IMPOSING WATER DEFICITS TO IMPROVE WINE QUALITY AND REDUCE COSTS

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Water deficits can improve winegrape fruit quality and reduce costs associated with irrigation. To maximize these benefits simultaneously, deficits must occur at specific vine canopy or fruit stages of development. Additionally, irrigation savings and fruit quality improvement varies with viticultural region, soil/water resource, variety, and production goal. This paper will discuss the conditions under which these improvements or savings can occur and management techniques used to achieve them.

Effects of Vine Water Supply on Vine and Fruit

The effects of vine water deficits can be both beneficial and harmful to the crop, depending on their timing and severity. When water deficits occur, the vine responds by closing pores in the leaf (called stomata) to limit water loss. Closing of stomata reduces water loss, creating a better balance between water demand and moisture extracted by the roots. This strategy of moderating the severity of water deficits works well initially when deficits are mild, generally limiting the effects to a reduction in vegetative growth. As water deficits increase in severity and duration, the stomata are closed for longer periods of time. Since the stomata are the entry points for carbon used in photosynthesis, severe water deficits limit the time the stomata are open which limits photosynthesis and the production of sugar leading to poor fruit quality and reduced yield.

Vegetative Structures

Water deficits occurring early season (bud break to fruit set) are usually not possible in most viticultural regions. Midseason (fruit set to veraison) water deficits are possible in soils that are shallow or coarse textured which limits (soil) water holding capacity. Areas, which receive low rainfall and most soils in drought years, can also make midseason deficits possible even in deep soils. During this period, shoot development (both shoot length and the number of laterals) can be restricted by water deficits. Reduced canopy development can result in reduced leaf area, which may be insufficient to develop and mature fruit in low vigor situations. However, when vine vigor provides adequate to more than adequate canopy to support the crop load, restricting or controlling additional in canopy (leaf area) may be desirable.

More severe water deficits, occurring in the period between veraison to harvest, can result in senescence of lower and interior canopy leaves providing more light to the fruit. Some loss of leaves in the fruit zone may occur without significantly reducing sugar accumulation. Moderate amounts of irrigation water during this period can successfully moderate water deficits, causing the desired effect. Excessive water deficits can cause defoliation, which can lead to sunburn, “raisining” or increased berry temperature, all causing reduced fruit quality.

Irrigation volumes should be adjusted to moderate, not eliminate, the deficit. Excessive irrigation during this period may cause resumption of lateral shoot growth, creating a competitive sink for photosynthate, which can increase shading, cause bunch rot in susceptible varieties, and delay fruit maturation and harvest.

A continued or increasing water deficit following harvest provides little or no benefit to vine and next year's crop. Root growth, which increases after harvest, can be restricted and can result in early-season nutrient deficiencies the next spring. In colder areas, low temperature injury of permanent wood fruiting structures can also result if too little or excessive water is applied.

Berry Growth

Berry growth begins after anthesis and pollination. It progresses at a rapid rate for 40-60 days. In this period, called Stage I, a berry diameter may double in size. Stage II follows for approximately 14-40 days where the growth rate slows or stops, often call the "lag" phase. The onset of Stage III is marked by veraison lasting until harvest (typically a 35-55 day period) in which berry growth resumes. Berry growth is less sensitive to water deficits than vegetative growth. However, water deficits depending on the timing and severity can significantly reduce berry size.

Water deficits during Stage I of fruit growth are thought to reduce potential berry size by reducing the number of cells per berry. The reduction in cell number can cause smaller berries and reduced yield. However as previously mentioned, water deficits at this time are unusual in most winegrape regions of California. Water deficits occurring during Stage II (lag phase) or III (cell enlargement) can only affect cell size. The common effect of water deficits during these later periods is to reduce berry (cell) size and reduce yield. Severe water deficits can cause reduced berry size at harvest by dehydration.

Yield

Reports on the effect of water deficits on yield are varied. Studies conducted in both the Central Valley and the North Coast show berry weight increases in a liner fashion with the water consumed up to about 80% of full vine water use. From 80%, the remainder of the consumed water supporting increased vegetative growth. In red varieties, water deficits at the same level have been shown to slightly decrease yield (3 to 19%) from that of full potential water use. Additionally, these yield reductions generally require moderate deficits to be repeated for one to two years before the yield reductions occur. Severe water deficits can reduce yield in the subsequent season as a result of reduced fruit load measured as cluster number and berries per cluster (and therefore, berry numbers). Water deficits in red varieties have been associated with increased fruit quality while full potential water use results in reduced fruit quality expressed as reduced color and character.

Fruit Composition

Potential wine quality is largely determined by the composition of the fruit. The solute composition of fruit at harvest is sensitive to vine water status throughout its development. Moderate water deficits can increase the rate of sugar accumulation resulting in an earlier harvest. If deficits are severe and/or the vine is carrying a large crop, sugar accumulation is generally slowed resulting in delayed harvest. The final increases in sugar are mostly driven by berry dehydration rather than sugar production. The result is a fruit with poor balance of solutes and reduced wine quality potential.

Water deficits result in only moderate decreases in total acidity; however, malic acid is apt to decrease sooner with early-season water deficits. With malic acid declining, the greatest effect of water deficits on the fruit is an increase in the tartaric to malic acid ratio. Juice acidity measured by pH, can also be reduced by water deficits.

Wine Color

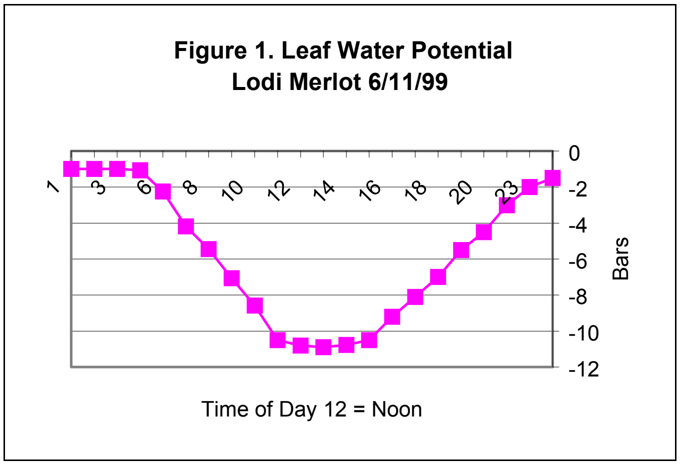
Water deficits can directly increase wine color by enhancing the production of pigments found in the skin of red wine varieties. Reductions in vine canopy using water deficits, also allows light into the fruit zone, which increases skin pigment. Additionally, a decreased berry size may also indirectly contribute to improved wine color by a larger skin to volume ratio. In areas that experience more severe climatic conditions for weeks at a time (Central Valley), excessive fruit exposure can raise the berry temperature, reversing the accumulation of pigments and causing poor berry color. Enhancement of color pigments (anthrocyanins) and flavor compounds (phenolics) appears to be a consistent result of better fruit light exposure.

Vine Water Deficits Caused by Reduced Soil Water Availability

As available water to the vine becomes limited through depletion of winter-stored soil water or irrigation water, a level is approached where the vine cannot sustain the full potential water use. It is at this point that the vine begins to undergo a water deficit.

Under normal early-season conditions, (1) water is readily available in the root zone, (2) the vine is not at full canopy expansion, and (3) the atmospheric-driven demand is small. Therefore, under normal early-season conditions, water deficits are uncommon in most if not all winegrowing regions of California. As the season progresses without irrigation, the canopy expands, climatic conditions intensify and the soil is further depleted of available water. It is at this time that the vine's water demand can exceed water uptake from the soil causing water deficits. Cooler growing regions and greater a volume of available water in the soil from winter storage or irrigation will cause water deficits to be postponed to later in the season. Generally, water deficits do not begin to occur until the vine has extracted about 50 percent of the available soil water contained in the root zone. Soil depth, texture and the total water stored in the root zone can influence this rule of thumb.

As water deficits begin, they occur only for a short period of time at the peak water demand period of the day. The vine then recovers from water deficits when atmospheric conditions relax in the later part of the day and during the night. This cycle continues each day, depending on the climate, available soil moisture and to some extent root extensiveness. Without irrigation, the deficits become longer in duration and more severe each day. Water deficits are monitored using a pressure chamber to measure mid day leaf water potential. Figure 1 illustrates a typical mid season vine water status measured over a 24-hour period. More negative numbers indicate more severe water deficits. For scheduling purposes, leaf water potential is measured at the most negative time—at midday.

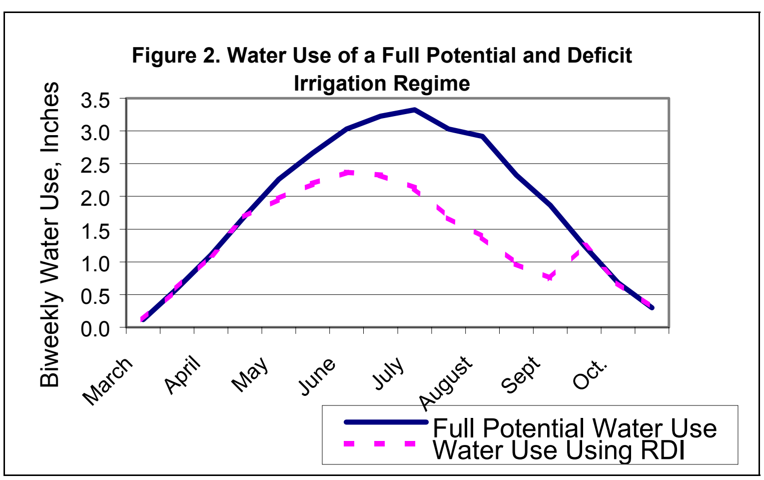


DEVELOPING AND IRRIGATION STRATEGY

<u>Regulated Deficit Irrigation</u>

Regulated deficit irrigation (RDI) is a term for the practice of regulating or restricting the application of irrigation water causing the vine water use to be below that of a fully watered vine. By restricting the irrigation water volumes, soil water available to the vine becomes limited to a level where the vine cannot sustain the full potential water use. It is at this point that the vine begins to undergo a water deficit. RDI can be a consistent reduction (i.e., consistent reduction of planned irrigation volumes over the entire season) or it can vary over the irrigation season to induce the desired vine response at the correct time.

Figure 2 shows the biweekly water use for full potential and the water use of the deficit treatment, which produced the best yield/quality relationship in a mature Cabernet Sauvignon vineyard in Lodi, California, over five years. The upper line represents the full potential water use of a mature vineyard. It is the volume of water consumed by the vineyard that occurs under condition when soil water availability is not limited and canopy size is near 60-70 % of the land surface shaded at midday measured at maximum canopy expansion. About 30% less water was consumed by the deficit irrigation regime.



Early Season Water Deficits

A review of vine irrigation research yields two conclusions: 1) pre-varaison / veraision water deficits usually produced higher quality fruit and therefore wines, and 2) pre-varaison / veraision deficits were usually the "best option" treatment for maintaining yields.

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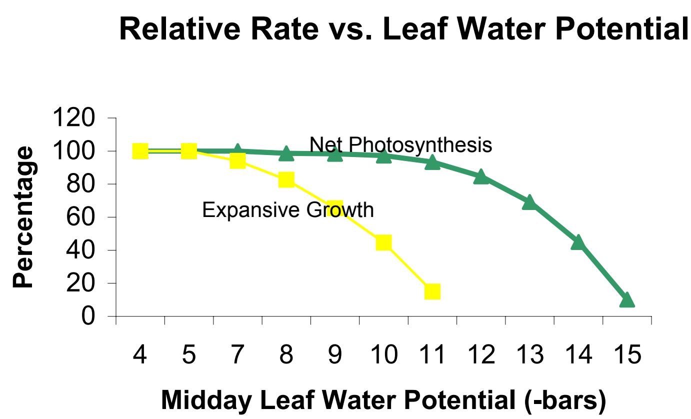
Using moderate water deficits to control expansive vegetative growth while allowing photosynthesis to continue unabated is the basis for successful deficit irrigation (Figure 3).

Figure 3.

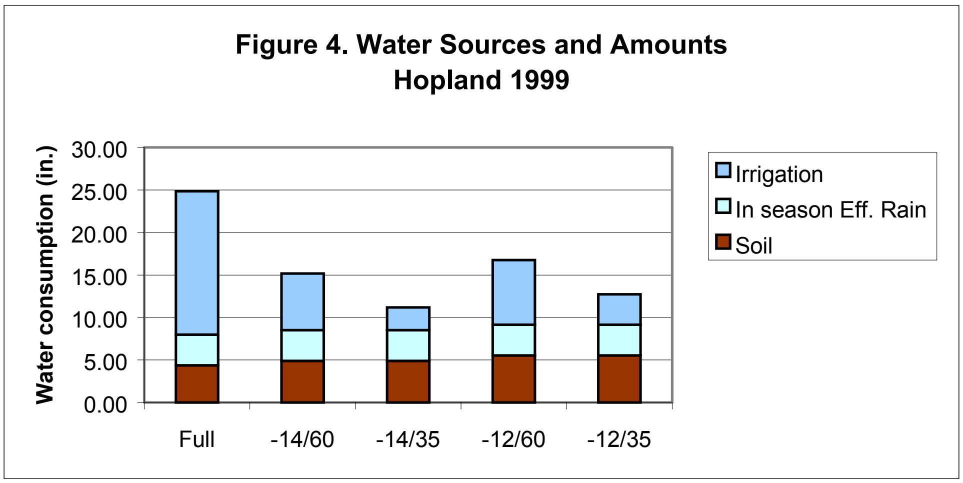


Deficit Threshold Irrigation

The Deficit Threshold Method (DTI) relies on a predetermined level of midday water deficit (the threshold) to begin irrigation. After the threshold is reached, a reduced water regime is used based on a portion of full water use (RDI%). Full vine water use is estimated using weather station data (Reference Evapotranspiration ETo) and canopy factors. The RDI% is the percent of the full water use, which is applied as the net irrigation volume for the period considered (week). The goal of the Deficit Threshold method combined with post threshold Regulated Deficit is to improve fruit quality and minimize yield reductions.

This method requires measurements of vine water deficits. The measurement device is called a pressure chamber often referred to as a pressure bomb. To measure vine water status, a leaf is removed from the vine at midday and placed in the chamber with the petiole sticking out through a silicone grommet. The leaf is covered with a plastic bag just prior to removing the leaf to prevent moisture loss while the measurement is made. Pressure is applied in the chamber until the sap exudes from the petiole. The pressure required to exude the sap is an indication of the level of water stress the vine is experiencing. This measurement is called leaf water potential.

Research trials have been conducted in Cabernet Sauvignon, Zinfandel, and Merlot with variable threshold water potentials and post threshold RDI%. Midday leaf water potential threshold of -12 to -15 bars were evaluated with post threshold RDI's of 35 to 60%. These treatments, designated as threshold/RDI% along with the consumed water and water sources, are shown for a Cabernet Sauvignon trial in Figure 4.



Results of higher fruit quality and little yield reduction generally support the –12 bar threshold and 60% post threshold RDI% as successful but conservative. Figure 5 shows the biweekly use of water by a full potential and a –12 bar threshold and 60% RDI in Lodi. The effect of both threshold and RDI% is more complex than indicated in this and is cultivar specific.

The Deficit Threshold Irrigation Method is an easier to use method requiring fewer measurements and fewer variables than the Volume Balance Method and seem to work well in moderate to cool climate regions.

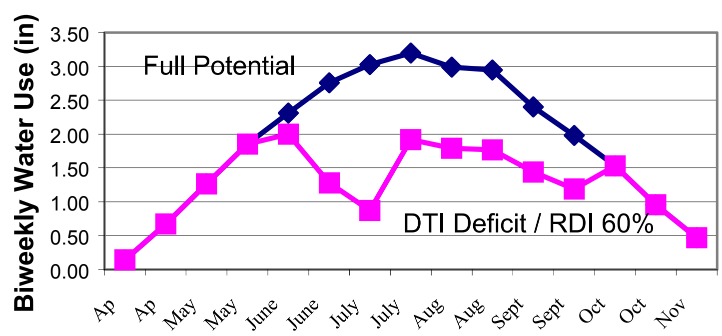


Figure 5. Biweekly Water Use, Lodi

How Much Water Can Be Save Using Deficit Irrigation

The volume of water that can be saved using a deficit irrigation strategy over full irrigation is dependent on the climatic demand, stored available water at bud break, spring-summer rains and the irrigation strategy selected. As an example to compare, we will look at three scenarios: San Joaquin Valley, Lodi and the North Coast. All canopies in size and trellis system are assumed to be the same. All three are drip irrigated. Full water use is compared with a similar deficit strategy in each area. Soils are different in depth and winter rainfall in each area. Values used were estimated on an area wide basis. Table 1 shows the range of the irrigation water volume savings to be 28 to 50%. The higher demand, low rainfall San Joaquin Valley was the least at 28% while the more moderate demand, higher rainfall Lodi area was 50%. The North Coast area was intermediate at 43%. These savings can be achieved while having little to no impact on yield and an increase in fruit quality given the appropriate deficit strategy is selected.

Table 1. Irrigation Water Comparison Full/Deficit in Three Areas

	San Joaquin Valley	Lodi	North Coast
Full water use (in)	29	27	24
Soil storage (in)	4	9	10
Net irrigation requirement (in)	25	18	14
Irrigation efficiency (%)	90	90	90
Gross irrigation requirement (in)	27.8	20	15.6
Deficit irrigation use (in)	22	18	16
Soil storage (in)	4	9	10
Net irrigation requirement (in)	18	9	6
Irrigation efficiency (%)	90	90	90
Gross irrigation requirement (in)	20	10	6.7
Deficit/Full (%)	28	50	43