Vegetable Irrigation: Sweet Pepper and Tomato

Tiffany Maughan, Dan Drost, and ***L. Niel Allen***

Proper irrigation is critical for sweet pepper and tomato production. Optimal irrigation management leads to healthy plants, maximum yields, and high quality fruit. Under-irrigation results in a reduction of yield, blossom end rot, and other fruit quality issues. Over-irrigation increases disease susceptibility, nutrient leaching, and water loss. For ideal fruit set and development, a consistent moisture supply throughout all growth stages, but particularly at bloom and during fruit sizing, is necessary. Sweet peppers and tomatoes are sensitive to water stress while flowering as under-irrigation at this time leads to blossom end rot, a calcium deficiency exacerbated by a lack of water. Uneven watering during fruit sizing leads to cracking in tomato fruit. Water stress also creates conditions leading to more sunburn of fruits. Different irrigation methods are commonly used to irrigate a sweet pepper or tomato crop, each with different management considerations. Furrow irrigation is quite common but many growers are beginning to use drip irrigation to save water and improve plant growth and productivity. Regardless of the irrigation system used, there are some basic principles to understand that will help ensure proper irrigation. This fact sheet will discuss these basic principles.

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:

- <u>Field Capacity</u> is the amount of water that can be held in the soil after excess water has percolated out due to gravity.
- <u>Permanent Wilting Point</u> 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.
- <u>Available Water</u> is the amount of water held in the soil between field capacity and permanent wilting point (Figure 1).
- <u>Allowable Depletion</u> (readily available) is the point where plants begin to experience drought stress. Depending on soil type, the amount of allowable depletion for sweet peppers and tomatoes is about 25% 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 and that plants do not experience water stress.

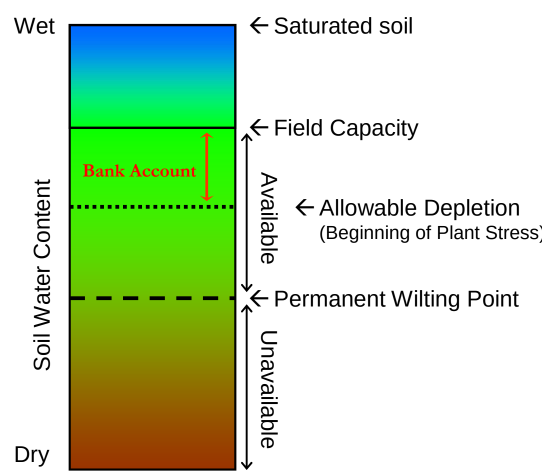

Figure 1. Soil water content from saturated to dry. Optimal soil moisture levels for plant growth are between field capacity and allowable depletion.

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 and variety. About 70% of sweet pepper and tomato roots are in the top foot of soil, with 30% in the second foot. 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). A deep sandy loam soil at field capacity, i.e., would contain 0.6 to 0.75 inch of readily available water in an effective rooting depth of 1 foot.

What's in the bank? – Measuring Soil Moisture

In order to assess soil water content, monitor soil moisture at two depths: 12 inches deep and near the bottom of the effective rooting depth (approximately 24 inches deep). 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.

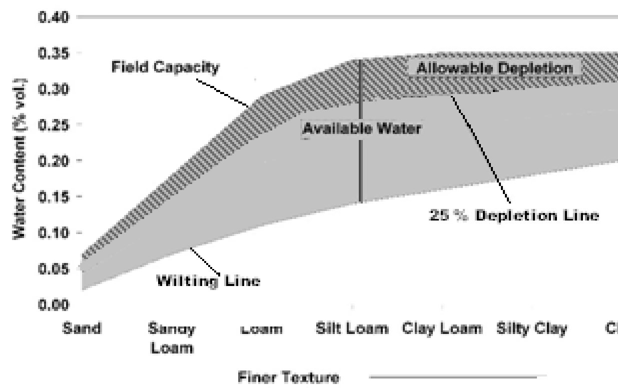

Figure 2. The amount of allowable depletion, or the readily available water, represents about 25% of the total available water.

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. Allowable depletion is approximately 30 % of total available for peppers and 40% for tomatoes.

Soil Texture	Total Available Water	Allowable Depletion *inches* (Readily available)	
	inch/foot	In top1'	In top1.5'
Sands and fine sands	0.5 - 0.75	0.15 0.23	0.23 0.34
Loamy sand	0.8 - 1.0	0.24 0.3	0.36 0.45
Sandy loam	1.2 - 1.5	0.36 - 0.45	0.54 - 0.68
Loam	1.9 - 2.0	0.57 - 0.6	0.85 - 0.9
Silt loam, silt	2.0 - 2.1	0.6 - 0.63	0.9 - 0.95
Silty clay loam	1.9 - 2.0	0.57 - 0.6	0.85 - 0.9
Sandy clay loam, clay loam	1.7 - 2.0	0.51 - 0.6	0.77 - 0.9

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 range of the sensor is calibrated to 0 to 200 centibars (higher values indicate drier soil), 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 25% of available water, which roughly corresponds to soil water potentials of 20 centibars for a loamy sand soil, and 30 centibars for a loam (Table 2, 25% depletion values for each soil texture).

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

Soil Type	Irrigation Needed
	(*centibars*)
Loamy sand	20 - 25
Sandy loam	22 - 27
Loam	25 - 30
Silt loam, silt	28 - 32
Clay loam or clay	30 - 35

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

Expenses – Evapotranspiration

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 average daily reference ET values for several cities across Utah. Many more sites are monitored in the state. If your city is not listed, visit climate.usurf.usu.edu to find a location near you.

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 sweet peppers and tomatoes is shown in Table 4. The K_{crop} varies depending on current growth stage. Water use increases gradually as the crop develops until the full canopy is established. After maturity is reached and early fruits begin to ripen, irrigation is often slightly reduced for both crops with tomato irrigation reduction being more significant. Some moisture stress at this time increases fruit soluble solid concentration.

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 bed length per day.

Month	Logan	Brigham City	Ogden	Farmington	Salt Lake City	Spanish Fork	Richfield	Cedar City	St. George
(A) Inches per day									
Mar	0.09	0.1	0.1	0.12	0.11	0.12	0.14	0.13	0.15
Apr	0.15	0.16	0.17	0.19	0.17	0.16	0.20	0.18	0.22
May	0.2	0.22	0.22	0.25	0.22	0.21	0.23	0.24	0.28
Jun	0.24	0.27	0.28	0.3	0.28	0.26	0.30	0.31	0.32
Jul	0.29	0.32	0.32	0.27	0.3	0.28	0.29	0.29	0.31
Aug	0.26	0.28	0.29	0.23	0.27	0.25	0.27	0.27	0.28
Sep	0.18	0.2	0.2	0.19	0.19	0.18	0.20	0.21	0.21
Oct	0.09	0.12	0.12	0.12	0.11	0.1	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	3259	2987	3259	3670	3451	4073
Apr	4073	4345	4617	5160	4617	4345	5386	5006	5974
May	5431	5974	5974	6789	5974	5703	6360	6412	7604
Jun	6517	7332	7604	8147	7604	7061	8102	8500	8690
Jul	7875	8690	8690	7332	8147	7604	7937	7788	8418
Aug	7061	7604	7875	6246	7332	6789	7385	7306	7604
Sep	4888	5431	5431	5160	5160	4888	5522	5739	5703
Oct	2444	3259	3259	3259	2987	2716	3609	3741	3802
(C) Drip-irrigated gallons per 100 feet of bed length per day based on 4-foot bed spacing. Irrigation amounts need to be adjusted by Crop Coefficient and Irrigation Efficiency.[2]									
Mar	22.4	24.9	24.9	29.9	27.4	29.9	33.7	31.7	37.4
Apr	37.4	39.9	42.4	47.4	42.4	39.9	49.5	46.0	54.9
May	49.9	54.9	54.9	62.3	54.9	52.4	58.4	58.9	69.8
Jun	59.8	67.3	69.8	74.8	69.8	64.8	74.4	78.1	79.8
Jul	72.3	79.8	79.8	67.3	74.8	69.8	72.9	71.5	77.3
Aug	64.8	69.8	72.3	57.4	67.3	62.3	67.8	67.1	69.8
Sep	44.9	49.9	49.9	47.4	47.4	44.9	50.7	52.7	52.4
Oct	22.4	29.9	29.9	29.9	27.4	24.9	33.1	34.3	34.9

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

[2]Calculation for drip-irrigation: (C) = (B) x 4 ft. (bed spacing) / 435.6. If different bed spacing is used, adjust calculation accordingly.

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

Table 4. Description of stages of growth and crop coefficient estimates for pepper and tomato crops.

Crop		Planting Date to 10% Ground Cover	10% to 70% Ground Cover	Maturity to Harvest
Sweet Pepper[1]	**Kcrop**	0.58	0.75	0.71
Tomato[1]	**Kcrop**	0.58	0.75	0.66

[1] From Crop Coefficients for Use in Irrigation Scheduling adjusted for alfalfa reference ET.

Income – Irrigation and Rainfall

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

Whichever irrigation system you utilize, it is important to calibrate your system so that you know precisely how much water is being applied. 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.

Drip irrigation tape comes with recommended operating pressures, a variety of emitter spacings, and various flow rates. Most drip tapes operate at 10 psi. Emitters may be spaced from 4 to 36 inches apart and come in a variety of flow rates. Peppers do well with 12 to 18 inch emitter spacing and tomatoes with 18 to 24 inch spacing. Flow rates are commonly reported in gallons per100 feet of tape per hour (GPH) or gallons/emitter/hr. For a tape 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 70 to 90% 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.

Case Study

Following is an example of how to calculate water needs for a tomato crop in Farmington, Utah, with a full canopy in July. The soil is a deep sandy loam with drip irrigated rows every 4 feet.

- Water use (Expenses)
  - ETr values are 0.27 inch /day (Table 1, weather station data).
  - Crop coefficient is 0.87 (Growth stage = Full Cover, from Table 4).
  - $ET_{crop} = ET_r \times K_{crop}$
  - ET_{crop} = 0.27 inch/day * 0.87 = 0.24 inches/day
- Soil storage capacity (potential bank balance)
  - The total storage capacity for readily available water over the 1.5 foot effective rooting depth is 1.5 inches (Table 1).
  - 1.5 inches / 0.24 inch per day = 6.25 (6) days between irrigations. In 6 days replace 1.5 inches.
- Restated, the soil moisture in the rootzone will go from field capacity to plant stress levels in 6.25 days.
- To recharge the soil profile, you will need to add a net of 1.5 inches of water every 6 days. Assuming a drip irrigation system with an efficiency of 90%, 1.67 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 0.27 inch per day (0.24/0.90). For a 2 day irrigation interval apply 0.53 inch (2*0.24/0.90).

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 applied irrigation water, and will optimize the long term health and productivity of your crop.

Irrigation Application Rates

• Surface Irrigation (flow usually in cubic feet per second)
Inches/hour = cubic feet per second (cfs) / acres
Example: 4 cfs/ 5 acres = 0.8 inches/hour

• Drip Irrigation (flow per emitter is usually in gallons per hour)
Inches/hour =
1.6 *gallons per hour (gph)/emitter spacing (feet^2)
Example: 1.6*0.5 gph / (1 feet* 4.5 feet) = 0.18 inches/hour

• Irrigation Set Times
Set time (hours) = Gross Irrigation Need (inches) / application rate (inches/hour)
Example: 3 inches / 0.28 inches/hour = 10.7 hours

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

Additional Resources

Crop coefficients for use in irrigation scheduling. Water Conservation Factsheet. No. 577.100-5. British Columbia Ministry of Agriculture and Food. October 2001. www.agf.gov.bc.ca/resmgmt/publist/500Series/577100-5.pdf.

Hartz, T., and B. Hanson. 2009. Drip irrigation and fertigation management of processing tomato. Vegetable Research and Information Center, University of California.

Hill, R.W. 2011. Crop and Wetland Consumptive Use and Open Water Surface Evaporation for Utah. Utah Ag. Exp. Stn. Res. Rpt. #213. Utah State University, Logan UT. Available on the Web at https://extension.usu.edu/irrigation/htm/research

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

ITRC. Row crop drip irrigation on peppers study – High Rise Farms. ITRC Report No. R 96-001

LeBoeuf, J., R. Shortt, C. Tan and A, Verhallen. 2008. Irrigation Scheduling for tomatoes – an introduction. Ministry of Agriculture, Food and Rural Affairs. Ontario, Canada. Order No. 08-011.