IRRIGATION STRATEGIES FOR WHITE AND RED GRAPES

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Water is a basic requirement for plant growth and performance. Both oversupply and shortage of water result in unbalanced vine growth and poor production. Irrigation is a powerful management tool for improving vine performance, as it allows us to manipulate an environmental variable (water). Not surprisingly, grapes have one of the longest histories of irrigation of any agricultural crop. Vineyards have reportedly been irrigated as long as 5000 years ago in Mesopotamia (modern-day Iraq, Syria, and eastern Turkey). Unlike those in Washington, vineyards in New York are not absolutely dependent on irrigation. Average annual precipitation is sufficient (30 inches or more) to grow grapes more or less successfully. However, the amount of rainfall can vary greatly from season to season, which may drastically impair vine performance and the economics of viticulture in some years. Moreover, the use of irrigation depends not only on how *much* rainfall a vineyard receives but also on *when* the rain falls, and on how rapidly it evaporates. In addition, the amount of available water varies for different soil types; for example, a fine loam soil has up to six times more available water than does coarse sand. Therefore, variation in soil moisture due to differences in water holding capacity and effective rootzone also has a pronounced impact on vine performance both between and within vineyards. Irrigation can be used as a supplement to compensate for the climatic shortcomings; i.e. to provide adequate moisture when nature does not supply it during the critical stages of the seasonal growth cycle. Of course, irrigation can do nothing to remove excessive soil moisture. That problem is best addressed using proper site selection and other soil management options, such as cover crops or permanent swards. In addition, higher planting density or lighter pruning (or even minimal pruning) could be used to increase water use early in the season due to the earlier canopy development.

Some principles of vine growth and fruit development have important implications for vineyard water management. First, although water uptake during budbreak is caused by root pressure, transpiration soon becomes the main driving force for water uptake and movement in the xylem up the vine to the leaves. Second, root growth starts after shoot growth and may continue after harvest if conditions permit. Third, bloom occurs well after budbreak and during a period of vigorous shoot growth. In vigorous vineyards, vegetative growth may continue throughout the season and compete with fruit development. Fourth, grape berries initially grow mostly by cell division and later exclusively by cell expansion. Fifth, most of the berry volume gain before veraison is due to water import in the xylem, whereas most of the post-veraison gain is due to water import in the phloem. And sixth, a good balance between shoot and fruit growth is critical for optimum fruit ripening.

The water status of grapevines is determined by the amount of water lost in transpiration to the atmosphere and the amount of water absorbed from the soil. Water influences the rate of shoot growth (vigor) and thus canopy microclimate. A high water status stimulates vigor, which can lead to a dense canopy and shaded fruit, slowing down the rate of fruit ripening. A larger leaf area also has a greater water demand due to transpiration, which in turn increases the vine's susceptibility to drought when soil water runs short. On non-stressed, vigorously growing shoots, the uppermost tendrils extend beyond the shoot tip. As water stress sets in and growth begins to slow, new tendrils remain small so that the shoot tip catches up with them. With more severe stress growth stops and the youngest leaf expands beyond the shoot tip. Moreover, unlignified tendrils are extremely sensitive to water stress and start wilting before the leaves do. Therefore, shoot vigor and the behavior of tendrils can be used as indicators of vine water status.

It is often stated that reproductive growth (and thus yield) is less sensitive to water deficit than is vegetative growth. However, the impact of water stress on yield depends on when the stress occurs. Early on (i.e. post-budbreak) the developing flower clusters can compete quite successfully with the growing shoots for limited water. But the closer the stress occurs to bloom time, the more susceptible the inflorescences become. Even moderate water stress during the bloom-fruit set period can lead to poor fruit set and abortion of entire clusters. Following fruit set, water-stressed vines generally maintain fruit growth and ripening at the expense of shoot and root growth and replenishment of storage reserves. Stress applied during the berry cell division phase can still lead to significant yield reductions by reducing berry size, whereas after veraison berries become increasingly insensitive to water deficit. Therefore, water stress should be avoided before fruit set, whereas the time between fruit set and veraison is the period when shoot growth and berry size can be most effectively controlled by water deficit. This principle is exploited by the concept of regulated deficit irrigation (RDI), where a short duration of water deficit is applied as soon as possible after fruit set. During the RDI period, the soil profile is allowed to dry down until control of shoot growth has been achieved. Once shoot growth stops and especially after veraison, vines should be stressed only sufficiently to discourage new shoot growth. At the end of the season the rootzone needs to be refilled to field capacity.

When vine roots experience both wet and dry soil, the reaction of shoot growth depends on whether the difference in soil moisture is perceived by the same or different roots. When the surface soil is dry while the subsoil is still wet, there is no reduction in shoot growth as long as the roots have access to the subsoil water. However, when separate roots of the same vine experience dry and wet soil columns, shoot growth is suppressed. This can be used in an irrigation method termed partial rootzone drying (PRD), in which water is supplied alternately to only one side of the vine, while the other side is allowed to dry down. This technique attempts to separate the biochemical responses to water stress from the physical effects of water stress by tricking the vine into 'thinking' it is water-stressed (and stops shoot growth) while the wet roots maintain a favorable plant water status to ripen the fruit. The maintenance of vine water status also normally maintains berry size and yield, while the smaller canopy often results in improved fruit quality. This is in contrast to other deficit irrigation techniques (e.g. RDI) which typically reduce berry size and yield. The fundamental difference between the two methods is that with RDI *soil*-water deficit is applied over time, whereas with PRD the deficit is applied over space. RDI always results in a *plant*-water deficit, while PRD usually does not. Although PRD can be targeted to a particular growth stage, it is normally maintained over the entire season. In Australia, where PRD was developed, this method can result in water savings of up to 50% compared with conventional drip irrigation. Drip irrigation is generally the technique of choice, but under-vine (micro-)sprinklers, over-vine sprinklers, furrow and flood irrigation have all been used successfully with both RDI and PRD.

The effect of water deficit on sugar accumulation is generally less pronounced than the effect on berry growth. Mild water deficit may increase sugar accumulation by limiting growth or by reducing canopy density. However, water stress can delay berry development because of a reduction in photosynthesis or, in extreme cases, leaf drop. Contrary to popular belief (and European regulations), post-veraison water stress often reduces fruit sugar rather than improving it. Soil moisture has little effect on tartrate content per berry, but malate tends to decline with a decrease in soil moisture. The reduction in malate is more pronounced when water deficit occurs before veraison than after veraison. The improved color of red grapes often observed with mild water stress is, in part, simply due to smaller berry size, which increases the skin:pulp ratio, and to improved fruit exposure. But there also seems to be a more direct effect of water deficit enhancing the production of anthocyanins, whereas accumulation of flavonols (quercetin-glycosides and relatives) and hydroxycinnamates (tartrates of caffeic, coumaric, and ferulic acids) is little affected by water stress. Carotenoid concentration, on the other hand, is lower in grapes grown at low soil moisture, but it is unclear if this is due to reduced production or increased breakdown (conversion to aroma compounds). In addition, the concentration of the yeast-assimilable amino acid arginine is lower in berries of water-stressed vines, whereas proline is not strongly affected by water stress.

The discussion thus far has concentrated primarily on red varieties. However, techniques for managing red grapes do not automatically transfer to white grapes. For one, berry size (skin:pulp ratio) is far less important in white grapes than in red grapes, simply because skin components are not usually extracted during white winemaking. Moreover, sun exposure of fruit due to reduced canopy size increases the formation of phenolics. The major phenolics of white grapes are the hydroxycinnamates. These free (i.e. non-glycosylated) phenolics are important because they can be converted during fermentation to volatile phenols (such as ethyl or vinyl guaiacol and eugenol), which are odor-active and at low concentrations smell ‘smoky’, ‘woody’, ‘leathery’, or ‘peppery’. However, at higher concentrations they become unpleasantly ‘pharmaceutical’ or ‘medicinal’ at the expense of varietal fruit aromas. Thus water stress can reduce the elegance of fruit character in white wines. In addition, the flavonoids (anthocyanins, tannins, and flavonols) located in the skin and seeds are fundamental to the quality of red grapes, but are of much less significance for white grapes. Nevertheless, overripe and overexposed white grapes can contain undesirably large concentrations of flavonoids, which are easily extracted into the juice. Even with minimal skin contact these phenolics can lead to a noticeable firmness or even bitterness in wine. Taken together it appears, therefore, that RDI is generally less applicable for white varieties, whereas PRD may be more suitable, as long as the reduced canopy size does not lead to overexposed fruit. This is particularly true for the more delicate ‘nose’ varieties, such as Riesling or Gewürztraminer. Chardonnay, on the other hand, can sometimes benefit from some flavonoid extraction which provides ‘structure’ to the wine. Of course, irrigation is not the only vineyard management option for manipulating fruit exposure. In fact, some water-stress induced reduction in canopy size may actually be beneficial even for white grapes, as it reduces the need for leaf removal and complex trellis designs. Regardless of variety and no matter which irrigation strategy is chosen, it is important to determine soil types and rooting depths in the vineyard and establish a means of monitoring soil moisture in the different blocks determined according to these physical attributes.

Further reading

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