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.

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.

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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.

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).

<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>Total Available Water inch/foot</th>
<th>Allowable Depletion inches (Readily available)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands and fine sands</td>
<td>0.5 - 0.75</td>
<td>0.13 - 0.19</td>
</tr>
<tr>
<td>Loamy sand</td>
<td>0.4 – 0.5</td>
<td>0.1 - 0.13</td>
</tr>
<tr>
<td>Sandy loam</td>
<td>1.2 - 1.5</td>
<td>0.3 - 0.38</td>
</tr>
<tr>
<td>Loam</td>
<td>1.9 - 2.0</td>
<td>0.48 - 0.5</td>
</tr>
<tr>
<td>Silt loam, silt</td>
<td>2.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Silty clay loam</td>
<td>1.9 - 2.0</td>
<td>0.48 - 0.5</td>
</tr>
<tr>
<td>Sandy clay loam, clay loam</td>
<td>1.7 - 2.0</td>
<td>0.43 - 0.5</td>
</tr>
</tbody>
</table>

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.
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.

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Irrigation Needed</th>
<th>(centibars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loamy sand</td>
<td></td>
<td>14-16</td>
</tr>
<tr>
<td>Sandy loam</td>
<td></td>
<td>16-18</td>
</tr>
<tr>
<td>Loam</td>
<td></td>
<td>18-20</td>
</tr>
<tr>
<td>Silt loam, silt</td>
<td></td>
<td>20-22</td>
</tr>
<tr>
<td>Clay loam or clay</td>
<td></td>
<td>22-24</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Month</th>
<th>Tremonton (A)</th>
<th>Corinne (A)</th>
<th>Brigham City (A)</th>
<th>Ogden (A)</th>
<th>Layton (A)</th>
<th>Farmington (A)</th>
<th>(B) Gallons per acre per day</th>
<th>(C) Drip-irrigated gallons per 100 feet of bed length per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar</td>
<td>0.11</td>
<td>0.11</td>
<td>0.10</td>
<td>0.10</td>
<td>0.11</td>
<td>0.11</td>
<td>2987</td>
<td>22.3</td>
</tr>
<tr>
<td>Apr</td>
<td>0.16</td>
<td>0.18</td>
<td>0.16</td>
<td>0.17</td>
<td>0.17</td>
<td>0.17</td>
<td>4345</td>
<td>32.4</td>
</tr>
<tr>
<td>May</td>
<td>0.22</td>
<td>0.24</td>
<td>0.22</td>
<td>0.22</td>
<td>0.22</td>
<td>0.22</td>
<td>5974</td>
<td>44.6</td>
</tr>
<tr>
<td>Jun</td>
<td>0.28</td>
<td>0.30</td>
<td>0.27</td>
<td>0.28</td>
<td>0.28</td>
<td>0.28</td>
<td>7604</td>
<td>56.7</td>
</tr>
<tr>
<td>Jul</td>
<td>0.34</td>
<td>0.33</td>
<td>0.32</td>
<td>0.32</td>
<td>0.31</td>
<td>0.31</td>
<td>9233</td>
<td>68.9</td>
</tr>
<tr>
<td>Aug</td>
<td>0.29</td>
<td>0.29</td>
<td>0.28</td>
<td>0.29</td>
<td>0.29</td>
<td>0.29</td>
<td>7875</td>
<td>81.3</td>
</tr>
<tr>
<td>Sep</td>
<td>0.22</td>
<td>0.21</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>5974</td>
<td>94.6</td>
</tr>
<tr>
<td>Oct</td>
<td>0.13</td>
<td>0.11</td>
<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
<td>3530</td>
<td>107.9</td>
</tr>
</tbody>
</table>

1Conversion to gallons per acre per day (B) = (A) x 7.481 (1 cubic foot)* 43560 / 12.
2Calculation 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.

<table>
<thead>
<tr>
<th>Growth Stage Indicator 1</th>
<th>Planting</th>
<th>Emergence</th>
<th>12-13 leaves</th>
<th>1.5 inch bulb size</th>
<th>Last Irrigation</th>
<th>Lifting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop coefficient</td>
<td>0.3</td>
<td>0.5</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>0.5</td>
</tr>
</tbody>
</table>

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 $E_T$ which is a grass reference ET instead of ET$_r$. $E_T$ uses a different set of $K_{crop}$ values. You can multiply ET$_r$ 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 per 100 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).
  - \( ET_{crop} = ET_r \times K_{crop} \)
  - \( ET_{crop} = 0.29 \text{ inches/day} \times 1.0 = 0.29 \text{ inches/day} \)

- **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 (feet²)
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 feet² (or sq. ft.)