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# Grape Irrigation

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Proper irrigation of grapes is essential to maintaining a healthy and productive planting. Over-irrigation slows root growth, increases iron chlorosis on alkaline soils, and leaches nitrogen, sulfur, and boron out of the root zone leading to nutrient deficiencies. Excessive soil moisture also promotes root rot, particularly on heavy soils. Applying insufficient irrigation water results in drought stress. Excessive drought stress during fruit development results in reduced fruit size and yield, and poor fruit quality.

Properly managing irrigation is analogous to managing a bank account. In addition to knowing the current bank balance (soil water content), it is important to track both expenses (evapotranspiration) and income (rainfall and irrigation).

## Bank Balance (Soil Water Content)

***How big is my bank account? – Water holding capacity***
First, some terminology:

- Field Capacity is the amount of water that can be held in the soil after excess water has percolated out due to gravity.
- Permanent Wilting Point is the point at which the water remaining in the soil is not available for uptake by plant roots. When the soil water content reaches this point, plants die.
- Available Water is the amount of water held in the soil between field capacity and permanent wilting point (Figure 1).
- Allowable Depletion (readily available) is the point where plants begin to experience drought stress. Depending on soil type, the amount of allowable depletion for grapes is about 60 percent of the total available water in the soil (Figure 2). However, allowable depletion can also differ during the seasonal development of grapes.

The goal of a well-managed irrigation program is to maintain soil moisture between field capacity and the point of allowable depletion, or in other words, to make sure that there is always readily available water and that plants do not experience water stress.

The amount of readily available water is related to the effective rooting depth of the plant, and the water holding capacity of the soil. The effective rooting depth depends on soil conditions and variety. Although some roots grow deeper, the majority of grape roots are found in the top 3 feet of soil. The water holding capacity within that rooting depth is related to soil texture, with coarser soils (sands) holding less water than fine textured soils such as silts and clays (Table 1). For example, a sandy loam soil at field capacity would contain 0.72 to 0.9 inches/foot of readily available water, compared to a clay loam which holds 1.02 to 1.20 inches/foot.

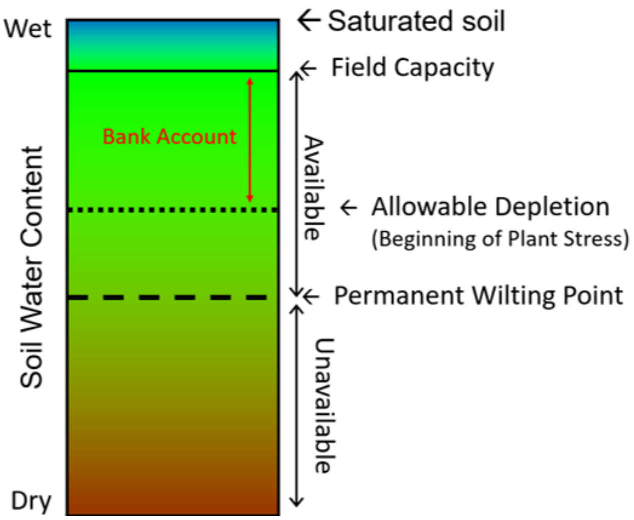

**Figure 1. Soil water content from saturated to dry. Optimal soil moisture levels for plant growth are between field capacity and allowable depletion.**

### *What's in the bank? -- Measuring Soil Moisture*

In order to assess soil water content, one needs to monitor soil moisture at several depths. Monitors should be placed in the primary root zone (12 inches) and near the bottom of where the thickly branched lateral roots grow (30 to 36 inches). One of the most cost effective and reliable methods for measuring soil moisture is by electrical resistance block, such as the Watermark$^{TM}$ sensor (Irrometer Co., Riverside, CA). These blocks are permanently installed in the soil, and wires from the sensors are attached to a handheld unit that measures electrical resistance. Resistance measurements are then related to soil water potential, which is an indicator of how hard the plant roots have to "pull" to obtain water from the soil.

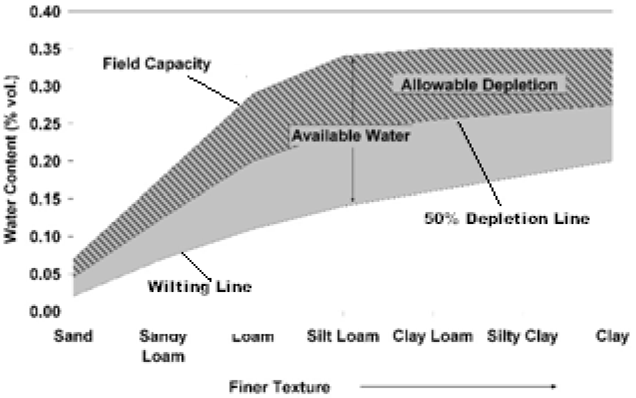

**Figure 2. The amount of allowable depletion, or the readily available water, represents about 50 percent of the total available water.**

The handheld unit reports soil moisture content in centibars, where values close to zero indicate a wet soil and higher values represent an increasingly dry soil. The relationship between soil water potential and available water differs by soil type. The range of the sensor is calibrated to 0 to 200 centibars which covers the range of allowable depletion in most soils.The sensors are less effective in coarse sandy soils, and will overestimate available soil water in saline soils. Remember that allowable depletion is about 60% of available water, which roughly corresponds to soil water potentials of 45-55 centibars for a loamy sand soil, and 65-95 centibars for a loam (Table 2, 60% depletion values for each soil texture).

Water is lost from the field through surface runoff, deep percolation (moving below the root zone), evaporation from the soil surface, and transpiration through the leaves of the plant. Of these, the biggest losses are typically due to evaporation and transpiration, collectively known as "evapotranspiration" or ET. Deep percolation from excess irrigation can be another large loss. Estimates of ET are based on weather data, including air temperature, relative humidity and wind speed. Table 3 lists historic average daily reference ET values for several representative locations across Utah. Many more sites are monitored in the state, if your location is not listed, visit climate.usu.edu to find a monitoring location near you. For updated ET estimates at 30 Utah locations, visit the "Plant Management" tab at the above website.

### *Grape Water Needs*

Some weather stations in Utah are programmed to calculate and report the ET estimates for alfalfa as a reference crop ($ET_{ref}$ or $ET_r$). The ET of grapes can be determined by multiplying the $ET_r$ by a correction factor or crop coefficient ($K_{crop}$) that is specific to grapes and stage of development. Note: Some publications use ETo which is a grass reference ET, which uses a different set of $K_{crop}$ values.

$$ET_{crop} = ET_r \times K_{crop}$$

**Table 1. Available water holding capacity for different soil textures, in inches of water per foot of soil. Total available water is the amount of water in the soil between field capacity and permanent wilting point. Allowable depletion (readily available water) is the amount of water the plant can use from the total available before experiencing drought stress. For grapes, allowable depletion is approximately 60 percent of total available.**

| Soil Texture | Total Available Water *inch/foot* | Allowable Depletion *inches* (Readily available) | |
|---|---|---|---|
| | | In top 1' | In top 3' |
| Sands and fine sands | 0.5 - 0.75 | 0.3 - 0.45 | 0.9 – 1.35 |
| Loamy sand | 0.8 - 1.0 | 0.48 - 0.6 | 1.44 – 1.8 |
| Sandy loam | 1.2 - 1.5 | 0.72 - 0.9 | 2.16 – 2.7 |
| Loam | 1.9 - 2.0 | 1.14 - 1.2 | 3.42 – 3.6 |
| Silt loam, silt | 2.0 | 1.2 | 3.6 |
| Silty clay loam | 1.9 - 2.0 | 1.14 - 1.2 | 3.42 – 3.6 |
| Sandy clay loam, clay loam | 1.7 - 2.0 | 1.02 - 1.2 | 3.06 – 3.6 |

The $K_{crop}$ for *table and juice* grapes are shown in Figure 3. At leaf emergence in the spring (Growth Stage = 0), both types of grapes use the same amount of water, about 16% of the amount of water used by the alfalfa reference crop. For table grapes, water use steadily increases until full canopy (growth stage = 100) when water use is 83% of a reference alfalfa crop. Crop coefficient remains steady through the end of summer and fall, until a killing frost stops leaf activity. Supplying full irrigation ensures large berry size, an important characteristic for table grapes.

For *wine* grapes, water use increases somewhat more quickly than table grapes during the early growth stages until just over half-filled canopy (growth stage = 60) when water use levels off at a much lower 65% of a reference alfalfa crop. Water use remains steady for the rest of the growing season until a killing frost.

**Table 2. Recommended Watermark™ sensor values at which to irrigate.**

| Soil Type | Irrigation Needed (*centibars*) |
|---|---|
| Loamy sand | 45 - 55 |
| Sandy loam | 55 - 75 |
| Loam | 65 - 95 |
| Silt loam, silt | 75 - 95 |
| Clay loam or clay | 95 - 125 |

™Watermark is a registered trademark of Irrometer, Co., Riverside, CA.

**Table 3. Daily total alfalfa reference evapotranspiration ($ET_r$) for nine Utah cities expressed in (A) inches per day, (B) gallons per acre per day, and (C) drip-irrigated gallons per 100 feet of row length per day.**

| Month | Logan | Brigham City | Ogden | Salt Lake City | Spanish Fork | Green River | Richfield | Cedar City | St. George |
|---|---|---|---|---|---|---|---|---|---|
| **(A) Inches per day** | | | | | | | | | |
| Mar | 0.09 | 0.1 | 0.1 | 0.11 | 0.12 | 0.15 | 0.14 | 0.13 | 0.15 |
| Apr | 0.15 | 0.16 | 0.17 | 0.17 | 0.16 | 0.23 | 0.2 | 0.18 | 0.22 |
| May | 0.2 | 0.22 | 0.22 | 0.22 | 0.21 | 0.29 | 0.23 | 0.24 | 0.28 |
| Jun | 0.24 | 0.27 | 0.28 | 0.28 | 0.26 | 0.32 | 0.3 | 0.31 | 0.32 |
| Jul | 0.29 | 0.32 | 0.32 | 0.3 | 0.28 | 0.32 | 0.29 | 0.29 | 0.31 |
| Aug | 0.26 | 0.28 | 0.29 | 0.27 | 0.25 | 0.25 | 0.27 | 0.27 | 0.28 |
| Sep | 0.18 | 0.2 | 0.2 | 0.19 | 0.18 | 0.2 | 0.2 | 0.21 | 0.21 |
| Oct | 0.09 | 0.12 | 0.12 | 0.11 | 0.1 | 0.12 | 0.13 | 0.14 | 0.14 |
| **(B) Gallons per acre per day. Irrigation amounts need to be adjusted by Crop Coefficient and Irrigation Efficiency. [1]** | | | | | | | | | |
| Mar | 2444 | 2716 | 2716 | 2987 | 3259 | 4073 | 3670 | 3451 | 4073 |
| Apr | 4073 | 4345 | 4617 | 4617 | 4345 | 6246 | 5386 | 5006 | 5974 |
| May | 5431 | 5974 | 5974 | 5974 | 5703 | 7875 | 6360 | 6412 | 7604 |
| Jun | 6517 | 7332 | 7604 | 7604 | 7061 | 8690 | 8102 | 8500 | 8690 |
| Jul | 7875 | 8690 | 8690 | 8147 | 7604 | 8690 | 7937 | 7788 | 8418 |
| Aug | 7061 | 7604 | 7875 | 7332 | 6789 | 6789 | 7385 | 7306 | 7604 |
| Sep | 4888 | 5431 | 5431 | 5160 | 4888 | 5431 | 5522 | 5739 | 5703 |
| Oct | 2444 | 3259 | 3259 | 2987 | 2716 | 3259 | 3609 | 3741 | 3802 |
| **(C) Drip-irrigated gallons per 100 feet of row length per day based on 10-foot[2] row spacing. Irrigation amounts need to be adjusted by Crop Coefficient and Irrigation Efficiency.[3]** | | | | | | | | | |
| Mar | 56 | 62 | 62 | 69 | 75 | 94 | 84 | 79 | 94 |
| Apr | 94 | 100 | 106 | 106 | 100 | 143 | 124 | 115 | 137 |
| May | 125 | 137 | 137 | 137 | 131 | 181 | 146 | 147 | 175 |
| Jun | 150 | 168 | 175 | 175 | 162 | 199 | 186 | 195 | 199 |
| Jul | 181 | 199 | 199 | 187 | 175 | 199 | 182 | 179 | 193 |
| Aug | 162 | 175 | 181 | 168 | 156 | 156 | 170 | 168 | 175 |
| Sep | 112 | 125 | 125 | 118 | 112 | 125 | 127 | 132 | 131 |
| Oct | 56 | 75 | 75 | 69 | 62 | 75 | 83 | 86 | 87 |

[1] Conversion to gallons per acre per day (B) = (A) x 7.481 * 43560 / 12.

[2] 10-foot bed spacing is appropriate for grape. Adjust calculation according to row spacing (see equation below).

[3] Calculation for drip-irrigation: (C) = (B) x 10 ft. (row spacing) / 435.6. If different row spacing is used, adjust calculation accordingly.

Calculated from long-term monthly evapotranspiration values from Hill, 2011.

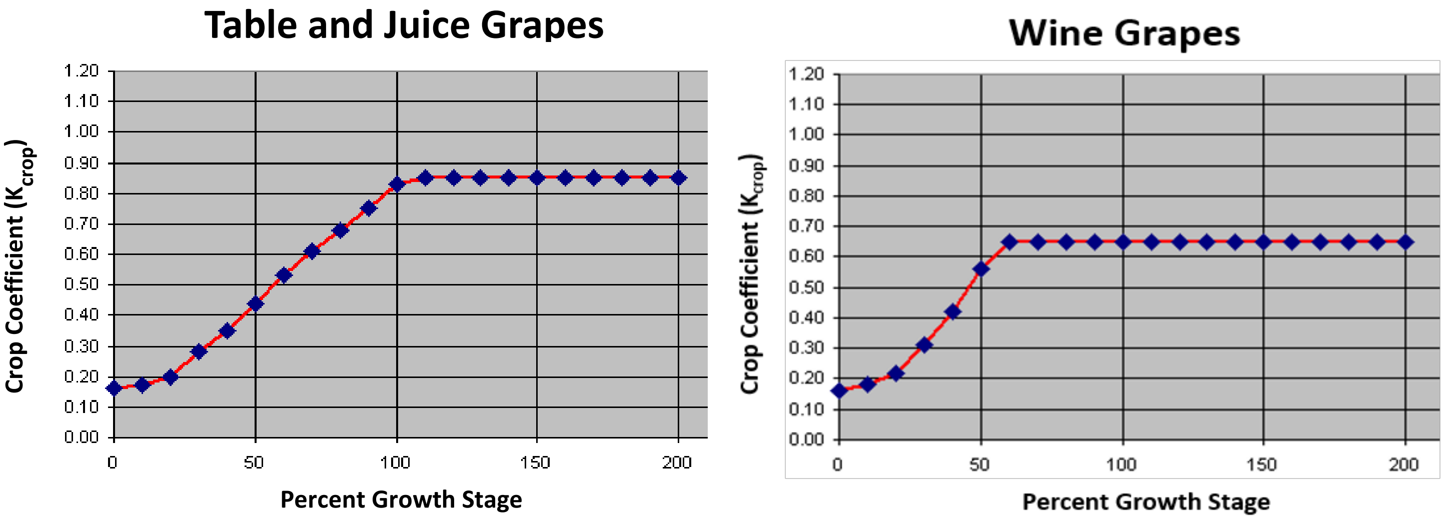

**Figure 3. Crop coefficients ($K_{crop}$) for table and the juice grape 'Concord' (left) and wine grapes (right) (AgriMet).**

Some grape producers will intentionally drought stress their plants at certain stages of crop development by applying less water than the vineyard would typically use under those conditions. This intentional drought stress is called Regulated Deficit Irrigation (RDI). RDI during the appropriate stage of development will reduce berry size, resulting in increased skin/pulp ratio. Smaller berries allow for better airflow within the cluster, reducing potential for disease and split berries. In red grape varieties, RDI often results in improved color. Vegetative growth is reduced with RDI, which decreases pruning and fruit shading. However, total yield is also reduced when compared to a planting receiving irrigation for 100% ET replacement. Growers accept this lower yield because of the increase in wine grape quality. Although many effects of deficit irrigation are beneficial, some can be harmful depending on timing and severity. Severe water deficits limit photosynthesis and the production of sugar and cause defoliation and sunburn.

The most important times to avoid water stresses are from flowering to pea-size grapes, softening of grapes to harvest, and then after harvest. Water use is relatively low from leaf emergence (0% growth stage) to flowering and water stress from pea-size to softening (coloration) is less critical than other stages. Avoid water stress from softening to harvest (ripening), especially with table and juice grapes, because grape size significantly increases and water use is high due to hotter temperatures and fruit growth. Avoid water stress after harvest so plants can build reserves for next season and grow roots. As fall air temperature decreases, less water is needed by the plants. Other factors that increase water use are groundcover between rows, grass cover or weedy alleys, and excessive canopy growth.

A very common RDI regime is to apply 60 to 70 percent of ET between fruit set and harvest. Once harvest is complete, RDI is not recommended. Instead, increase irrigation to facilitate root growth and to prepare the plant for winter. Since each vineyard is different (climate, soil, vigor, variety, trellis design) and production goals vary, exact irrigation scheduling must be determined individually. Knowing what level of water reduction, at what time and for how long takes careful monitoring of soil moisture, shoot length and growth rate, shoot tip condition, and leaf water potential. See the additional resources section for more information on RDI. Vineyards with very low vigor should not be subjected to RDI.

## Income – Irrigation and Rainfall

In Utah's high elevation desert climate, rainfall only contributes a small fraction of the in-season water requirements of grapes. Therefore, regular irrigation is needed to supply plant water needs. Irrigation water can be supplied by furrow, impact sprinklers, microsprinklers, or drip lines.

Flood and furrow irrigation requires the land to be well graded to allow for uniform distribution. Slope of the field should not exceed 2% to reduce erosion. Flood irrigation can increase pest problems such as powdery mildew and increased weed pressure from weed seed in unfiltered irrigation water. Field access after irrigation events is also limited.

Overhead sprinklers can be used on uneven lands and can save on field grading costs. The irrigation water must be low in salts to reduce the risk of leaf burn. Excessive wetting can lead to disease problems. Sprinkler irrigation frequency should allow several days for canopy drying. During hot summer weather, overhead irrigation can give some evaporative cooling of the leaves and fruit, but irrigation must be stopped in the late afternoon to allow leaves and fruit to dry out before night time, to prevent disease incidence.

Microsprinklers and drip irrigation (Figure 4) both have the advantage of being able to be used over uneven topography, like overhead sprinklers, but do not wet the plant canopy, which minimizes disease risks. Irrigation events must be more frequent than flood and overhead sprinklers. This may be an issue if timing of your irrigation water is limited. In a drip system the irrigation water must be filtered to prevent particles in the water from clogging emitters.

Whichever irrigation system you utilize, it is important to calibrate your system so that you know precisely how much water is being applied. With sprinklers and microsprinklers, the simplest way to do this is to place catch cans in multiple locations in your planting and collect water for a set period of time. The amount of water collected over time will give you an application rate (inches per hour), and differences in water collected among the catch cans will tell you how uniform the application is within your planting. When trying to determine application uniformity, it is best to measure output at both ends of your irrigation system. Also, if your planting is on a slope, you should measure output at the highest and lowest points of your field. Elevation differences and the distance the water travels through the irrigation lines both affect water pressure, and consequently the flow rate at the nozzle.

**Figure 4. Grape vineyard with drip irrigation suspended between trellis posts.**

Drip irrigation tubing comes with recommended operating pressures, a range of emitter spacings, and flow rates. Most drip tubes operate at 10-20 psi depending on field topography. Emitters may be spaced from 4 to 36 inches apart and come in a variety of flow rates. Flow rates are commonly reported in gallons per 100 feet of tape per hour (GPH) or gallons/emitter/hr. For a tube with a 12-inch emitter spacing, 24 gallons/100ft/hr = 24/100 = 0.24 gallons/emitter/hr. Pressure compensating emitters (PC) provide the best uniformity. Flow rate from each emitter and emitter spacing can be used to calculate rate per area (Table 3). Drip irrigation systems are usually operated every day or every few days to maintain optimal soil moisture.

The efficiency of your system is a measure of how much you have to over-water the wettest spots in the field to get adequate water to the dry spots. Efficiency is related to the uniformity of application and to the amount of evaporation that occurs before the water can move into the soil. A well-designed drip system can be 80 to 90% efficient. Overhead sprinkler systems are typically 60 to 75% efficient, while flood and furrow irrigation is typically 30 to 50% efficient. If your water supply is limited, a more efficient system can make a large difference in water savings and crop productivity.

## Summary

Good irrigation management requires:

1. An understanding of the soil-plant-water relationship.
2. Properly designed and maintained irrigation system, and understanding of system efficiency.
3. Proper timing based on
    a. Soil water holding capacity
    b. Weather and its effects on crop demand
    c. Stage of growth.

Each of these components requires a commitment to proper management. Proper management will lead to the maximum yields per available water and will optimize the long-term health and productivity of your planting.

## Case Study

Following is an example of how to calculate water needs for a *wine* grape vineyard in St. George, Utah, in July with a full canopy. The soil is a deep loam with drip irrigated rows every 10 feet.

- Water use (Expenses)
    - ETr values are 0.31 inches per day (weather station data, Table 3).
    - Crop coefficient is 0.65 (Growth stage = 100%, Figure 3).
    - $ET_{crop} = ET_r \times K_{crop}$
    - $ET_{crop}$ = 0.31 inches/day * 0.65 = 0.2 inches/day
- Soil storage capacity (potential bank balance).
    - The total storage capacity for readily available water over the 3-foot effective rooting depth is 3.5 inches (Table 1). However, using a drip system with a single drip line per row results in only about ¼ of the soil being irrigated. Therefore, storage capacity is 1/4 of 3.5 inches, or 0.88 inches.
    - 0.88 inches of storage, with 0.2 inches consumed per day = 4 days between

irrigations. In 4 days replace 0.88 inches (4 x 0.88 inches).

- Restated, the soil moisture in the root zone will go from field capacity to plant stress levels in 4 days.
- To recharge the soil profile, you will need to add a net of 0.88 inches of water every 4 days. Assuming a drip irrigation system with an efficiency of 80%, 1 inches of water application will be required for each watering. If you are operating your drip system on a daily basis you would set your system to apply 0.25 inch per day (0.2/0.80). However, this would not encourage deep rooting as a longer interval between irrigation would. Microsprinklers wet more of the soil volume and calculations should be adjusted accordingly.

## Irrigation Application Rates

- Surface Irrigation Flow (usually expressed as cubic feet per second, or cfs)

  Inches of application per hour (in/hr) = cfs divided by the number of acres (ac)

  Example: 4 cfs /5 ac = 0.8 in/hr
- Sprinkler Irrigation Flow (based on gallons per minute (gpm) per nozzle (noz))

  In/hr = 96.4 times gpm/noz divided by nozzle coverage area (ft$^2$)

  Note: Nozzle coverage area is calculated as the nozzle spacing times the line spacing, or the width times the length of the coverage area under a single nozzle.

  Example: 96.4 x 7 gpm/noz / (40 ft x 60 ft) = 0.28 in/hr
- Drip Irrigation Flow (based on the flow per emitter in gallons per hour, or gph)

  In/hr = 1.6 times gph divided by emitter coverage area (ft$^2$)

  Note: Emitter coverage area is calculated as the emitter spacing times the line spacing.

  Example: 1.6 x 0.5 gph/ (1 ft x 2.5 ft) = 0.32 in/hr
- Irrigation Set Times

  Set time (hrs) = Gross Irrigation Need (in) divided by the application rate (in/hr)

  Example: Set Time = 3 in / 0.28 in/hr = 10.7 hrs
- Conversions

  1 cfs = 448.8 gpm
  1 gpm = 60 gph
  1 acre = 43,560 feet$^2$

## Additional Resources

AgriMet Crop Coefficients, Pacific Northwest Regional office of the Bureau of Reclamation, U.S. Department of the Interior. https://www.usbr.gov/pn/agrimet/cropcurves/crop_curves.html

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