Effects of Water Deficits Upon Winegrape Yield and Quality

Terry L. Prichard, Water Management Specialist, University of California Davis
Paul S. Verdegaal, Farm Advisor, University of California San Joaquin County

The main purpose of controlling the application of irrigation water to winegrapes is to produce high quality fruit. The volume of irrigation water required to produce high quality fruit varies from year to year, depending primarily on the extensiveness of the vine canopy, soil resources, and climatic conditions of both the previous winter and current season. However, regardless of the exact volume of applied water, the goal is to ensure irrigation produces the desired effect on the vine and fruit. Controlling irrigation application often results in supplying less water than the full potential water requirement of the vineyard. This practice is known as deficit irrigation.

This article describes the forces and conditions that determine vine water use and discusses the effects of water deficits on the vine and fruit.

Winegrape Water Use

Winegrape water use is driven by a vine's canopy exposure to the energy of the sun. The vine encounters this energy as direct radiation from the sun and indirect radiation sources such as heated low humidity air, and wind. The combined effect of these energy sources on the vine canopy determines vine water use when available soil water is not limited.

The variable intensity of these atmospheric factors, measured as the reference evapotranspiration (ETo), alone indicates vine water use will vary over the season (Figure 1). Normal or average years data is shown. Water use is also influenced by vine canopy growth from bud break to full canopy expansion. Together these factors contribute to a water use pattern that begins at a low rate in spring, peaks in mid-summer and then declines as leaf drop approaches (Figure 2). For this discussion we will assume the canopy is at a full practical land surface coverage of 70 percent. This can be measured mid-day as the percent of shade on the vineyard floor at full canopy expansion. This factor is predominately influenced by row spacing and vine vigor; however, canopy management practices (such as hedging or canopy disruption by machine harvesting) can further modify this pattern by reducing the energy interception of the vine. For a more in-depth discussion of winegrape water use and irrigation scheduling, see *Irrigation of Quality Winegrapes.*

Figure 3 illustrates both the full potential water use and the water use of a deficit irrigation regime on a biweekly basis. Early season water use is similar since adequate moisture is available in the soil. Once soil moisture becomes limiting towards mid-season differences in water use can be seen. Irrigation can be applied to significantly influence the differences shown in water use. Figure 4 illustrates seasonal cumulative water use of the same vineyard in the Lodi area with adequate soil moisture for the entire season and one of a deficit irrigation regime. Notice the near 30 percent difference in water use between full potential water use and a deficit irrigation regime over the season.

Figure 1. Normal Eto, Sta. 42, Lodi

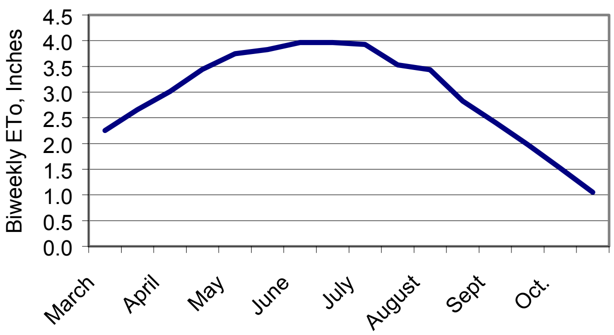


Figure 2. Full Potential Water Use(ETc) Lodi

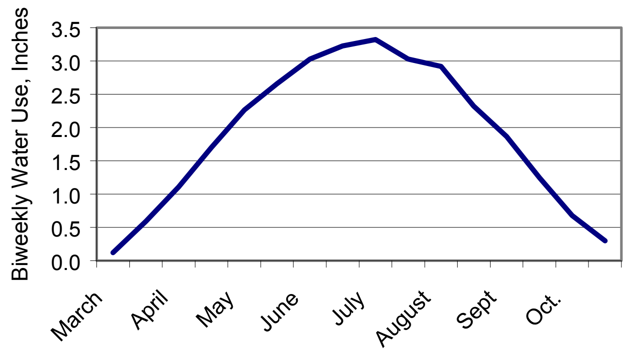


Figure 3. Full Potential & Deficit Irrigation Vine Water Use

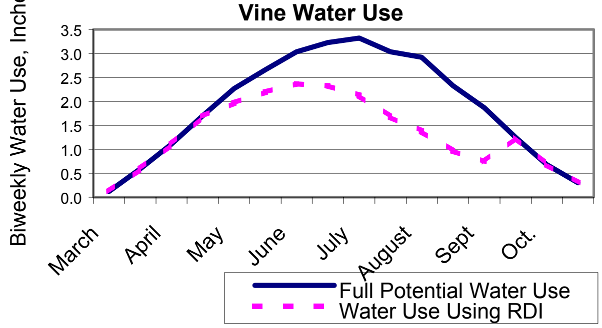
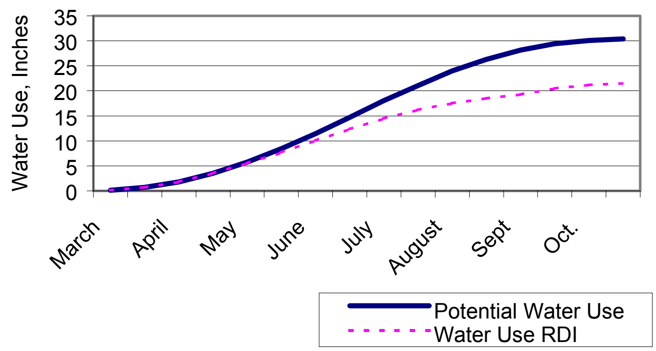


Figure 4. Cumulative Normal Potential ETc, Lodi



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.

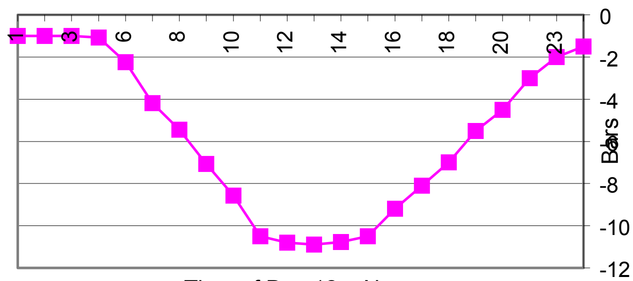
Water Deficits

Water deficits occur when the energy expressed to the canopy creates a water demand that exceeds the vine's ability to extract moisture from the soil.

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 5 illustrates a typical mid season vine water status measured over a 24-hour period. For a more in depth discussion on how to measure and use leaf water potential measurements see *Soil Moisture Measurement Technology*. (On the web, see: http://cesanjoaquin.ucdavis.edu/Prichard/Publications).

Figure 5. Leaf Water Potential
Lodi Merlot 6/11/99



Vine Response to Water Deficits

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. This 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, 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.

Water Deficit Severity

In areas of moderate climatic water demand or adequate soil water increases, deficits can be mild and expressed by a reduction of vegetative growth.

In areas of higher climatic water demand or in soils of limited water storage, deficits can be severe enough to cause reduced photosynthesis and partial or complete defoliation.

Vegetative Growth

Water deficits occurring early season (bud break to fruit set) are usually not possible in most viticultural regions as previously discussed. 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 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 lateral shoot growth to resume, creating a competitive sink for photosynthate, which can increase shading, cause bunch rot in susceptible varieties, and delay fruit maturation and harvest.

Timing of Water Deficits

Midseason, moderate water deficits can cause reduced vegetative canopy growth, allowing increased fruit exposure to light without limiting photosynthesis. Later season water deficits can reduce leaf cover in the fruiting zone.

Severity of Water Deficits

It is apparent that moderate, midseason vine water deficits can have a beneficial effect by reducing vegetative growth and limiting lateral growth. If too severe deficits in mid to late season, can restrict sugar accumulation or cause excessive fruit exposure.

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 wine grape 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. Results from both California and Australia indicate white varieties (Chenin blanc, Thompson and Chardonnay) maximize yield at near 60-70 percent of full potential vine water use. With 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. Water deficits, as mentioned above, can reduce yield by reducing berry size. 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). Yield reductions in red varieties has been associated with increased fruit quality while full potential water use results in reduced fruit quality expressed as reduced color and character.

Symptoms of Water Deficits

- Decrease in the angle formed by the axis of the leaf petiole and the plane of the lamina (blade)
- Internode growth is inhibited
- Reduced tendril growth in relation to the shoot tip
- Reduced number and length of lateral shoots
- Abscission of oldest leaves

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 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 light exposure.

Summary

Careful water management can be used as a tool to control the vine water status, moderate vine growth and achieve desired fruit characteristics. Generally, the desired effects are the result of moderate water deficits, creating a vine balanced in growth and fruit production.

However, there are conditions when water deficits may not be appropriate.

1. When vines are young in a developing vineyard
2. When vegetative growth is not adequate to mature the crop
3. When vines are affected by root pests which limit soil exploration
4. Periods of excessive heat for extended periods
5. During the post harvest period, prior to leaf drop

Postharvest Water Deficits

Little positive effects have been seen from water deficits after harvest. Early harvest varieties have significant periods of time before leaf drop to accumulate and store carbohydrates.

Terry Prichard is a CE Water Management Specialist in the Department of Land, Air and Water Resources, University of California Davis. His email address: tlprichard@ucdavis.edu.
Paul Verdegaal is a University of California Cooperative Extension Farm Advisor in San Joaquin County. His email address: psverdegaal@ucdavis.edu.

February 2001