
Figure 1: *High watering regime in Eastern Washington vineyard.*


Figure 2: *Low watering regime in same vineyard.*

When Understanding Irrigation—Many things are to be considered!

Robert L. Wample

Whether it is because we would like to maintain (or increase) the yield of our grapevines, or we are concerned with the production of higher quality grapes for fresh market or processing, irrigation is becoming a topic of discussion around the world. Even in areas where irrigation has historically been prohibited, it is now being considered as a viable practice under certain circumstances. Fortunately, other viticultural regions of the world have been exploring the influence of irrigation on grape production. The results of these efforts are not entirely conclusive, but they have provided some insights regarding the conditions under which irrigation is needed, or is at least beneficial.

Most of the wine, raisin and table grapes (Vitis vinifera) grown in the world evolved in the relatively arid Middle East and therefore have developed good drought tolerance or drought avoidance characteristics. Juice grapes (Vitis labrusca), especially those used for unblended grape juice drinks, jams and jellies, are primarily of a North American origin and are more sensitive to drought stress. Despite these differences, viticulturists have clearly recognized that even the drought tolerant vines are often more productive and produce higher quality fruit with the careful use of irrigation to supplement natural, although unpredictable, precipitation patterns.

In considering the question of whether or not to irrigate and if so, how and how much, it is necessary to understand the factors that contribute to vine water stress and what the effects of different water management strategies have on grapevine development and productivity.

Grapevine Stress: Timing and Symptoms

Grapevine water stress develops when the supply of water from the soil through the root system to the growing shoots is less than the evaporative demand. The cause for this imbalance may be low available soil moisture, poorly developed or injured root system, an unbalanced development of shoot and root systems, and/or high evaporative demand conditions. Salts, either in the irrigation water or in the soil, can also reduce the water available to vines. Also, ex-

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The author is a horticulturist at the Washington State University Irrigated Agriculture Research and Extension Center, Prosser, WA tensive trellis systems may contribute to more leaf exposure and consequently to a higher rate of transpiration than can be supplied by the roots. This latter type of stress is more likely to be transient in nature and less of a concern.

Grapevines—especially Vitis vinifera—generally do not show immediate signs of water stress, but will show the effects of repeated stress by cumulative effects on shoot or fruit development. For a review of reports on the effects of water stress and other environmental effects on grapevines, the reader is directed to a review by Williams, Dokoozlian and Wample (1994). The following is a brief summary of the symptoms associated with water stress at different stages of grapevine development.

Bud break to flowering. Although water stress is infrequent during this stage of development due to the vine's low vine water use, if it occurs, bud break will be uneven and shoot growth will be stunted. It is also possible that flower cluster development and pistil and pollen viability can be reduced. Under severe conditions, nutritional deficiencies might also become evident. This is potentially due to reduced root growth in dry soil. Most of the nutrients required by grapevines early in the season are derived from stored sources, thus reducing the likelihood of early season deficiency symptoms. Early season zinc (Zn) and boron (B) deficiency are often the result of water stress the previous season and reduced root growth and nutrient uptake from the soil.

Flowering to fruit set. Poor pollen and pistil viability and hence poor fruit set are associated with water stress during flowering. Severe water stress during this time is associated with hormone changes that may contribute to flower abortion and cluster abscission. Water stress during this stage of development could, if left uncorrected, result in reduced canopy development and consequently insufficient leaf area to adequately support fruit development and maturation. For spur pruned vines, initiation of clusters in nodes 1-4 for the following season begins about 2 weeks prior to full bloom and continues for about 2 weeks. Water stress during this stage thus has the potential of reducing the following season's crop potential. The predominant effect at this stage is believed to be a reduction in the number of clusters per shoot, not the number of flowers per cluster, which develop later in the season and perhaps throughout the dormant season as conditions permit.

Fruit set to veraison. Cell division and early cell enlargement in berries, that occurs immediately after fruit set, will be reduced under water stress. Hence, the potential berry size at harvest will be reduced and may significantly reduce yield. The "lag phase" which follows this early berry development is much less susceptible to detrimental effects of water stress. However, shoot development, which normally continues during this stage of development, would be reduced by water stress. If sufficient canopy has not developed prior to this time, the photosynthetic capacity of the vine will be limited and potentially restrict fruit development and quality. Aside from reduced yield potential and fruit soluble solids accumulation, we might anticipate higher pH, decreased acidity and color development in red varieties and possible sunburn in white varieties. Insufficient leaf area could also inhibit vine acclimation and increase the susceptibility to fall frosts and low winter temperatures.

Veraison to harvest. Water stress at this time results in rapid senescence of lower leaves, followed by leaf abscission and progressive loss of canopy. Sudden fruit exposure due to loss of canopy would result in sunburn of both red and white varieties. If the stress developed slowly there would be a loss of acidity and a rise in pH and soluble solids. With more rapid stress onset these processes would be arrested as fruit raisining occurred. Acclimation of one-year-old wood is accelerated by stress at this time and begins from the base towards the tip. High levels of stress will result in abscission of shoot tips. If this is followed by over irrigation it can result in lateral shoot growth, creating a competitive sink for the products of photosynthesis and delaying fruit maturation and harvest. Such late irrigation following water stress could also reduce cane and vine acclimation. Such vines are unlikely to have adequate viable buds the following season and if exposed to extreme low temperatures often show reduced survival of buds, trunks and cordons.

Harvest to dormancy. Reduced root growth is perhaps the most detrimental effect of water stress following harvest. Boron deficiency symptoms the following spring have also been associated with late season water stress. Cane and vine maturation are often promoted by mild and slow developing water stress following harvest. This may occur at the expense of more distal portions of canes. However, poor vine acclimation is expected if severe stress occurs at this time and prior to cane and vine hardening and is associated with excessive die-back of canes and significant reduction in fruiting buds for the following season. Low temperature injury of roots is also a concern if the soil remains dry, thus increasing the depth of frost during long periods of cold weather. This is more likely in areas with lighter soils and little or no precipitation prior to winter conditions. Root injury often expresses itself the following spring as delayed and erratic bud break and eventual collapse of the developing shoots.

The effects of water stress described above only develop if the stress is severe and prolonged for most Vitis vinifera. The response of American varieties and hybrids is similar but often at lower levels of stress. The other observation that has been made is that American varieties, especially concord, do not like mid-season stress followed by high levels of irrigation. Under these conditions, this variety fails to show good cane maturation and consequently has a low crop potential the following year.

Under more moderate and slowly developing stress, the response of vines to water is less severe. In fact, it is now recognized that careful water management can be used as a tool to achieve desired canopy and fruit characteristics. This management strategy may involve moderate stress at different stages of development to achieve specific results.

The decision to irrigate requires, of course, that you have well-defined goals for your vineyard with respect to yield, quality, harvest date, canopy structure, and winter survival. To achieve these goals in the face of ever-variable weather conditions demands a good understanding of the factors that can be controlled—and those that can't. Since this article's focus is on irrigation, it will not address factors such as pruning level, trellis type, nutrition, pest and disease management and others that can be controlled, but will focus on those factors associated with grapevine water use and its management.

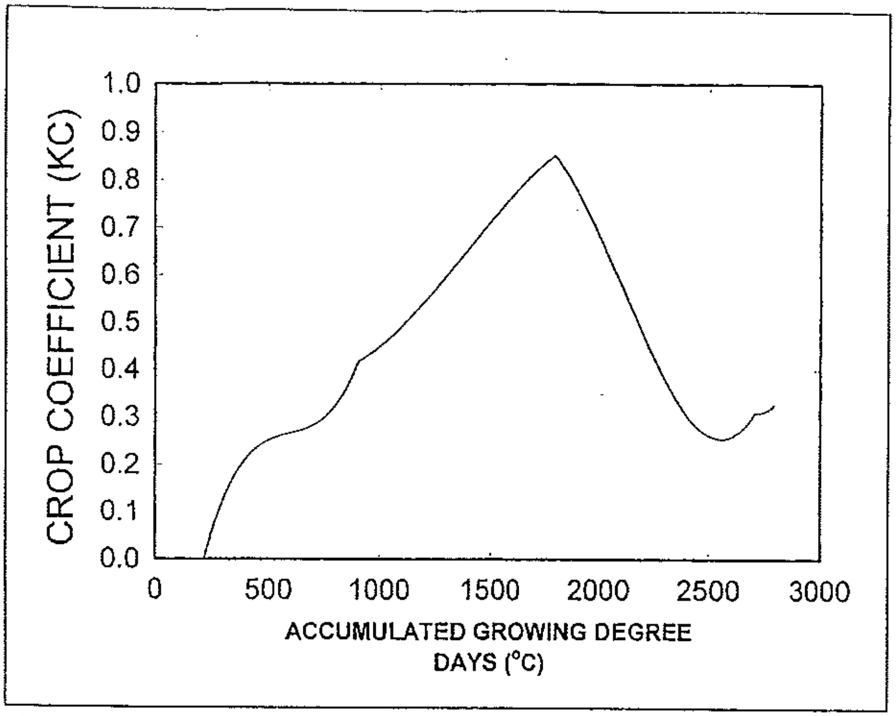


Figure 3

Deciding on Irrigation? Begin at The Beginning

Understanding the soil as the reservoir from which vines get their water and nutrients is essential in developing a water management strategy for your vineyard. Contact your local soil conservation office for information about the soil types and profiles in your area. This should include information on total and available water holding capacities for your vineyard soils and the potential rooting depths. For instance, sandy loam soils generally hold about 2 inches of water per foot of soil. About half of this is available to the plant. Thus, in a soil of this type 3 feet deep, there would be approximately 3 inches of available water. Recognizing how changes in soil type and depth can affect the vine available water is an important part of the water balance equation. Of course, this assumes the root system fully occupies the available depth of the soil profile being monitored. This can be determined by simply digging some pits along the row and observing the root system.

Alternatively, if you have soil moisture monitoring devices at various depths, you can use these to see if the vines are extracting available water. Recognize that if you have a cover crop that this will also use some of this water. For this reason, you need to know the effective rooting depth of the vines and the cover crop. In areas where most of the water available to the plants during root development is from irrigation water, the distribution of the roots both vertically and horizontally can be influenced by irrigation practice. Application of large quantities of water that fill the profile (3-4 feet or more) that are followed by several weeks without further irrigation will encourage deep root development. On the other hand, frequent, low volume irrigation will have the tendency to promote shallow root systems. Rootstocks used to deal with phylloxera and nematodes may also have characteristic rooting patterns with which vineyard managers should be familiar.

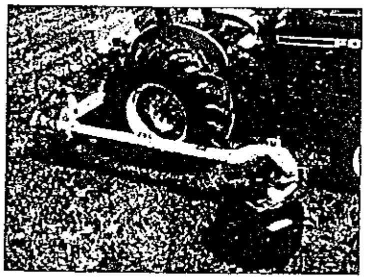
Once the soil and rooting characteristics are known, it is possible to estimate the total water available to the vine at any time–the volume of soil occupied by the roots can be measured and the percent of available water can be estimated by several techniques (neutron probe, tensiometers, resistance blocks). Knowing this and being familiar with procedures used to estimate vine water use allow us to estimate the time before the vines will begin to experience water stress.

One method of estimating vine water use involves the use of crop coefficients (Kc) and measurements or calculations of the evaporation and transpiration potential for a given time period. Grapevine crop coefficients have been developed in several different locations (Evans et.al. 1993; Grimes and Williams, 1990; Doorenbos and Pruitt, 1977) and reflect the development of leaf surface area and vine water demand as the growing season progresses. Since they represent the fraction or percentage of the potential evapotranspiration, their values are typically less than one. Furthermore, because of the variability in development in different years, they are usually associated with accumulated growing degree days (GDD) rather than day of the year. The base temperature for GDD accumulation is 50° F (10° C) and in north temperate climates begins in April. The calculation of daily GDD is based on the daily maximum plus the daily minimum temperature divided by 2 minus the base temperature ((max F + min F)/2) - 50° F . The use of GDD helps overcome year to year variation in vine development since vine growth is heavily influenced by temperature.

Figure 1 represents the Kc developed for mature vines of cabernet sauvignon, white riesling and chenin blanc grown in Washington state. As expected, early in the season the Kc is low due to the small leaf area and hence low vine water use. The Kc approaches one as the canopy reaches maximum development in July and August in northern climates and earlier in more southern locations. The reference crop typically used to estimate maximum water use is a well-watered and mowed grass area and the values are represented by ETP. Hence the calculation of daily water use (DWU) would take the published Kc for the appropriate accumulated GDD times the ETP (DWU = ETP x Kc). The availability and use of computers make these calculations and record keeping easy and facilitate better water management than in the past. Knowing the available water and the rate of water use makes it possible to schedule irrigation before vine water stress develops. These calculations must also take into consideration any rainfall that occurs during the irrigation intervals. In considering rainfall, it is important to recognize that not all rainfall reaches the vine's root zone. Some reasons for this include interception by cover crops and vine canopy, light rainfall followed by sufficient evaporative demand to prevent movement into the soil, insufficient rainfall to fill more than the upper part of the soil profile, and poor infiltration due to surface barriers, and/or rates of rainfall that are too high for the infiltration rate of the soil that result in high runoff.

A part of the decision to irrigate must be based on the delivery capacity of the irrigation system. This is particularly true for large acreage where it would be unlikely that it could all be irrigated simultaneously. Recognizing that in a hypothetical situation it may take 24 to 48 hours to apply the necessary amount of water to bring one-third of the vineyard to the desired soil moisture level means it will take 3 to 6 days to complete the irrigation cycle.

On deeper soils with higher water holding capacity this would not present as much of a problem because of the "buffering capacity" of the deeper soil. However, on shallow soils with low water holding capacity, during high evaporative demand conditions, this could mean that some vines would experience significant water stress. This scenario would suggest that the irrigation design was insufficient to meet the peak demand of this vineyard. This situation often develops when an initial irrigation system is used to service acreage that is developed at a later date.



Knowing when and how much irrigation will be required are important factors to be considered in choosing the method of irrigation. Vineyards planted on hillsides or with rolling terrain are not amenable to furrow or flood irrigation practices. Soils with low infiltration rates and with a significant slope also present runoff problems for overhead sprinkler systems with high delivery rates. Drip irrigation can accommodate all of these situations, but has a higher initial capital investment cost and is generally considered to require a higher level of management. These and other considerations such as water quality, filtration requirements, system automation, and local availability of equipment, supplies and support make drip irrigation not something to approach lightly. Because of the number of variables involved, it is recommended that vineyard managers contact local irrigation design and equipment companies for recommendations tailored to their vineyard.

Good Water Stress?

The principal focus of this article up to this point has been an understanding of the conditions that result in water stress of grapevines, their response to water stress, and how to determine if, when and how much to irrigate. However, in some situations it may be advantageous to allow water stress to occur. As mentioned above, grapevines require a small percentage of their yearly water requirement during the early part of the growing season. This is associated with the severe pruning practices used for grapevines and the subsequent slow canopy development. However, it is relatively well recognized that grapevines and particularly European wine grapes, if provided with an abundance of water and fertilizer, will grow vigorously and perhaps excessively. Development of such excessive shoot growth has been associated with several problems: poor fruit set and fruit bud initiation for the following season; abortion of buds for the next season's crop; early bunch stem necrosis; increased powdery and downy mildew pressure; increased pressure from Botrytis and other bunch rot disease organisms; and a more desirable habitat for insects such as leaf hoppers. Large canopies therefore require more inputs to produce the quality fruit demanded by wineries and processors. Therefore, recognizing the water needs of vines early in the season and estimating the soil moisture levels may provide an opportunity to control grapevine canopy growth. This approach to vine water management is clearly much easier in regions with little or no rainfall during the growing season. However, vineyards on shallow soils that are currently irrigated might also benefit from considering this approach to canopy control.

The following is a brief summary of research that has used irrigation to control grapevine growth. The study began in 1992 with the support and cooperation of Stimson Lane Vineyards and Estates, Washington Association of Wine Grape Growers, Washington Wine Grape Advisory Board, Northwest Center for Small Fruit Research and Washington State University.

Four irrigation strategies have been applied since 1992 to a 64-acre sauvignon blanc vineyard located at the Columbia Crest Vineyard in south central Washington. They involve high and low rates of irrigation defined respectively as 2.2 and 1.2 inches of water per foot of soil in the top 3 feet of the soil profile. The strategies are:

HL. High irrigation applied early in the growing season followed by low irrigation from the point where control of canopy development has been achieved in the low irrigation treatment. The high irrigation treatment phase typically occurs from bud break to early or mid July. This is similar to the irrigation practice that had been established as the standard for wine grapes in Washington State.

HH. High irrigation maintained throughout the growing season. This extreme treatment is being applied primarily for comparative purposes.

LL. Low irrigation applied throughout the growing season. This extreme treatment is also being applied primarily for comparative purposes.

LH. Low irrigation applied early in the growing season until control of canopy development has been achieved, which typically occurs by early to mid July, followed by high irrigation through harvest.

At the end of each season, all treatments were irrigated to bring the top 18-24 inches of soil to near field capacity. This was to provide winter protection of the root system and provide adequate moisture for early season growth the following year. It was anticipated that there would be sufficient precipitation during the dormant season to fill the soil profile to the 3-foot level.

Each treatment was replicated 4 times with 4 acres each. Treatments were randomized within each 16-acre replicate. Each 4-acre block was irrigated independently and equipped with a flow meter. Sixteen neutron probe sites within each block (128 total) were read weekly during the growing season. Vines were spur pruned, leaving an average of 36-40 buds per vine for all treatments.

The number of growing-degree-days (GDD degrees F) accumulated at the vineyard site has averaged 2,875, with extremes of around 2,600 to 3,195. The average cumulative irrigation over 5 years for the HH vines is about 20 inches. The average for the LH vines is about 16 inches, while the LL vines received about 12 inches and the HL vines about 14 inches. The HL vines only received about 1-2 inches more than the LL vines, because of the low irrigation requirement early in the season (the Kc and ETP values are lower during April-June than in July-August.) Although the HH vines received 20 inches of water, this is still considerably less than the 30-36 inches typically used previously in the Yakima Valley.

Soil moisture measurements taken over the 5 years of the study during the third week of April indicated no differences between treatments in the top 3 feet of the soil. This was important since the soil moisure provided for early season growth served as the starting point for irrigation planning. Since all treatments started at the same soil moisture level, and we assumed all other factors were equal, we expected similar growth from each set of vines until water became the limiting factor. Irrigation maintained the HH and HL soils near 2.2 inches of water per foot of soil through the first week of July, while the moisture in the LL and LH soils declined to 1.2 inches of water per foot of soil in the top 3 feet of the soil profile. Once it appeared that shoot growth was slowing down in the LL and LH vines, based on shoot growth and leaf area measurements, the transition in irrigation treatment was made. This generally took place during the first or second week of July.

In some seasons, because of the hot weather during late July and early August, it took nearly 3 weeks to bring the LH soils up to the desired 2.2 inches per foot for the top 3 feet of soil. However, a significant increase in soil moisture in the top 2 feet was achieved within 2 weeks.

Over the first 3 years of the study, pruning weights were higher in the early season, high irrigation treatments (HH). This clearly indicates that we were able to achieve control of canopy development. However, late season high irrigation (LH) in 1993 and 1994 stimulated shoot growth that increased pruning weights. This suggests that less water could be applied once the desired level of canopy development has been achieved. Thus a low-to-medium irrigation practice might be the most desirable for canopy control and fruit quality considerations.

Measurements of shoot length and node number support the pruning weight analysis, indicating control of shoot growth by irrigation management. Figures 1 and 2 represent the typical differences in canopy development between the HH (Figure 1) and LL (Figure 2) irrigation treatments (taken August 1996).

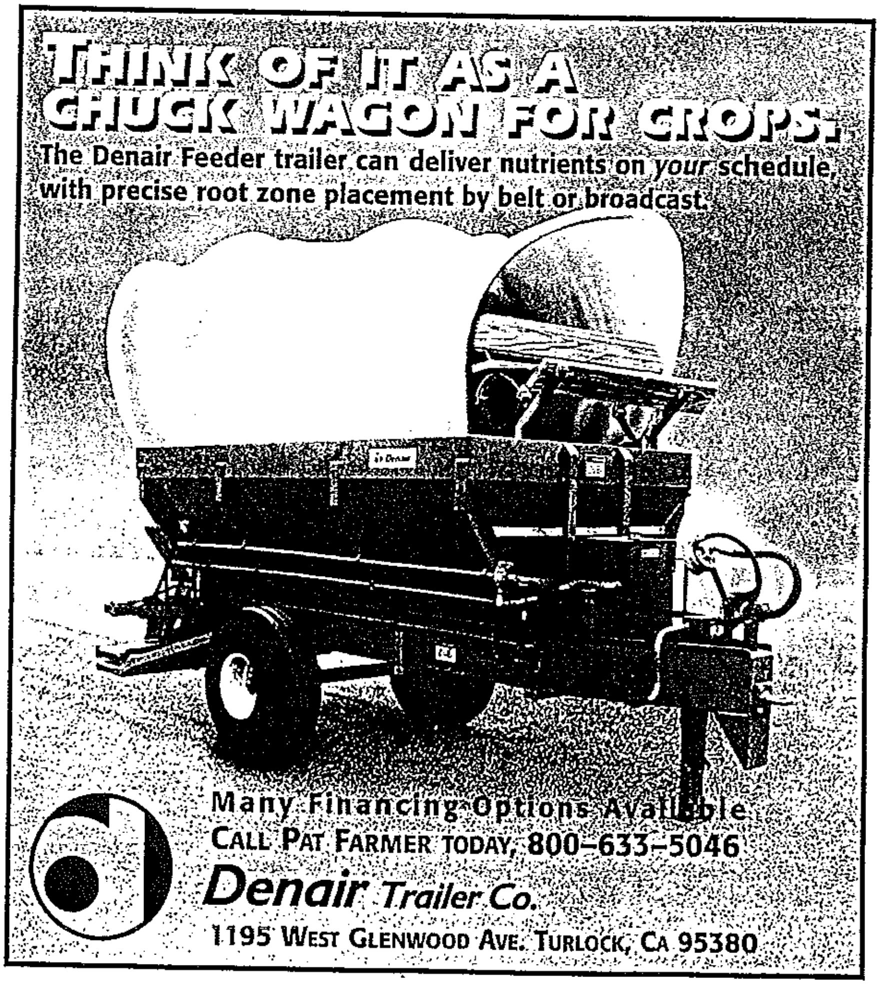
The information indicates that despite the previous year's irrigation, there is essentially no difference in shoot length from bud break until approximately 30 days after bloom. This is despite significant differences in weather conditions over the 4 years and the lower irrigation in the LL and LH treatments. This suggests several things.

First, the similarity in shoot growth of all irrigation treatments early in the season indicates that water was not a limiting factor at this time.

Second, because there are nearly 20 nodes present by the time differences in shoot growth begin to occur, it indicates there should be sufficient leaf area present to mature the crop.

Third, since even the HH irrigation treatment showed a change in shoot length around 30 days after bloom, it appears that fruit set and early cluster development reduce shoot growth. In general, the HL vines stopped initiating nodes shortly after the change in irrigation treatment, while there was an increase in shoot growth in the LH vines.

Leaf area measurements also showed that the sizes of leaves up to



about leaf number 15 were very similar regardless of irrigation treatment. This further supports the suggestion that early season soil moisture is not limiting, and that there was little difference in the water status of the irrigation treatments until late June or early July.

Leaf area development is more sensitive to soil moisture depletion, with differences in leaf area occurring 10 to 14 days prior to differences in shoot elongation. Thus, changes in leaf area enlargement can be used as an early indicator of soil moisture depletion. If carefully monitored, they can be used as a means to schedule irrigation. By mid- to late-August, there was typically interior leaf senescence and defoliation in the HL treatment associated with water stress. However, in the LL vines, although less irrigation was applied, there was less leaf senescence. This indicates physiological adjustments by the LL vines that probably include osmotic adjustment, and changes in the cuticle thickness and stomatal regulation to increase water use efficiency.

From late July through the end of the season, following the change in irrigation, although there was no difference in soil moisture between the LH and HH treatments, the LH vines showed less stress as indicated by leaf and xylem water potential measurements. This is presumed to be the result of smaller canopy and physiological adjustments associated with the early season low irrigation (LH). Although the LL treatment often showed high levels of water stress, these vines showed less leaf senescence and loss than the HL vines. There has been little effect of these irrigation treatments on the number of clusters. The similarity in cluster number indicates that early season low irrigation was not detrimental to the cluster initiation process.

Table 1

		1992	1993	1994	1995	1996
Yield Per Acre	HL	4.09B	6.50A	4.11A	5.36B	5.41A
	HH	4.74A	7.29A	4.09A	7.13A	6.39A
	LL	2.91C	6.47A	3.5B	5.13B	5.92A
	LH	3.00C	6.78A	3.15B	5.37B	5.94A

Table 2

		1992	1993	1994	1995	1996
% Soluble Solids	HL	22.6A	22.50A	22.65A	23.25A	22.38A
	HH	22.3A	22.20A	22.30A	21.93A	22.08A
	LL	22.9A	23.00A	23.20A	23.33A	22.90A
	LH	23.4A	23.10A	21.80A	22.80A	23.83A

Table 3

		1992	1993	1994	1995	1996
TA	HL	0.73A	0.75BC	0.60B	0.68B	0.76B
	HH	0.81A	0.93A	1.07A	1.01A	1.03A
	LL	0.74A	0.67C	0.59B	0.70B	0.67C
	LH	0.68A	0.78B	0.90A	0.96A	0.84B

Table 4

		1992	1993	1994	1995	1996
pH	HL	3.38A	3.28A	3.40A	3.41A	3.17AB
	HH	3.31A	3.11B	3.27A	3.16B	3.10B
	LL	3.40A	3.35A	3.43A	3.30A	3.23A
	LH	3.41A	3.28B	3.29A	3.20B	3.13B

During the first year of the study, which was a very hot year, the LL and LH vines averaged 11/2 - 2 tons lower yield per acre than the HH vines (Table 1).

The HL produced about 1 ton less than the HH vines. In 1993, which was a cooler growing season, there were no yield differences, while in 1994 the LL and LH vines again had lower yields but closer to the HH vines than in 1992. The HH vines had the highest yield (7 tons per acre) in 1995, while the other treatments produced 5 1/2 tons per acre. There were no significant differences in yield in 1996, with all treatments producing about 6 tons per acre. Higher yields in the HH vines are due primarily to larger berry size. Throughout the study there have tended to be more berries per cluster in the LL and LH treatments.

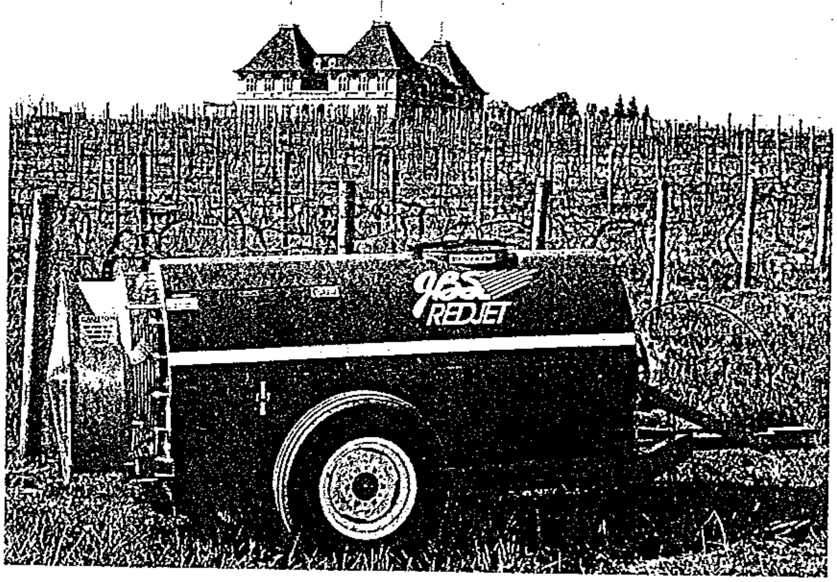
Fruit and wine quality analysis was based on harvesting the fruit from the different irrigation treatments at the same soluble solids. Post-harvest soluble solids measurements were based on samples taken from 3000-gallon tanks for each of the 4 replicates of each treatment. There were no differences between treatments in 4 of the 5 years of the study (Table 2). In 1995 the HH treatment was harvested at about 22% soluble solids while the other treatments were all near 23%. Late season high irrigation (HH and LH) has tended to delay harvest and lower the soluble solids slightly throughout the study. In 1993 the HH vines were harvested nearly a week after the LH vines which have tended to be the first to reach 23% soluble solids. In cool, wet years like 1995 earlier harvest can be an advantage by avoiding fruit rot problems. Titratable acidity (reported as milligrams of tartaric acid equivalents per 100 milliliters of juice) of 1995 tank samples was significantly higher in the HH and LH must (1.0) than in the HL and LL must (0.7) (Table 3). Although this is undoubtedly due in part to the lower soluble solids for the HH treatment in 1995, this trend can be seen in at least 4 of the 5 years. The lack of differences in 1992 is most likely due to the high temperatures that occurred throughout the season. These differences are generally accompanied by lower pH in the HH and LH musts than in the HL and LL musts (Table 4). Fruit and must analysis over the past 5 years have shown similar results. The lack of differences in soluble solids, while consistent differences occurred in pH and acidity seem to clearly indicate the effect of irrigation practices on these fruit and potentially wine characteristics.

Vine evaluation during early August typically showed that treatments involving reduced irrigation had more lignified nodes than the HH treatment. This has been consistent over the 5 years of the study. This indicates better cold hardiness during late summer and early fall and although this is not important in most years, it could be a significant advantage in those years with exceptionally early killing frost. Cold hardiness evaluations undertaken each year starting in October and continued through March also indicate no difference in bud cold hardiness as a function of irrigation treatment.

The information produced by this study demonstrates that, given the variety and location, it is possible to produce a satisfactory crop of wine grapes with between 12-20 inches (300 and 500 mm) of water per year including a post harvest irrigation to bring the soil to a moisture level that will protect the root system from cold injury. Based on this study, there are several points that are applicable to vineyard water management in general. First, water requirements of grapevines change as the season progresses and, second, their response to changes in water availability at different stages of development is an important consideration.

A grower's decision to adopt the concept of irrigation as a management practice for his or her vineyard should be based on a clear understanding of management objectives and an understanding of how irrigation management will overcome some or all of the problems to be addressed. If the "problem" is vine water stress, and irrigation water is available, the question is simply one of economics associated with the installation of an appropriate irrigation system and the expected improvement in vine growth and productivity. Depending upon when and why the stress occurs, soil and site characteristics and the variety of grape being grown, the decision to irrigate and the choice of irrigation system will vary significantly. If the "problem" is one or more of the many others discussed earlier, the question is whether or not vine water management will be successful in overcoming these problems.

Based on this research, the only "vine-related" expense of using regulated deficit irrigation as a management tool is a potential loss of yield if stress becomes excessive. Lighter pruning can compensate for this, al-



though it would be preferable to do a better job of water management. The other costs are those associated with establishing, maintaining and operating an irrigation system. These costs must be carefully evaluated based on the potential for more consistent, balanced vine growth and fruit production of higher quality that would result in higher net returns to the grower.

While this article has primarily focused on European wine grape varieties (Vitis vinifera), American varieties (Vitis labrusca) such as concord, may require irrigation in many areas where they are grown. Our experience in Washington State indicates that these vines require a more uniform level of soil moisture throughout the growing season than wine grapes. Observations indicate early season stress that results in reduced shoot growth, when followed by high irrigation, results in poor maturation of the buds and canes, with a resulting loss of fruitful wood for the following season. There also appears to be a strong association between mid-season stress and the development of "Black Leaf" in concord grapevines. This disorder, often associated with potassium deficiency, usually is not visibly present until veraison. Under severe conditions, it can defoliate vines and result in significant crop and vine loss. Clearly, maintaining higher, more uniform soil moisture for American grapevine varieties may be more critical than for European varieties.

Summary

The decision to irrigate requires a comprehensive evaluation by vineyard managers. Growers need to gather the information discussed at the beginning of this article and become familiar with the procedures to estimate soil moisture and its use by the vines in their vineyard. Furthermore, they need to recognize that their management practices will have a significant influence on grapevine canopy development, physiology and hence evapotranspiration. Answers to the questions regarding irrigation require careful evaluation of the goals to be achieved and a good understanding of the potential benefits and costs associated with irrigation options available. Each grower must determine the goals for his/her vineyard and how irrigation fits into the achievement of those goals. ❦

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