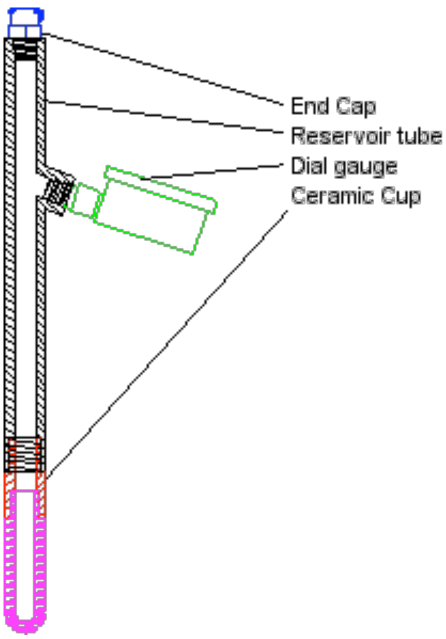
Tensiometer User's Guide

The tensiometer is a simple and reliable instrument designed to directly measure the potential, or tension, of water held in the soil profile. Tension is a measure of how tightly the water is bound to the soil, and is an indication of the availability of the water for uptake by plant roots and for movement within the soil profile. Tension is also related to water content, and can give an indication of the amount of water in the profile.



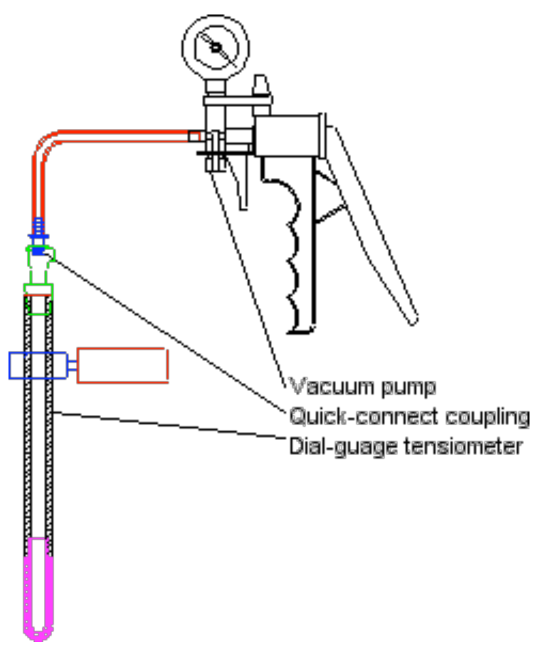
The tensiometer consists of several main components: a porous ceramic cup, a water reservoir tube, a dial gauge, and an endcap. The porous ceramic cup regulates the flow of water into and out of the tensiometer, and comes into equilibrium with the tension in the soil. The reservoir tube holds a supply of water, which the tensiometer needs to operate. An endcap seals the unit and allows tension to be maintained inside the tensiometer. The dial gauge provides a reading of the tension.

Theory of operation
Water is held in the soil by attraction of the water molecules to the soil particles. Water is held in pore spaces between soil particles, and moves through interconnected pore spaces. When a soil is saturated, all of the pore spaces are filled with water. As water drains or is removed by plant roots or due to evaporation, the water content of the pores decreases, with air entering the

pore spaces. Water in the center of the pores, farthest away from the soil particles, is held less tightly and moves easily. As the water held less tightly is removed, water bound more tightly remains, and the tension of the soil water increases.

Preparing for installation
The tensiometer must be prepared prior to installation in the soil. Preparation consists of filling the tensiometer with water, checking the dial gauge, and marking the depth of installation on the tube.

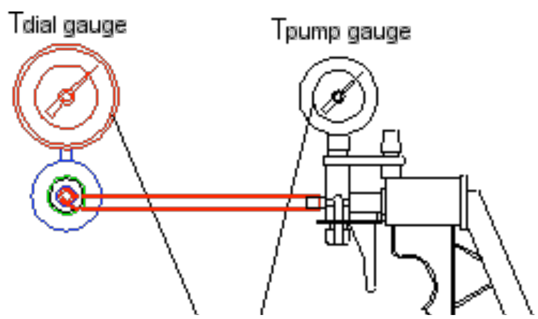
Filling the tensiometer
The tensiometer must be filled with water, and all air removed, in order to operate. This is accomplished by immersing the ceramic cup in a container of water and drawing water into the tensiometer reservoir tube with a vacuum pump. Water is drawn



into the tensiometer tube through the porous cup, filling the pores and replacing the air in the cup with water. When the reservoir tube is completely filled with water, the vacuum pump is removed, and the tensiometer is removed from the container of water. To ensure that all air is removed, deaerated water is used to fill the tensiometer. Deaerated water is prepared by boiling water until all air bubbles are removed, and then cooling the water. If deaerated water is not available, air dissolved in the water can be removed by applying a vacuum and drawing the air out of solution. After the tensiometer is filled and removed from the container of water, the pump is attached and a vacuum is applied, which draws air out of the water and also removes air bubbles held onto the sides of the tube and inside the dial gauge. With the tensiometer filled and all air removed, the tensiometer is sealed by replacing the endcap. Water may begin to evaporate from the ceramic cup, which will increase the tension inside the tensiometer. If the gauge does not respond, the tensiometer should be checked for leaks, especially around the dial gauge connection.

Checking the dial gauge

The dial gauge should be checked for accuracy in order to obtain the most reliable measurements with the tensiometer. The Bourdon-tube gauge, used on most commercially available tensiometers, is an inexpensive yet reliable gauge but frequently has a bias or offset which can be measured and corrected for. To determine the offset of the gauge, the endcap on the tensiometer reservoir tube is removed, and a vacuum pump with an accurate gauge is attached. A vacuum is created inside the tensiometer with the vacuum pump, and the reading on the pump gauge is compared to the reading on the tensiometer gauge. The vacuum level should be set to several different values, and the gauge readings compared in order to obtain an accurate offset value, and to ensure that the offset is constant. The difference between the two gauge readings is the gauge offset,



offset = Tpump gauge – Tdial gauge

where

offset = gauge offset, or bias, measured in centibars (cb)

Tpump gauge = tension measured

by tensiometer dial gauge, measured in cb.
Tdial gauge = tension measured by tensiometer dial gauge, measured in cb.

The gauge offset is recorded and used to correct the dial-gauge readings,

Tactual = Tdial gauge + offset.

The offset can be written on the dial gauge itself with a permanent marker so that gauge readings can be adjusted as the gauge is read.

Column-height adjustment

The column of water inside the tensiometer affects the tensiometer measurements due to the gravitational pull, or weight, of the water. The tension inside the tensiometer is in equilibrium with the tension exerted by the soil plus the additional pull due to the weight of the water column. The tension measured by the gauge can be adjusted to indicate the actual water tension in the soil by subtracting the contribution due to the weight of the water,

Tsoil water = Tdial gauge – weight of water column.

The influence of the weight of the water column is determined by measuring the height of the water column and converting it to an equivalent pressure. A column of water 10 cm high exerts a pressure of approximately 1 cb, so for each 1 cm of water a pressure of 0.1 cb is exerted. The water column-height adjustment is found by measuring the height of the water column and multiplying by 0.1 cb,

$$wc = h * 0.1\ cb/cm,$$

where

> wc = water column-height adjustment, measured in cb
> h = height of the water column, measured in cm.

Tensiometer readings can then be adjusted to more accurately indicate the tension in the soil by subtracting the water-column adjustment,

$$T_{soil\ water} = T_{dial\ gauge} - wc.$$

Adjusting for the water-column height can be simplified by maintaining the water level inside the tensiometer at a constant height. Water-level changes of less than 10 cm will cause errors of less than 1 cb, which can often be ignored.

Marking installation and water-column depths

To ensure that the tensiometer is installed at the proper depth, the intended depth of installation can be measured and marked on the tensiometer body prior to installation. The depth of installation is measured from the center of the ceramic cup up along the reservoir tube. A mark is made on the body tube with a permanent marker.

The height of the water column inside the body tube can also be measured. This height is measured from the center of the ceramic cup up to the water level. A mark is made on the reservoir tube with a permanent marker. If the water level is maintained at this level, the column-height adjustment will be constant, simplifying the column-height adjustment.

Installation

The tensiometer is installed in the field by first selecting a suitable location. Factors which can influence the location include soil type and variability, crop type, rooting depth and pattern, and irrigation system type and operation. For shallow-rooted crops, a single tensiometer is often used, while two or more are used with deeper-rooted crops. When two tensiometers are used, one is placed in the active root zone, at a depth of approximately one quarter of the root-zone depth. The second tensiometer is placed at the bottom of the root zone. The upper tensiometer is used to indicate conditions in the active root zone, while the lower one is used to indicate when over-irrigation or leaching from the root zone occur.

After the location has been determined, a hole is excavated in the soil. An auger with a diameter of 22 mm (0.87 in) will produce the properly sized hole. Since the depth of measurement is measured from the center of the ceramic cup, the depth of the hole will be slightly deeper, approximately 3 cm, to accommodate the extra length of the ceramic cup.

If a hole larger than 22 mm in diameter is excavated, care must be taken to repack soil around the tensiometer as it is installed. The porous ceramic cup must be in good physical contact with the soil to allow proper transfer of water into and out of the tensiometer. Soil excavated from the hole, which has been sifted to remove larger particles, can be made into a slurry by adding water, and used to repack around the ceramic cup.

The excavated hole is refilled and repacked to the original bulk density. If the soil is too loosely packed, air gaps around the tensiometer tube may allow rain or irrigation water to run down along the tube and into the soil profile, influencing the moisture conditions and tensiometer readings in the immediate area.

Operation

The tensiometer is read periodically to determine the moisture conditions in the soil and to examine the water-use behavior of the crop. The frequency of readings depends on the soil's water-holding characteristics, crop-water use, and evaporative demands. Readings should be made frequently enough to detect water-use patterns, establish the point where soil water becomes limited and irrigation is necessary, and predict water use and anticipate when the next irrigation will be required. Recording and plotting the tensiometer readings, as well as rainfall and irrigation amounts, provides the user with information that can be used to better understand the crop's water-use behavior and to predict the timing and amount of irrigation necessary.

The tensiometer is read by first tapping the side of the dial gauge lightly. This will provide a more accurate reading by overcoming any slight mechanical forces built up inside the dial gauge. The gauge offset and water column-height adjustments are then applied to the gauge reading to give the soil-water tension.

Recommendations for using the tensiometer measurements to schedule irrigations for a number of crops are shown in Table 1.

The actual tension values at which to begin an irrigation are selected by the irrigator, and are based on factors such as crop, variety, growth stage, and soil characteristics. Values in Table 1 can be used as guidelines and adjusted to fit the irrigator's specific conditions as required.

Table 1. **Guidelines for interpreting tensiometer readings: tension at which to begin irrigation for various crops.**

Crop	Tension kPa (cb)	Ref	Crop	Tension kPa (cb)	Ref
Alfalfa	70-80	(4)	Grapes	50	(10)
Apricot	20-50	(7)	Grapes	30-40	(12)
Avocado	40-50	(4)	Greens (turnip, mustard, kale)	25	(2)
Beans (dry, Lima, snap)	45	(2)	Leek	25	(2)
Beans (pole)	34	(2)	Lettuce (head, Bibb, leaf)	34	(2)
Beet	200	(2)	Lettuce	40-50	(4)
Broccoli	25	(2)	Okra	70	(2)
Brussels Sprouts	25	(2)	Onion	25	(2)
Cabbage	34	(2)	Parsnip	70	(2)
Carrot	45	(2)	Peas	70	(2)
Cantalope	35-40	(4)	Peppers	45	(2)
Cantaloupes	34	(2)	Potato (Irish)	35	(2)

Cauliflower	34	(2)	Potato	30-50	(4)
Celery	25	(2)	Pumpkin	70	(2)
Celery	20-30	(4)	Radish	25	(2)
Chinese Cabbage	25	(2)	Raspberry	20-40	(5)
Citrus	50-70	(4)	Rhubarb	200	(2)
Collards	45	(2)	Rutabagas	45	(2)
Corn (sweet)	45	(2)	Small grains	70-80	(4)
Corn	50-80	(4)	Squash (summer)	25	(2)
Cotton	70-80	(4)	Squash (winter)	70	(2)
Cucumber (pickles, slicer)	45	(2)	Strawberry	10-20	(6)
Deciduous trees	60-80	(4)	Strawberry	20-30	(9)
Edible Soy	70	(2)	Sweetpotato	200	(2)
Eggplant	45	(2)	Tomato	45	(2)
Fruit trees	20-25	(8)	Tomato	60-70	(4)
Fruit trees	30-40	(11)	Turnip	45	(2)
Grapes	40-60	(4)	Watermelon	200	(2)

Maintenance

Maintenance involves periodic checks of the water level inside the tensiometer, refilling the reservoir and removing any air bubbles if needed. Under irrigated conditions, minimal maintenance may be required since the tensiometer will often refill automatically as water is drawn in from the soil after an irrigation. If the tensiometer is allowed to dry sufficiently, it will need to be refilled by the user and the air removed with a vacuum pump.

Where freezing conditions may occur, the tensiometer must be removed to avoid damage to the ceramic cup and dial gauge. The ceramic cup may crack, or the internal mechanisms of the dial gauge may be damaged, if water held in these is allowed to freeze. The tensiometers can be stored safely by removing all water and storing with the endcaps removed, which will allow any water in the cups or dial gauge to evaporate.

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