ETN 007
November 2004
Kabul, Afghanistan

Extension Toolkit Notes

Roots of Peace ◦ University of California—Davis
ROP GRAPE Project funded by USAID administered by Chemonics International

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Water Relations & Vineyard Water Management

Notes Compiled from—

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I. Water Relations

Water science, or hydrology, describes the interaction of water with its environment. It also defines models that predict water behavior. Water science uses many specialized terms and concepts. Extension Toolkit 007 presents some of the terms and concepts important to the agricultural uses of water.

Water adheres to soil particles and occupies the spaces between soil particles, called **pores**. **Infiltration** is the movement of water into the soil from above, **percolation** is the through-flow of infiltrated water to the groundwater. **Interflow** is subsurface lateral flow and occurs through soils on slopes, or when vertical flow, i.e. percolation, through subsoil is impeded. The difference between the precipitation amount that reaches the soil surface (net precipitation) and the infiltrated water is the **surface runoff**.

Gravity pulls water out of larger soil pores in saturated soils, leaving air in those spaces. Once all of the water that gravity can pull away has been removed, the soil is at its naturally 'full' level. This is called **field capacity** (FC). Since sandy soils have generally larger pores than clay soils, gravity will remove a larger percentage of water from sandy soils. Thus, sandy soils have a lower FC than clay soils.

After a season of rainfall or a thorough irrigation, all of the pores in the soil are completely filled with water and FC is reached. The soil at that point is **saturated** and can hold no more water. Further irrigation or rainfall cannot add to FC and the excess water is lost as either surface runoff, deep percolation beyond the root zone, or it interflows through the soil to areas outside the vineyard that are below FC.

Water applied to a field—either as rainfall or irrigation—is often measured in **acre-feet**. An acre-foot is the volume of water required to cover one acre to a depth of one foot. Likewise, when the water requirement for a crop is described as 20 inches, then a volume of water sufficient to cover the field that the crop occupies to a depth of 20 inches is meant.

An **aquifer** is soil or rock below the land surface that is saturated with water. The saturated surface of an aquifer is called the **water table**. A **watershed** is the land area that drains surface and ground water to a particular river, stream or lake. Excess irrigation water enters the watershed and is drained away from the vineyard.

Soil moisture or **water content** is a term that describes how much water is in the soil. It is expressed as a fraction usually defined as the volume of water in a given volume of soil. After the soil has reached FC, its water content will remain stable unless outside forces remove it. One force is **evaporation** at the soil surface. Another force is extraction by vine roots, which is part of the process of **transpiration**. Transpiration is the release of water vapor from the leaves of a plant; it occurs through the stomata on the leaf surface. The transpiration process occurring in the leaves helps continuously lower the water concentration within the roots by removing some of the water there. When the water concentration in the roots becomes lower than that in the surrounding soil, water flows into the roots. Together, these two forces are referred to as **evapotranspiration** and describe the total loss of water from a field that is at or below FC.

After a significant amount of water has been extracted by vine roots, the attraction (think of this as suction) of soil particles to the remaining water eventually exceeds the roots' ability to extract (again, 'suck') the water away through transpiration. This low level of soil moisture is called the **permanent wilting point** (PWP). At PWP plants are wilted and do not recover turgor pressure when transpiration stops at night; death of leaves and green stems then occurs. Vine death occurs if the water level is maintained at PWP for too long. Soil at PWP still contains water; the vines just can't pull it out. So, while soil can range from fully saturated to completely dry, the useful range of water content— from a farmer's perspective— is from field capacity at the highest, down to the permanent wilting point at the lowest. That range of water content is referred to as **plant available water** (PAW). Water held more loosely than FC drains away by gravity. PAW is the water content between FC and PWP. Not all PAW is used by plants; some of it is lost through evaporation.

II. Measuring Soil Moisture

The most accurate way to measure soil water content is to take a sample of soil, measure its volume or mass, then bake it to absolute dryness and re-measure. (This process also is the way to determine the water content of vine foliage.) But even beyond the hassle factor, this method isn't practical in real-world vineyards since farmers would not want to repeatedly dig up vineyard soil at various depths during the growing season.

Another way to measure water content is by the level of attraction (suction) of the soil to its water; several types of instruments do this: e.g., tensiometers, neutron probes and porous blocks. Terms for soil suction that are more scientific are **tension** and **soil water potential**. Water potential describes the potential energy of water in soil. Potential energy is defined as the ability to do work. Work is done whenever an object (i.e., mass) is moved through a distance. Water potential measures the ability of soil water to move.

Water potential is important to any process where soil water moves such as infiltration and redistribution of water within the soil, or the removal of water from the soil by evaporation or transpiration. Regardless of the reason (e.g., gravity, pressure, or concentration of solute particles) for the water potential, water moves from a region where water potential is greater to a region where water potential is lower. The greater the difference that occurs between the water potentials of the two areas, then the greater the pressure on the water to move.

III. Vineyard Water Management

The annual water requirement—evapotransporation—of a mature vineyard in California varies from 22 to 28 inches (558 to 711mm) depending on the size of the leaf canopy (Worldwide that requirement ranges from 10 to 30 inches). In addition to evapotransporation, 6 to 8 inches (158 to 203mm) may be needed to leach salts or provide frost protection.

Water use by grapevines begins with bud-break in early April (depending on location). It gradually increases as the canopy develops and temperatures climb. The canopy is fully developed by early to mid-June, and peak water use occurs in June, July and August. It is then that water stress is usually first observed.

The first sign of water stress is a drooping of the leaves. As water stress increases, shoot growth slows and internode growth is inhibited. As water stress becomes more acute the shoot tips and tendrils die. In extreme water stress, leaf abscission occurs, originating with the most mature leaves and progressing towards the shoot tip. Severe water stress can result in delayed and poor bud-break the following spring, as well as flower clusters that are smaller and reduced in number.

The growing season can be divided into five stages. For a hypothetical crop having dates for bloom (June 6), veraisin (August 15) and harvest September 17):

Stage I. Bud-break to bloom. Fraction of annual water use: ~5%. Soil moisture stored from winter rains should be adequate to meet this demand. Vines rarely show signs of water stress during this stage, even with no spring irrigation.

Stage II. Bloom to fruit set. Fraction of annual water use: ~15%. Uncorrected water stress during this stage of development may result in reduced canopy development and insufficient leaf area to support fruit development and maturation. Water stress during this stage may reduce the following season's crop potential by affecting bud initiation.

Stage III. Fruit set to veraisin. Fraction of annual water use: ~15%. Veraison is the point when fruit begins to soften or break color, it can be as early as late-June or early-July for some varieties. Water stress is very harmful to the crop during stage III. Rapid cell division is occurring in fruit and water stress can reduce berry size and yields. The fruit of many varieties are susceptible to sunburn during stage III, which is another reason water stress should be avoided.

Stage IV. Veraison to harvest (the ripening phase). Fraction of annual water use: ~20%. Table grape varieties should be irrigated sufficiently to avoid water stress and maximize berry size. Mild stress may be beneficial to varieties prone to berry cracking and bunch rot. Excessive irrigation during stage IV can delay fruit maturity, encourage bunch rot and berry cracking, and delay or reduce wood maturity. Excessive water stress during stage IV can reduce berry size, color, maturity and yield.

Stage IV. Harvest to dormancy. Fraction of annual water use: ~5%. The length of stage V depends on the harvest date. It is about 60 days for varieties harvested in early September. Stage V irrigations should be applied in amounts to maintain the canopy but not to encourage growth. Vines of vigorous varieties will continue to grow or start new growth after harvest and fail to ripen wood if irrigated too much. Mild to moderate water stress is beneficial by stopping shoot growth and promoting wood maturity. However, vines should not be allowed to defoliate. In late October or early November (i.e. when temperatures are too low for shoot growth), a heavy irrigation is recommended to replenish some of the soil-water reservoir and to leach any accumulated salts. Vines entering dormancy with a dry root zone tend to have poorer bud-break the following spring.

IV Extension.

You talk to one of your client farmers and learn that his yield was much lower than his neighbors and also lower than the average for the district. You ask him about his management practices and learn that he irrigated twice during the year: a heavy irrigation before bud-break and a lighter irrigation about one month before harvest. The vineyard has sandy soil.

You explain to him the four stages of vine growth and recommend that he not irrigate so heavily in stage I (and to be aware that exceeding FC is wasteful) and that he should provide more frequent smaller irrigations during stage II and part of stage III. You also recommend a heavy irrigation before winter to help ensure the vines have a good start in the spring.

Water Measurement Conversion Factors http://www.scijournals.org/misc/conversion/shtml			
Multiply Column 1 by Y to convert to Column 2 Units Multiply Column 2 by Z to convert to Column 1 Units			
Y	Column 1	Column 2	Z
9.73×10^{-3}	Cubic meter, m^3	Acre-inches, acre-in	102.8
981×10^{-3}	Cubic meter per hour, m^3h^{-1}	Cubic feet per second, ft^3s^{-1}	101.9
4.40	Cubic meter per hour	U.S. gallons per minute, gal min^{-1}	0.227
8.11	Hectare-meters, ha-m	Acre-feet, acre-ft	0.123
97.28	Hectare-meters,	Acre-inches, acre-in	1.03×10^{-2}
8.1×10^{-2}	Hectare-centimeters,	Acre-feet, acre-ft	12.33