Irrigating Winegrape Varieties

A Question of Individuality

Joelle Martinez and Melissa Hansen

Joelle Martinez was a Ph.D. student in the viticulture and enology program at Washington State University. Her research interests included vine water relations, water stress physiology and irrigation management. She conducted research to unveil the variable responses among winegrape varieties to water stress, a project that will lead to the irrigation management of vineyards by variety and allow fine-tuning of fruit quality and water resources.

Melissa Hansen is research program director for the Washington State Wine Commission and works to make viticulture and enology research supported by the Washington wine industry more accessible to the state's growers and winemakers. Hansen was a journalist for nearly 20 years for *Good Fruit Grower*, a Washington-based magazine, and was involved with California's table grape and tree fruit industries for 15 years.

WINEGRAPE WATER MANAGEMENT HAS witnessed many breakthroughs during the last two decades, from deficit irrigation optimization to vine and berry water relation studies. Most recently, scientists have looked to optimize irrigation management for red and white varieties. Beside the emphasis on the different berry composition needed in reds and whites, many differences remain at the variety level. Such differences are present even when the vines are grown side by side.

The classic tale offered by past research describes winegrape varieties as isohydric, or pessimists, and anisohydric, or optimists.[1] It is thought that a pessimist variety, such as Grenache, maintains a high leaf water potential during soil drying by closing stomata and shutting down photosynthesis. The opposite can be said about an optimist variety, such as Syrah, that keeps stomata open but drops its water potential to low levels while maintaining photosynthesis.

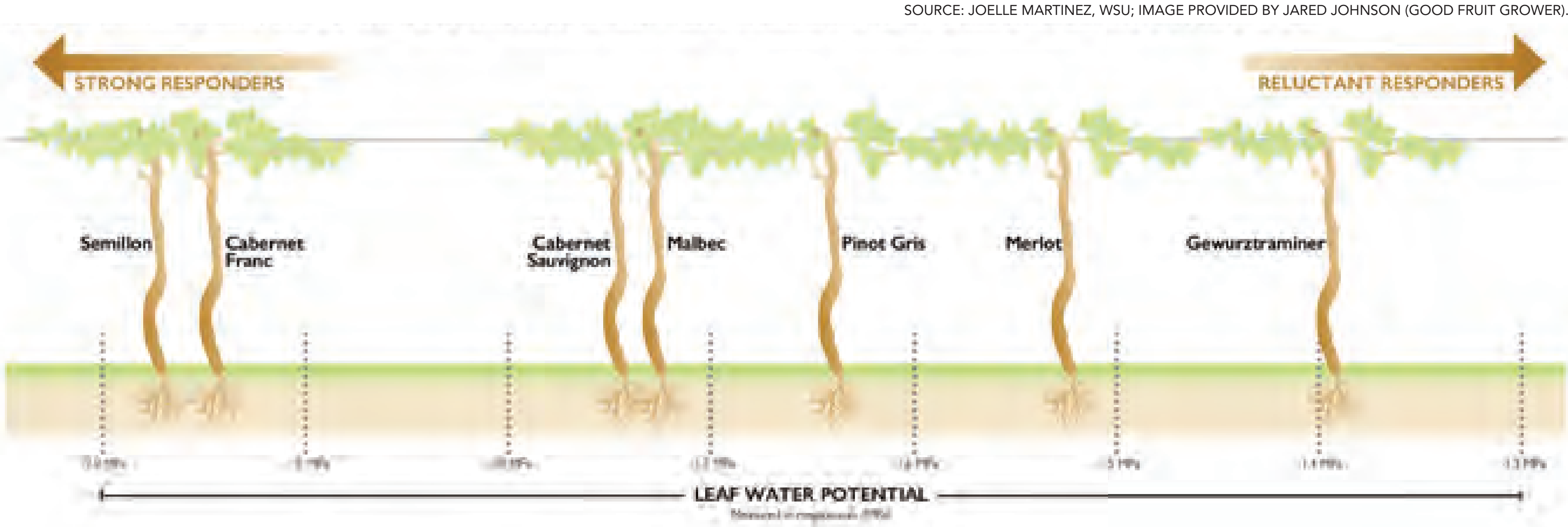
The Washington State Wine Commission, a state agency that represents all winegrape growers and wineries in Washington state, in conjunction with Washington State University (WSU) and the Auction of Washington Wines, has funded a four-year research project to reduce the guesswork in water management when different winegrape varieties are grown.

By following the water stress responses of 18 different winegrape varieties grown on their own roots side by side in a WSU experimental vineyard in Prosser, the research was able to better elucidate stress behavior classification of own-rooted winegrape varieties. It was shown that the varietal response to water stress cannot be put into two classes. Moreover, the results generated preliminary recommendations on a monitoring approach that growers could adopt if they want to optimize irrigation management of the differences seen in their vineyards.

Degrees of Response

A four-year study of winegrapes' leaf water potential versus soil moisture found that different varieties respond to water stress in varying degrees. Varieties such as Semillon and Cabernet Franc respond strongly. Gewürztraminer responds reluctantly while other varieties fall at various spots in the middle. Previously, conventional belief held that different varieties were either at one end (strong) or the other (reluctant).

SOURCE: JOELLE MARTINEZ, WSU; IMAGE PROVIDED BY JARED JOHNSON (GOOD FRUIT GROWER).



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Key Points

- Winegrape varieties cannot be classified in two separate categories of optimists and pessimists as it has been long proposed. Responses to water stress are more complex than this cookie-cutter approach and are specific for each variety. Recent research conducted on 18 winegrape varieties grown in Washington state on their own roots showed that there is a continuum of responses among varieties when it comes to vine stress management during soil drying.
- Stress monitoring in winegrapes should be done by variety and include at least two different tools to pin the "when" and "how much" water to add. For example, each variety in the research showed a different combination of the range and the pattern of leaf water potential decrease as the soil was drying.

Water Relations in Winegrapes

Water is taken up by the plant from the soil and exits to the atmosphere through leaf openings called stomata. This creates a continuous column of water, much like pumping water out of a well. The force for pumping the water is called the water potential. Water potential can be described as the intensity with which water is drawn to a medium and is expressed in negative pressure unit, such as MPa (megapascal, a measurement used to describe pressure ranges in hydraulic systems).

The lower (more negative) the water potential of a medium, the drier the medium is, and the stronger it can draw water to it. The water potential of a leaf is lower than the water potential of a wet soil, and thus, water is drawn from the soil to the leaf. The lowest water potential is that of the atmosphere so the water evaporates from the leaves. As a result, water flows up the plant following a gradient of water potential from high in a wet soil to low in the dry atmosphere.

As the soil dries out and the soil water potential decreases, the leaf water potential should decrease in parallel so that water pumping from the soil to the leaf remains constant. However, there comes a point when water potential becomes too low, much like a pump force would exceed the well capacity, and the water column would end up breaking. This is not desirable in plants and leads to air entering the system, which prevents water from being further conducted and leads to irreversible damage. This is why the leaf water potential should not drop below a certain value that draws the limit for water uptake.

On the other hand, when the leaf water potential drops with the drying soil, it will directly affect plant growth, by allowing vigor to decrease, giving the grower the ability to control canopy size. In winegrape production, irrigation is withheld so that leaf water potential drops enough to reduce canopy vigor but not too much to avoid permanently affecting the ability of the plant to extract water. To stay in this sweet spot, growers can monitor the leaf water potential using a pressure chamber, which helps answer the question of "when" to apply water.

However, the exact values to aim for and the amount of water to apply remain blurry. It has long been accepted that there is a difference among winegrape varieties in the way they respond to soil water depletion. Some varieties have been classified as "optimists" since their leaf water potential keeps decreasing as the soil is drying. They are viewed as optimists because they exploit all soil water, hoping that more will be available later. A typical optimist variety is Syrah.

On the other hand, some varieties have been classified as "pessimists" since their leaf water potential does not decrease noticeably as the soil is drying. Instead, the leaf water potential remains almost constant as these varieties close stomata in anticipation that water supply will eventually deplete. Like a thirsty person in the desert, they meter out their water use. Ever since this two-category classification emerged, it has led to many contradictions when trying to place a variety of interest in either category. This classic tale has proven incorrect.

Part of the problem is that the same grape variety can behave differently under different environmental conditions. For example, a root mass more developed in one vineyard than another vineyard can lead to the same variety tapping water from deeper soil layers. The leaf water potential will thus remain at higher values when irrigation is withheld compared to the vineyard where root volume was more constrained. In the shallow-rooted vineyard, the variety would be classified as pessimist, showing higher water potential ranges, while in the deep-rooted vineyard, the variety would be classified as optimist.

Similarly, differences in canopy management can impact transpiration into the atmosphere and extraction from the soil, resulting in the same variety being classified in one vineyard as optimist and in another vineyard as pessimist. As a result of these management and environmental influences, the cookie-cutter approach to classify winegrape varieties into two defined categories lacks accuracy. Moreover, this approach leaves no room for continuity across grape varieties. There are approximately 5,000 winegrape varieties. A more flexible approach to represent water stress responses among varieties is needed than just two categories.

Research Approach

To remove the guesswork of irrigating winegrapes by grape variety, a large number of different winegrape varieties grown under the same environmental conditions in eastern Washington were monitored during soil dry-down cycles. The goal was to characterize how the leaf water potential in different winegrape varieties behaves as soil moisture decreases while controlling for the influence of environmental elements, such as soil type, canopy management style, vapor pressure deficit, rootstock material and plant age.

Eighteen winegrape varieties were studied. The vines were planted in 2010 in an 8-acre research vineyard on their own roots with 6 by 9 foot spacing. Soil texture for all varieties in the study was Warden silt loam. The vines were dual-trunked/bi-laterally trained with loose vertical shoot positioning. The vineyard was drip-irrigated using regulated deficit irrigation followed by refilling the soil profile after harvest to prevent cold injury to roots. Data was collected from 144 vines.

The experiment was repeated over four growing seasons (2015 to 2018). During each year, the soil was allowed to dry from fully watered to dry, reaching a low average of 10 percent soil moisture level (permanent wilting point estimated at 7.6 percent for this soil) by withholding water until signs of severe stress showed in the vineyard. Water was then replenished, and another dry-down cycle begun.

Each week during a dry-down cycle, leaf water potential was monitored with a pressure chamber for each variety at midday; during this time of the day the atmosphere is at its driest and the vine is under maximal water stress. In parallel, soil moisture was measured with a neutron probe using access tubes located under the data vines. Variability was evaluated by replicating each variety in four groups of five vines. Two vines from each group were measured, for a total of eight vines per variety across the vineyard.

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A Semillon grapevine, with dual trunks and somewhat "loose" vertical shoot positioning, is part of a trial at Washington State University's research vineyard in Prosser, WA, that is studying responses to water stress of different wine grape varieties. The fruiting zone is three to four feet above ground.

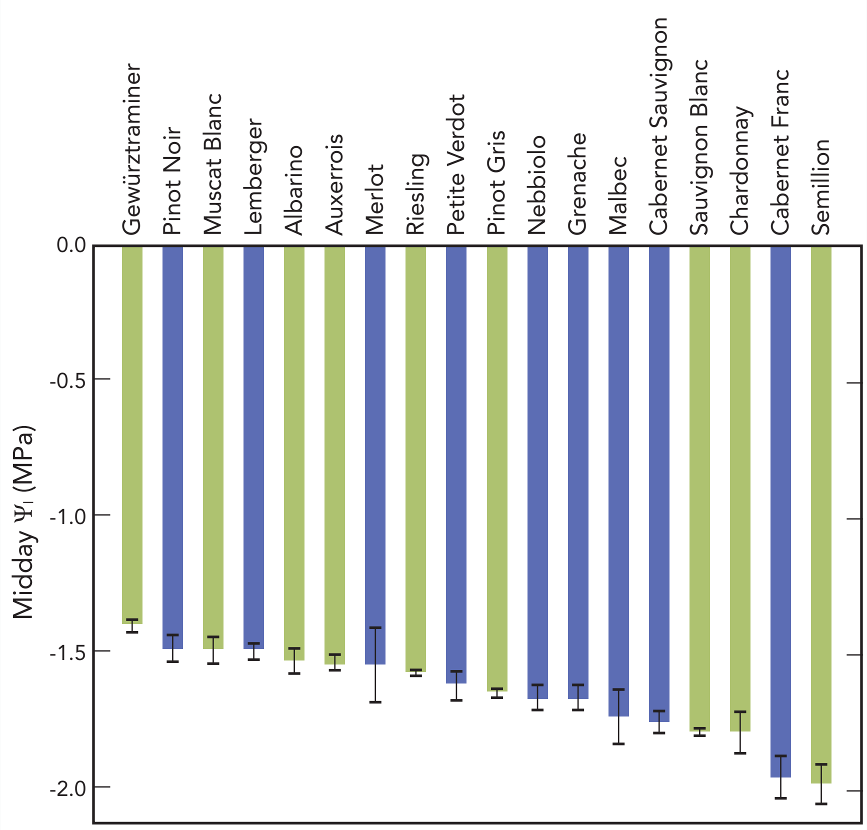

FIGURE 1 Minimal leaf water potential (Ψ_l) at which each of the 18 winegrape varieties operates at 10 percent soil moisture in a Warden silt loam (average of 2014 through 2018).

Although the grape variety irrigation research seems simple, it is fairly innovative. Few field experiments have been conducted in which the water stress responses of a large number of winegrape varieties were explored, all while controlling for environment effects in a replicated design.

Grape Varieties are Nonconformists

Monitoring the minimal value of leaf water potential that each grape variety can reach during soil drying revealed a more complicated picture of the differences among grape varieties. The four-year results showed a continuum in the minimal leaf water potential values for different varieties. Of the 18 varieties studied, Gewürztraminer dropped its water potential the least at 10 percent soil moisture while Semillon dropped its water potential the most at the same soil moisture level (see **FIGURE 1**).

Because each grape variety was found to operate at a specific range of water potential (operating range), there was no apparent way to assign the varieties into groups. Moreover, the operating range of the 18 grape varieties was not captured by grouping the varieties into pessimist and optimist categories.

Grape varieties differed in how their midday leaf water potential decreased while the soil was drying. The varieties not only differed in the lowest point recorded during soil-drying but also in the trajectory they took to get there.

The classic optimist tale considered a linear decrease in leaf water potential with decreasing soil moisture. Our results showed that leaf water potential did indeed drop in a straight line in some grape varieties but with varying slopes. Varieties like Semillon and Chardonnay showed a straight drop with a steep slope while Riesling and Muscat Blanc showed a straight drop with a milder slope.

Our results showed that some varieties, like Grenache and Malbec, could more or less maintain their leaf water potential, loosely following the isohydric "pessimist" model. In some varieties, however, this "plateau" could only be maintained until a certain soil moisture level, below which the water potential dropped in a straight line. Again, varying slopes were observed, before and after the shift, as seen by varieties in **FIGURE 2-B**. Our results indicate the presence of a continuum of trajectories among varieties, with no clear division of classifying varieties in two groups.

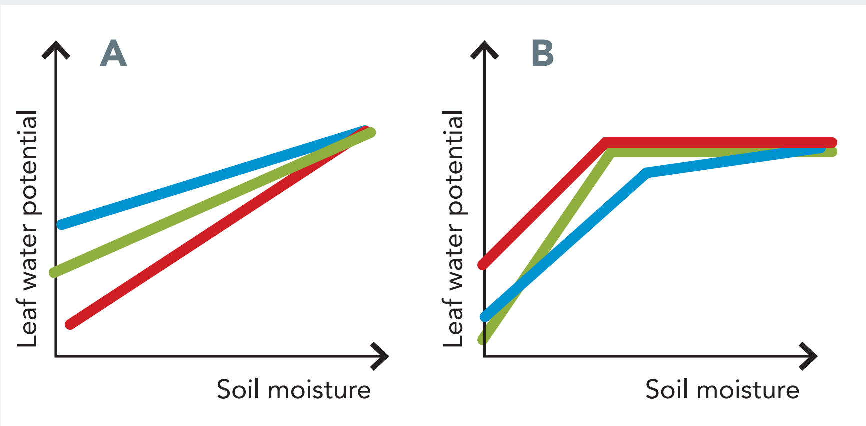

FIGURE 2 Observed trajectories of leaf water potential with decreasing soil moisture for different winegrape varieties.

(A) Example of winegrape varieties exhibiting linear drop with multiple slope values possible: Riesling (blue line), Chardonnay (green line), Semillon (red line).

(B) Example of winegrape varieties exhibiting plateau with multiple slope values possible, until a certain soil moisture is reached, after which a linear drop with multiple slope values possible: Cabernet Franc (blue line), Malbec (green line), Gewürztraminer (red line).

FIGURES 1-3 SOURCE: JOELLE MARTINEZ, WSU

In addition, there was no relation between the operating range of water potential and the trajectory it follows during soil drying. For example, Cabernet Franc started with no decrease in water potential down to 14 percent soil moisture, below which the water potential decreased linearly. However, this variety still managed to maintain a low water potential (low operating range) similar to Semillon, a variety that decreased its water potential in a straight line.

Both the operating range and the trajectory that water potential follows with the drying soil are a continuum of values between grape varieties. It would be most accurate to characterize the water potential behavior of each variety alone, and in conjunction with soil moisture measurement, when irrigation is withheld. Our work shows that winegrape varieties have specific responses of stress establishment with soil moisture decrease that need to be characterized and managed independently.

Practical Implications

Leaf water potential is a powerful indicator of the stress level a vine is experiencing since it directly affects vegetative growth and vigor control. Given that the relationship between leaf water potential and soil moisture is specific for each grape variety, we recommend that growers managing different winegrape varieties in the same vineyard and soil type characterize this relation for each variety. Information is needed on how both soil moisture and leaf water potential are changing together for each variety under a certain set of environmental conditions.

Determining when and how much water to apply based on soil moisture alone may not lead to the same level of leaf water potential or guarantee the same desired stress level in different varieties as shown in FIGURE 3.

This explains why some grape varieties are a challenge in terms of their canopy management when a uniform irrigation strategy based on soil moisture monitoring alone is used in a vineyard planted with different varieties. If we refer to Figure 3-B, watering Cabernet Franc an extra 2 percent of soil moisture from 12 percent to 14 percent will increase the water potential to -1.5 MPa, which may be a desirable stress goal. However, this 2 percent soil moisture addition would be inadequate for Semillon (3-A) or Albariño (3-C) since it will increase the water potential to -1.3 and -0.9 MPa, respectively, due to the steep trajectory and/or the high operating range present in these varieties.

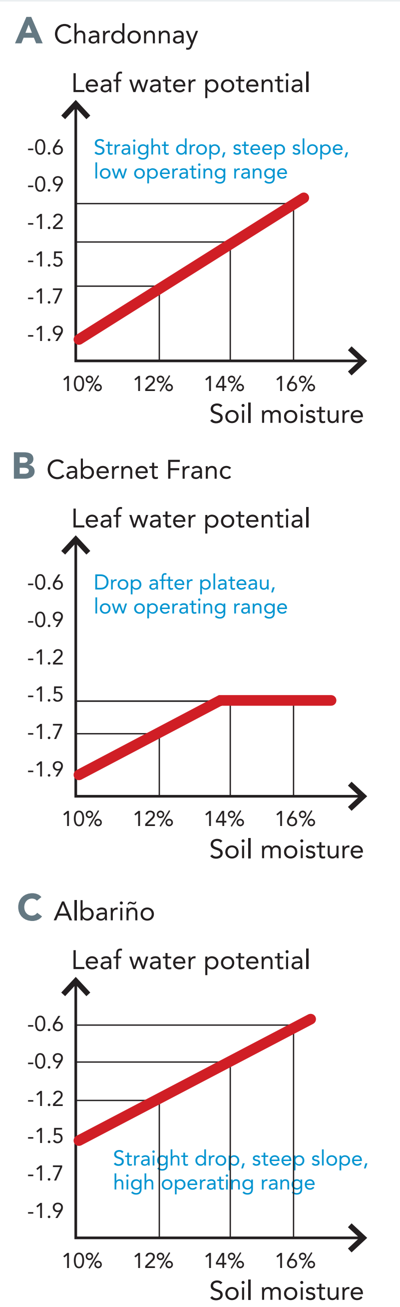

FIGURE 3 Examples of possible combinations of leaf water potential trajectory and operating range, during soil moisture depletion, for different winegrape varieties.

Similarly, estimating how much water to apply once a desired level of leaf water potential is reached, without understanding the specific relation between water potential and soil moisture for that variety, could lead to less than optimal management. For example, adding water to remain around -1.5 MPa in Chardonnay (3-A), should be done very carefully because any excess water in this variety might generate a fast increase in leaf water potential and stimulate regrowth in the canopy. This is not the case in Cabernet Franc (3-B), which shows no increase in water potential above 14 percent. Adding more water will not decrease the level of stress in this grape variety.

Proposed Irrigation Approach

Our experiment generated a monitoring approach to follow if we were to optimally manage irrigation of a vineyard planted with different grape varieties on their own roots.

Soil moisture monitoring varies in its sophistication level among commercial vineyards. Although leaf water potential is not always used to monitor vine stress, the study demonstrated that both variables—one related to soil moisture and the other to vine stress—should be concurrently monitored during a dry-down for each variety.

This approach can be summarized as follows:

1. **Understand each variety individually:** How fast and how severely does the vine respond to different levels of soil moisture depletion? Record parallel values of water potential and of soil moisture from well-watered to dry soil for each variety in the vineyard.
2. **When to water each variety:** Decide on your desired stress goal and your desired water potential at various growth stages based on vintage and wine quality history.
3. **How much to water-back each variety:** To stay in the range of stress desired for a particular variety, decide how much to increase soil moisture, without causing too much increase in leaf water potential, based on the information gathered in step 1.
4. **Repeat for every block separately:** Each vineyard block has its specific environment of soil, temperature, rootstock material, humidity etc. that impacts water stress management in a certain variety.

Bottom Line

Winegrape varieties cannot be grouped into a few categories in terms of how they respond to water stress. Rather, each variety should be treated individually. A grower should aim to characterize how both soil moisture and water potential change together for each variety to make sound decisions on when and how much to irrigate. Using only one of the monitoring tools without the other may lead to inaccurate management of the variety differences present in a vineyard. WBM

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