University of Idaho
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Sugarbeet Irrigation Management

Using Watermark Moisture Sensors

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Introduction

Proper irrigation timing can maximize sugarbeet yields while minimizing disease, water costs, fertilizer leaching, and soil erosion. Crop yields can suffer from either under- or overirrigation. Underirrigation limits water flow into the plant, which reduces movement of water, nutrients, and photosynthates within the plant. Overirrigation reduces yield through increased incidence of disease, loss of nutrients from the soil root zone, and reduced oxygen to roots. Overirrigation can also reduce sugarbeet quality by lowering the sugar percentage.

Overirrigation of sugarbeets is common, especially with furrow irrigation. Root diseases such as rhizomania and rhizoctonia root and crown rots flourish in saturated soils. If soil saturation can be minimized, development and spread of these diseases will be reduced.

Unnecessary irrigations can be reduced if growers use information on water status at deeper soil depths to allow sugarbeets to extract water from more of the soil profile. This publication explains how to install soil moisture sensors and use them to schedule irrigations more efficiently.

Sugarbeet water requirement

Sugarbeet plants have a deep root system, enabling them to use soil water from as deep as 6 feet. However, if water is abundant, sugarbeets will satisfy the majority of their water requirements from the top 2 feet of soil. In addition, excess moisture can cause the taproot to rot, resulting in a shallow, sprangled root system.

Young sugarbeet plants should not be stressed for moisture. Frequent, light irrigations encourage rapid foliage production and plant establishment. Later in the season, irrigations can be spaced apart to ensure the top 1 foot of soil never gets drier than 50% available soil moisture. MAD (management allowable depletion) is the percentage of available soil moisture that can be used without reducing crop yield or quality. Soil moisture sensors can help growers determine when 50% available soil moisture has been used by the crop (50% MAD has been reached) and they should begin irrigating.

Watermark soil moisture sensors

A Watermark soil moisture sensor is an electrical resistance block that measures soil matric potential (fig. 1). Matric potential is expressed in units of centibars (cbar) and is a measure of how tightly soil particles hold moisture. The energy exerted by plants to remove water from the soil must be greater than the soil matric potential.

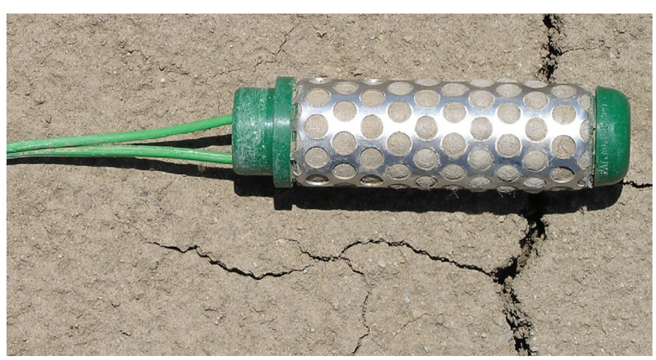

Figure 1. Watermark soil moisture sensor.

A sensor placed in saturated soil will show a reading of near 0 centibars. As soil moisture is depleted due to evapotranspiration, the matric potential increases. Irrigation should occur when allowable soil moisture reaches a level critical for the specific crop and soil texture.

Sensors and soil texture

The centibar reading used to initiate irrigation depends on soil texture (percentages sand, silt, clay). Clay soils and soils high in organic matter hold more water than sandy soils. Sandy soils should be irrigated more frequently and at lower centibar readings. Growers should know the general textural class of their fields to use soil sensors accurately.

Table 1 shows an example of soil sensor readings and irrigation recommendations for a loam soil. For sugarbeets in a loam-textured soil, irrigation should be started when the 1-foot sensor indicates about 50% MAD. As shown in table 1, the sensor reading is 58 centibars. Irrigation guidelines for other soil textures and crops can be obtained by contacting one of the authors.

Table 1. Soil sensor readings and irrigation recommendations for a loam-textured soil.

Available soil moisture	Watermark reading[1]	Irrigation to refill 1 ft of soil	
		pivot or linear	hand or wheelline
(%)	(cbar)	(inch)	(inch)
100	20	0	0
85	25	0.26	0.30
80	29	0.35	0.40
75	34	0.44	0.50
70	38	0.53	0.60
65	41	0.62	0.70
60	45	0.70	0.80
55	50	0.79	0.91
50	58	0.88	1.01
40	81	1.06	1.21
30	133	1.23	1.41

[1] 0 = saturated soil, 0-20 = leaching possible, 20-58 = best crop growth, >58 = crop water stress

Figure 2. Hansen AM400 data logger.

Data logger

Soil sensor readings can be recorded and displayed using various data loggers (such as Hansen AM400) (fig. 2). Data loggers make daily readings convenient and can help growers plan the next irrigation. The Hansen AM400 data logger reads and records sensor data every 8 hours for up to six sensors. Data from the entire season can be stored to provide a record of seasonal irrigation management.

Using sensors in sugarbeets

Furrow irrigation

Soil moisture sensors should be placed together in "stations" (three sensors at 1-, 2-, and 3-foot depths) about 100 feet from the head and tail ends of furrow-irrigated fields. Sensors should be located in areas that best represent the field.

The crop should be irrigated when sensors at the 1 foot depth indicate about 50% MAD. Soil moisture readings at lower depths can be used to help schedule the length of irrigations.

For example, if 50% MAD has been reached at the 1-foot depth and sensor readings at the 2- and 3-foot depths show adequate moisture, an irrigation set can be shorter than usual. If, on the other hand, sensor readings at 2- and 3-foot depths indicate greater than 50% MAD, the irrigation set time could be extended so water reaches these deeper depths.

Sprinkler irrigation

Irrigation scheduling strategies for pivots and linears are different from furrow irrigation strategies because of two factors: (1) pivots and linears are typically not designed to meet peak ET (evapotranspiration) and (2) water intake characteristics of most medium- and heavy-textured soils limit application to about 3/4 to 1 inch per pass. For a net irrigation of 3/4 inch, the water applied will be used in about 2 to 3 days in mid season. If irrigation is delayed beyond that point, the system begins to fall behind and cannot catch up until peak use has dropped below the design application rate. As a result, most of these machines run on about a 2.5-day cycle.

Sensors are useful for determining when the system needs to be turned on or off during the nonpeak part of the season and during a low-ET period in mid-season. To find the sensor “threshold” for initiating irrigation with a sprinkler system on a loam-textured soil (table 1), use the Watermark reading in the column to the left of the “irrigation to refill” columns.

For example, for a pivot that applies 0.7 inch gross irrigation per pass, the sensor threshold will be 45 cbar. This means that when the soil in the top foot dries to 45 cbar, sufficient room is available in the soil to hold the 0.7 inch applied. In this example, soil moisture fluctuations between irrigations, like those shown in figure 3, will range from 0 (saturated) to about 45 cbar. However, the pivot will be unable to refill the soil profile if readings exceed 45 cbar.

Another useful feature of sensors is that overirrigation can be spotted easily. Pivot or linear sensors that give curves like those shown in figure 4 indicate overwatering. The pivot needs to be sped up to give smaller irrigations per pass or shut down between irrigations to allow the soil to dry down.

Soil moisture graphs

Data stored in the data logger can be downloaded to a computer to produce soil moisture graphs like those in figures 3, 4, and 5. These graphs can be used to review soil moisture content, evaluate effectiveness of irrigations, and improve efficiency.

Example: Correct irrigation

Figure 3 shows a sugarbeet field irrigated close to the recommendations. Notice that the 1-foot sensor was often allowed to reach the 50% MAD range before irrigation was started. There was also abundant moisture at the 2- and 3-foot soil depths (near field capacity). Irrigation set times were kept short because the sensors indicated adequate moisture at 2- and 3-foot soil depths. This schedule prevented saturation at deeper depths and possible leaching of nitrates to groundwater. Because the grower knew he had moisture at deeper depths, he had confidence in letting the 1-foot sensor dry out to the recommended levels.

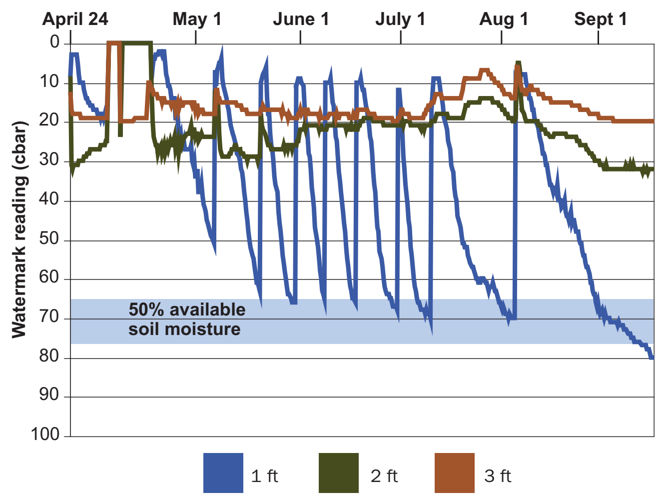

Figure 3. Correct irrigation of furrow-irrigated sugarbeets in clay-loam soil, 2004 (0 cbar = saturation, 25 cbar = field capacity).

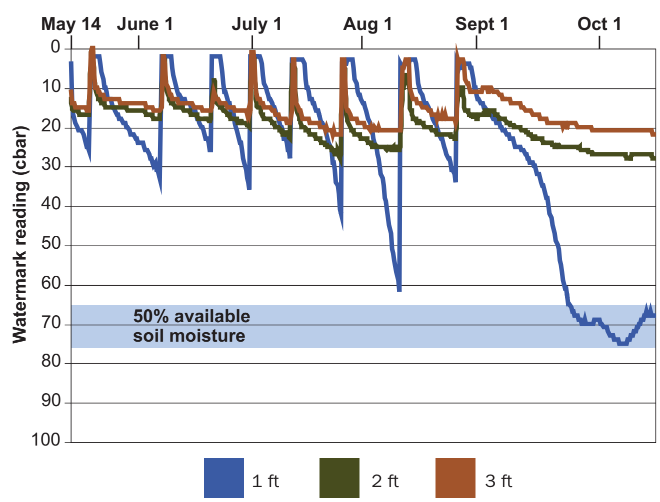

Figure 4. Overirrigation of furrow-irrigated sugarbeets in clay-loam soil, 2000.

Example: Excessive irrigation

Figure 4 shows an example of an overirrigated sugarbeet field. Six irrigations were made before the soil at the 1-foot depth was allowed to dry to the 50% MAD recommendation.

Soil moisture at the 2- and 3-foot depths remained near field capacity for much of the season and reached saturation (near 0 cbar) with nearly every irrigation. Reaching saturation at these depths is unnecessary and promotes nitrate leaching below the crop root zone.

The grower could have spaced out his irrigations, especially in late June and July. He could also have reduced his irrigation set time so water penetration would not have been so deep.

Example: Sprinkler irrigation

Figure 5 is an example of a linear-move sprinkler-irrigated sugarbeet field. The graph shows some excessive drying during August at the 1-foot depth. However, this field produced a good yield because there was abundant moisture at deeper soil depths and the crop was deep rooted. The 3-foot sensor indicated plenty of moisture (near field capacity) consistently through the season. The 2-foot sensor indicated less soil moisture, as was expected, and did show a drying trend toward the end of the season. The 3-foot sensor also indicated there was not saturation at this depth. Nitrates and other nutrients stayed in the crop root zone and leaching was minimized.

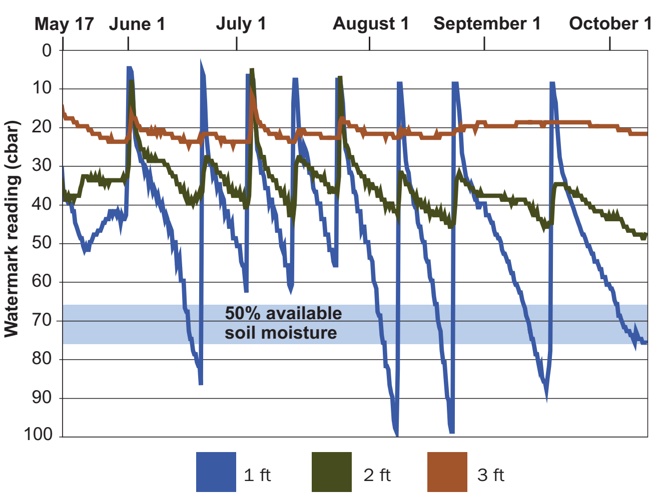

Figure 5. Sprinkler-irrigated sugarbeets in clay-loam soil, 2002.

Soil sensor installation

Location

Place sensors in areas that are most representative of your field. Sensors should be placed together in “stations” of 1-, 2-, and 3-foot depths. Stations should be located approximately 100 feet from the head and tail ends of furrow-irrigated fields. In sprinkler-irrigated fields, locate sensors in areas that best represent the field to provide information on irrigation uniformity and to indicate whether irrigation set time or water volume need changing.

Sensor preparation

For ease of installation and removal, glue soil sensors into one end of 1/2-inch PVC pipe (IPS 315 psi) that has been precut to the sample depths (fig. 6). Glue the tapered base of the sensor into the pipe, leaving the remainder of the sensor exposed. The wire leads from the sensors can be run up through and out of the pipe for later connection to the communication cable. Attaching the sensors to PVC pipe makes retrieval of the sensors much easier at the end of season.

Field installation

Make soil holes directly in the seedling row. Use a 1 1/4-inch diameter soil auger to drill holes spaced approximately 10 to 12 inches apart. Before installing the sensors, soak them overnight so they are saturated (0 cbar). Presoaking insures that the sensors will reach equilibrium with the surrounding soil moisture and begin reporting accurate readings quickly. Before installing them, check the sensors for accuracy by connecting them directly to the monitor. If a sensor reads over -5 centibars at saturation, consider replacing it.

Before placing a sensor, pour a small amount of soil/water slurry into the hole (fig. 7). Next, place the PVC-mounted sensor into the hole and press it into the slurry. This provides good contact between the sensor and surrounding soil for accurate readings. Pour additional slurry around the PVC pipe to fill the hole.

Wire connections

The sensors are now ready to be connected to the communication cable (a CAT II communication cable has worked well) leading to the data logger (fig. 8). The communication cable should be laid along the top of the row and as close as possible to the seedlings. Sensors have been wired over 700 feet from the data logger with no signal problem. The communication cable is then connected to the data logger.

Figure 6. PVC-mounted sensors ready for installation.

Figure 7. Pouring soil slurry into sensor holes.

Figure 8. Completed installation of a sensor "station."

Data logger

Mount the data logger on a post so it is off the ground and above standing water. Locate it where it is most accessible and useful. We have found that irrigation ditch banks or spots near irrigation riser pipes are the most practical locations.

The data logger will display the current soil moisture reading for each sensor when the activation button is pushed. The display window will also show the soil temperature, battery status, and a moisture graph for each sensor for the past 5 weeks.

Growers often use the combination of soil moisture readings and graphs for determining the rate of soil drying and need for the next irrigation.

Soil moisture data is automatically recorded three times per day. Soil moisture readings for the entire season are stored and can be retrieved to produce graphs.

Both soil sensors and data loggers can be removed and stored for the next season or placed in a different crop. Soil sensors and data loggers have been used for up to five seasons with reliable results, although sensor calibrations should be checked each year to insure accuracy.

Results of research studies

A 5-year project was conducted in Canyon and Washington counties to demonstrate irrigation management through the use of soil moisture sensors and data loggers. Sugarbeet fields were divided into control and treatment sides. Control sides were irrigated according to the grower's normal irrigation scheduling methods. Treatment sides were irrigated according to soil sensor readings and visual observation.

In a 2000 Canyon County furrow-irrigated field, the grower applied 14.5% less water on the treatment side than on the control side of the field (table 2). The treatment side produced an additional 1.7 tons/acre of sugarbeets. This grower saved nearly $90 per acre in water costs, pumping costs, and irrigation labor (table 2). (Data logger, sensors, and communication cable can be purchased for approximately $500 and installed without special equipment or expertise. The logger will run for an entire season with two AA batteries.) Results of a 2001 furrow-irrigated demonstration plot showed a similar trend.

In a 2002 Washington County sprinkler-irrigated field, the grower applied 18% less water on the treatment side than on the control side of the field. The treatment side produced a slightly higher yield and sugar percentage (table 3).

Several demonstration plot studies conducted by the authors on different sugarbeet fields using different irrigation systems showed similar trends. Growers who irrigated based on sensor readings often applied less water and reduced expenses. Beet yields were slightly higher or unaffected by the reduced irrigation. In addition, soil and water samples indicated less nitrate loss from the treatment sides than the control sides.

Use of soil sensors also alerted growers to other field characteristics such as natural hardpans that restrict water penetration and high water tables that provide season-long moisture.

Growers may curtail irrigations earlier in the season if they know sufficient moisture is available at deeper depths. Some growers completed their irrigations in mid to late August. Although the 1-foot depth was dry, the deeper soil depths provided sufficient soil moisture.

Table 2. Furrow irrigation of sugarbeets in Canyon County, Idaho, using soil sensor readings (treated) or the grower's customary scheduling method (control), 2000 and 2001.

	2000		2001	
	Treated	Control	Treated	Control
Yield (ton/acre)	36.3	34.6	35.7	34.0
Irrigation (inch/acre)	71.0	83.0	54.0	67.0
Sugar (%)	16.4	16.7	16.9	16.5

Table 3. Sprinkler irrigation of sugarbeets in Washington County, Idaho, using soil senor readings (treated) or the grower's customary scheduling method (control), 2002.

	Treated	Control
Yield (ton/acre)	38.0	35.0
Irrigation (inch/acre)	30.0	37.0
Sugar (%)	16.7	16.2

Problems encountered using this technology

As with any new technology, growers have encountered some challenges with the equipment. Growers have reported snagging or cutting the surface communication cable with tillage equipment. Keeping the cable close to the seedlings will usually keep it out of the way of field operations. For cultivation of head rows, the cable must be disconnected or the equipment must be lifted over the cable.

Growers who have fields with clay soils have reported that soil cracking occurs before the sensors reach the recommended moisture status. Soil cracking may damage sugarbeet roots and can give inaccurate sensor readings. These soils may need to be kept wetter than the 50% MAD recommendation.

Some growers have reported rodents chewing on communication cables. Control of rodents is necessary to avoid numerous cable repairs.

Conclusions

- Soil moisture sensors have proven to be reliable, useful, affordable tools that can help growers schedule irrigations more efficiently. Sensor readings should be considered along with other methods such as visual observation, not solely. Growers should know the rooting depth of the crop and the soil texture of the field.
- Most growers who have used soil sensors reduced their water use and observed slight increases in yield.
- Growers should install sensors in locations that best represent the majority of the field.
- Sensors should be installed in stations at depths 1, 2, and 3 feet. Good contact between the sensor and surrounding soil is needed to obtain good readings.
- Growers should check the moisture readings on the data logger frequently to anticipate the rate of soil moisture depletion.

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