

Using Midday Stem Water Potential to Assess Irrigation Needs of Landscape Valley Oaks¹

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Abstract

In a number of deciduous tree crops a reliable pressure chamber measurement of water stress (midday stem water potential or SWP) has been recently developed and found to be closely related to both irrigation regime and tree physiological responses to stress. A standard pressure chamber is used for the measurement of SWP, but prior to sampling, the leaf is enclosed in a reflective plastic bag and allowed to equilibrate with the water potential in the stem at the point of leaf attachment. In this study, measurements were made on valley oak trees under a variety of landscape conditions in Napa and Sonoma Counties, CA. Measurements on leaves that were only allowed to equilibrate for relatively short times (10 to 15 minutes) were compared to the SWP as measured by adjacent leaves that were allowed to equilibrate for over 1h. As found in other tree species, a 10- to 15-minute covering period appears sufficient in valley oaks for interior canopy shaded leaves to equilibrate with SWP. Using SWP in valley oaks that were nearby construction sites or agricultural land preparation, we confirmed that water stress was associated with root damage caused by these activities. SWP was also sensitive enough to follow the development of and the recovery from water stress over a number of irrigation cycles in an individual tree. We believe that SWP will be a valuable tool to determine the water needs of landscape valley oaks, particularly those with damaged root systems, while avoiding the potential for root disease development due to over-irrigation.

Introduction

Pressure chambers were designed to measure the water status of plants, and have been commercially available since the 1960s. However, the measurement of leaf water potential with the pressure chamber, especially at midday when water stress should be at it's maximum, has proven to be of little use in diagnosing water stress and scheduling irrigation. This is due to high measurement variability and an unclear relation of leaf water potential to plant physiological performance (e.g., Sinclair and Ludlow 1985). A more reliable pressure chamber measurement of water stress (midday stem water potential or SWP) was developed by McCutchan and Shackel (1992), and found for a number of tree crops to be closely related to both irrigation regime and to a range of physiological responses to stress such as reduced vegetative

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and fruit growth (Shackel and others 1997) and reduced stomatal opening (Shackel and others 1998).

Oak trees in the landscape are often subjected to stressful conditions such as soil compaction, prolonged drought, over irrigation or direct root damage, and these conditions may impair root health. Impaired root system health and function should lead to increased levels of tree water stress, hence an objective measure of water stress in oak trees may allow for the diagnosis and treatment of root system problems before appreciable decline occurs. The objectives of this study were to evaluate sampling protocols for the measurement of midday SWP in valley oaks (*Quercus lobata* Nee.) under field conditions and to determine whether SWP could reliably reflect changes in oak water stress associated with root damage and irrigation cycles.

Materials and Methods

The methods for sampling and measuring SWP have been previously described (McCutchan and Shackel 1992). Briefly, a lower canopy, shaded leaf, located near the trunk or a main scaffold branch, is enclosed in a reflective plastic envelope to suppress leaf transpiration for a sufficient amount of time to allow the water potential of the leaf to equilibrate with the water potential of the stem at the point of attachment (Begg and Turner 1970) and is called stem water potential (SWP). Equilibration periods of 1-2h are common (McCutchan and Shackel 1992). Since the water potential in the stem is determined by soil water availability, plant transpiration and root and stem resistance to water movement, SWP changes throughout the day and is typically lowest at midday (from about 1:00 pm to 3:00 pm).

In this study, measurements were made on valley oak trees under a variety of landscape conditions in Napa and Sonoma Counties, California. Measurements taken of leaves that were allowed to equilibrate for only 10 to 15 minutes were compared to the SWP as measured on adjacent leaves that were allowed to equilibrate for over 1h. Thirty trees were used for this comparison: 9 trees in a Yountville vineyard, 7 trees along the Lake County Highway in Calistoga, and 14 trees at Santa Rosa Junior College, 6 in an irrigated turf location (Burbank Auditorium) and 8 in a nearby unirrigated site (Bailey Field). A study was also conducted from 1997 to 1998 on five trees located in the Dominus vineyard in Yountville, California. The vineyard was supplementally irrigated with a single line per row drip irrigation system, but all oak trees were at least 12 ft. from the nearest irrigation point. All of the oak trees were located along an ephemeral stream bed that ran through the vineyard, but one was located near a construction site, and the roots of this tree had been severely damaged during various phases of construction (*table 1*).

On three occasions (October 7, 1997, June 3 and August 3, 1998), SWP was measured on all of the trees at the Yountville vineyard site. From August 3 to November 15, 1998, SWP was measured on tree number 2, which received three localized sprinkler irrigations during this period to minimize tree water stress. Weather data was obtained from a nearby California Irrigation and Information System (CIMIS) weather station (#77, Napa, CA), and was used to calculate a fully irrigated reference SWP value based on midday vapor pressure deficit. The approach

was similar to that used by McCutchan and Shackel (1992), but in this case the values used were those developed for fully irrigated pear trees.⁴

Table 1—Size, crown condition, and notes regarding location and root/soil conditions for five valley oak trees growing in a Yountville, California, vineyard that were monitored between October 7, 1997 and August 3, 1998.

Tree No.	DBH (inches)	Crown rating (1 = Poor, 10 = Good)	Notes
1	47	3	Extensive construction related root damage, <50 ft. to the nearest vineyard irrigation line
2	39	2	Located at the edge of the stream bed, with many roots exposed by stream flow, 20 ft. to the nearest vineyard irrigation line
3	31	6	No apparent root disturbance, 15' to the nearest vineyard irrigation line
4	30	6	No apparent root disturbance, 12' to the nearest vineyard irrigation line
5	42	7	No apparent root disturbance, 18' to the nearest vineyard irrigation line

Results and Discussion

Measurements of SWP made on lower canopy, shaded leaves which had only equilibrated for about 10 to 15 minutes showed a significant correlation to adjacent leaves which had equilibrated for 1-2h (*fig. 1*). The slope and intercept of this regression were not statistically different from 1 and 0 respectively, and hence any equilibration time of 10 to 15 minutes or longer appears to be sufficient for the measurement of SWP in valley oak. In some cases the difference between adjacent leaves was substantial however, on the order of 0.5 MPa, and hence when an accurate estimate of an individual trees SWP is desired, it may be advisable to sample more than a single leaf per tree.

For the first three dates of sampling in the Yountville vineyard location, tree-to-tree variation was significant, with tree number 1, the root damaged tree, always showing the lowest SWP (most water stress), and tree number 5 generally showing the highest SWP (*table 2*).

These rankings in SWP were consistent with subjective crown ratings and the degree of root disturbance (*table 1*), with less vigorous crowns and more disturbed root systems generally associated with low SWP. It is interesting to note the consistency of tree ranking in SWP from October 7, when the soil profile was dry and SWP values were generally low, to June 3, when the soil profile had presumably not yet been depleted from the substantial winter rains of 1997/1998, and SWP values were both higher and with much smaller absolute differences in between trees. This indicates that impaired root health or impairment in other aspects of root water uptake may have chronic effects even under adequate soil water conditions.

⁴ Unpublished data: 1996 Research Reports of the California Pear Advisory Board.

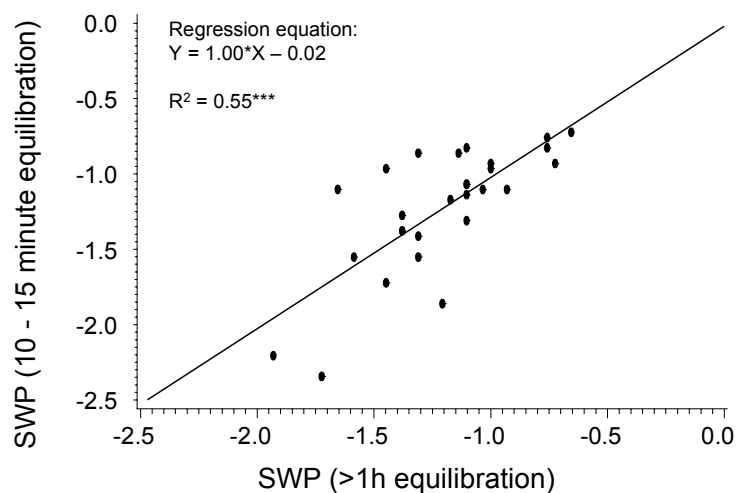


Figure 1—Comparison of midday stem water potential (SWP) measured on adjacent leaves with a short equilibration period (10 to 15 minutes, Y-axis), and a long equilibration period (>1h, X-axis). (***) denotes statistical significance of the regression at $P < 0.01$).

Table 2—Average SWP for individual trees on three dates in a vineyard in Yountville, California. Means followed by the same letter are not statistically different at the 5 percent level of Duncan's new multiple range test. Means are from two to four leaves per tree on each sampling date.

October 7, 1997		June 3, 1998		August 3, 1998	
Tree No.	SWP (MPa)	Tree No.	SWP (MPa)	Tree No.	SWP (MPa)
3	-1.04 a	5	-0.15 a	5	-0.83 a
5	-1.49 b	3	-0.17 ab	2	-0.87 ab
2	-1.84 c	4	-0.21 bc	3	-0.99 b
4	-1.86 c	2	-0.22 bc	4	-1.33 c
1	-2.29 d	1	-0.23 c	1	-1.85 d

In addition to comparisons among trees, for tree number 1 in the Yountville vineyard, SWP showed a consistent effect of sprinkler irrigation during the 1998 growing season (fig. 2). Immediately following each irrigation, tree number 1 exhibited SWP values that were similar to those expected for a fully irrigated pear tree (typically about -0.7 MPa), but as time after irrigation increased, SWP progressively declined to values of between -1.5 and -1.8 MPa. These data indicate that, as found in other species of tree, SWP responds in a straightforward and sensitive manner to soil water availability, and hence should serve as a sensitive indicator of plant water status in oaks. If a suitable baseline or operational range of SWP can be established for oak trees, then this sensitivity should prove useful in deciding whether or not a particular tree, whose root system has been compromised by damage or disease, requires periodic supplemental irrigation to prevent excessive stress. Based on the tree with the best crown rating in this study (tree number 5, table 1), we can suggest that SWP values of about -1.5 by the end of the growing season may not represent excessive stress for oak trees, but this must be established with additional research. As in pears, SWP values on the order of -1.0 MPa or above appear to be associated with high soil water availability, and hence we can further suggest that any supplemental irrigation when oak SWP values are in this upper range may be considered unnecessary. Because both over- and under-irrigation can be determined by measuring SWP, we believe that SWP will be a valuable tool to insure adequate soil moisture of landscape valley oaks, particularly those with damaged root systems, without encouraging root disease development due to over-irrigation.

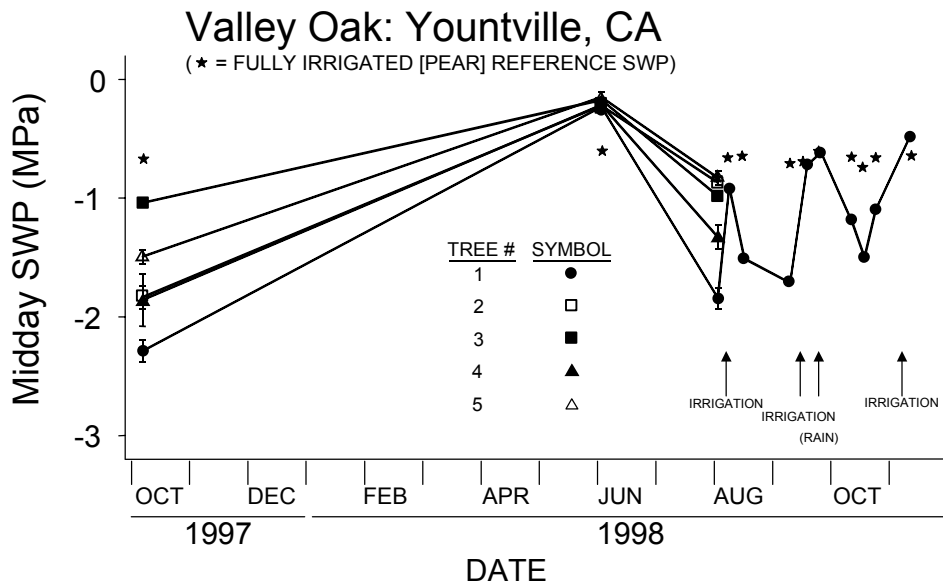


Figure 2—Midday SWP measured on five valley oak trees in 1997 and 1998, and for one of the trees (number 1), measured over three irrigation cycles in 1998. Also shown for reference are the SWP values expected for a fully irrigated pear tree under the same midday environmental conditions as the oaks.

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