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A newsletter from the University of California Cooperative Extension seeking to support wise and judicious use of limited water and land resources in the Northern Sacramento Valley.

In This Issue

This issue discusses a plant-based technique of directly measuring the water status in orchards to determine when to irrigate. Some individuals have simply described the method as "asking the tree when it needs water". The technique is still in development stages and this article is provided as an update. Portions of this newsletter are taken from an article written by Professor Ken Shackel, Department of Pomology at UC Davis. This article can be accessed in its full content at http://fruitsandnuts.ucdavis.edu/pressure-chamber.html, select Agriculture icon and Pressure Bomb Information tab. If you are interested in this topic, you are encouraged to visit this website as it provides more information and visuals. Thank you!

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What is a Pressure Chamber, a.k.a. "The Bomb"?

Simply put, the pressure chamber is just a device for applying air pressure to a leaf (or small shoot), where most of the leaf is inside an air-tight chamber but a small part of the leaf stem (the petiole) is exposed to the outside of the chamber through a seal. The amount of pressure that it takes to cause water to appear at the cut surface of the petiole on the outside of the chamber tells you how much tension the leaf is experiencing on its water: a high value of pressure means a high value of tension and a high degree of water stress. The units of pressure most commonly used are the Bar (1 Bar = 14.5 pounds per square inch).

Figure 1 shows two different types of pressure chambers. Presently, there are two manufactures of pressure chambers, PMS Instrument Company and SOILMOISTURE Equipment Corporation. Both manufactures have websites describing their equipment. Typical prices range from roughly $1400 for the "manual Pump-up" model on the left and as high as $4400 for the "gas pressured console" on the right in Figure 1. Other gas pressured models are available but are not shown in this picture cost about $2000 - $2800.

Figure 1. Example of manually operated “pump-up” pressure bomb (left) and pressure bomb console (right).

What is measured with the pressure chamber?

In simplest terms, the pressure chamber can be thought of as measuring the "blood pressure" of a plant, except for plants it is water rather than blood, and the water is not pumped by a heart using pressure, but rather pulled with a suction force as water evaporates from the leaves. Water within the plant mainly moves through very small interconnected cells, collectively called xylem, which are essentially a network of pipes carrying water from the roots to the leaves. The current model of how this works is that the water in the xylem is under tension, and as the soil dries, or for some other reason the roots become unable to keep pace with evaporation from the leaves, then the tension increases. Under these conditions you could say that the plant begins to experience "high blood pressure”. Figure 2 provides an illustration of the soil-plant-atmospheric continuum and of what the pressure chamber is measuring.

Because tension is measured, values are reported as negative numbers. An easy way to remember this is to think of water stress as a "deficit:" the more the stress, the more the plant is experiencing deficit water. The scientific name given to this deficit is the "water potential" of the plant. The actual physics of how the water moves from the leaf within the pressure chamber to the cut surface just outside the chamber is more complex than just "squeezing" water out of a leaf, or just bringing water back to where it was when the leaf was cut. In practice, however, the only important factor is for the operator to recognize when water just begins to appear at the cut end of the petiole.

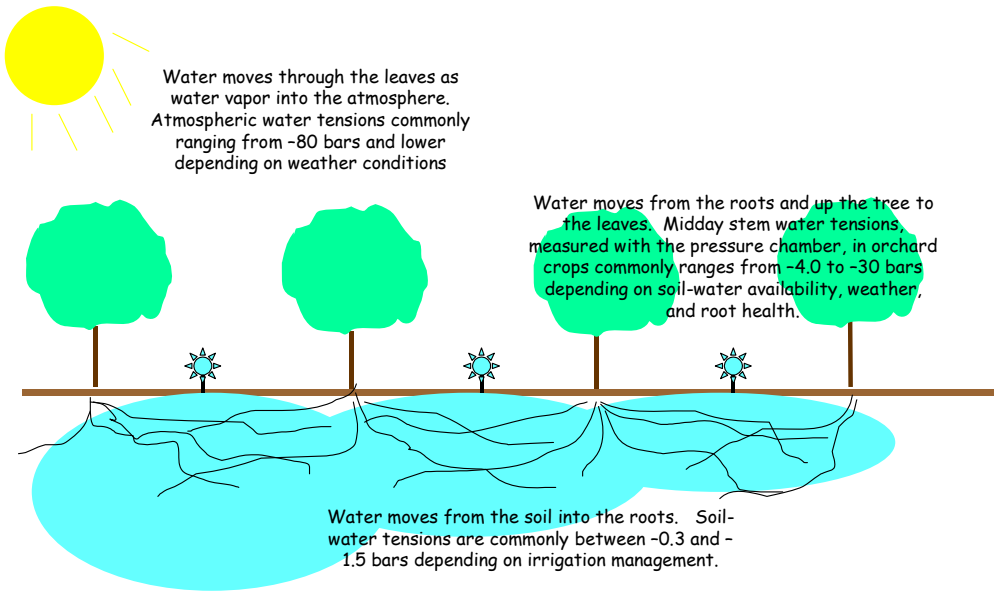
Why the interest in the pressure chamber?

In irrigation management of orchards, there are several approaches that can be taken to help determine when to irrigate and the pressure chamber is a tool that enables a plant-

based approach to be taken. Other scientific-based approaches include soil and climate based approaches. Examples of common tools used in soil-based approaches are resistance blocks, neutron probe, capacitance probes, tensiometers, hand augers, probes, or a shovel. Water budgeting by using crop evapotranspiration (ET) estimates from historic or real-time weather measurements is an example of a climate-based approach. Other non-scientific approaches may involve timing irrigation based on past experiences that have appeared to work well and have been convenient or have been mandated by some type of constraint such as when the water is available. Rising irrigation costs, the need for high yielding and high quality orchards, and greater competitiveness for water supplies are making the non-scientific approaches less acceptable.

Orchard crops have unique features where plant-based measurements offer some specific advantages that may be particularly useful in management. A measure of crop water status with a pressure chamber is more sensitive and can be more closely related to shoot growth and fruit development than either the measure of soil or climatic conditions. Larger, perennial trees and vines may have far reaching root zones that can be difficult to quantify and monitor with soil moisture measurement devices that have site specific placement and depth. This is particularly true for orchard crops grown under micro or drip irrigation where only a portion of the soil surface is irrigated. Stored water from winter rains in the non-irrigated areas may contribute to the crops water needs but it is difficult to know to what extent and when.

Figure 2. Illustration of the soil-plant-atmospheric continuum and water tension gradient, and how the pressure chamber enables field measurement of the plant-based portion.



Is the pressure chamber method practical and ready for on-farm adoption?

A quick review of the science-based knowledge gained in the past 10 years and advancements with measurement equipment and technique may help understand the level

of readiness. A decade ago, pre-dawn measurements were used for research purposes only, whereas, today measurements are taken mid-afternoon on a non-transpiring leaf. A less expensive manual "pump-up" pressure chamber has been developed and is manufactured commercially. Experience has been gained in prune, almond, and walnut and differences among the crops has been recognized. Only a very small amount of work has been completed with olive and citrus but there does not appear to be any reason to believe it cannot be developed for these crops. Crops such as pistachio and fig are problematic though because of the sticky, latex characteristics of the plant sap. It is also recognized that weather conditions at the time of measurement influence the results and a technique has been developed and field-tested for its effectiveness in understanding the influence of real-time weather on the field measurement and its interpretation.

Today, the proper sampling technique is much better understood and more easily implemented. It is referred to as measurement of midday stem water potential. The recommended sampling procedure is outlined below:

- Measuring stem water potential (SWP) between 1:00 and 3:00 p.m. is suggested but the sampling time can be expanded to 12:00 to 4:00 p.m. if more time is needed. **The sampling time must be limited to the afternoon to assure that the water potential is measured at peak crop water demand.**

- Ideally, take measurements on 10 trees within an orchard. The trees should be representative of the general orchard characteristics. If the orchard has two or more areas with distinctly different horticultural, growth and production, or soil characteristics, select trees for sampling that reflect these differences. If the soils, orchard, and irrigation system characteristics are reasonably uniform, a sample from 10 trees may represent substantial acreage (about 40 acres or possibly more). Plan on sampling the same trees about weekly throughout the irrigation season.

- Preparation of the leaf before sampling is simple but critically important to using the pressure chamber to accurately measure plant-water tension. A single, interior or shaded leaf is selected from the lower canopy of the tree (5 to 8 feet height) and covered with a light and water impervious bag for more than 10 minutes. In the case of walnut, the end leaflet from the compound leaf should be selected because it has a longer petiole and makes it easier to measure with the pressure chamber. The bag can either be homemade using black plastic as a waterproof inside liner and aluminum foil as the reflective outside liner. Masking tape can be used to assemble the inside and outside liners together into a small bag just slightly larger in dimension than the prune, almond, or walnut leaf that is sampled. If preferred, mylar bags (constructed of the same material used in the fancy birthday balloons) can be purchased from one of the pressure chamber manufactures. Covering the leaf interrupts transpiration and eliminates measurement errors that may be an artifact of the leaf selected, an example is whether the leaf is fully exposed to the sun, partially shaded, or completely shaded. By stopping the transpiration of the leaf, the non-transpiring leaf equilibrates with the tree trunk (stem), hence the term midday "stem" water potential and the pressure chamber measurement then indicates the water tension experienced by the whole tree.

- After the leaf has been covered for more than 10 minutes, it is ready to be cut from the tree. The leaf must remain in the bag when it is cut from the tree and when it is inserted into the pressure chamber. If the leaf is removed from the bag after it is cut it will begin to dry out and the water tension in the leaf will change immediately. No more than 45 to 90 seconds should elapse between the time the covered leaf is excised from the tree to the time the pressure chamber measurement is completed for that tree. Figure 3 displays the general steps of midday stem water potential measurement.

- It requires about 30 to 60 minutes to measure midday stem water potential on 10 trees, one leaf per tree. It is convenient to cover the leaves on all sample trees first, then return to the first tree where the leaf was covered to begin measurement. The time needed for the non-transpiring leaf to equilibrate with the tree trunk will have passed while the leaves on the other trees were being covered. For monitoring larger acreages, midday stem water potential measurements are taken more rapidly and efficiently with the more expensive, gas pressured console type pressure chamber, especially if the pressure chamber is mounted on an all terrain vehicle (ATV). It is reasonable to sample 40 to 60 trees in one afternoon. This may potentially represent a range of about 40 to 240 acres depending on the extent of orchard variability.

Figure 3. Using a pressure chamber to measure plant-water tension.

a) Basic tools to use a pressure chamber include a bag to cover the leaf, a razor blade knife to excise the leaf from the tree, and a magnifying glass to observe the end point of the measurement.

c) Inserting the bag into pressure chamber may require gently folding the bag and leaf without creasing or breaking the leaf. Notice the cut end of the walnut petiole in the center of the compression fitting.

b) Light and water impervious bag covering a terminal walnut leaflet. Folding the bag to snuggly fit around the petiole and paper clipping the bag to leaf will help secure it.

What are the critical management levels of midday stem water potential?

Dried plum has the longest history of research and field observation with midday stem water potential among the tree crops. In general, well-watered plant-water tension levels in dried plum are between –6.0 and –8.0 bars and modestly stressed dried plums may have plant water tensions of about –15.0 bars. Remember, the more negative the field value the

greater the plant-water tension. Extremely stressed dried plums that have been deprived of water have midday stem water potential levels lower than –25 bars tension. Dr. Shackel and numerous Farm Advisors who work with the dried plum commodity have developed management guidelines for dried plum. These guidelines can be accessed at the "fruitsandnuts" website referenced at the beginning of this newsletter by reviewing the publications listed for prune. In general, the benefits of using midday stem water potential in dried plum have been reduced irrigation costs, lower dehydration costs, and increased sugar without any negative effect on yield.

Experience with almond is increasing. Midday stem water potential in almond has been observed to range from –6.0 bars tension to as high as –34.0 bars tension. Plant water tension levels of –6.0 to –9.0 bars is an indicator of well-watered conditions where shoot growth should be optimized. Midday stem water potential levels of –14 to –18 bars is considered to be modest levels of plant-water tension that may actually have horticultural and economic value if these levels occur after hull split. Midday stem water potential levels of –25 to –30 bars plant-water tension indicate high crop stress and complete defoliation of trees has been observed at –32 bars plant water tension. Field research is ongoing in almonds to develop management strategies using midday stem water potential to maximize yield and quality, minimize irrigation costs, and achieve other horticultural value such as reduced incidence of disease.

Experience in walnut is not as advanced as with almond or dried plum. Only about three seasons of experience have been invested in walnut and midday stem water potential measurement. Much of the experience has simply been field monitoring of commonly occurring levels of plant-water tension in commercial walnut orchards. Figures 4 and 5 show common midday stem water potential levels observed in several commercial walnut orchards in Tehama County during the 2000 and 2001 seasons. The figures suggest that use of the pressure chamber to measure plant-water tension is an effective way to detect and respond to seasonal differences in crop water status. Based upon these experiences and others, it appears that levels of plant-water potential in walnut are quite different than for almond or dried plum. Midday stem water potential has been observed to range from –3.0 to –14.0 bars. Plant-water tensions of –4.0 to –6.0 bars are thought to be indicators of well-watered conditions but not over-irrigation. At levels of –11.0 to –12.0 bars, temporary wilting of leaves has been observed during mid-afternoon peak temperatures.

More research-based knowledge is needed to define critical levels of plant-water tension for perennial orchard crops and how they relate to tree growth, crop development, productivity, and water use.

What are some potential management applications of the pressure chamber?

Besides benefits to fruit and nut production and reductions in irrigation costs in bearing orchards, adopting midday stem water potential may be useful to manage pruning costs and late season vegetative growth as it relates to winter cold injury. Plant water tension is more sensitive to shoot growth than soil or climate based techniques of irrigation scheduling, therefore, it offers more precision in managing the cause and effect relationships between orchard water status and canopy growth. While it has not been

researched, it may also have application in conditioning seedling trees for successful grafting and it certainly has promise for ensuring adequate vegetative growth of non-bearing trees so they reach full bearing potential without delay.

Figure 4. Midday stem water potential in seven Tehama County walnut orchards compared to a "well-watered" baseline prediction, 2000 season.

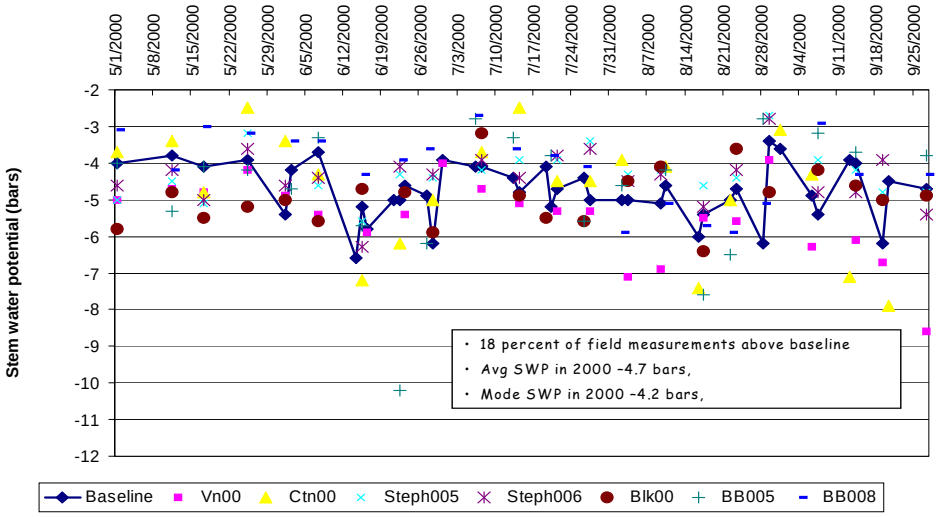
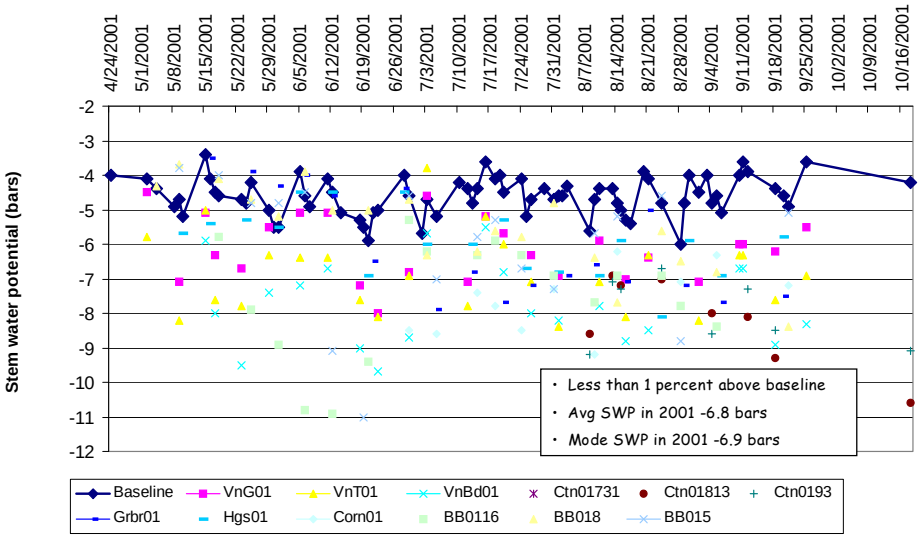


Figure 5. Stem water potential in eight Tehama County walnut orchards compared to a "well-watered" baseline prediction, 2001 season.



Are there limitations?

One debatable limit of using the pressure chamber is that it can only give an indicator of when to irrigate. It does not quantify how long to irrigate or how much water to apply. This raises the question whether a pressured chamber can "stand alone" as an irrigation tool. One approach is to use the pressure chamber in combination with climate-based ET scheduling. Real-time ET would serve to anticipate and plan irrigation frequency and irrigation set times for seasonal weather conditions and the midday stem water potential measurements would provide reliable feedback to adjust the ET-based schedule. In time, use of midday stem water potential may lead to redefining current ET levels for these crops. Another possibility is that the pressure chamber can be used alone and it is a matter of gaining enough experience in site-specific applications to determine how to operate the irrigation system. Using the pressure chamber and soil-based measurements in combination may also be valuable.