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Irrigation Scheduling with Tensiometers

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Irrigation scheduling is a management practice used to determine how often to irrigate and how much water to apply with each application. Soil moisture monitoring is an important procedure used in many irrigation scheduling schemes. Proper irrigation timing can be determined from soil moisture content measurements. Proper irrigation depth can be determined from known plant and soil characteristics.

Soil Water-Holding Capacity and Available Water

Soil in the plant root zone acts as a reservoir for water. Soil texture is the primary factor influencing the amount of water that the soil reservoir can store. Available water is defined as amount of water that plants are able to withdraw from the soil and use. Fine textured soils, such as clays, silt loams, or loams, are able to hold much more available water than sandy, coarse-textured soils (see Table 1). Soil water-holding capacity is an important factor to consider in determining the proper depth of irrigation water to apply.

The water storage capacity of soils is also influenced by soil depth. Nearly all vegetables and agronomic crops grown under irrigated conditions extract water from the top 2 feet of the soil profile, even though the roots of some crops can extend much deeper. In fact, in most crops, 75%-95% of the roots are in the top 12 inches of the soil profile. For this reason, manage irrigation events with the top 12 inches of the root zone in mind. Water which seeps beyond this depth may

TABLE 1. Influence of Soil Texture on Available Water-Holding Capacity

Soil Texture	Available Water-Holding Capacity (inches of water per foot of soil)
Sand	0.25 - 1.00
Loamy sand	0.75 - 1.50
Sandy loam	1.25 - 1.75
Loam and Silt loam	2.00 - 2.75
Clay loam	1.75 - 2.50
Clay	1.50 - 2.25

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not be used by the crop. Together, soil water-holding capacity and plant rooting depth can be used to determine the appropriate irrigation depth.

The appropriate irrigation frequency is influenced by soil water-holding capacity and by the rate at which plants use water, and can be determined by monitoring soil moisture. Tensiometers are simple and inexpensive devices which can be used to monitor soil moisture.

Tensiometers—Operation and Interpretation

Tensiometers measure soil tension. This is also often referred to as soil suction or vacuum. Soil tension is a measure of how tightly water is held in the soil, and is measured in pressure units of centibars (cb) or kilopascals (kPa). These are equivalent units. One-hundred centibars are approximately equal to 15 psi.

Soil tension increases as moisture in the soil is depleted. This force also draws water out of the tensiometer through its porous tip, creating a vacuum inside the tensiometer. This negative pressure, or tension, is registered on the tensiometer vacuum gauge. The soil tension measured with tensiometers is an indirect indication of soil moisture content and can be used as an indicator of irrigation need.

Shown in Table 2 are guidelines for using soil tension data to schedule irrigation events. Field capacity is the moisture content at which a soil is holding the maximum amount of water it can against the force of gravity. This moisture content is reached 24-72 hours after a saturating rain or irrigation. Field capacity corresponds to soil tension levels ranging from 5-10 cb in coarse-textured soils and as high as 40 cb in fine-textured soils.

The soil tension range corresponding to the time when irrigation should begin is also influenced by soil texture. In coarse-textured soils, irrigation should begin at soil tensions of 20-40 cb. In extremely coarse-textured soils, irrigation may be necessary at even lower tensions. Medium- and fine-textured soils do not need to be irrigated until soil tensions reach higher values, as shown in Table 2. In all soils, irrigate when 50% of available water has been depleted.

The utility of tensiometers in fine-textured soils is limited because of the upper limit of tension that can be measured with tensiometers. When soil dries beyond the 80 cb tension level, the column of water in the tensiometer "breaks," allowing air to enter the device. After breaking tension, the device ceases to operate correctly until it is serviced. Thus, tensiometers are more

TABLE 2. Irrigation Guidelines for Using Tensiometers

Soil Moisture and Irrigation Status	Soil Texture	Soil Tension (cb)
Soil at Field Capacity No Irrigation Required	Sand, loamy sand	5 - 10
	Sandy loam, loam, silt loam	10 - 20
	Clay loam, clay	20 - 40
50% of Available Water Depleted Irrigation Required	Sand, loamy sand	20 - 40
	Sandy loam, loam, silt loam	40 - 60
	Clay loam, clay	50 - 100

practical in coarse-textured soils where appropriate soil tension levels are well below the point of breaking tension.

Tensiometers—Preparation, Placement and Service

A new tensiometer is prepared for use by filling the tensiometer with clean water and placing it upright in a container of water deep enough to cover the tensiometer tip. The tensiometer cap is removed during this procedure. Water will drain through the tip over the next few hours. This procedure should be repeated two or three times.

Next, an indicating solution (available in concentrated form from the tensiometer manufacturer) is prepared and used to fill the tensiometer. This solution can easily be seen through the transparent tensiometer and allows the user to visually assure that the tensiometer contains fluid. Air can be extracted from the fluid in the tensiometer using a hand-operated vacuum pump (also available from the tensiometer manufacturer). This step is not absolutely necessary but may increase meter sensitivity. More importantly, the vacuum pump may also contain a pressure gauge which can be used to assure that the tensiometer vacuum gauge is operating properly. Finally, the tensiometer is capped shut and transported to the field with the tensiometer tip remaining submerged in water.

Field installation is relatively simple. Using a pipe, rod or soil probe which is the same diameter as the tensiometer, a hole is made to the depth to which the tensiometer will be installed. Next, a small amount of water is poured down the hole and the tensiometer is inserted, making sure it is well seated in the hole without using excessive force. Rough treatment may break the fragile tensiometer tip.

It is important to use more than one tensiometer in a single management zone because of soil texture variability. Four tensiometers per management zone are suggested, with at least one in the droughtiest portion of the zone. This area will need water sooner than other parts of the field.

Tensiometer placement location influences measured soil tension levels. Tensiometers should be placed where plant roots are actively growing. Therefore, it is appropriate to monitor soil tension 6-12 inches below the soil surface and within 6-12 inches from the plant base. If using trickle irrigation, place the tensiometer close to the trickle tape or hose. This will insure that tensiometer readings decrease when an irrigation occurs. Placement near the trickle tape is even more important when using raised, mulched beds and on coarse-textured soils. In these situations, the bed shoulders often remain dry. Placing tensiometers in the bed shoulders will not give an accurate measure of soil tension in the active crop root zone.

Tensiometers can also be used in other ways. Placing tensiometers at various soil depths at the same location is useful for determining whether or not an irrigation or rainfall has reached a certain depth. Placing tensiometers at various depths is also useful for determining the depth from which plants draw the most water.

Service of tensiometers after they are placed in the field is simple but very important. Very little service is required unless a tensiometer breaks tension. This occurs when soils are allowed to dry to tensions greater than 80 cb. When the tensiometer breaks tension, the gauge reading will either remain at 70-80 cb or it will drop to a deceptively low value. In either case, the tension reading is meaningless and the tensiometer must be serviced before readings can again be made. The only reliable method for judging when a tensiometer has broken tension is to observe the water column near the vacuum gauge. If a break in the water column can be seen, the gauge has broken tension. After breaking tension, some of the water is lost from the tensiometer. To service the meter, the device must be refilled with water by uncapping the tensiometer and assuring that water from the reservoir fills the tensiometer body. Gently slapping the open reservoir with a cupped hand may be necessary to coax water from the reservoir into the tensiometer column. After being refilled and capped shut, the tensiometer is ready to use. It is not necessary to remove the tensiometer from the soil when servicing.

At season's end, tensiometers must be removed from the field to prevent freezing and splitting. Tensiometers should be emptied and cleaned before being stored for the season.

Tensiometers—Management Practices

As with any tool, expect to spend extra time at first to learn how the tensiometer reacts to soil moisture and to learn how to base irrigation decisions on tensiometer readings. Begin by reading the tensiometer every day, noticing how it climbs quicker on bright, hot, windy days than it does on cool, cloudy days when plants use less water. Observe how young, small plants use less water than older, larger plants by noting how the tensiometer climbs slower early in the season. Use Table 2 to guide your first irrigation decisions. Adjust your practices as required to meet plant water demands. With time, you will begin to place faith in basing irrigation decisions on tensiometer readings.

As an example of how to schedule irrigations using tensiometers, assume tomatoes are being grown on soils of fine sand texture, and that the plants have a 1-foot root zone depth. Use Table 1 to determine that these soils have an available water-holding capacity of 1 inch per foot of soil depth. After using the tensiometers and Table 2 to decide that irrigation is required, determine the appropriate irrigation depth by multiplying the root zone depth by the available water-holding capacity of the soil and by the percent available water depletion. In this case:

$$\text{Irrigation depth} = \text{1-ft root zone depth} \times \frac{\text{1 in. available water}}{\text{foot of soil}} \times 50\% = \tfrac{1}{2}\text{ inch}$$

Tensiometers are one of many tools available for irrigation management. With practice, tensiometers can provide you with the information required to make proper irrigation decisions. Improving irrigation management practices will allow you to maximize yields and profits by more efficiently using water and nutrients.

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