FIELD EXPERIENCES WITH INTERPRETING MIDDAY STEM WATER POTENTIAL LEVELS FOR WALNUT

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ABSTRACT

A common concern with interpreting midday stem water potential (SWP) field data is distinguishing the effects of weather at the time of field measurement from the real effects of changing orchard water status. For example, SWP is –8.0 bars (more negative, more stressed) on one day of measurement and seven days later it is only –6.0 bars (less negative, less stressed) but no rainfall or irrigation has occurred between measurements and the soils in the root zone are drier. These results may be unexpected, why does SWP indicate less water stress seven days later when the soil-water deficit has increased? On the other hand, if field SWP measurements are taken under cooler, more humid conditions it seems reasonable to experience higher values (less negative, indicating less stress). In this example, field temperature was 19°F cooler, skies were overcast, and wind speed was 7 mph lower at the time of the second measurement. A variety of questions arise from such experiences: (1) Is SWP indicating the orchard water status or responses to temporary, abnormal weather conditions? (2) Can the effects of unusual weather be factored out? (3) Is there value in measuring SWP under abnormal weather conditions or can it result in misinterpretations?

Two methods have been proposed to address the effect of dynamic weather on SWP field measurements. One method uses a regression model to predict a “well-watered baseline” SWP based upon air temperature and relative humidity at the time of each field measurement. The difference between the baseline SWP and the field measured SWP (bars below baseline) is used to interpret orchard water status. Some advocate measuring the baseline rather than predicting it. This requires purposely over-irrigating selected trees to assure well-watered conditions and measuring the SWP of those trees along with a sample of normally irrigated trees. The second method uses field values for interpretation without an adjustment for baseline SWP. However, measurements on abnormally cool, overcast or extremely hot, windy afternoons must be avoided.

The method of comparing field measurements with a baseline SWP effectively expressed the extent of deficit irrigation in two Tehama County walnut orchards. At two other sites, field values of SWP were routinely higher (less negative, indicating less stress) than the baseline SWP values indicating the well-watered baseline may be underestimated for walnut and supporting the idea that baseline SWP should be measured rather than predicted. At a fifth site, SWP recovered to levels near the baseline SWP more than five weeks after the most recent irrigation. It appeared the baseline SWP prediction did not account for overcast conditions at the time of field measurement, perhaps because solar radiation is not considered in the prediction. At a sixth site, use of field values without comparison to a baseline SWP appeared to work reasonably well as long as measurements were not taken under severely abnormal weather conditions. Further studies may reveal that the latter method is simpler, offers enough accuracy, and is more suitable for on-farm adoption.
OBJECTIVES

- To understand how dynamic weather may affect field measurements of SWP.
- To gain experience with different methods of interpreting field measurements of SWP in walnut.

METHODS

Midday SWP was measured in six Tehama County walnut orchards during the 2000 and 2001 growing seasons. These orchards were located on a wide range of soil types and irrigated with either pressurized or gravity irrigation systems. The walnut varieties included Chandler, Howard, and Vina on paradox rootstock. All of the orchards were fully bearing except two sites, a third leaf Howard orchard and a fourth leaf Chandler orchard.

The first two orchards represent water deficits in 2001. The third and fourth orchards represent intensive irrigation in 2000 where water was applied at high frequency and exceeded estimates of real-time crop evapotranspiration for walnut by about 10 percent. The fifth orchard represents a flood-irrigated orchard and an instance where data was taken under abnormal weather conditions in 2001. The last orchard represents a site in 2001 where corresponding shoot growth measurements were taken and compared to SWP using two methods of data interpretation.

Stem water potential was measured with a plant stress monitoring console (pressure chamber) manufactured by Soil Moisture Equipment Corporation approximately weekly from early May through September. In the flood irrigated orchard care was taken to assure that measurements were taken 3 or 4 days after irrigation and just before the next irrigation. Measurements were taken between 1200 and 1600 hours on 5 to 10 trees per orchard.

Baseline SWP was calculated for each field measurement to predict the SWP that would be expected if the orchard was abundantly irrigated and soil-water was not limited. The regression model was developed by Shackel et al (personal communication, May 2001). The model is as follows:

\[
\text{Baseline SWP} = (-0.28 - (0.064 \times \text{VPD}) \times 10)
\]

where,

\( \text{VPD (Kpa)} = \text{hourly vapor pressure deficit} \)

\( \text{Baseline SWP (bars)} = \text{midday SWP under well-water orchard conditions.} \)

Vapor pressure deficit (VPD) was calculated using hourly CIMIS (www.cimis.water.ca.gov) weather data from station #8 located in Gerber, CA in Tehama County. It was calculated as follows:
Hourly VPD = VP x ((100/RH)-1)

where,

VPD = hourly vapor pressure deficit (Kpa)
VP = hourly vapor pressure (Kpa)
RH = hourly relative humidity (%)

The predicted baseline SWP is plotted against the actual field measurement of SWP for the respective days and hours of measurement for comparison. For one orchard, the difference between the baseline SWP and the field measurement are calculated and compared to actual field values to determine possible benefits to interpretation.

RESULTS AND DISCUSSION

Figure 1 illustrates the use of the baseline SWP along with the field measured SWP for two Chandler orchards irrigated with minisprinklers and under periods of deficit irrigation in 2001. The baseline SWP levels generally ranged from −4.0 to −5.0 bars throughout the growing season. On four occasions (May 30, June 20, August 15, and August 29) baseline SWP was lower than −5.0 bars and approached −6.0 bars, indicating warmer temperatures, lower humidity, and perhaps higher winds at the time of measurement. Field SWP levels were generally lower (more negative) in both orchards, ranging from 0.0 to -6.0 bars below the baseline. On four occasions (June 6, June 20, June 27, and August 2) SWP field levels recovered to the baseline SWP after irrigation. Overall, use of baseline SWP added perspective and understanding of the field measurements and the extent of water deficit at these two sites.

Figure 2 compares baseline SWP levels and actual field measurements in 2000 for two fully bearing, intensively irrigated Chandler orchards. Each orchard was irrigated with microsprinkler up to three times per week with water applications rates exceeding real-time estimates of crop evapotranspiration by about 10 percent. The baseline SWP ranged from −3.5 (cool, clear days) to nearly −7.0 bars (hot, windy days). Field measurements of SWP were generally higher (less negative, less stressed) than the well-watered baseline SWP, particularly from mid June through mid September. The field measurements were as much as 1.0 to 2.0 bars higher (less negative, less stressed) than the baseline. These results indicate that the prediction of a well-watered baseline are underestimated and may be a source of error in interpretation. These data also support the contention that the well-watered baseline should be measured rather than predicted.

Figure 3 presents the well-watered baseline SWP and field measurements of SWP for a flood irrigated Vina orchard in 2000 (arrows denote three irrigations on May 25, July 13, and September 5, 2001). Baseline values ranged from about −3.3 to −5.5 bars. In comparison, the field measurements indicated deficit irrigation with levels as low as −8.0 bars. Baseline and field data for May 16, July 6 and 13, and August 8 and 22 are examples of how the baseline SWP improved interpretation. On each date both the baseline and the field measured SWP increased (less negative) but the difference between them for each day changed only slightly since the previous measurement. This indicated cooler, more humid weather on those measurement days primarily affected the field value rather than change in orchard water status. On June 20, August 15, and August 29, baseline and field values both decreased (more negative, indicating more
stress) but the difference between them for each day showed moderate change since the previous measurement. This suggested that part of the response related to warmer, less humid weather at the time of field measurement and part from change in orchard water status since the previous measurement.

The baseline prediction and field measurement for July 3 is an example of the baseline not effectively accounting for weather at the time of field. Approximately five weeks had passed since the last irrigation and the three preceding field SWP measurements had been between –6.9 and –8.0 bars or -2.0 to -3.0 bars below baseline. However, on July 3, the field SWP recovered to –4.7 bars only 0.4 bar below the well-watered baseline but no irrigation had occurred. In response, plans to irrigate were delayed. When SWP was measured eight days later, field SWP was –7.2 bars or -2.9 bars below the well-watered baseline. It is hypothesized that the regression model did not accurately predict the baseline SWP for July 3 because it was an overcast day and the regression model does not use solar radiation as a variable in its prediction. According to hourly weather data at CIMIS station #8, net solar radiation on July 3 was at least five times lower than on June 22 and 29 (previous field measurements) and the following measurement on July 12. Another noteworthy observation was that field SWP three or four days after flood irrigation did not recover to the well-watered baseline levels.

A sixth location, a third leaf Howard walnut orchard under minisprinkler provided more experience in 2001 with interpreting field measurements of SWP. More discussions of this study are presented in this annual walnut research report in the article “Shoot Growth Response of Third Leaf Howard Walnuts to Midday Stem Water Potential”.

Care was taken to avoid measuring SWP at this site on overcast or abnormally cool afternoons. Table 1 presents shoot growth relationships to SWP field measurements (bars) and to the differences between the baseline SWP and the field SWP (bars below the well-watered baseline). Field levels of SWP averaged from –7.4 to –9.1 bars (range of –1.7 bars). When the baseline SWP value was subtracted from each field measurement to account for weather at the time of measurement, the adjusted SWP values ranged from an average of -2.4 to –4.8 bars below baseline (range of –2.4 bars). Subtracting the baseline SWP from the field measurements at this site appeared to improve interpretation by increasing the resolution of scale. When the SWP field data (bars) and adjusted SWP (bars below baseline) were compared to corresponding ranges of shoot growth, deviation from the mean SWP values were similar. Irrespective of whether the field measurements were used alone or adjusted by subtracting the baseline value, one standard deviation from the average SWP was observed to be ± 0.5 to 1.6 bars or bars below baseline.

These field experiences suggest:

- Interpretation of field measurements of midday SWP in walnut is sensitive to the weather conditions at the time of measurement. Effects of weather conditions at the time of field measurement must be distinguished from real changes in orchard water status to make correct interpretations.
Weather at the time of measuring SWP in the field can be successfully factored out, to some extent, by using a regression model to predict SWP for well-watered walnuts. However, these experiences suggest that the model might underestimate well-watered SWP levels and not effectively account for overcast conditions. Acquiring the necessary weather data and computing baseline SWP values for each day of measurement is a formidable task that may constrain adoption of this plant-based scheduling technique.

It appears possible to interpret field measurements of SWP without comparison to baseline SWP as long as measurements are avoided under highly abnormal weather conditions such as overcast, cool or extremely hot, windy days. However, some accuracy in the interpretation may be lost.

Tradeoffs appear to exist, calculating a well-watered baseline to assist interpretation of field measurements of SWP may increase the resolution of the measurement scale and accuracy but the procedure is more complex. Interpreting field values alone may compromise some accuracy but the procedure is much more suitable for on-farm adoption. At some point a choice may be necessary, but more research is needed that relates walnut tree and nut growth responses to both measures of SWP before an informed decision can be made.
Figure 1. Comparison of predicted well-watered "baseline" stem water potential (SWP) and field measured SWP in two Chandler orchards under different levels of deficit irrigation, 2001 season. "Baseline" effectively assists with interpretation.

Figure 2. Predicted well-watered "baseline" SWP compared to field measured SWP in two intensively managed Chandler walnut orchards, 2000 season. Field measurements higher (less negative, less stressed than baseline).
Figure 3. Predicted "baseline" stem water potential (SWP) compared to field measurements under deficit irrigation. Effects of overcast weather on interpretation.

Table 1. Shoot growth response to stem water potential (SWP).

<table>
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<tr>
<th>Rate of Shoot Growth (mm/day)</th>
<th>Frequency of Occurrence (no.)</th>
<th>Avg Corresponding SWP (bars)</th>
<th>SWP Standard Deviation (bars)</th>
<th>Avg Corresponding SWP (bars below baseline)</th>
<th>SWP Standard Deviation (bars below baseline)</th>
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<tr>
<td>0</td>
<td>36</td>
<td>-9.1</td>
<td>1.5</td>
<td>-4.8</td>
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<td>-8.0</td>
<td>1.4</td>
<td>-3.3</td>
<td>1.6</td>
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<tr>
<td>2.1 – 4.0</td>
<td>26</td>
<td>-7.8</td>
<td>0.7</td>
<td>-3.0</td>
<td>1.1</td>
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<tr>
<td>4.1 – 6.0</td>
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<td>-7.7</td>
<td>1.0</td>
<td>-2.6</td>
<td>1.0</td>
</tr>
<tr>
<td>6.1 – 8.0</td>
<td>10</td>
<td>-7.8</td>
<td>0.5</td>
<td>-2.3</td>
<td>1.1</td>
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<tr>
<td>&gt; 8.0</td>
<td>2</td>
<td>-7.4</td>
<td>0.8</td>
<td>-2.4</td>
<td>0.8</td>
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