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Corn Kernels

Vernon G. James Research and Extension Center, Plymouth, NC 27962

Sensors and Monitors for Measuring Soil Moisture

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The Situation

The decision of when to irrigate is usually based on past experiences, weather-based information (crop evapotranspiration data), or soil-based measurements. Past experiences may not be correct and are often not adjusted for annual changes in weather. Scheduling irrigations based on crop evapotranspiration can be difficult because it is hard to obtain accurate data for some locations and, even when data are available, the task of keeping track of evapotranspiration data for individual fields can be time consuming. Because of the difficulties and shortcomings of these methods, soil-based irrigation scheduling may be the preferred technique. Fortunately, there are several inexpensive technologies may help growers monitor soil moisture. These technologies can be described in two categories: Soil Moisture Sensors and Monitoring Equipment for automated reading of moisture sensors.

Soil Moisture Sensors

There are three types of practical, commercial based sensors on the market for growers. Each has its benefits and drawbacks. Each type can be matched with monitoring equipment to allow growers to obtain information manually or through wireless links.

Tensiometers

Tensiometers are the simplest soil moisture sensor available. They measure moisture by measuring the water tension in the soil. The typical reading is in centibars with the higher the reading the dryer the soil. In most soils moisture tensions above 70 centibars would require addition of water through irrigations.

ADVANTAGES:
- Inexpensive ~$100-120
- Simple to install
- Can be used multiple times

DISADVANTAGES
- Requires a service kit to fill water chamber
- Does not work well on sandy soils
- Difficult to maintain

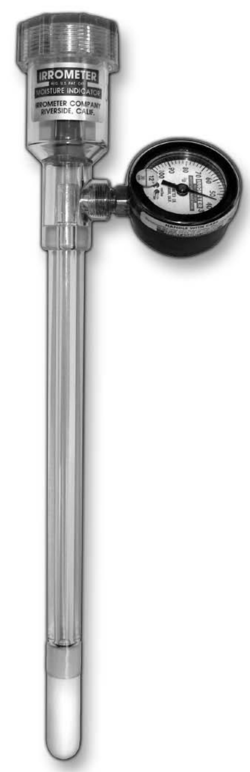

Fig. 1 Sandard tensiometer with guage

While there are several commercial sources for tensiometers the most widely known is a company called Irrometer

THE IRROMETER COMPANY, INC.
P.O. Box 2424, Riverside, CA 92516
(951) 689-1701 PHONE
(951) 689-3706 FAX
www.IRROMETER.com
sales@IRROMETER.com

Electrical Resistance or Gypsum Blocks
Electrical resistance or gypsum blocks work in a similar manner to tensiometers. They measure soil moisture tension. They do this by using a block of material (often gypsum) that absorbs water from the soil. Electrical probes in the block measure how much water the block contains. Again, the readings are reported in centibars with the higher the reading the dryer the soil.

Fig. 2 Electrical resistance probe with wire leads.

ADVANTAGES:
- Relatively Inexpensive ~$300+
- Can be used multiple times
- Can be placed in groups at multiple depths
- Work well with automated monitoring systems
- Little or no maintenance in the field

DISADVANTAGES
- Requires a probe or auger to install
- Must be pre-primed before installation

The leading manufacturer of commercials electrical resistance blocks is the watermark company. Watermark sensors can be found at many commercial companies including: The Irrometer Company, Spectrum Technologies, Gemplers and other companies handling irrigation sensors.

Time-Domain-Reflectometry (TDR) or other Dynamic Resonance Probes
TDR probes measure soil moisture directly using reflected electrical signals. The advantage to these probes is that they can measure moisture accurately in any type of soil and give the percent moisture content. Unlike other sensors TDRs reading show how much water is in the soil with higher readings indicating more moisture.

Fig. 3 TDR probe capable of reading soil moisture at multiple depths..

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ADVANTAGES:

- Can be used multiple times
- Can read multiple depths from one probe
- Gives direct measurement of soil moisture as a percent
- Little or no maintenance in the field
- Works well with automated monitoring systems

DISADVANTAGES

- Requires a probe or auger to install
- Expensive ~$2,000 - 3,000

Several companies handle TDR systems the most common being the Trime-Pico systems handled by Mesa Systems, Van Walt Systems, and other companies.

MESA Systems Co.
20 Cove Road, Unit 1 Stonington, CT, 06378, USA
Phone: 508-655-6372 (8:30 am to 5:00 pm EST)
Fax: 508-318-6537 (anytime)

In addition, TDR systems by the Dynamax Company come with segmented probes in several sizes (see chart below).

Model types	PR2/4 and PR2/6	
Sensing depths	PR2/6: 10, 20, 30, 40, 60, 100cm PR2/4: 10, 20, 30, 40cm (nominal)	
Measurement	Volumetric soil moisture content V ($m^3.m^{-3}$ or % vol)	
Range	Accuracy figures apply from 0 to 0.4 $m^3.m^{-3}$ Full range is from 0.0 to 1.0 $m^3.m^{-3}$	
Accuracy[1] **0.0 to 0.4 $m^3.m^{-3}$**	±0.04 $m^3.m^{-3}$, 0 to 40°C	Typical, after calibration to a specific soil type
0.0 to 0.4 $m^3.m^{-3}$	±0.06 $m^3.m^{-3}$, 0 to 40°C	Typical, using the generalized soil calibrations in 'normal' soils
Salinity errors	Included in above accuracy figures (50 to 400 $mS.m^{-1}$, 0.5 to 4 $dS.m^{-1}$, pore water conductivity).	
Soil sampling volume	Vertically: ~95% sensitivity within ±50mm of upper ring of each pair. Horizontally: ~95% sensitivity within a cylinder of radius 100mm.	
Environment	0 to 40°C for full accuracy specification, –20 to +70°C full operating range. IP67 rated when installed in access tube.	
Response time	Full accuracy achieved within 1 second[2]	
Power requirement	Minimum: 5.5V DC with 2m cable, 7.5V with 100m. Maximum: 15V DC. PR2/4 consumption: < 80 mA PR2/6 consumption: < 120 mA	
Outputs	4 (PR2/4) or 6 (PR2/6) analogue voltage outputs: 0 to 1.0V DC corresponding to 0 to 0.6 m^3m^{-3} (mineral calibration).	
Cable	Standard and extension cables (see ordering information)	
Construction	25.4mm polycarbonate with pairs of stainless steel rings.	
Size/Weight	PR2/4 length: 29" Weight: 1.3 lbs. PR2/6 length: 53" Weight: 2 lbs.	

Dynamax Inc.
10808 Fallstone Rd #350 Houston, TX 77099
Tel: 281-564-5100 Fax: 281-564-5200
Toll Free for US & Canada: 1-800-896-7108
www.dynamax.com

Deere and Co has just acquired a company and is planning on selling soil moisture monitoring systems based on TDR probes. Look for information on the John Deere website.

Monitors

In addition to the soil moisture probe selected growers can select different ways of monitoring and accessing data from the probes. All moisture sensors can be configured with different ways of taking readings from the sensors and for recording the data. The most inexpensive way is to visit each probe and use a hand-held reader or logger.

Fig. 4 Handheld device for taking readings from Watermark Soil moisture probes.

This requires a grower to visit each probe on a weekly schedule and provides only a snapshot of soil moisture at a given time. Other monitors can be purchased that use radio signals, wireless networks, or cell phones to send the data to a computer or other recording device. The choice depends on the availability of cell phone service, the need to acquire a radio license, and the technical resources available. Most of these types of remote monitoring systems come with computer software that plot the data over time and provide information about trends in soil moisture

Fig. 5. Station for sending soil moisture data via a cell phone link.

Using a variety of components (cables, solar panels, and radio or wireless network signals) a grower can develop a system for reading and recording data from multiple probes at many locations in a field or over several fields.

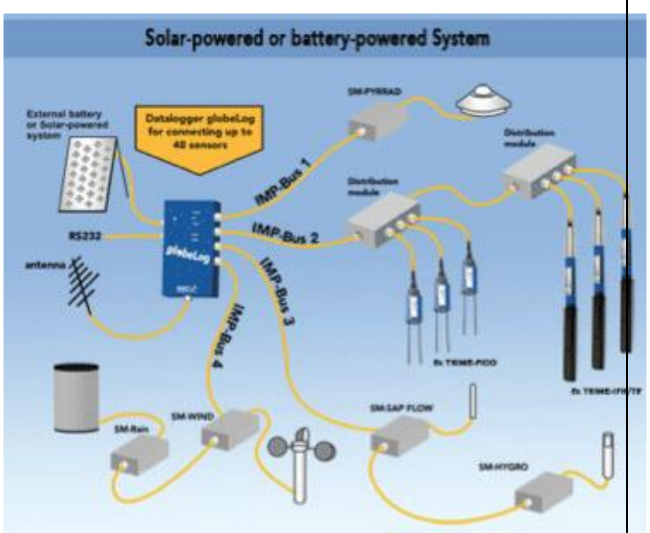

Fig. 6. Diagram of systems available for automatically reading and recording data from multiple TDR probes.

The Goal:
The ultimate goal of any system should be to provide the grower with enough information in a timely manner to make a decision about when to irrigate and how much water to apply. The graphs on the following page show how soil moisture probes can be used in an automated monitoring system to produce graphs of soil moisture over time. These graphs can then be used with the proper interpretation to help growers identify when to irrigate. This type of information should be the goal of any grower who is serious about water use efficiency. This type of information is useful in obtaining the highest yield possible with the least amount of water.

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Interpreting Soil Moisture Data

Figure 1. Proper Irrigation Management.

Shaded area indicates where irrigations should occur. At the start of the season the soil is moist from winter and spring rains—the readings are less than 20 centibars (**A**). Gradually the soil dries and the readings increase, beginning with the sensor located at the one-foot depth followed by the deeper depths. When the soil moisture reading dropped to near 80 in early May (**B**), irrigation water was applied and the centibar readings at all three depths went to below 20, indicating the soil profile had been refilled. The drying cycle resumed until a partial irrigation occurred in late May (**D**). A partial irrigation was needed to replenish enough soil moisture to carry the crop through the harvest period without excessive soil moisture depletion and crop stress. The first cutting occurred in early June [note point on graph when soil moisture content was lowest; (**E**)]. Following cutting, irrigation resumed until the soil moisture content at all three depths was restored (all readings below 20 centibars at point **F**).

Figure 2. Under-irrigation example.

Soil moisture tension levels for an irrigated alfalfa/grass field. The first irrigation occurred too late, and soil moisture remained extremely low for much of the season. Not until late August was the soil profile refilled—too late for much benefit to the crop. This field would have benefitted from careful monitoring of soil moisture and timely early irrigation.

Figure 3. Over-irrigation example.

Soil moisture levels for an irrigated alfalfa field. Soil moisture tension never exceeded 50 centibars and remained below 30 centibars for most of the season. *(Irrigation should occur at 60–90 centibars; shaded area)*. One or two irrigations could have been eliminated or less water applied per irrigation.