

Successful Onion Irrigation Scheduling

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Photo: Clint Shock

The scientific name for onion is *Allium cepa*.
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Irrigation scheduling is directly related to profitable onion production and sustainable agricultural practices. Research at the Oregon State University Malheur Experiment Station has demonstrated that onion yield and grade are very closely related to irrigation practices, especially the criterion used to schedule irrigations. Careful attention to irrigation scheduling can help assure high onion yields, better bulb storability, and better internal quality. Small errors in irrigation can result in large losses in yield, especially in marketable yield of the larger size class bulbs.

By the late 1990s, bulb single centeredness had become an important marketing attribute. Single centeredness is primarily a variety attribute, but it can also be influenced by growing conditions. Research at the Malheur Experiment Station showed that reduced water stress at the four- to six-leaf stage can increase single centeredness.

Errors in irrigation scheduling can also have negative environmental consequences. In 1989, northern Malheur County was declared a groundwater management area due to groundwater nitrate contamination. This contamination was linked, at least in part, to furrow irrigation of onion. All irrigation systems in arid regions require some leaching fraction to avoid salt accumulation. However, the high nitrogen (N) fertilizer rates used through the 1980s, combined with heavy water applications to furrow-irrigated onion, promote the loss of nitrate-N and other mobile nutrients to deep percolation and runoff. In response to these problems, OSU Malheur Experiment Station began research to determine the soil water requirements for onion production in the Treasure Valley by carefully monitoring soil water status using soil moisture sensors.

Irrigation methods

Irrigation method is an important consideration in irrigation scheduling. Through the early 1990s, the leading irrigation methods for onions in the Pacific Northwest were sprinkler and furrow irrigation.

Onions need frequent irrigation to maintain high soil moisture (Shock et al., 1998). It can be difficult to reduce nitrate leaching with furrow irrigation because wide oscillations in soil moisture are unavoidable (Figure 1). Each time the soil becomes saturated, mobile nutrients such as nitrate tend to be leached through the soil.

Research at the Malheur Experiment Station found that N applications to onion can be lower with drip irrigation than with furrow irrigation because better control of water application is possible (Shock et al., 2004). With drip systems, smaller amounts of water can be applied more frequently, resulting in smaller oscillations in soil moisture (Figure 2) and better control of leaching. Drip irrigation advantages, disadvantages, and methods are discussed in *Drip Irrigation Guide for Onions in the Treasure Valley*, EM 8901 (Shock et al., 2005c).

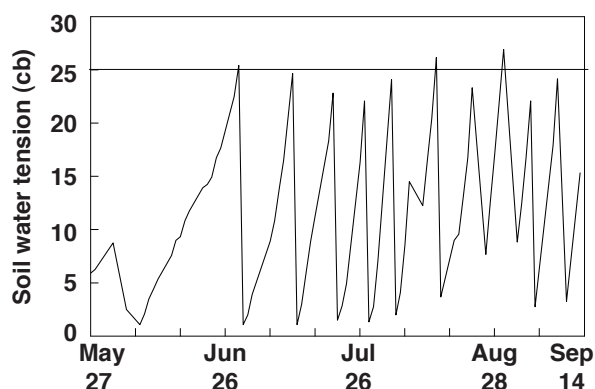


Figure 1. Soil water tension (SWT) at 8-inch depth for onion furrow irrigated at 25 cb (centibar). SWT of 0–10 represents saturated soil. Note the wide fluctuations in SWT and the frequent instances of saturated soil.

Importance of irrigation scheduling

Onions have little tolerance for water stress. Bulb market grade and single centeredness are critically influenced by small increments of water stress. The incentives to maintain a precise irrigation schedule in order to keep the soil water potential within a narrow range of values are significant.

- Optimal irrigation scheduling leads to maximum yields and good bulb quality (Figures 3–5, page 3)
- Under-irrigation leads to losses in total yield, market grade, and single centeredness.
- Over-irrigation leads to soil erosion, bulb disease susceptibility, water loss, extra energy costs for pumping, N leaching, and increased crop N needs.

Research at the Malheur Experiment Station has shown that a single episode of moderate water stress (higher than 60 cb) any time from the four-leaf stage to the eight-leaf stage can result in reduced bulb single centeredness (Figure 5, page 3).

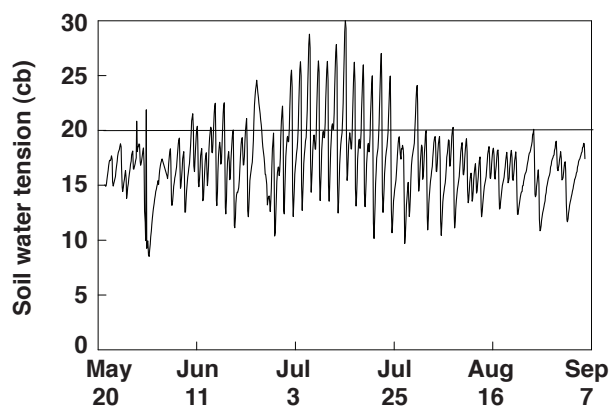


Figure 2. Soil water tension (SWT) at 8-inch depth for onion drip irrigated at 20 cb (0.48 inch of water per irrigation). SWT of 0–10 represents saturated soil. Note the narrow range of SWT and almost complete absence of saturated soil.

Irrigation scheduling matters!

Onions are extremely sensitive to water stress. Regardless of the type of irrigation system used, both yield and quality can suffer if irrigation is delayed and available soil moisture is allowed to drop too low.

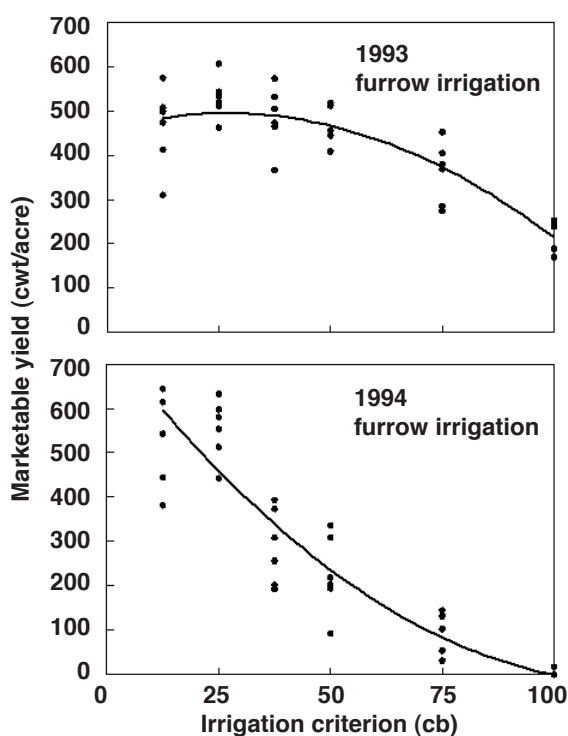


Figure 3. **Furrow irrigation:** Research at the Malheur Experiment Station in 1993 and 1994 showed that onion yield decreased in response to increasing soil water tension (SWT) irrigation criteria for furrow irrigation. Delaying irrigation until SWT was higher (soil moisture was more depleted) reduced marketable yield. Based on these results, an SWT of 25–27 cb is recommended for **onset** of furrow irrigation of onion.

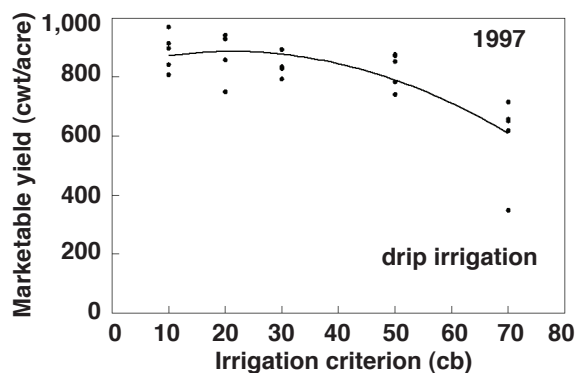


Figure 4. **Drip irrigation:** Research at the Malheur Experiment Station in 1997 and 1998 showed that onion yield decreased in response to increasing soil water tension (SWT) irrigation criteria for drip irrigation. Delaying irrigation until SWT was higher (soil moisture was more depleted) reduced marketable yield. Based on these results, an SWT of 17–20 cb is recommended for **onset** of drip irrigation of onion.

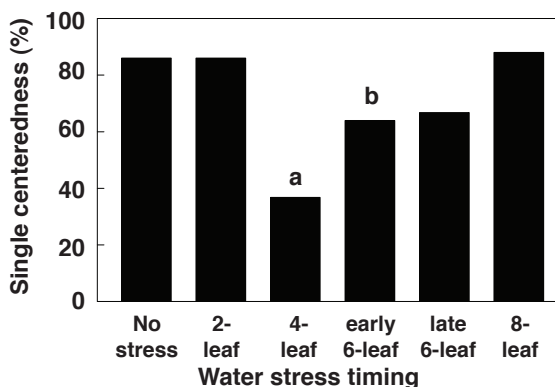


Figure 5. Onion single centeredness in response to short-duration water stress at different onion development stages (2005). Mild water stress to onions was achieved by allowing SWT to reach 60 cb before resuming irrigations. Bars with different letters (a, b) are significantly different with 95 percent confidence.

Scheduling methods

In order for an irrigation schedule to be effective, it must tell us **when** to water and **how much** to apply. Scheduling methods that are successfully used in the Treasure Valley of Oregon and Idaho are:

- Soil water tension (SWT) using a graph of soil moisture (may be combined with soil water depletion)
- Crop evapotranspiration (ET) using the checkbook method

Irrigation scheduling by soil water tension (SWT)

Onion plant performance is closely related to the amount of tension the plant has to exert to move water from the soil into the plant roots. Thus, one effective method of irrigation scheduling is based on soil water tension (SWT). SWT is a measure of how strongly water is held by the soil. The higher the SWT, the drier the soil. This method consists of establishing a maximum SWT as the criterion for beginning irrigation and then irrigating when that SWT is reached. Since 1988, Malheur County onion growers have successfully used SWT to schedule irrigation.

Using soil moisture sensors

SWT can be measured using tensiometers, Granular Matrix Sensors (GMS), or other instruments. GMS (manufactured as Watermark soil moisture sensors by Irrrometer Co., Riverside, CA) has two electrodes in a porous matrix. The electrical resistance between the two electrodes is measured and converted to SWT using equations developed by the Malheur Experiment Station for silt loam.

Six or more GMS can characterize the SWT in a field, provided they are installed in representative areas and are responsive to ET and irrigations. The six GMS may be distributed widely across an area with similar irrigation needs.

Place sensors directly below double rows of onions between three to four healthy plants. The placement of soil moisture sensors at a depth central to the crop root zone is very important. We have found that sensors placed 8 inches deep in a representative part of the field can provide consistent readings. If sensors are placed at a more shallow depth, they dry very quickly and predict the need for irrigation before irrigation is needed. If sensors are centered deeper than 8 inches, they respond very slowly to plant water use and fail to indicate when onion irrigations are needed.

Wires from sensors in a given area are brought to a single easily accessible location, such as a field edge, for rapid reading. The GMS can be read using a hand-held battery-powered meter or by dataloggers. Read sensors daily and plot the data on a graph for immediate interpretation. When viewed in graphical form, SWT clearly indicates the current condition of the crop root zone and how rapidly water is being depleted. These measurements provide information about **when** to irrigate.

Methods for determining crop water needs and installing and managing granular matrix sensors and tensiometers are discussed more thoroughly in *Irrigation Monitoring Using Soil Water Tension*, EM 8900 (Shock et al., 2005b).

Irrigation onset criteria must be developed for each production environment

Criteria for irrigation onset based on SWT depend on the climate, soil, and irrigation system. Thus, the SWT irrigation criteria that optimize onion yield and grade vary by production area. Studies with onions have determined criteria from 10 to 35 cb, depending on the class of onion, irrigation system, and growing region.

In wetter climates, SWT criteria should be higher (irrigation begins when soil is drier), because precipitation can result in excessively wet soils. In sandy soil, a lower SWT criterion should be used (irrigation begins when soil is

moister), because the water-holding capacity of these soils is much lower. With a lower water-holding capacity, SWT increases more rapidly as the soil dries than it does in silt loam or clay, which have higher water-holding capacities.

When to irrigate on silt loam in the Treasure Valley

On silt loam, onion growth and grade are maximized when irrigation occurs before the average sensor readings at the 8-inch depth reach 25 cb for furrow-irrigation systems or 20 cb for drip-irrigation systems. Based on onion yield and grade responses to irrigation, research at the Malheur Experiment Station has shown that ideal onion SWT irrigation criteria on silt loam in eastern Oregon and southwestern Idaho are as follows:

- 25–27 cb for furrow-irrigated onion
- 17–20 cb for drip-irrigated onion

Some growers believe that reducing irrigations later in the season can prevent bulb decomposition in storage. This idea was tested at the Malheur Experiment Station. Onions were drip irrigated all season using a criterion of 20 cb. Some plots were switched to drier criteria of 30, 50, or 70 cb during the final 5 weeks of the season. Irrigating onion at an SWT higher than 20 cb during the final 5 weeks of the season reduced yield and bulb size but did not improve onion storability (Shock et al., 2000a).

Thus, it is critical to maintain SWT at adequate levels the entire season. Onion plants use less water toward the end of the season, so SWT will increase at a slower rate, reducing the frequency of irrigations. It is important to maintain the same SWT, however, all the way to the end of the season.

SWT scale for onion grown on silt loam in eastern Oregon and southwestern Idaho

- > 25 cb indicates dry soil for onion and water stress for onion plants.
- 15 to 25 cb is the range that indicates it's time to irrigate.
- 10 cb is close to field capacity.
- 0 to 10 cb indicates the soil is saturated with water.

How much to irrigate?

A powerful way to schedule irrigation is to combine SWT with soil water depletion. The strong point of SWT is its ability to predict stress before it occurs, thus telling you **when** to irrigate. By estimating soil water depletion, you can also decide **how much** to irrigate, thus avoiding over-irrigation. With this method, you irrigate when the average tensiometer or GMS reading reaches the SWT criterion and apply **only** enough water to replenish the root zone.

The goal is to make sure the amount of water applied at each irrigation does not exceed the water-holding capacity of the soil volume containing the onion root zone (top foot of soil). Thus, the amount of water to apply depends on how wet the soil is at the time of irrigation. As a general guide, Table 1 (page 6) shows approximate soil water depletion and maximum amounts of water to add per irrigation at different SWT. These guidelines are for a silt loam soil with a maximum water-holding capacity of 1.5 inches per foot of soil. Keep in mind that water-holding capacity and SWT vary within a soil type (Nyssa silt loam, Owyhee silt loam, etc.) and can also vary between and within fields.

Table 1. Soil water content, soil water tension, and amounts of water to add per irrigation for a silt loam soil with a water-holding capacity of 1.5 inches per foot of soil.

Soil water content (in/ft)	Soil water tension (cb)	Depletion (%)	Amount per irrigation (in)
1.50	<10	0	0
1.38	10	8	0.12
1.26	15	16	0.24
1.02	20	32	0.48

Automated SWT readings

Dataloggers that automatically read GMS and record SWT can facilitate irrigation management. The data can be viewed with the push of a button and can be downloaded to a laptop computer or PDA. Downloaded data can be imported into a spreadsheet and graphed. The SWT graphs constructed from the stored data make it possible to determine soil moisture trends and to predict or modify irrigation schedules at each GMS location. The dataloggers also can include soil temperature sensors to correct the SWT data.

The AM400 (Figure 6), by M.K. Hansen Co. (East Wenatchee, WA), automatically records readings every 4 or 8 hours from six GMS and a temperature sensor. By pushing a button, you can view soil moisture graphs of the recorded data.

Irrrometer Co., Inc. (Riverside, CA) makes the Watermark Monitor (Figure 7), which

automatically stores readings from up to eight sensors. The Watermark Monitor includes a temperature sensor and pressure switches for recording irrigation events. Data intervals can be set from once a minute to once every 24 hours. Data also can be transmitted by radio or cell phone from the Watermark Monitor to a computer.

Irrigation scheduling by crop evapotranspiration (ET)

Crop evapotranspiration (ET) is the combined evaporation of water from the soil surface and crop water use (transpiration of water through plant tissue). Crop ET values can be calculated using weather stations in a production region. In the Treasure Valley, ET data are available online through AgriMet, a U.S Bureau of Reclamation cooperative agricultural meteorological network for the Pacific Northwest. Other areas are served with public meteorological networks. Weather stations to estimate ET are also sold for use on private farms.

Long-day onions grown in eastern Oregon use much less water per day at the beginning and the end of the season than during the middle of the season (Figure 8, page 7). Daily onion ET ranges from about 0.05 inch at the beginning of the season to 0.5 inch in the middle of the season. Total seasonal onion ET is usually in the range of 28 to 32 inches of water.



Figure 6. The AM400 by M.K. Hansen Co. (East Wenatchee, WA). Photo: Clint Shock



Figure 7. The Watermark Monitor by Irrrometer Co., Inc. (Riverside, CA). Photo: Clint Shock

The checkbook method uses ET to determine when to irrigate. It consists of keeping a record of irrigation, rainfall, estimated daily ET, and the accumulated net ET from one irrigation to the next. Think of the soil as a checking account and the water in it as the money in the account. You keep a record (an ET log) of all the charges (ET) and deposits (irrigation and rainfall) made to the account. You can run up your charges only to a certain point; after that you must make a deposit, or get “zapped.”

To use this method of irrigation scheduling to determine when to irrigate, you must have access to the following:

- AgriMet or other local weather station information to estimate onion crop water use (ET) based on the crop coefficient and crop development data. For example, the estimated daily ET for Ontario, Oregon is available online from AgriMet at <http://www.usbr.gov/pn/agrimet/h2ouse.html>
- A rain gauge placed in each production field or group of adjacent fields
- A good estimate for the allowable depletion of water for each soil (or some other criterion to determine when to start irrigation). The allowable depletion is the amount of water that can be removed from the soil before the onion plant is stressed. The allowable soil water depletion for onion can be calculated if you know the following: (1) the onion plants' effective rooting depth in a given soil and (b) the soil's water retention characteristics in the range where the onion plant does not suffer water stress. Be careful not to overestimate either the root zone depth or the soil's capacity to hold water. For onion growing on silt loam soil in the Treasure Valley, the allowable depletion is typically 0.6 inch.

With this method, there is no mystery to irrigation scheduling. You know when to irrigate and how much water to apply; the result is successful onion irrigation. You will decide **when** to irrigate by not allowing net ET to exceed the

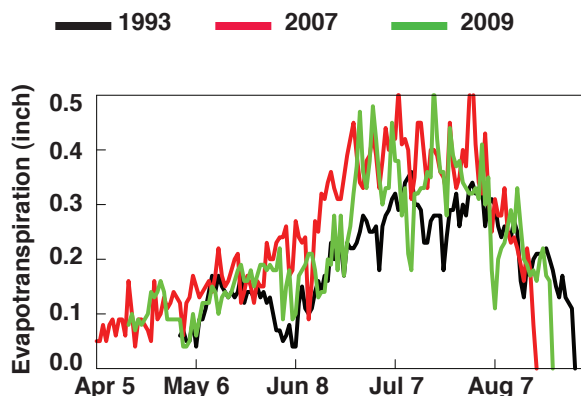


Figure 8. Daily onion evapotranspiration (ET) measured at the Malheur Experiment Station. The amount of onion ET varies by year. Daily water use at the beginning and end of the season is less than in the middle of the season.

allowable depletion. To avoid getting zapped, you must guess and begin irrigation on the day the depletion would have exceeded 0.6 inch. You will know **how much** to irrigate by replacing only the soil's allowable depletion (0.6 inch). The example on page 8 illustrates this method.

Checkbook method

Spending depletes your account. Water use by the plant plus losses from evaporation from the soil make up the ET estimated by AgriMet.

Deposits refill the account. Irrigation plus rainfall (measured at the field) are considered deposits.

Getting zapped. Overdrafting your bank account or paying your bills late results in a penalty. The same is true here. Letting the field get too dry will result in bulb yield and grade penalties. Keep in mind that **water stress can occur by watering only 1 day late.**

Unlike your bank account, the soil water account has a limit on the maximum balance. If there is more rain or irrigation than the soil can hold, the excess is lost.

The checkbook method: An example

Table 2 shows an example of using the checkbook method of irrigation scheduling by crop ET. The soil is Owyhee silt loam, a common soil around Ontario, Oregon. Allowable soil water depletion is 0.6 inch. The daily onion ET amounts shown in Table 2 are the July 2006 AgriMet estimates at this arid location, but the rainfall events are hypothetical, for instructional purposes. Let's suppose that each irrigation supplies 0.6 inch of water, replenishing the soil water.

As an example, let's say that today is July 4.

1. Begin with the previous day's net ET (column 6). *Example: net ET for July 3 is 0.48.*
2. Add today's ET (column 4). *Example: Estimated ET for July 4 is 0.37. So, $0.48 + 0.37 = 0.85$.*
3. Subtract today's rainfall (column 5). If the result is greater than 0.6, it's time to irrigate. *Example: There is no rainfall on July 4. So, $0.85 - 0 = 0.85$. This net ET is greater than 0.6, so it's time to irrigate.*
4. Irrigate to refill the root zone and record the amount in column 3. In our example, irrigation applications are 0.6 inch to refill the root zone. Irrigation never exceeds 0.6 inch because the extra water could not be held in the soil and would be quickly lost to runoff or leaching.
5. Subtract the irrigation water applied (column 3) from the total found in step 3. The result is the day's net ET value. Enter this value in column 6. This will be the net ET value you start with tomorrow. *Example: $0.85 - 0.6 = 0.25$. We enter 0.25 in column 6 for July 4. Tomorrow, July 5, we will use this value to begin again with step 1.*

Now let's see what happens on July 14.

1. Again, begin with the previous day's net ET (column 6). *Example: net ET for July 13 is 0.17.*
2. Add today's ET (column 4). *Example: Estimated ET for July 14 is 0.37. So, $0.17 + 0.37 = 0.54$.*

3. Subtract today's rainfall (column 5). If the result is greater than 0.6, it's time to irrigate. If not, enter this value as today's net ET (column 6). This will be the net ET value you start with tomorrow. *Example: Rainfall for July 14 is 0.08. So, $0.54 - 0.08 = 0.46$. This net ET is less than 0.6, so it's not time to irrigate yet. We enter 0.46 in column 6 for July 14. Tomorrow, July 15, we will use this value to begin again with step 1.* Note: If rainfall makes the net ET account negative, drop the negative balance and set the net ET to zero for that day. (The negative balance represents water applied in excess of the root-zone water-holding capacity; this water is lost to runoff or leaching, typically within 24 hours).

Table 2. To calculate the net ET (accumulated ET minus irrigation and rainfall), begin with the accumulated ET for the previous day, add the expected ET for the current day, and subtract rainfall and irrigation applied. This silt loam soil has 0.6 inch of allowable depletion for onions, and the drip system applies 0.6 inch during each irrigation.

Action	July	Irrigation Daily ET Rain Net ET*			
			(in/day)		
—	1	—	0.40	—	0.40
irrigate	2	0.6	0.31	—	0.11
—	3	—	0.37	—	0.48
irrigate	4	0.6	0.37	—	0.25
—	5	—	0.33	—	0.58
—	6	0.6	0.33	—	0.31
irrigate	7	0.6	0.45	—	0.16
—	8	—	0.39	—	0.55
—	9	0.6	0.41	—	0.36
irrigate	10	0.6	0.39	—	0.15
—	11	—	0.41	—	0.56
—	12	0.6	0.41	—	0.37
irrigate	13	0.6	0.40	—	0.17
—	14	—	0.37	0.08	0.46
—	15	—	0.41	1.20	0.00
—	16	—	0.44	—	0.44
—	17	0.6	0.45	—	0.29
—	18	0.6	0.48	—	0.17

*Accumulated ET minus irrigation and rainfall

The checkbook method on sandy soil?

The checkbook method operates in the same way on a sandy soil, but irrigation occurs much more frequently and irrigations typically are much smaller. For onion, assume 0.4 inch allowable water depletion and irrigations of 0.33 inch (Table 3).

On sandy soils, irrigation scheduling by the checkbook method alone has a narrow margin of error. Measuring the trend in soil water content in conjunction with the checkbook method can help assure that the field is not getting too dry or too wet. Soil water content is the volume of water in the soil as a percentage of the total soil volume. Take measurements regularly using a neutron probe or other equipment and plot them over time.

Table 3. An example of the checkbook method of irrigation scheduling on a sandy soil with 0.4 inch allowable depletion for onions.

Action	Aug	Irrigation Daily ET Rain Net ET*			
			(in/day)		
—	1	—	0.35	—	0.35
irrigate	2	0.33	0.34	—	0.36
irrigate	3	0.33	0.34	—	0.37
irrigate	4	0.33	0.32	—	0.36
irrigate	5	0.33	0.31	—	0.34
irrigate	6	0.33	0.29	0.08	0.22
—	7	—	0.27	1.45	0.00
—	8	—	0.29	—	0.29
irrigate	9	0.33	0.31	—	0.27
irrigate	10	0.33	0.40	—	0.34

*Accumulated ET minus irrigation and rainfall

Other considerations

Drip irrigation systems

With drip irrigation, frequent application of small amounts of water is possible. How frequently should you irrigate? How much water should you apply at each irrigation? The answer to these questions depends partly on practical issues, such as availability of irrigation water for a particular field, the irrigation system design, and the feasibility of irrigation automation.

Can soil water content be used to schedule irrigation?

Using soil water content alone to decide when to irrigate is problematic, because the ideal soil water content for a crop needs to be determined for each location. The problem is that the criterion for deciding when to irrigate is based on SWT—a measurement of how hard the plant must work to extract water from the soil. Unfortunately, the relationship between soil water content and SWT varies, depending on the soil series (Owyhee silt loam, Nyssa silt loam, etc.) within a soil type. It can also vary across a field (because of differences in soil structure) or from year to year within a field. Thus, knowing the soil water content does not necessarily tell you the SWT or whether it is time to irrigate. For a specific location, the ideal soil water content would need to be determined in relation to the ideal SWT. Irrigation scheduling by soil water content is better suited to crops grown in fields with highly uniform soil texture.

Research at the Malheur Experiment Station has shown that drip irrigating more frequently than once per day does not result in any yield or market grade benefits (Shock et al., 2005a). At the Malheur Experiment Station, to maintain SWT below 20 cb in drip-irrigated onions (0.48 inch applied per irrigation), irrigations have to be made every 1 to 1.5 days during the period of peak water use.

Application rate

Take care to apply irrigation water at a rate that does not exceed the infiltration rate of the soil. The infiltration rate for silt loam at the experiment station is about 0.10 to 0.15 inch per hour.

Irrigation and disease

Excessively wet soil is conducive to bulb-rotting pathogens. It encourages neck rot, which can reduce crop marketability at harvest or from storage. Experience has shown that onions that are over-irrigated are especially prone to storage decomposition, particularly if significant rainfall events occurred during the growing season.

For onions, small increments of soil water stress are highly detrimental to bulb yields when Iris Yellow Spot Virus (IYSV) is present (Figure 9). In the presence of IYSV, irrigation scheduling becomes more critical.

For more information

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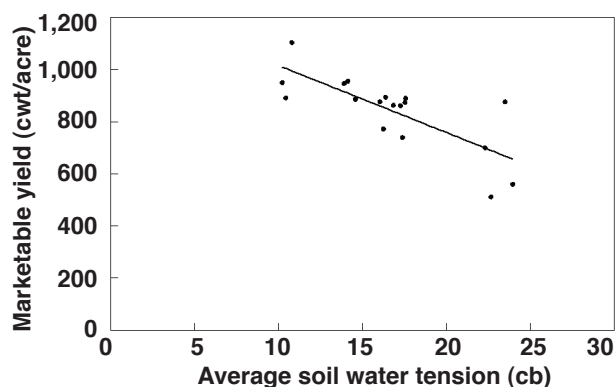


Figure 9. Under moderate IYSV pressure in 2008, onion yields responded to the seasonal average soil water tension. The irrigation onset criteria for drip irrigation were 10, 15, 20, or 30 cb.

Oregon State University Extension publication EM 8901. <http://extension.oregonstate.edu/catalog/html/em/em8901/>

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