F. Methods for Determining When to Begin Irrigation

The decision of when to irrigate encompasses the desire to produce a specific quality crop and the soil resource and climate in a specific year. If winter rainfall is inadequate to fill the soil storage capacity to a normal season level one might irrigate to bring the soil to a normal bud break level. This practice should bring about normal or adequate shoot growth. If the vineyard normally has excessive shoot growth this may be an opportunity to reduce shoot growth by not adding irrigation water.

Once the season begins and shoot growth progresses the decision of when to begin irrigation depends on the level of water stress the vine experiences and how that relates to your overall strategy to produce quality fruit. This strategy includes the level of stress at which you plan to irrigate. There are a number of visual and measured indicators of water stress. In a Cabernet Sauvignon trial located in Hopland, California, a number of visual and measured indicators were evaluated. Treatments are explained in *Figure E-1*.

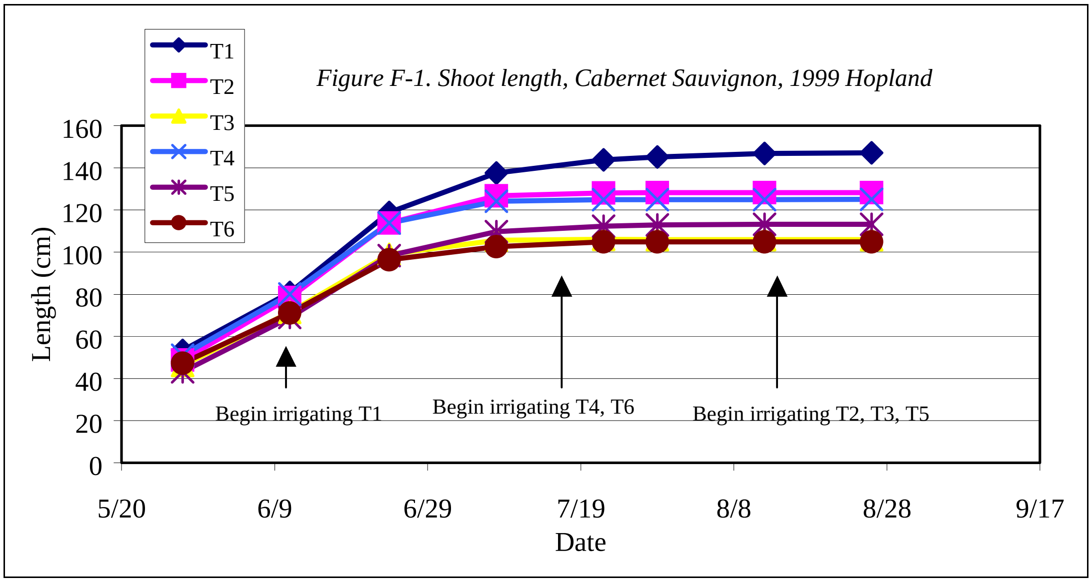
Visual and Measurements

Shoot length

Many of the symptoms of water deficits are visual and therefore can be observed or easily measured. However, for a method to be used to determine when to begin irrigation, it must not only be easy to use but also reliable. It should be able to predict a certain level of water deficits each season. A number of these indicators have been proposed and are in use to determine when to begin irrigation. They include shoot length, shoot growth rate, and tip ratings. Measurement of plant water status through direct methods using a pressure chamber and indirect methods using infrared devices to measure canopy temperature are also in use.

Shoot Growth

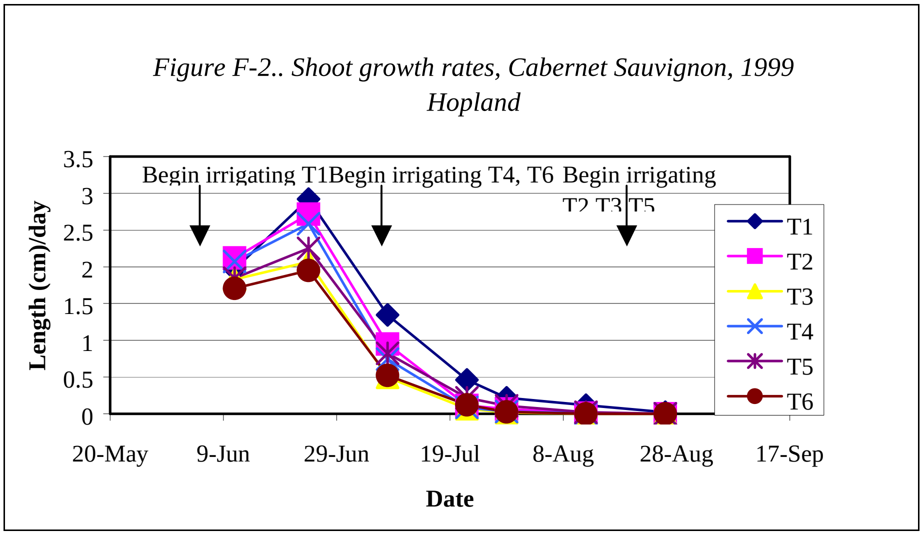
Shoot lengths are influenced by water deficits if the deficits occur soon enough to slow shoot growth more than the normal slowing as veraison is approached. *Figure F-1* shows shoot growth of the Cabernet Sauvignon vineyard near Hopland, California, for the 1999 season. The full irrigation (T1) began receiving irrigation June 1 while treatments 4 and 6 began on July16th at –12 bars. All non-irrigated treatments had stopped growing by July 9. Even with irrigation, the growth slows with time. It appears that shoot length is a better indicator of the seasonal strategy rather than an indicator of when to begin irrigation.



Shoot Growth Rate

Shoot Growth Rate

Shoot growth rate begins after bud break and increases with time to a maximum usually in mid-June then decline rapidly to near zero within about 30 days (*Figure F-2*). Shoot growth was about 0.75 cm/day when treatments 4 and 6 reached the –12 bars mid-day leaf water potential. Treatment 5 reached –12 bars after all growth had stopped on August 13th. In the year 2000 in the same trial, –12 bars level was reached at 0.2 cm/day growth rate. Based on the results, it seems the slowing of growth rate varies as does midday leaf water potential, (and therefore water deficits), but is not strongly related.



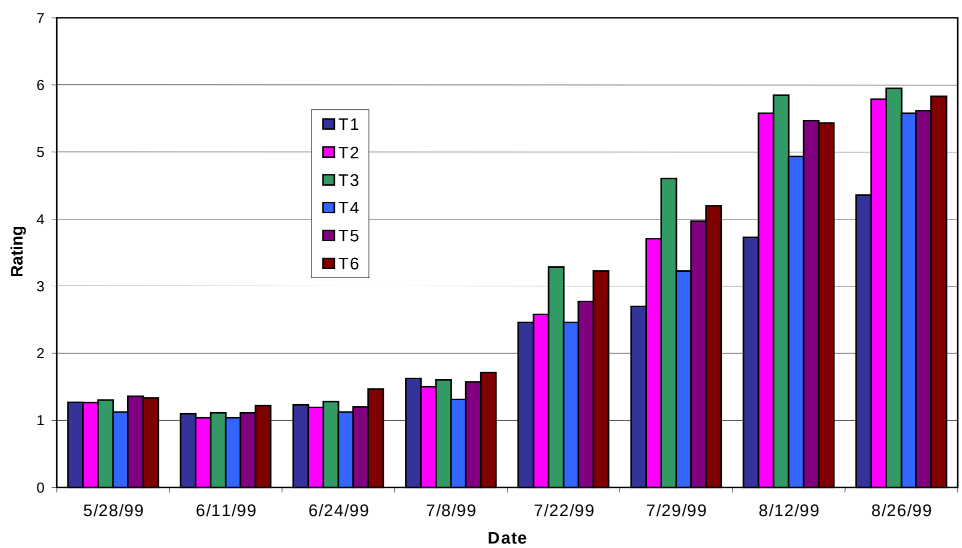
Tip Ratings

Shoot Tip Condition Rating

Another indicator used to determine when to begin irrigation is shoot tip condition. A rating system has been devised using numbers 1-6. A rating of 1 is when the tendril extends past the tip. A rating of 2 is when the tendril is equal to the tip; a 3 rating is when tendril is behind the tip. A 4 rating is tendril yellow, a 5 rating when there is no tendril present, and a 6 rating when the tip growing point is dead. The array of tip conditions in the vineyard is great. Often tips will span a rating of 3 levels. It is a challenge to obtain a representative value.

Figure F-3 shows the tip ratings for the 1999 Hopland trial. All readings prior to July 22 were from 1 to 1.5 and not significantly different between treatment and dates. The July 22 readings increased to an average of 2.7 with no significant difference between treatments including the T1, which had been receiving water since June 1st. On July 29th, the average had increased to 3.6 with no significant differences between the treatments irrigated on July 16th (T4 and 6) and those not yet irrigated (T2, 3, and 5). On August 12, the average of all yet to be irrigated treatments (T2, 3 and 5) was 5.4 which not significantly different from those irrigated four weeks earlier. Tip ratings do not seem to be responsive to irrigation unless it begins early in the season,. Based on the results, shoot tip ratings increase in a linear fashion once shoot growth declines

Figure F-2. Shoot tip ratings, Cabernet Sauvignon, 1999 Hopland

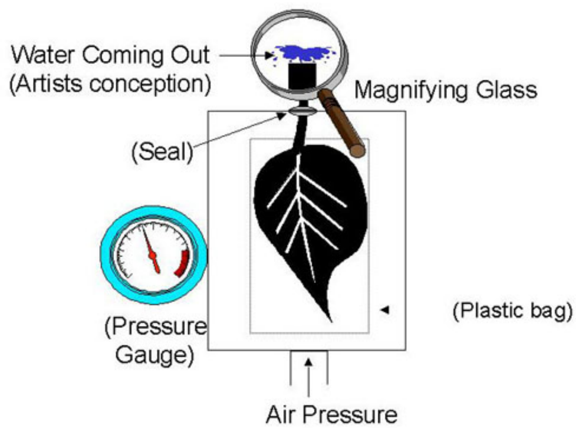


Midday Leaf Water Potential

Water is pulled from the soil up through the plant by forces driven by water loss 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 water in the xylem is under tension, and as the soil dries, or for if some other reason the roots become unable to keep pace with the evaporative demand from the leaves, the tension increases. Under these conditions, the vine experiences a water deficit.

The pressure chamber (often called a pressure bomb) is a device for applying gas pressure to a leaf where most of the leaf is inside the chamber but a small part of the leaf stem (the petiole) is exposed to the outside of the chamber through a seal (*Figure F-4*). The amount of pressure that it takes to cause water to appear at the end of petiole indicates the level of tension the leaf is experiencing. A high pressure means a high amount 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) and the Mega Pascal (1 MPa = 10 Bars).

Figure F-4. Parts of a pressure chamber.



Courtesy of PMS Instruments

The pressure chamber measures water potential using a positive pressure to overcome the force (tension) under which the water is held in the leaf. The tension is therefore expressed as a negative number. Typical mid season reading for a well-watered vine would be more than (less negative)-9 bars. The physics of how the water moves from the leaf to the atmosphere 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. However in practice, it is only important for the operator to recognize when water just begins to appear at the cut end of the petiole and note the pressure required.

Midday leaf water potential was measured weekly after June 1 (*Figure F-5*) in the Hopland trial. The full potential water use treatment (T1) maintained an average of more than -10 bars for the entire season. The all the other not yet irrigated treatments increased in water stress until irrigation was applied. In the case of treatment 4 was irrigated at a threshold of -12 bars whereas treatment 2 was irrigated at -14 bars. The use of the pressure chamber to measure mid-day leaf water potential appears to be and accurate and reliable method used as an indicator of when to begin irrigation.

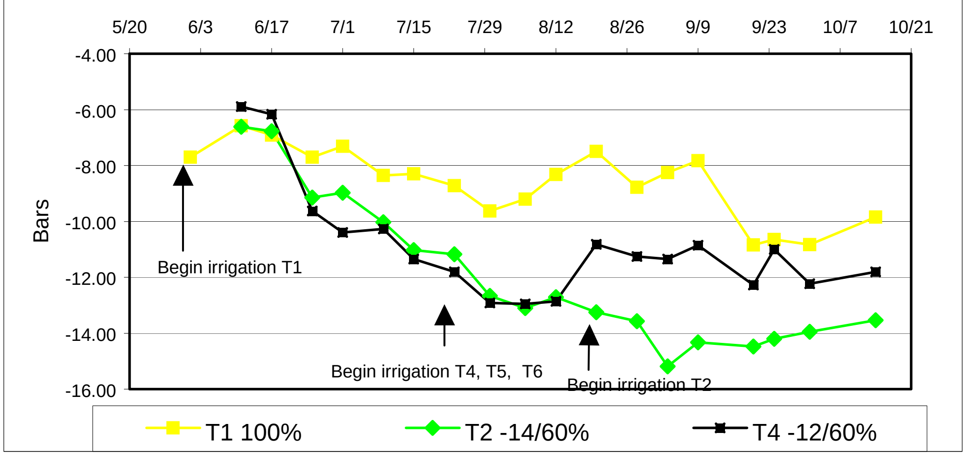


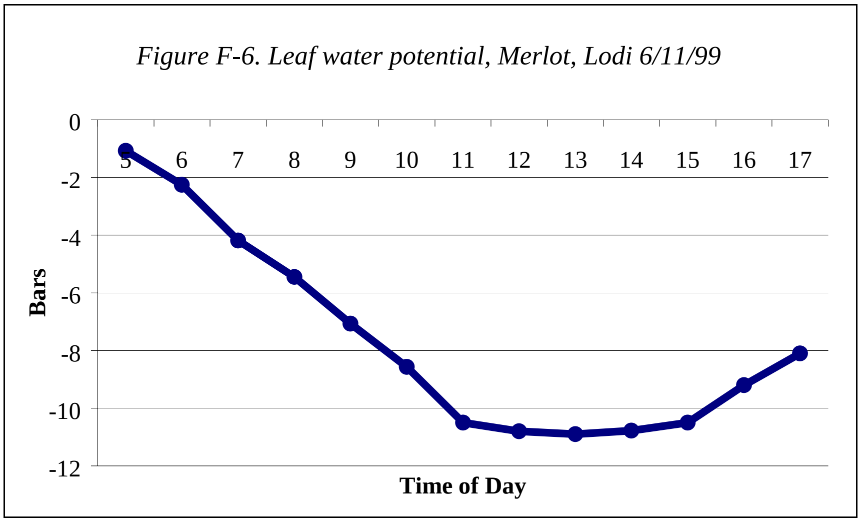
Figure F-5. Leaf Water Potentials
Hopland Cabernet Sauvignon 1999

Using the Pressure Chamber in Winegrape Irrigation Scheduling

The pressure chamber can be used to measure the severity of water deficits throughout the season. Water deficits are commonly used in the culture of winegrapes to produce desirable fruit quality. Using the pressure chamber to measure leaf water potential is a key step in determining when to begin irrigation. The pressure chamber can also be used to monitor the vine water status after irrigation begins.

When to Sample

The loss of water from the leaf is not constant throughout the day and varies with a number of factors including the environmental demand. This factor can be minimized however by measuring when the leaf water potential is relative static. Before the sun reaches the leaf in the morning, the vine has had a chance to uptake water and translocates it to all parts of the plant relieving to some degree the previous day's deficit. The leaf water potential is the least negative at this time for the day. As the sun contacts the leaf and heats the surface, the rate of transpiration increases, causing a more negative leaf water status. During the midday (solar noon), the water potential is again static at the daily maximum deficit (*Figure F-6*).



Factors that Influence Leaf Water Potential

The most important factors are:

- weather conditions at the time of sampling, and
- soil dryness

For fully irrigated vines with a healthy root system, weather conditions can have a large impact. *Table F-1* lists the effect of air temperature and relative humidity on fully watered prunus species. In all cases, hotter and dryer conditions cause a more negative water potential. For midsummer conditions in California, the values of water potential measured on a fully irrigated grapevine will typically be between -7.0 bars and -10.0 bars. To minimize the effect of temperature, measurements should be taken only when average conditions exist. For example: If average midday temperatures are 92ºF., measurements can be made on days with midday temperatures of 90 to 95º with no need to make an adjustment for climate. The same case can be made for low or high humidity days. Cloudy or foggy days or days with high winds should be avoided. The level of water stress as gauged by the mid-day leaf water potential can be generalized as shown in *Table F-2*.

Table F-1. Values of midday stem water potential (in Bars) to expect for fully irrigated prune vines, under different conditions of air temperature and relative humidity. (from Ken. Shackel)							
Temperature (°F)	Air Relative Humidity (RH, %)						
	10	20	30	40	50	60	70
70	-6.8	-6.5	-6.2	-5.9	-5.6	-5.3	-5.0
75	-7.3	-7.0	-6.6	-6.2	-5.9	-5.5	-5.2
80	-7.9	-7.5	-7.0	-6.6	-6.2	-5.8	-5.4
85	-8.5	-8.1	-7.6	-7.1	-6.6	-6.1	-5.6
90	-9.3	-8.7	-8.2	-7.6	-7.0	-6.4	-5.8
95	-10.2	-9.5	-8.8	-8.2	-7.5	-6.8	-6.1
100	-11.2	-10.4	-9.6	-8.8	-8.0	-7.2	-6.5
105	-12.3	-11.4	-10.5	-9.6	-8.7	-7.8	-6.8
110	-13.6	-12.6	-11.5	-10.4	-9.4	-8.3	-7.3
115	-15.1	-13.9	-12.6	-11.4	-10.2	-9.0	-7.8

Table F-2. Levels of winegrape water deficits measured by mid-day leaf water potential		
1	less than -10 Bars	no stress
2	-10 to -12 Bars	mild stress
3	-12 to -14 Bars	moderate stress
4	-14 to -16 Bars	high stress
5	above -16 Bars	severe stress

The relationship of soil dryness to water potential is straightforward: as the soil becomes dryer, water potential will become more negative given static climatic conditions. The pressure chamber measures effective soil dryness throughout the root system as a whole. This is very different from soil-based monitoring methods, which only measure the soil in part of the root zone.

Operation and Use of the Pressure Chamber

The leaf should be covered to prevent water loss just before removal from the plant. This practice minimizes water loss from the leaf. A small thin sandwich bag is most commonly used. The use of a bag reduces the loss of moisture from the leaf and lessens the need to complete the measurement quickly, thereby making measurements more consistent.

Vine Selection

It is important to select vines for measurement that represent the average vine condition. Select those that do not have obvious nutritional, disease or other visual problems. All vineyards are variable in terms of soil uniformity. If distinct differences in soil type/depth occur in the vineyard, select vines in each area or block to monitor differences. Mark vines so the same vines can be measured each sampling.

Sample Number

The number of vines, measured depends somewhat on the variability of the vineyard; however it is necessary to measure enough leaves to closely approximate the average condition. For a 20-acre vineyard, selection of six vines located in all parts of the vineyard should be adequate. Select two leaves per vine for measurement.

Leaf Selection

Select a young fully expanded leaf that has been in full sun for a few hours from the sun side of the vine. This will be the south side of east-west rows and the west side of north-south rows. Leaves in the interior of the canopies, which are shaded, will not accurately represent the maximum leaf water potential and should be avoided. Young leaves, which have not achieved full size, should also be avoided.

Sample Collection

It is most convenient to cover the leaf with a plastic sandwich bag then pick the leaf from the plant by gently snapping the leaf off at its connection to the shoot. Place the leaf into the flexible grommet in the pressure chamber gland and tighten only till enough resistance is felt to hold the petiole. Place the bagged leaf into the chamber and lock the lid in place. Re-cut the leaf petiole to a flat surface with a sharp razor. The time from leaf collection and tension measurement should be small delays will lead to erroneous values.

Measurement

With the leaf inside the chamber, the measurement is made by simply increasing the pressure in the chamber until water begins to come out of the xylem that is exposed at the petiole cut surface. Usually, the pressure at which sap appears is very. Using a hand lens, the water coming out of the petiole cut surface will glisten then as pressure increases it looks like an up welling of water from a porous surface.

The rate of pressure increase should be no more than 0.3 bars per second (Naor and Peres, 2001). A leaf with a reading of –10 bars would take a minimum of 30 seconds. Additionally, a fast rate of pressurization can cause an over estimation of water potential due to the time taken to stop the pressurization or read the gauge. If you overshoot, nearly the same value can be obtained if you re-measure the same leaf. You should also get nearly the same value (typically within 0.5 bar) when you measure adjacent leaves on the same shoot. Taking multiple reading on the same vine is a good way to check your reproducibility or compare the effects of different operators or techniques. The practice of rapidly increasing pressure to near the expected reading, then increasing the pressure slowly to the end point is discouraged due to unacceptably high error.

Problems

There are two common problems that can make the endpoint difficult to detect: bubbling and the appearance of non-xylem water. If there are breaks in the leaf inside the chamber, then air can be forced through the xylem and come out of the cut end. If this air pushes some water out, or if there is a little fluid from the cells at the cut surface, then the air coming out can bubble through the water, and it can look like there is water coming out when in fact it is just the same water being bubbled around. Discard the leaf and select another sample.

Non-xylem water can occur when you squeeze the petiole in the seal and water is physically squeezed out the cut end. If you think it is the endpoint, note the pressure, then dry off the cut end and raise the pressure a bit. If more water comes out of the cut surface, then it probably was the endpoint, but if it remains dry, then it probably was non-xylem water. If in doubt sample another leaf.

Reproducibility

Two or more leaves on the same vine should give almost identical readings, i.e., within about 0.5 bars. It is good practice for beginners to sample more than one leaf per vine to check for reproducibility of measurement. With experience, only one leaf per vine is necessary. You should also get nearly the same value if you re-measure the same leaf. This is done once you see the first endpoint by reducing the pressure enough that water disappears into the petiole, and then increasing the pressure until you see the endpoint again. Different vines can give different readings, however, and these will reflect real differences in water potential, so it is important to keep track of each vine separately.