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Vegetable Irrigation: Onion

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Proper irrigation is critical for onion production. Optimal irrigation management leads to steady plant growth, uniform bulb size, maximum yields, and superior bulb quality. Under-irrigation results in a reduction of yield, single centeredness, and quality. However, over-irrigation increases disease susceptibility, nutrient leaching, and inefficient water use. For ideal bulb development, a consistent moisture supply throughout the season is necessary. Onions are extremely sensitive to water stress with the most critical time being during bulb swelling.

Different irrigation methods are commonly used to irrigate onions, each with different management considerations. Historically, furrow irrigation was the method of choice. Furrow irrigation results in large fluctuations in soil moisture, nutrient leaching, and low water use efficiency. Drip irrigation is becoming more widely used to grow onions. The advantages of drip include better fertilizer management, reduced water use, improved pest and weed control, and increased onion bulb size, uniformity, and 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.

Drip irrigation being used for onions.

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 onions is about 25 to 30% 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, but in general onions are a shallow-rooted crop. About 70% of onion roots are in the top foot of soil, with 25% in the second foot and some roots extending deeper. 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.

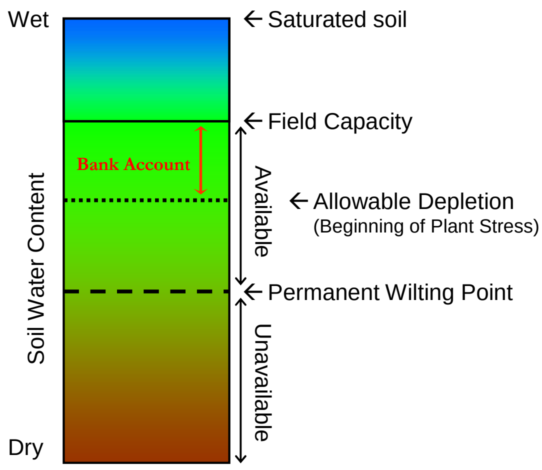

Figure 1. Soil water content from saturated to dry. Optimal soil moisture levels for plant growth are between field capacity and allowable depletion.

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

In order to assess soil water content, one needs to monitor soil moisture. Monitors should be placed in the primary root zone (approximately 8 inches). 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, Calif.). 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.

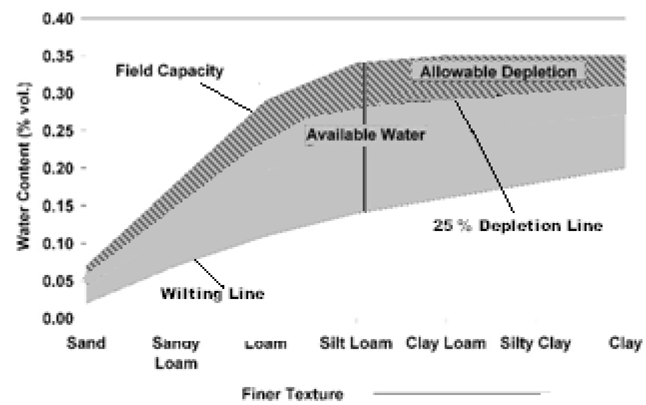

Figure 2. For onion, the amount of allowable depletion, or the readily available water, represents about 25 percent of the total available water.

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 for onion is approximately 25% of total available.

Soil Texture	Total Available Water *inch/foot*	Allowable Depletion *inches* (Readily available) In top1'		In top1.5'	
Sands and fine sands	0.5 - 0.75	0.13	0.19	0.19	0.29
Loamy sand	0.8 - 1.0	0.2	0.25	0.30	0.38
Sandy loam	1.2 - 1.5	0.3	0.38	0.45	0.57
Loam	1.9 - 2.0	0.48	0.5	0.72	0.75
Silt loam, silt	2.0 - 2.1	0.5	0.53	0.75	0.79
Silty clay loam	1.9 - 2.0	0.48	0.5	0.72	0.75
Sandy clay loam, clay loam	1.7 - 2.0	0.43	0.5	0.65	0.75

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 25 to 30% of available water, which roughly corresponds to soil water potentials of 14 centibars for a loamy sand soil, and 20 centibars for a silt loam (Table 2, 25% depletion values for each soil texture).

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 in key onion production areas of 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. Current ET for 30 sites in Utah can be found at https://climate.usurf.usu.edu/agweather.php.

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

Soil Type	Irrigation Needed (*centibars*)
Loamy sand	14-16
Sandy loam	16-18
Loam	18-20
Silt loam, silt	20-22
Clay loam or clay	22-24

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

Table 3. Daily total reference evapotranspiration (ET) for six Utah cities expressed in (A) inches per day, (B) gallons per acre per day, and (C) drip-irrigated gallons per 100 feet per day.

Month	Tremonton	Corinne	Brigham City	Ogden	Layton	Farmington
(A) Inches per day						
Mar	0.11	0.11	0.10	0.10	0.11	0.11
Apr	0.16	0.18	0.16	0.17	0.17	0.17
May	0.22	0.24	0.22	0.22	0.22	0.22
Jun	0.28	0.30	0.27	0.28	0.28	0.28
Jul	0.34	0.33	0.32	0.32	0.31	0.31
Aug	0.29	0.29	0.28	0.29	0.29	0.28
Sep	0.22	0.21	0.20	0.20	0.20	0.20
Oct	0.13	0.11	0.12	0.12	0.12	0.12
(B) Gallons per acre per day. Irrigation amounts need to be adjusted by Crop Coefficient and Irrigation Efficiency. [1]						
Mar	2987	2987	2716	2716	2987	2987
Apr	4345	4888	4345	4617	4617	4617
May	5974	6517	5974	5974	5974	5974
Jun	7604	8147	7332	7604	7604	7604
Jul	9233	8961	8690	8690	8418	8418
Aug	7875	7875	7604	7875	7875	7604
Sep	5974	5703	5431	5431	5431	5431
Oct	3530	2987	3259	3259	3259	3259
(C) Drip-irrigated gallons per 100 feet of bed length per day based on 3.25 foot bed spacing. Irrigation amounts need to be adjusted by Crop Coefficient and Irrigation Efficiency.[2]						
Mar	22.3	22.3	20.3	20.3	22.3	22.3
Apr	32.4	36.5	32.4	34.4	34.4	34.4
May	44.6	48.6	44.6	44.6	44.6	44.6
Jun	56.7	60.8	54.7	56.7	56.7	56.7
Jul	68.9	66.9	64.8	64.8	62.8	62.8
Aug	58.8	58.8	56.7	58.8	58.8	56.7
Sep	44.6	42.5	40.5	40.5	40.5	40.5
Oct	26.3	22.3	24.3	24.3	24.3	24.3

[1]Conversion to gallons per acre per day (B) = (A) x 7.481 (1 cubic foot)* 43560 / 12.
[2]Calculation for drip-irrigation: (C) = (B) x 3.25 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 onion crops.

	Growth Stage Indicator [1]					
	Planting	Emergence	12-13 leaves	1.5 inch bulb size	Last Irrigation	Lifting
Crop coefficient	0.3	0.5	1.0	1.0	1.0	0.5

[1] From AgriMet Cooperative Agricultural Weather Network with alfalfa as the reference crop

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 ET_o which is a grass reference ET instead of ET_r. ET_o uses a different set of K_{crop} values. You can multiply ET_o by 1.25 to get a good estimate of ET_r.

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

The K_{crop} for onions 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. For onions, irrigation is stopped a few weeks before harvesting to allow curing and improve storability.

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. Onion irrigation is supplied by furrow or drip irrigation. Furrow irrigation has historically been used to irrigate onion crops in Utah and the infrastructure for flood irrigating is already in place. However, in areas prone to water shortages, furrow irrigation may be a poor choice due to lower efficiency. Onions are commonly furrow irrigated once per week with irrigation sets of 12 hours or more.

Drip irrigation is expensive to install. However, with the potential water savings, combined with advantages of water uniformity and fertilizer applications many growers have been able to justify the material costs. Whichever irrigation system you utilize, it is important to know precisely how much water is being applied (see Irrigation Application Rate section).

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. 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 (typical for onions), 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 uniformity of your system is a measure of how much you have to over-water the wetter areas in the field to get adequate water to the drier areas. Efficiency is related to the uniformity of application, scheduling of irrigations, and the amount of evaporation from the soil. A well-designed drip system can be 90 to even 95% efficient, while furrow irrigation of onion is typically about 50% efficient due to difficulty of applying frequent light irrigations. 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 an onion crop in August with a full canopy in Corinne, Utah. The soil is a loam with drip irrigated rows every 3.25 feet.

- Water use (Expenses)
  - ETr values are 0.29 inches per day (weather station data).
  - Crop coefficient is 1.0 (Growth stage = 1.5 inch bulb size, from Table 4).
  - $ET_{crop} = ET_r \times K_{crop}$
  - ET_{crop} = 0.29 inches/day * 1.0 = 0.29 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 0.7 inches (Table 1).
  - 0.7 inches / 0.29 inches per day = 2.4 (2) days between irrigations. In 2 days replace 0.58 inches.
- Restated, the soil moisture in the root zone will go from field capacity to plant stress levels in 2.4 days.
- To recharge the soil profile, you will need to add a net of 0.58 inches of water every 2 days. Assuming a drip irrigation system with an efficiency of 90%, 0.64 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 0.32 inches per day (0.29/0.9). For a two day interval the application would be 0.64 inches.

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* 3.25 feet) = 0.25 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 $feet^2$ (or sq. ft.)

Additional Resources

AgriMet Crop Coefficients. Pacific Northwest Regional office of the Bureau of Reclamation.US Dept. of the Interior www.usbr.gov/pn/agrimet/cropcurves/crop_curves.html.

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