WINEGROWING

Figure 1: Desirable Cabernet Sauvignon shoot growth during period of regulated stress.

Five-step irrigation schedule

Promoting fruit quality and vine health

BY **Stan Grant, Progressive Viticulture**

Most winegrape growers and viticulturists agree that irrigation is the most important management practice for quality wine grape production known to directly effect fruit acidity, pH, and phenolics, including anthocyanins in red grape berries.[2, 5, 9, 14, 16, 18, 20, 21] The influence of irrigation on berry size and foliage growth, particularly canopy growth relative to the amount of crop, also may indirectly affect fruit characteristics and bunch rot incidence.

Technological advances in water delivery systems, vineyard water use modeling, and soil moisture monitoring during the last 30 years have given growers many tools for optimizing irrigation for fruit quality. Perhaps most prominent among these is drip irrigation, which has given growers complete control over water application timing and amounts.

A water use model that uses weather data to estimate combined water loss as evaporation from the soil and transpiration from leaves produces values for grape evapotranspiration (ET) which can be used in "check book" method of irrigation scheduling.[6, 7]

Soil moisture monitoring has advanced well beyond the "feel method." Today's technologies include tensiometers, resistance blocks, heat dissipation sensors, neutron probes, frequency domain capacitance sensors, and time domain reflectance sensors (For comparisons of soil moisture measuring instruments see references 10, 11, and 12).

Research and experience have shown that irrigations applied to meet or exceed 100% vineyard water use (such as grape ET) are not conducive to high winegrape quality.[2, 3, 5, 13, 16] Such irrigation management leads directly to reductions in phenolics, decreases in the ratio of tartaric to malic acid, and to excessive growth of the foliage and poor canopy microclimates conducive to disease.

Winegrape quality is improved when reduced amounts of water are applied during the growing season. However, too little irrigation of most vineyards during the growing season is also detrimental to fruit quality due to sunburn, berry shrivel, and impaired ripening associated with insufficient leaf surface and photosynthesis.[3, 9] The questions of how much and when to apply irrigation remain subject to debate.

Regulated deficit irrigation (RDI) involves applying less than the full vineyard water requirement during specific periods of the growing season. It takes advantage of the differing sensitivities of foliage growth, fruit growth, and sugar accumulation to water stress, which are listed here in order of decreasing sensitivity.[22] By inducing controlled moderate water stress, foliage growth and berry size are reduced, fruit quality is enhanced, and sugar accumulation may be unaffected or enhanced.[9, 20, 21]

In Australia, where the concept originated, the RDI method of irrigation scheduling is promoted using soil moisture measurements to determine when to apply water.[9] In California, RDI strategies are being tested using plant moisture status and estimated vineyard water use.[16] These strategies are promising, but they are still in development. Currently RDI is limited by the ability to maintain moderate water stress while avoiding under irrigation and severe water stress.

Partial root zone drying (PRD) is a recent concept that also originated in Australia.[4] It involves alternatively withholding water from each side of the vine from fruit set until harvest. Experimental evidence indicates that roots respond to the drying soil by producing abscisic acid (ABA), a hormone. ABA is translocated to the leaves where it induces closure of the stomata, the tiny pores that allow water vapor to escape and atmospheric gases to enter leaves. The vine responses that follow are those of mild

Table 1

Calculation of irrigation system run time and seasonal irrigation records

	Calculation of Irrigation Run Time							Seasonal Irrigation Records	
Date	Reference ET (1) (in)	Crop Coefficient (2)	Grape ET (3)	Management Factor (4)	Application Rate (5) (in/hr)	Irrigation System Efficiency (6)	Irrigation Hours (7)	Accumulated Grape ET (in)	Accumulated Water Applied (in)
Jun 1	0.19	0.55	0.10	0.75	0.026	0.90	3.21	3.43	2.83
Jun 2	0.16	0.55	0.09	0.75	0.026	0.90	2.82	3.52	2.91
Jun 3	0.19	0.56	0.11	0.75	0.026	0.90	3.41	3.62	2.99
Jun 4	0.19	0.57	0.11	0.75	0.026	0.90	3.47	3.73	3.08
Jun 5	0.23	0.58	0.13	0.75	0.026	0.90	4.28	3.87	3.19
Jun 6	0.27	0.58	0.16	0.75	0.026	0.90	5.02	4.02	3.32

1. From a local weather station
2. From a model (e.g. Fig. 2)
3. Grape ET = Reference ET x Crop coefficient
4. Selected by grower based on vine and vineyard observations, and management objectives
5. Application Rate = (Emitters per Acre x Gallons per hour per emitter) / 27154
6. Irrigation system efficiency may be either measured or estimated
7. Irrigation Hours = ((Grape ET x Management Factor) / (Application Rate x System Efficiency)

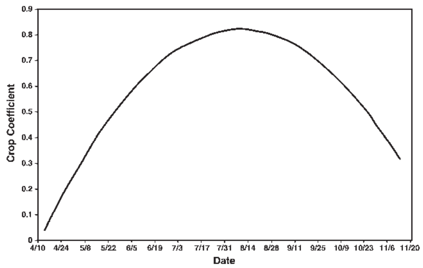

Figure 2: Crop coefficient curve (after Grimes and Williams[6]).

water stress, which result in a reduction of foliage growth.

Production of ABA by roots in drying soil is temporary, lasting only a couple of weeks. In order to maintain the vine in a mild stress state, water is withheld from the opposite side of the vine while the side previously dried is irrigated. The cycle of wetting and drying on alternating sides of the vine is repeated several times before harvest.

The end result of PRD is reduced water use and pumping costs, reduced foliage growth, and conceivably, improved fruit quality without the risk of severe stress that sometimes occurs with RDI. In Australia, PRD has been adopted by only a few growers and in California it has only begun to be studied.[8]

Until the RDI and PRD techniques are ready for routine use, the following question remains: How does one manage soil moisture within a vineyard to optimize fruit for winemaking?

The following systematic five-step irrigation strategy is one that we have used successfully at our vineyards in the Linden Hills area of San Joaquin County. It combines elements of both science and art, with steps #1, #2, and #5 predominantly the former, and steps #3 and #4 predominantly the latter.

It normally contains a period of induced water stress for enhancing fruit quality and is therefore, a RDI method. All that is needed for this method is access to reference evapotranspiration (ET) information from a local weather station, calibrated and functional soil moisture measuring devices (the type of device is not critical), frequent observations of vine foliage and fruit, and some simple record keeping. In this method, soil moisture monitoring devices are required at a minimum of two depths within the root zone. The five steps are listed below:

1. **Initiate irrigation after soil moisture measurements indicate drying**. Look for a sustained decrease in soil moisture indicated by at least two measurements made a few days apart. Assuming that at the beginning of the growing season the soil profile is full of moisture from winter rains, irrigation before the soil begins to dry wastes energy, water, leaches mineral nutrients from the root zone, and creates an unhealthy root environment conducive to diseases. If the soil is dry prior to budbreak, irrigation will be necessary to assure proper root and bud function as vines come out of dormancy.[17]

2. **Irrigate at 75% to 100% grape ET until the canopy is developed as desired.** During the early part of the growing season, vine resources are directed mainly into foliage growth. During this period it is essential that the amount of leaf surface produced be sufficient to ripen the grape crop (10 to 20 leaves per shoot[18]). If it is not, it will be extremely difficult, if not impossible, to do so later. However, it is critical that a moderate rate and not an excessively rapid rate of foliage growth be maintained for normal shoot development and minimum competition between developing shoots and clusters.

The crop coefficient used in the ET model represents vine factors that effect water use, particularly the amount of active foliage. Because it was developed with vigorous vines, it sometimes overestimates the water requirement of vines.

During the early part of the growing season, a management factor is included to compensate for small canopies of low-vigor vines. Later in the season, it is based on other management objectives such as maintenance of canopy and berry size. Management factor values are usually discussed as percentages, but must be decimal fractions for irrigation scheduling calculations as in Table I.

3. **Withhold water to arrest foliage growth.** Do not resume irrigation until foliage darkens, the angle between the leaf and the stem decreases, internodes near the tip shorten, and tendrils lose some turgidity. Do not withhold water so long that tendrils wilt, shoot tips die, and leaves near the base of the shoots become excessively chlorotic or scorched. You have invested in the leaves during step #2 and, unless leaf removal from the fruit zone is desired and planned, they are required to perform their sugar-making function at least until after harvest.

4. **Resume irrigation and repeat as needed until harvest, applying enough water to maintain healthy, dark green leaves but not so much as to stimulate renewed growth of shoot tips** (normally between 35% and 50% of grape ET). This is the period of regulated deficit irrigation.

During this time, frequent monitoring and consideration of vine appearance, soil moisture, and estimated vineyard water use (grape ET) are essential to making irrigation decisions (Fig 2). Of the three, vine appearance is the most important, but the others should also be monitored. Leaves should remain dark green and healthy. As the growing season continues, shoot tips and tendrils will likely die and drop. Scorching on leaves low on the shoot indicates too much stress and the need to apply water.

Continually monitor the weather, particularly current vineyard water use (grape ET) and temperature forecasts, and soil moisture. Apply much more water than usual in advance of and during extreme heat to maintain foliage and avoid excessive stress that lead to fruit sunburn, shrivel, and impaired ripening.[9]

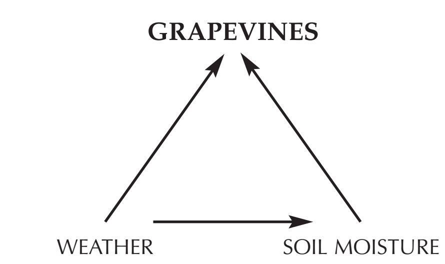

Figure 3: The three components of irrigation scheduling decisions.

During this period, soil moisture readings will vary depending on soil texture and type of monitoring device, but will frequently reach the dryer portion of the available moisture range before harvest.

Mite infestations can sometimes become damaging while vines are being moderately water stressed and frequent monitoring of their numbers is also required. Mite control measures may become necessary.

5. **After harvest, irrigate at 65% to 80% grape ET until the onset of leaf fall**, when irrigations cease. Posthavest maintenance of foliage through continued irrigation is important for storage of carbohydrates and mineral nutrients within the permanent structure of the vine (such as roots, trunks, and cordons), which in turn is important to vine health and resilience during the next growing season. After prolonged drying during step #4, soils with high clay content may require a few long irrigations to rewet.

Summary

An example in 1999 of grape ET soil moisture tension, and irrigation water applied is in fig. 3. The photo in figure 1 illustrates the shoots from a Cabernet Sauvignon vineyard during the ripening period prior to harvest. This vineyard experienced a mild ripening season water stress with moderate soil moisture depletion.

Note that after the onset of irrigation in this vineyard, water was applied almost every day. Water need not be applied this frequently, but the time between irrigations should never exceed one week.

In fig. 3, the difference between the grape ET curve and the water applied line is the management factor. The management factor is determined by the grower based on management objectives and decisions based on vine appearance, weather forecasts, grape ET, and soil moisture. The management factor varies somewhat from year to year, due to variations in conditions such as nutrient status, crop load, and effective leaf area, but after a few years, an average line may be calculated and used for planning and scheduling.

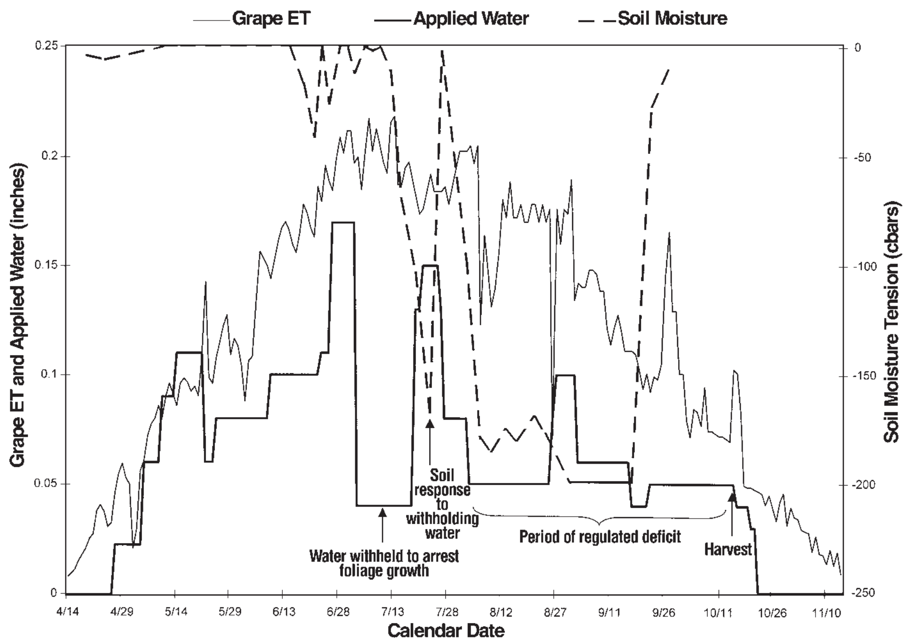

Fig. 4: Estimated vineyard water use (grape ET), applied water, and soil moisture for LindenHills West Cabernet Sauvignon during the 1999 growing season.

The earlier in the growing season that foliage is produced, the earlier water can be withheld to impose a regulated deficit. Moderate water stress prior to veraison frequently results in smaller berries with a larger proportion of skin compared to later moderate water stress.[9, 15, 21] Smaller berries have the potential for greater concentration of compounds that produce flavor and color in wine. However, the production of adequate foliage must always be the first priority because without it, fruit will fail to ripen.

It may not be possible to impose water stress where the soil is deep and contains large amounts of clay or when spring rains are frequent. In the instances given below, imposing water stress may have detrimental effects on fruit production and quality.[1, 3, 7, 9]

Low vigor vineyards may require most of the growing season to produce sufficient canopy, in which case steps #3 and #4 in the above strategy are omitted. Also, vineyards with a drought-sensitive variety such as Merlot or rootstocks will need to be managed differently than described above and may not be suitable for RDI.

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References

1. Bianchi, M. "Deficit irrigation only healthy vines." *California Grower*. 21: 13-14 (Oct. 1997).

2. Bravdo, B., Y. Hepner, C. Loinger, S. Cohen, and H. Tabacman. "Effect of irrigation and crop level on growth, yield and wine quality of Cabernet Sauvignon." *Am. J. Enol. Vitic*. 36, 132-139 (1985).

3. Davidson, D. "Irrigation, vine health, and fruit quality." *Australian Grapegrower & Winemaker*. pp. 66-69. (Nov. 1994).

4. Dry, P., B. Loveys, D. Botting, and H. During. "Effects of partial root-zone drying on grapevine vigor, yield, composition of fruit, and use of water." Proc. 9th Aust. Wine Indus. Tech. Conf. pp. 128-131. (1995).

5. Freeman, B. M. "Effects of irrigation and pruning of Shiraz grapevines on subsequent red wine pigments." *Am. J. Enol. Vitic*. 34, 23-26 (1983).

6. Grimes, D. W. and L. E. Williams. "Developing an optimum water balance for Central Valley vineyards." Final Report UC/IPM (Grape). 29 pp. (1987).

7. Grimes, D. W., and L. E. Williams. "Irrigation effects on plant water relations and productivity of Thompson Seedless grapevines." *Crop. Sci*. 30, 255-260. (1990).

8. Gu, S. "Partial rootzone drying (PRD) to improve fruit quality and water use efficiency." Proc. 2000 Calif. Plant and Soil Conf. Calif. Chapt. Am. Soc. Agron. and Calif. Fert. Assoc. pp. 75-80. (2000).

9. Hardie, W. J., and J. A. Considine. "Response of grapes to water-deficit stress in

particular stages of development." *Am. J. Enol. & Vitic*. 27, 55-61 (1976).

10. Hickey, T. "Irrigation practices for wine grapes — irrigation monitoring equipment." *Australian Grapegrower & Winemaker.* pp. 45-46. (Feb. 1995).

11. Leib, B. G. "Soil moisture sensors for wine grapes." *Wine Business Monthly* pp. 52-55. (Feb. 2000).

12. Ley, T. W. "An in-depth look at soil water monitoring and measurement tools." *Irrigation Journal*. pp. 8-20. (April 1999).

13. Matthews, M. A., R. Ishii, M. M. Anderson, and M. O'Mahony. "Dependence of wine sensory attributes on vine water status." *J. Sci. Food Agric*. 51: 321-335 (1990).

14. Matthews, M. A., and M. M. Anderson. "Fruit ripening in *Vitis vinifera* L.: responses to seasonal water deficits." *Am. J. Enol. Vitic*. 39, 313-320 (1988).

15. Matthews, M. A. and M. M. Anderson. "Reproductive development in grape (*Vitis vinifera* L.): responses to seasonal water deficit." *Am J. Enol. & Vitic*. 40: 52-60 (1989).

16. Prichard, T., P. S. Verdegaal, and C. Rous. "Modification of wine characteristics through irrigation management." *Grape Grower*. pp. 8-13. (May 1995).

17. Smart, R. E. and B. G. Coombe. "Water relations of grapevines." In: *Water deficits and plant growth*. Vol. III. pp. 137-196. Academic Press, New York. (1983).

18. Smart, R. E. and M. Robinson. *Sunlight into wine.* Winetitles, Adelaide. (1991).

19. Steven, R. M. and P. J. Cole. "Grape must composition on irrigation management." Proc. 9th Aust. Wine Indus. Tech. Conf. pp. 159-164. (1995).

20. Vaadia, Y. and A. N. Kasimatis. "Vineyard irrigation trials." *Am. J. Enol. & Vitic*. 12, 88-98 (1961).

21. van Zyl, J. L. "Response of Colobar grapevines to irrigation as regards to quality aspects and growth." *S. Afr. J. Enol. Vitic.* 5, 19-28 (1984).

22. Williams, L. E. and M. A. Matthews. "Grapevine. Irrigation of Agricultural Crops." B. A. Stewart and D. R. Nielsen (Ed.). Madison, Wis: American Society of Agronomy. pp. 1019-1055 (1990).

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