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Orchard Irrigation: Apple

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Proper irrigation is essential to maintaining a healthy and productive apple orchard. Over irrigation slows root growth, increases the potential for iron chlorosis on alkaline soils, and leaches nitrogen, sulfur and boron out of the root zone leading to nutrient deficiencies. Excessive soil moisture also provides an environment ideal for crown and collar rots. Over irrigation can also induce excessive vegetative vigor. Applying insufficient irrigation water results in drought stress and reduced fruit quality.

Apple fruit growth occurs in two distinct phases. The first phase is primarily a function of cell division and occurs from bloom to about 50 days after bloom (Faust, 1989). Second phase growth, from 50 days after bloom to harvest, is mostly due to expansion of existing cells. This cell expansion is driven by the presence of available water, and occurs during the hottest and driest summer conditions.

Properly managing irrigation is analogous to managing money. In addition to knowing your 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. For apples, the amount of allowable depletion, or the *readily* available water represents about 50% of the total available water in the soil. (Figure 2.)

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.

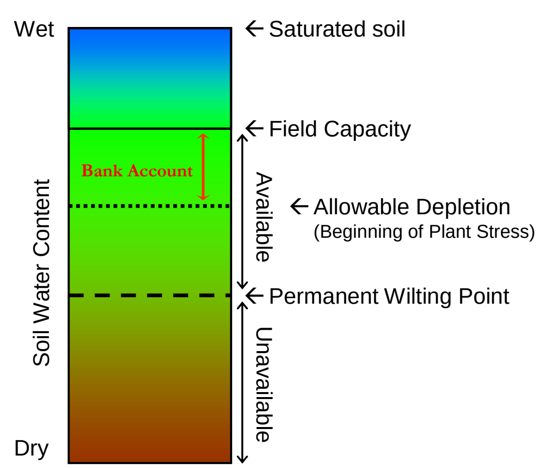

Figure 1. Soil water content from saturated to dry. Optimal levels for plant growth are between field capacity and allowable depletion.

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, variety and rootstock. Although apple roots can grow to a depth of several yards, nearly all of the roots of a mature tree are typically in the top 30 to 36 inches (Atkinson, 1980).

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 (See Table 1.). A deep sandy loam soil at field capacity, for example, would contain 1.8 to 2.25 inches of readily available water in an effective rooting depth of 3 feet.

Table 1. Available water holding capacity for different soil textures, in inches of water per foot of soil. Available water is the amount of water in the soil between field capacity and permanent wilting point. Readily available water is approximately 50% of available.

Soil Texture	Available (*inch/foot*)	Readily available (*inches*) 2 ft root depth	Readily available (*inches*) 3 ft root depth
Sands and fine sands	0.5 - 0.75	0.5 - 0.75	0.75 - 1.13
Loamy sand	0.8 - 1.0	0.8 - 1.0	1.2 - 1.5
Sandy loam	1.2 - 1.5	1.2 - 1.5	1.8 - 2.25
Loam	1.9 - 2.0	1.9 - 2.0	2.85 - 3.0
Silt loam, silt	2.0	2.0	3.0
Silty clay loam	1.9 - 2.0	1.9 - 2.0	2.85 - 3.0
Sandy clay loam, clay loam	1.7 - 2.0	1.7 - 2.0	2.6 - 3.0

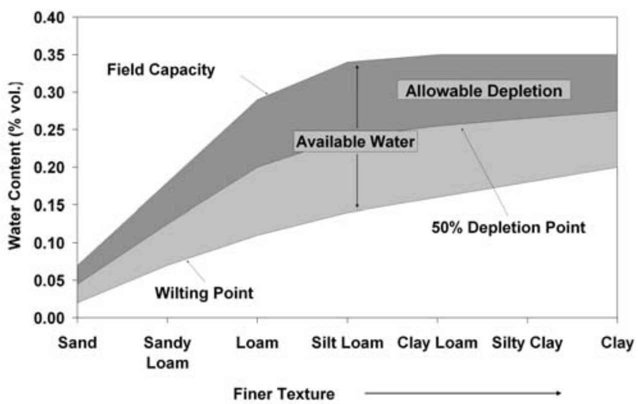

Figure 2. The amount of allowable depletion, or the readily available water, represents about 50 percent of the total available water.

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

In order to assess soil water content, one needs to monitor soil moisture at several depths, from just below the sod layer or cultivation depth (4 to 6 inches), to about 70 percent of effective rooting depth (2 feet). One of the more cost effective and reliable methods for measuring soil moisture is by electrical resistance block, such as the Watermark™ 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. The handheld unit reports soil moisture content in centibars, where values close to zero indicate a wet soil and high values represent dry soil. The relationship between soil water potential and available water differs by soil type. The maximum range of the sensor is 200 centibars, which covers the range of allowable depletion in most soils. The sensors are less effective in coarse sandy soils, and will overestimate soil water potential in saline soils. Remember that allowable depletion is 50% of available water, which roughly corresponds to soil water potentials of 50 centibars for a loamy sand soil, and 70 centibars for a loam (Table 2, 50% depletion values for each soil texture).

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

Soil Type	Irrigation Needed (*centibars*)
Loamy sand	40 – 50
Sandy loam	50 - 70
Loam	60 - 90
Silt loam, silt	70 - 90
Clay loam or clay	90 – 120

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

Expenses – Evapotranspiration

Water is lost from the orchard 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. 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 your crop can be determined by multiplying the ET_r by a correction factor or crop coefficient (K_{crop}) that is specific to your crop and its stage of development.

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

The K_{crop} for apples is shown in Figure 3. At full bloom (Growth Stage = 0), an apple orchard is using about 20% of the amount of water used by the alfalfa reference crop. Water use increases dramatically until the full canopy is established (growth stage = 100) when water use is 95% of a reference alfalfa crop. Water use increases slightly during the second phase of fruit growth (mid-season to harvest) when water use is at 100% of the reference alfalfa crop. After harvest (growth stage = 170), water use quickly decreases.

Typical weekly ET_r values are shown in Table 3. Calculated ET_r for your location can be determined by accessing weather data from a nearby weather station at the following Web site: http://extension.usu.edu/agweather/.

Table 3. Typical weekly alfalfa reference evapotranspiration (ET_r) values for Utah locations.

Location	May	June	July	August
	(inches per week)			
Logan	1.38	1.83	1.94	1.68
Ogden	1.48	1.98	2.10	1.80
Spanish Fork	1.48	1.94	2.08	1.74
Santaquin	1.47	1.92	2.03	1.67
Moab	1.63	2.08	2.19	1.87
Cedar City	1.57	1.95	2.04	1.74
St. George	1.95	2.40	2.53	2.02

Calculated from consumptive water use tables (Hill, 1994) available on the Web at: http://nrwrt1.nr.state.ut.us/techinfo/consumpt/default.asp

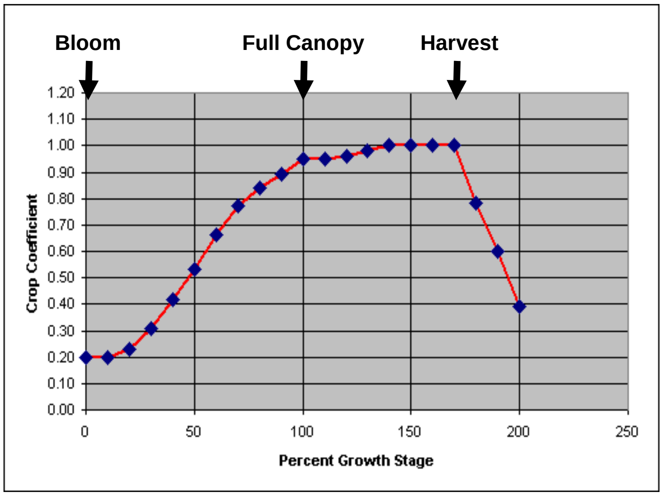

Figure 3. Crop coefficients for apples, based on an alfalfa reference crop. From AgriMet values available online at: www.usbr.gov/pn/agrimet/ cropcurves/crop_curves.html

Income – Irrigation and Rainfall

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

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. If you have trickle irrigation, you can place catch cans under the emitters and determine flow rate for each emitter. Flow rate from each emitter and emitter spacing can be used to calculate rate per area.

The efficiency of your system is a measure of how much you have to over water the wettest spots in the orchard 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 microsprinkler or drip system can be 70 to 90% efficient. Overhead sprinkler systems are typically 60 to 75% efficient, while flood and furrow irrigation is typically 30 to 50% efficient.

Case Study

Following is an example of how to calculate water needs for a mature apple orchard in late July (Growth stage = 140). The orchard is on a deep sandy loam soil with row middles planted to grass cover.

- Water use (Expenses)
  - ETr values are 2.10 inches per week (weather station data).
  - Crop coefficient is 1.0 (Figure 3).
  - $ET_{crop} = ET_r \times K_{crop}$
  - ET_{crop} = 2.10 inches/week * 1.0 = 2.1 inches/week
- Soil storage capacity (potential bank balance)

- The total storage capacity for readily available water over an effective rooting depth of 3 feet is between 1.8 and 2.25 inches (Table 1).
- 1.8 to 2.25 inches / 2.1 inches per week = 0.86 to 1.07 weeks or 6 to 7 days between irrigations.

o Restated, the soil moisture in the rootzone will go from field capacity to plant stress levels in 6 days.

o To recharge the soil profile, you will need to add 1.8 inches of water. Assuming a microsprinkler irrigation system with an efficiency of 90%, 2.0 acre inches of water application will be required per acre for each watering.

Summary

Good irrigation management requires:

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

Additional Resources

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

Atkinson, D. 1980. The distribution and effectiveness of the roots of tree crops. Horticultural Reviews 2:424-490.

Faust, M. 1989. Physiology of Temperate Zone Fruit Trees. Wiley and Sons, New York.

Irrigation Scheduling Techniques. Water Conservation Factsheet. No. 577.100-1. British Columbia Ministry of Agriculture and Food. March 1997. http://www.agf.gov.bc.ca/resmgmt/publist/500series/577100-1.pdf.

Hill, R.W. 1994. Consumptive Use of Irrigated Crops in Utah. Utah Ag. Exp. Stn. Res. Rpt. #145. Utah State University, Logan UT. Available on the Web at http://nrwrt1.nr.state.ut.us/techinfo/consumpt/default.asp

Smith, T. Irrigating Tree Fruits for Top Quality. Washington State University Extension. http://www.ncw.wsu.edu/treefruit/irrigation/how.htm

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