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Vegetable Irrigation: Squash and Pumpkin

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Proper irrigation is critical for squash and pumpkin production. Optimal irrigation management leads to large, healthy plants, capable of producing maximum yields of superior quality fruit. Under-irrigation results in a reduction of yield, increased incidence of blossom end rot, and irregularly shaped fruit. Proper irrigation is particularly critical at seedling emergence, when water shortages can result in poor and uneven emergence. Water shortages during vine extension limit leaf area and contribute to low productivity. Without adequate water at bloom and during fruit sizing, flowers abort or fruit do not reach full size. Additionally, water stressed plants are more susceptible to insect attack. Over-irrigation increases disease susceptibility, particularly powdery mildew, leads to nutrient leaching, causes more fruit rots, and lowers water use efficiency.

Different irrigation methods are commonly used to irrigate pumpkin and squash, each with different management considerations. Furrow, sprinkler and drip irrigation are all used for production. Furrow irrigation is the most common but results in large fluctuations in soil moisture, increased nutrient leaching, and lower water use efficiency. Sprinkler irrigation can be effective but may lead to increased disease problems due to moisture on the foliage and may increase weed pressure. Some growers are using drip irrigation as it is a much more water efficient system but cost relative to crop value may not be justified in all cases. The advantages of drip include better fertilizer management, reduced water use, improved pest and weed control, and increased marketable yield. 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:

- 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 pumpkins and squash is about 50 percent 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.

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. Pumpkin plants typically root slightly deeper than squash. Tap roots can grow to 4 to 5 feet deep, but the highly branched lateral roots are found mostly in the top 2 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). A deep sandy loam soil at field capacity; e.g., would contain 0.6 to 0.75 inch of readily available water in an effective rooting depth of 1 foot.

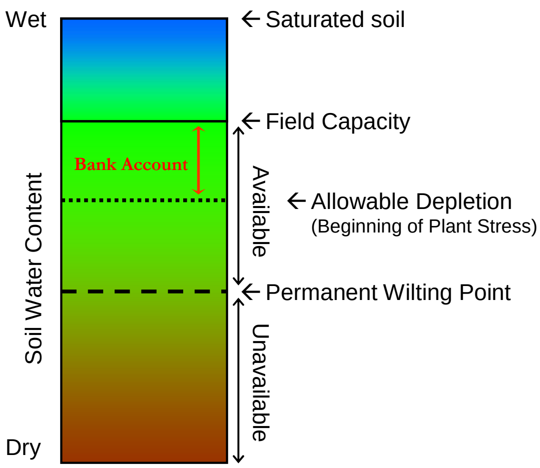

Figure 1. Soil water content from saturated to dry. Optimal soil moisture levels for plant growth are between field capacity and allowable depletion.

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 (18 to 24 inches) grow. One of the most 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.

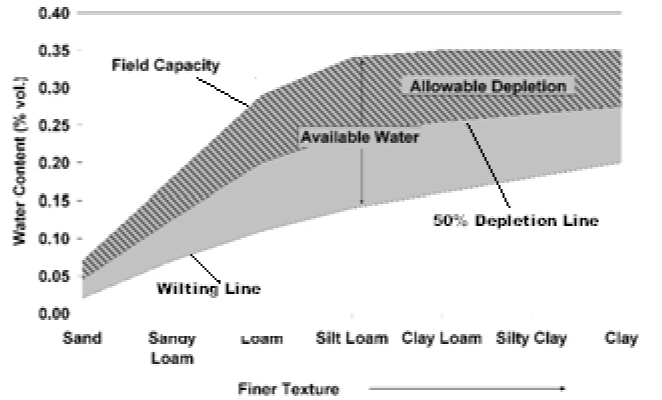

Figure 2. The amount of allowable depletion, or the readily available water, represents about 50 percent of the total available water.

The handheld unit reports soil moisture content in centibars, where values close to zero indicate a wet soil and 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 about 50% of available water, which roughly corresponds to soil water potentials of 40-50 centibars for a loamy sand soil, and 60-90 centibars for a loam (Table 2, 50% depletion values for each soil texture).

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 squash and pumpkin, allowable depletion is approximately 50 percent of total available.

Soil Texture	Total Available Water *inch/foot*	Allowable Depletion *inches* (Readily available)	
		In top 1'	In top 2'
Sands and fine sands	0.5 - 0.75	0.25 - 0.38	0.5 - 0.75
Loamy sand	0.8 - 1.0	0.4 - 0.5	0.8 – 1.0
Sandy loam	1.2 - 1.5	0.6 - 0.75	1.2 – 1.5
Loam	1.9 - 2.0	0.9 - 1.0	1.8 – 2.0
Silt loam, silt	2.0	1.0	2.0
Silty clay loam	1.9 - 2.0	0.9 - 1.0	1.8 – 2.0
Sandy clay loam, clay loam	1.7 - 2.0	0.85 - 1.0	1.7 – 2.0

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 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 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. Additionally, current ET for 30 sites in Utah can be found at https://climate.usurf.usu.edu/agweather.php.

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. Note: Some publications use ETo which is a grass reference ET, which uses a different set of K_{crop}.

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

The K_{crop} for pumpkin and squash are 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.

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, impact sprinklers, 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. With sprinklers, 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.

Drip irrigation tape comes with recommended operating pressures, a variety of emitter spacings, and various flow rates. Most drip tapes 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 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 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. 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 component requires a commitment to proper management which will lead to the maximum yields per applied irrigation water, and will optimize the long term health and productivity of your crop**.**

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	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	0.20	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	0.30	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	0.20	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 bed length per day based on 8-foot[2] bed spacing. Irrigation amounts need to be adjusted by Crop Coefficient and Irrigation Efficiency.[3]									
Mar	44.9	49.9	49.9	54.9	59.8	74.8	67.4	63.4	74.8
Apr	74.8	79.8	84.8	84.8	79.8	114.7	98.9	91.9	109.7
May	99.7	109.7	109.7	109.7	104.7	144.6	116.8	117.8	139.6
Jun	119.7	134.7	139.6	139.6	129.7	159.6	148.8	156.1	159.6
Jul	144.6	159.6	159.6	149.6	139.6	159.6	145.8	143.0	154.6
Aug	129.7	139.6	144.6	134.7	124.7	124.7	135.6	134.2	139.6
Sep	89.8	99.7	99.7	94.8	89.8	99.7	101.4	105.4	104.7
Oct	44.9	59.8	59.8	54.9	49.9	59.8	66.3	68.7	69.8

[1]Conversion to gallons per acre per day (B) = (A) x 7.481 * 43560 / 12.
[2]8-foot bed spacing is appropriate for pumpkin and winter squash; for summer squash 4-foot bed spacing is often used. Adjust calculation according to bed spacing (see equation below).
[3]Calculation for drip-irrigation: (C) = (B) x 8 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 pumpkin and squash crops.

Crop		Planting to 10% Ground Cover	10% to 60% Ground Cover	Full Cover to Mid-Fruit Size	Mid-Fruit Size to Harvest[3]
Pumpkin[1]	**Kcrop**	0.42	0.62	0.83	0.66
Winter Squash[1]	**Kcrop**	0.42	0.58	0.79	0.62
Summer Squash[2]	**Kcrop**	0.42	0.78	0.78	--

1. Ministry of Agriculture and Food. October 2001 (adjusted for alfalfa reference ET).
2. Allen et al., 1998 (adjusted for alfalfa reference ET).
3. Summer squash are commercially harvested as immature fruits.

Case Study

Following is an example of how to calculate water needs for a pumpkin crop in Spanish Fork, Utah, in July with a full canopy. The soil is a deep loam with drip irrigated rows every 8 feet. To increase the irrigated root zone, two drip tapes per row could be used.

- Water use (Expenses)
  - ETr values are 0.28 inches per day (weather station data, Table 3).
  - Crop coefficient is 0.83 (Growth stage = Full Cover, Table 4).
  - $ET_{crop} = ET_r \times K_{crop}$
  - ET_{crop} = 0.28 inches/day * 0.83 = 0.23 inches/day
- Soil storage capacity (potential bank balance).
  - The total storage capacity for readily available water over the2-foot effective rooting depth is 1.4 inches (Table 1).
  - 1.4 inches / 0.23 inches per day = 6 days between irrigations. In 6 days replace 1.4 inches.
- Restated, the soil moisture in the root zone will go from field capacity to plant stress levels in 6 days.
- To recharge the soil profile, you will need to add a net of 1.4 inches of water every 6 days. Assuming a drip irrigation system with an efficiency of 90%, 1.6 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 0.26 inch per day (0.23/0.90). For a 2 day irrigation interval apply 0.51 inch (2*0.23/0.90) each watering.

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* 2.5 feet) = 0.32 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

Agriculture and Agri-Food Canada. 2007. Pumpkin Irrigation Scheduling. Canada-Saskatchewan Irrigation Diversification Centre. www5.agr.gc.ca/resources/prod/doc/pfra/csidc/pumpkin-citrouille_eng.pdf

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Ministry of Agriculture and Food. 2001Crop coefficients for use in irrigation scheduling. Order No. 577.100-5. Agdex 561. British Columbia, Ministry of Agriculture, Food and Fisheries. http://www.agf.gov.bc.ca/resmgmt/publist/500Series/577100-5.pdf

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