruitfulness is determined the year prior to harvest when inflorescence primordia are initiated in the developing buds (Fig. 2). This process begins just after flowering and is completed by veraison[5]. Ultimately, the number and size of inflorescences per bud is determined by veraison in the year preceding harvest. Water deficits during these developmental periods have the potential to reduce bud fruitfulness, and subsequently yield in the following season.

The set-up and launch of IVES Technical Reviews are supported by the LabEx COTE via its Transfer and valorization call for projects.
The translation of this article into English was offered to you by Moët Hennessy.

Indeed, vineyard observations and studies have shown that long term and frequent water deficits can decrease bud fruitfulness.

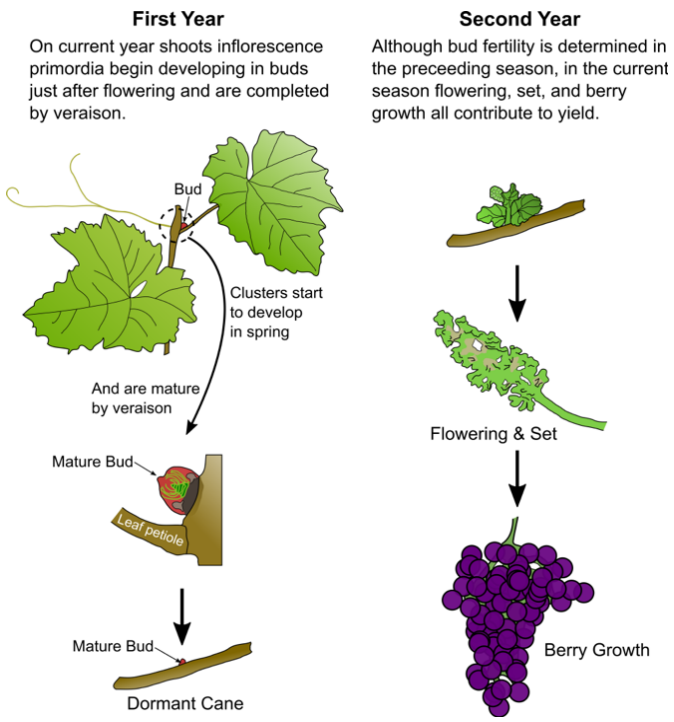


Figure 2. Bud fertility is determined the year prior to harvest when inflorescence primordia are initiated in the developing buds. Adapted from Matthews M. (2016)[6].

Recently, a long-term study of 15 red wine grape cultivars grown in a spur-pruned system evaluated reproductive development over five years. Cultivars were subjected to yearly pre- and postveraison water deficits, and results showed that only preveraison water deficits negatively impacted bud fruitfulness, with very few differences among cultivars[7]. In that study, reproductive development was still relatively tolerant of moderate water deficit, as the number of clusters per vine was not reduced with midday leaf water potential (Ψ_l) values down to -1.3 MPa. Repeated preveraison water deficits below this threshold were required to significantly reduce clusters per vine. Interestingly, the number of berries per cluster was not affected by water deficits either pre- or postveraison, suggesting that the differentiation of individual flowers (in contrast to the initiation of whole inflorescences) may not be as sensitive to within season water deficits. It should be noted that vine responses grown in cane-pruned systems may not be the same because inflorescence initiation at higher node positions occurs on a later phenological schedule than for lowest node positions. Overall, yield components were ranked from most to least sensitive to water deficits: (1) berry size, (2) clusters per vine, and (3) berries per cluster.

In the final year of the study, all vines were kept well-watered to observe true carryover effects on yield. Yields recovered somewhat due to increased berry size, but clusters per vine (and yield) remained low in vines that had previously experienced preveraison water deficits. While this confirmed the negative carryover effects of preveraison water deficits, clusters per vine never fell below a minimum value. This shows that despite severe preveraison water deficits over the long term, vines remained somewhat productive and continued to initiate clusters in buds. Presumably, previously accumulated carbohydrate reserves were being remobilized to support this minimum level of production, but it is unclear to what degree this minimum level of productivity would have remained, and for how long into the future.

Managing water deficit preveraison

Budbreak	Flowering & Set	Veraison
Water deficits during this time can inhibit shoot and leaf growth and thus should be avoided to promote a healthy canopy, flowering, and set.	Moderate water deficits ($\Psi_l \geq$ -1.3 MPa) can control berry size and will likely not impact yield the following year. **More severe water deficits can potentially reduce yield the following year.**	

Figure 3. When managing preveraison water deficits specific practices are advised depending on the phenological stage.

This implies that younger vines – carrying less stored carbohydrate reserves – may be more susceptible to production loses across multiple seasons. With respect to preveraison water deficits, specific practices and impacts can be considered in two phenological stages (Fig. 3).

■ Conclusions

In viticulture, water deficits can vary in their intensity, timing, and duration. All of these factors will affect the exact impact that the deficit has on fruit yield. However, it is clear from the literature that severe preveraison water deficits will reduce berry size in the current season, and clusters per vine in subsequent seasons[8]. First, pre-budbreak soil water content is crucial for healthy latent bud development. Second, cultural practices from budbreak to veraison can have lasting impacts on long-term grapevine productivity and vineyard sustainability. ■

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