ISO-/ANISOHYDRIC BEHAVIOR IN WINE GRAPES MAY BE A MATTER OF SOIL MOISTURE

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Abstract:

Context and purpose of the study

There are claims that wine grape cultivars are either isohydric or anisohydric; the former maintaining, and the latter decreasing, their plant water status as soil moisture declines. However, available information is inconsistent. There are those that show an existence of a continuum in cultivar response to soil moisture rather than a distinct categorization. Others even show both behaviors in the same cultivar grown in different environments. In this study we investigated the behavior of 30 own rooted *Vitis vinifera* cultivars during successive drydown and rewatering cycles over two growing seasons in arid eastern Washington (<200 mm annual precipitation).

Material and methods

A field trial was conducted in 2021 and 2022 in a drip-irrigated research vineyard in Washington's Yakima Valley. All cultivars were fully irrigated through bloom, then the soil was subjected to two drydown cycles to create a gradual soil water deficit. The first cycle began at fruit set, and the second at veraison following irrigation to replenish soil moisture to near field capacity. Fortnightly measurements of soil moisture, predawn and midday leaf water potential (Ψleaf), and gas exchange were conducted throughout the season. Volumetric soil moisture data were converted to relative extractable soil water (ESW) to normalize the influence of soil texture. These measurements were supplemented with measurements of shoot growth and canopy size.

Results

Findings showed that the cultivars differed in shoot growth, and this was consistent in the two growing seasons. In both seasons, there was a two-fold difference in shoot growth between the most and the least vigorous cultivars. Moreover, the unusually wet spring in 2022 caused most cultivars to grow more vigorously than in 2021. Regarding soil moisture, all cultivars initially behaved isohydrically as the soil dried down from ESW ≥ 1.0 but became anisohydric at ESW < 0.4. Even cultivars with "known" contrasting responses to water stress (Grenache and Sémillon) and those with varied shoot growth responded similarly. In addition, there was a steeper decline in cultivars' midday Ψleaf with moisture stress in 2022 than in 2021. These findings imply that wine grape cultivars are both isohydric and anisohydric, depending on soil moisture. They are isohydric under no and mild soil moisture deficit conditions and become anisohydric as moisture stress worsens. Canopy size may be a poor predictor of a vine's physiological behavior under drought stress. But bigger canopies can dry the soil more quickly, leading to a greater decline in Ψleaf.

Keywords: Leaf water potential, Water deficit, Irrigation, Field capacity, Vine physiology.

1. Introduction

Frequent droughts and heatwaves make the understanding of drought tolerance a crucial step in crop improvement. In viticulture, the general understanding is that *Vitis vinifera* L. cultivars are either isohydric plants that maintain a constant leaf water potential (Ψleaf) regardless of the soil water potential (Ψsoil), or anisohydric plants that progressively lower their Ψleaf as Ψsoil declines (Hochberg et al., 2018). To many wine grape growers who rely heavily on irrigation to produce a crop in dry regions this knowledge simply means that the isohydric cultivars need less water compared to the anisohydric types. As such, the growers might be tempted to cut back water on the isohydric types and channel the water saved and/or apply more water on the anisohydric ones. So, are *V. vinifera* cultivars strictly isohydric or anisohydric? Could they be both?

The literature shows several inadequacies regarding the isohydric and anisohydric concept in *V. vinifera*. Firstly, the concept is based mostly on the relationship between stomatal conductance and plant water potential (Schultz, 2003; Tardieu and Simonneau, 1998). Nevertheless, the literature indicates that a tighter stomatal control does not necessarily equate to greater regulation of Ψleaf (Martínez-Vilalta and Garcia-Forner, 2017). Secondly, iso-/anisohydric behavior in *V. vinifera* might be more of a continuum than a dichotomy (Levin et al., 2020). Grapevines are widely cultivated in environments ranging from cool/moist to warm/dry (Santos et al., 2020). Thus, *V. vinifera* cultivars may also show a range in stomatal behavior in response to soil moisture deficit. In fact, Bartlett and Sinclair (2020) showed that cultivars with more negative water potential were more associated with cooler regions and those with tighter stomatal regulation with warmer regions. Thirdly, there is the inconsistency of the iso-/anisohydric response of the same *V. vinifera* cultivars in various locations. For instance, there are studies that have classified Grenache, Cabernet Sauvignon and Malbec as isohydric (Hochberg et al., 2013; Pou et al., 2012) and Syrah, Chardonnay as anisohydric (Chaves et al., 2010; Gutiérrez-Gamboa et al., 2019; Prieto et al., 2010). Yet, others found the contrary (Hugalde and Vila, 2014; Prieto et al., 2010). Others have also hinted that cultivars can switch their behaviors depending on soil moisture (Rogiers et al., 2012; Zhang et al., 2012).

Taken together these inconsistencies suggest that *V. vinifera* cultivars are both iso- and anisohydric. Although there is some evidence (e.g., Zhang et al., 2012), the soil moisture thresholds associated with each behavior are still unclear. This study explored the response of 30 own-rooted *V. vinifera* cultivars to gradual soil moisture deficit for two growing seasons in arid eastern Washington (<200 mm annual precipitation). We hypothesized that cultivars were both iso- and anisohydric and that it was a matter of soil moisture that determined the type of behavior.

2. Material and methods

Field experiment, data collection and analysis

Field experiment – During the 2021 and 2022 growing seasons, a field trial was conducted in a drip-irrigated research vineyard planted in 2010 at Washington State University, Irrigated Agriculture Research and Extension Center, Yakima Valley, Washington, USA, to evaluate the responses to imposed water deficit of 30 own-rooted *V. vinifera* cultivars. The cultivars were grown side by side, on a spur-pruned, vertically trained system in south-north running rows at a plant spacing of 2.7 m (between rows) × 1.8 m (within rows). In both seasons, all cultivars were fully irrigated through bloom, and then the soil was subjected to two drydown cycles to create a gradual soil moisture deficit. The first cycle began at fruit set and the second at veraison following irrigation to replenish soil moisture to near field capacity.

Data collection – Fortnightly measurements of soil moisture (by neutron probe) and midday Ψleaf (by pressure chamber) were taken from fruit set through harvest. Midday Ψleaf measurements were collected between 1 and 3 pm on a fully expanded leaf between the 7^{th} and 15^{th} node from the growing tip of the main shoot. Soil moisture measurements were conducted under the same vines in two soil horizons (30 and 60 cm). These measurements were collected between 7 and 9 am.

Canopy size was estimated by measuring shoot length at fruit set and shoot number and pruning weight in winter. Shoot measurements were collected from two shoots, one on each cordon, of two vines in each replicated row of each cultivar.

Data analysis – To compare soil water deficit across different soil types, volumetric soil water content (VWC) was converted to extractable soil water (ESW), defined as the relative water content normalized to field capacity (FC) and permanent wilting point (PWP) as follows (Gerakis and Zalidis, 1998):

$$ESW = \frac{VWC - PWP}{FC - PWP}$$

The VWC in the vineyard is 30% at FC and 7% at PWP.

One-way analysis of variance (ANOVA) was used to analyze the effect of cultivar on canopy size. A regression model was used to determine the response of midday Ψleaf of the 30 cultivars to ESW.

3. Results and discussion

Canopy size varied considerably across the 30 *V. vinifera* cultivars. Compared to Cabernet Sauvignon, vigorous cultivars such as Tempranillo and Albariño had 10% to 20% longer shoots and the less vigorous cultivars such as Durif and Melon had 20% to 40% shorter shoots (Fig. 1). This was consistent in both seasons. But all cultivars had bigger canopies in 2022 compared to 2021, likely due to the wet spring of 2022 compared to drier conditions in 2021. This is because water availability has a direct impact on vine growth (Schultz and Mathews, 1988).

All cultivars maintained a constant, high leaf water status as the soil dried from >1 ESW to about 0.4 ESW, below which they lowered their water status (Fig. 2). Even cultivars with "known" divergent responses to water stress (Grenache and Sémillon; Fig. 3) and those with widely different canopy size (Tempranillo, Albariño, Durif, Melon; Fig. 4) showed the same response. However, cultivars with bigger canopies dried the soil quicker than did cultivars with smaller canopies.

The transition from isohydric to anisohydric behavior as the soil moisture deficit worsens observed in this study with *V. vinifera* cultivars is new. Although a similar isohydric–anisohydric transition has been reported, but this was only in a study with large, machine-pruned Concord juice grapes with mixed *Vitis labrusca* and *V. vinifera* ancestry (Keller et al., 2023). This transition confirms our hypothesis that *V. vinefera* cultivars are both iso-and anisohydric. Also new is the finding that there exists a soil moisture threshold at which one behavior transitions into another and may have implications on how different *V. vinifera* cultivars are irrigated in future.

4. Conclusions

Vitis vinifera cultivars are both iso-and anisohydric. The isohydric and anisohydric behavior may depend on soil moisture. All 30 cultivars tested here behaved isohydrically under no and mild soil moisture deficit conditions and became anisohydric as the soil dried below a common threshold. Canopy size may be a poor predictor of a vine's physiological behavior under drought stress. However, cultivars with larger canopies can dry the soil more quickly, leading to a greater decline in Ψleaf.

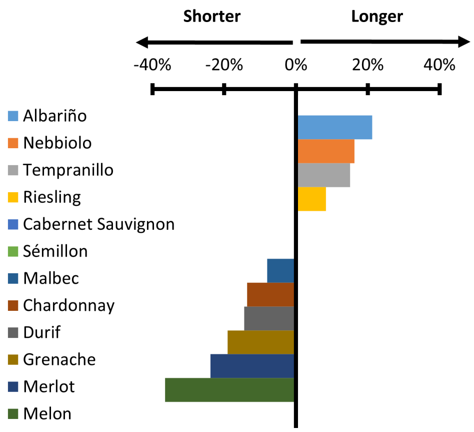

Figure 1. Shoot growth of selected wine grape cultivars compared to that of Cabernet Sauvignon. Shoot length was measured at fruit set from two shoots (one on each cordon) on two randomly selected vines per each replicated cultivar row.

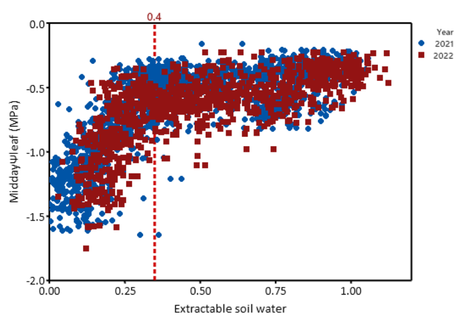

Figure 2. Response of midday Ψleaf of 30 Vitis vinifera cultivars to a gradual decline in extractable soil water in 2021 and 2022.

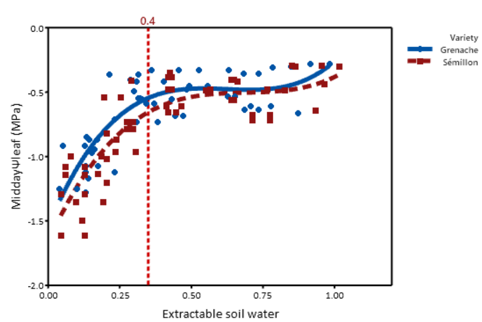

Figure 3. Response of midday Ψleaf to extractable soil water of two wine grape cultivars known for their divergent response to water stress. Data from each cultivar include all drydowns of 2021 and 2022.

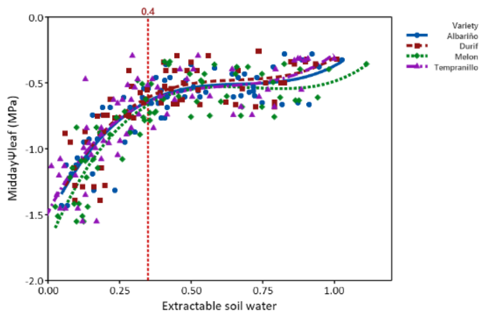

Figure 4. Response of midday Ψleaf to extractable soil water of wine grape cultivars with different vigour. Data from each cultivar include all drydowns of 2021 and 2022.

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