

## A Comparison of the Three Most Common Methods of Measuring Vine Water Status

In the last decade, deficit irrigation has become commonplace as a method to improve winegrape quality. By imposing a predetermined, measurable level of water stress at a particular stage of vine growth, winegrowers have found that they can enhance the intrinsic value of their crops while they save money on labor and their energy bills and help preserve a very valuable natural resource. Because plant water status is a key metabolic indicator, its actual measurement provides a valuable indicator of vine growth and winegrape development. This measurement can be accomplished in a number of ways, but plant-based monitoring is the most reliable, practical approach because vine vegetative and reproductive growth processes relate directly to plant water status and only indirectly to soil moisture and atmospheric conditions. The pressure chamber, also called a pressure bomb, is an invaluable tool for measuring vine water status in the field. It is commercially available at a reasonable cost, it's portable and measurements are done in real time so irrigation management decisions can be made as data is collected.

There are basically three ways to measure vine water status using a pressure chamber. These include predawn leaf water potential (PDLWP), midday leaf water potential (LWP) and midday stem water potential (SWP). The three methodologies vary mainly in the timing of the test and in the preparation of the leaf to be sampled. Because water potential can be effectively measured in these three different ways, there has been some confusion about which method is most reliable and accurate in a specific situation or environment. In 2002, L.E. Williams and F.J. Araujo published the results of a study they conducted comparing the three methods of measuring winegrape water potential and also correlating the data from those trials to other measures of soil and plant water status (Williams, L.E. and F.J. Araujo, 2002. Correlations among predawn leaf, midday leaf and midday stem water potential and their correlations with other measures of soil and plant water status in *Vitis vinifera*. J. Amer. Soc. Hort. Sci. 127(3): 448-454). The conclusions presented in the balance of this review are a restatement of the conclusions demonstrated in the Williams publication.

The differences in the three plant-based water status methods, stated simply, are as follows; measurements of midday water potential, either stem or leaf, should be taken in the one-hour period beginning thirty minutes prior to solar noon and commencing thirty minutes after solar noon. This short time limit has been the most common restraint to the use of midday leaf water potential in the field. A fully expanded leaf exposed to direct sunlight is chosen for the test. To measure midday leaf water potential, the targeted leaf, prior to excision, must be covered entirely with a small plastic bag that is wrapped tightly around the leaf and secured. This avoids any transpiration after the leaf is excised from the shoot. Within several seconds, the petiole of the targeted, bagged leaf is cut with a sharp razor as close to the shoot as possible. The covered leaf is then quickly placed in the chamber lid with the cut edge of the petiole facing outside and the leaf blade inside the chamber. The chamber is sealed and then pressurized with nitrogen. As the pressure in the chamber containing the leaf blade increases, the attendant carefully watches the exposed cut edge of the petiole for the appearance of a sap bubble. When the sap bubble appears, the corresponding

pressure is read from the chamber gauge. This pressure value is the leaf water potential, read in negative (-) Bars.

In comparison, midday stem water potential tests are done during the same time period as midday leaf water potential but the handling of the leaf is changed. In this test, a leaf on the shaded side of the canopy is chosen to minimize any possible heating effects. The leaf is wrapped in a black plastic bag that is covered with aluminum foil. This effectively stops transpiration and allows the leaf to come into equilibrium with the water potential of the stem. The bag is left on the leaf from 90 to 120 minutes. Then the leaf is excised and tested in the pressure chamber as stated above.

Lastly, predawn leaf water potential is determined using the same basic methodology as LWP, but the readings are taken beginning at 3:30am and commencing before sunrise, using fully expanded leaves. It has been assumed that before sunrise the vine is in equilibrium with the soil's water potential, therefore making PDWP a more sensitive indicator of soil water availability. But the obvious difficulty with the method is the timing: readings must be done prior to sunrise, making its practicality dubious.

For a measure of plant water status to be a sensitive indicator of water stress, it has been stated that it must be responsive to differences in soil moisture status and/or resulting growth differences due to water application. It should also be closely related to short- and medium-term plant stress responses and less dependent on changes in environmental conditions. For winegrapes, it would seem that LWP, SWP and PDLWP each meet these criteria. So the best indicator of which method is the most effective and yet most practical might be as simple as the ease of operation if the data from all three can be proven to be highly correlated. And the value of that plant-based stress data would be even greater if it could also be shown to be highly correlated with other indicators of vine water status. In the Williams and Araujo study, the other indicators of vine water status used for further correlation with vine water potential are net CO<sub>2</sub> assimilation rates (A) and stomatal conductance to water vapor (g<sub>s</sub>), both measured at solar noon, and soil water status (SWC), using a neutron probe.

The three indicators of vine water potential in this study were measured on both Chardonnay and Cabernet Sauvignon vines grown in the Napa Valley in the 1999 growing season. Because both fields were part of a study on the effects of deficit irrigation, all the vines had been irrigated weekly at various fractions of estimated vineyard evapotranspiration from berry set until the dates of measurements. Vine water status and leaf gas exchange were measured on two dates in the Chardonnay vineyard and one date in the Cabernet Sauvignon vineyard. Individual leaf replicates numbered six for each scion-rootstock combination and irrigation treatment in the Chardonnay vineyard on the first date, August 24, 1999 and five for each treatment in the Chardonnay on the second date, September 21, 1999. The individual leaf replicates for the Cabernet sauvignon on the only date measured, August 24, 1999 was also five. This produced eighty-six total data points.

Use of irrigation treatments at both locations resulted in a wide range of vine water statuses. The lowest values of PDLWP, LWP and SWP recorded for an individual leaf were -0.85, -1.85 and -1.65 MPa, respectively. The highest values of PDLWP, LWP and SWP were -0.02, -0.75 and -0.55 MPa, respectively. In most cases, significant differences among irrigation treatments for one measure of vine water status were also similarly different for the other two.

The test results showed that all three methods of estimating vine water status were highly correlated with one another. The best correlation was between midday LWP and midday SWP. All three methods were significantly correlated with soil water status in the Chardonnay vineyard and significantly correlated with net CO<sub>2</sub> assimilation and stomatal conductance in both vineyards. Interestingly, all three measures of vine leaf water potential were linearly correlated ( $r^2=0.93$ ) with berry weight and vine yield when measured the first week of October, 1999. These data would indicate that either measurement of midday leaf water potential would give a good estimate of the water status of grapevines.

Predawn leaf water potential has been used in many studies as the standard to which other measures of vine water status are compared. It is assumed that this is the period when the vine is in equilibrium with the soil water potential. It has also been demonstrated that season-long measurements of midday LWP have been shown to be highly correlated with the seasonal changes in SWC of treatments irrigated with differing amounts of water. That data and the data from this study indicate that midday LWP is reflective of the amount of water in the soil profile.

Because all three methods of estimating vine water status in this study were similarly correlated with SWC, applied amounts of water and with one another and were also significantly correlated with leaf gas exchange, the criterion that measures of plant water status should reflect the availability of soil moisture and/or applied water amounts or measures of plant water stress were met for all measures of leaf water potential under the conditions of this study. Critical values of midday leaf water potential, stem water potential and predawn water potential could be established and utilized to make such decisions as when to begin irrigating each season and the interval between irrigation events to maintain a specific degree of stress, based on the wine style desired. However, from a purely practical standpoint, measurement of midday leaf water potential would be the most convenient. The main limitation is the time frame allowable to assure consistency. In this study, that time was one half hour before and after solar noon. The short time limits the acreage or the number of vines that can be measured in a day. The time can be lengthened, however, if a calibration is done with several other environmental variables. Lastly, and importantly, it has been demonstrated that the individual making measurements of plant water status is a significant source of variation. It is, therefore, imperative that technicians be well trained in the use of the pressure bomb and the choice of leaves to sample.

In conclusion, in the study under review here, it was shown that midday leaf water potential, midday stem water potential and predawn leaf water potential values from two vineyards on three dates were linearly correlated with each other and with measurements of net CO<sub>2</sub> assimilation and stomatal conductance. In Chardonnay, they were highly correlated with measures of soil water availability, also. It can be assumed, then, that they all represent equally viable methods of assessing the water status of winegrape vines. So, in a practical situation, it may be more favorable to choose the method that best fits each manager's strategy, then be sure that method is followed precisely throughout the season. Although there is significant correlation between the methodologies, that does not suggest that it would be advisable or even admissible to interchange the methods in a vineyard in a given season. And, lastly, be

sure all technicians are well-trained to assure the consistency that is required in building a valuable database.