https://doi.org/10.20870/IVES-TR.2021.4681

Nighttime transpiration: does it contribute to water stress in grape?

Sourced from the research article "Nighttime transpiration represents a negligible part of water loss and does not increase the risk of water stress in grapevine" (Plant, Cell & Environment, 2021)[1].

>>> Climate change is driving the search for grapevine cultivars and/or rootstocks that use water more efficiently. Recently, there has been increasing attention on nighttime transpiration. The reasoning is simple. While daytime transpiration results from the necessity to have stomata open so the plant can take up carbon dioxide for photosynthesis, nighttime transpiration could be considered a "waste" of water since no photosynthesis occurs at night. So how significant is nighttime water use in grape, and does it serve some other purpose that benefits the vine? <<<

How much do grapevines transpire at night?

Many studies highlight the idea that nighttime transpiration could be great enough to represent an important source of water loss for the plant[2]. Reports across different plant species indicate that it typically represents about 12-15 % of daily transpiration[3], although in some cases it can exceed 30 %[4, 5]. But what is this percentage in grapevines?

In grape, it was observed that average nighttime transpiration in three cultivars (Syrah, Grenache and Semillon) represented 5 to 13 % of daytime values, with no differences among them[1]. These values are similar to other studies, and although 5-13 % is a relatively small percentage, it may be significant. So there remains the question of whether or not nighttime transpiration could significantly contribute to the risk of water stress in grape.

Could nighttime transpiration contribute to the risk of water stress?

To address this question, a modeling approach was used to explore the relative contributions of day- and nighttime transpiration in contributing to the risk of water stress[1]. In the hypothetical modeling scenario, the amount of time it would take vines to deplete soil relative water content (RWC) from 100 to 20 % was determined. Then the following question was asked: if day- or nighttime transpiration were reduced (by reducing day- or nighttime stomatal conductance; g_{day} or g_{night}), how long would it take a vine to deplete soil RWC to 20 %?

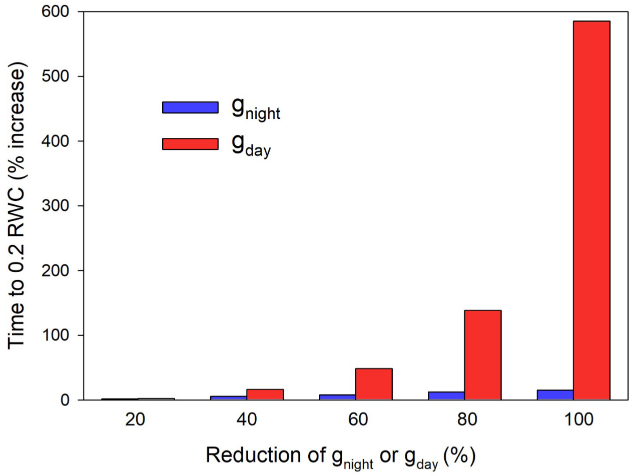

Figure 1. The effects of reducing day or night stomatal conductance on the amount of time it takes a vine to deplete soil relative water content to 20 %.

Clearly, reducing daytime stomatal conductance (red bars) had a much greater effect on lengthening the time it takes a vine to deplete soil RWC to 20 % (Figure 1). Even if nighttime stomatal conductance (blue bars) was reduced by 100 %, there was only a modest 15 % increase in the time to 20 % soil RWC. These results demonstrate that nighttime water use does not contribute significantly to the risk of water stress, especially when compared to daytime water use.

Could nighttime transpiration have potential benefits for the vine?

The opening of stomata at night raises the question if there is some sort of benefit underlying this behavior. If not, nighttime water loss would be detrimental since there is no photosynthesis at night. When stomatal conductance was examined dynamically across the nighttime hours, a peculiar behavior was observed. Vines actually anticipated sunrise, and began to open their stomata (i.e. increased g_{night}) during the pre-dawn hours[1]. Even more striking, it was observed that this pre-dawn stomatal opening was strongly correlated with daytime variables related to productivity such as maximum stomatal conductance and photosynthesis, and even with total leaf area (Figure 2).

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.

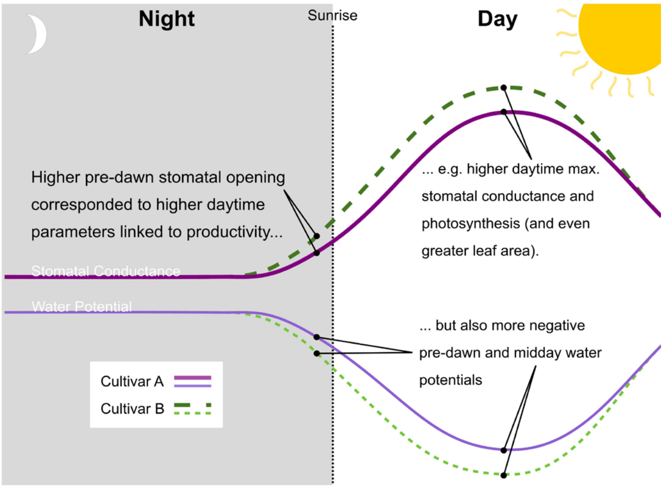

Figure 2. Overview of the link between pre-dawn stomatal opening and daytime water use behavior.

In other words, vines that opened their stomata to a greater extent in anticipation of sunrise performed better during the day as if they had a "head start". These results suggest that priming photosynthesis with stomatal opening before sunrise could contribute to enhanced growth. For example, faster stomatal opening before dawn would accelerate plant response to radiation, shortening the time needed to reach optimum stomatal conductance and carbon gain by photosynthesis[2, 4, 6].

But are there any other consequences for this pre-dawn stomatal opening? The answer appears to be yes. Observations indicated that cultivars that exhibited greater pre-dawn stomatal opening (e.g., Semillon) also exhibited more negative pre-dawn and midday water potentials (Figure 2)[1]. However, it is still unknown if the magnitude of these more negative water potentials is great enough to be detrimental in some way.

■ Conclusion

Nighttime transpiration in grapevine makes up a small percentage of its daily water use and does not contribute significantly to the risk of water stress especially when compared to daytime transpiration. Pre-dawn stomatal opening appears to benefit the vine through priming higher daytime gas exchange and productivity, but also results in more negative pre-dawn and midday water potentials. ■

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