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Using Tensiometers for Measuring Soil Water and Scheduling Irrigation

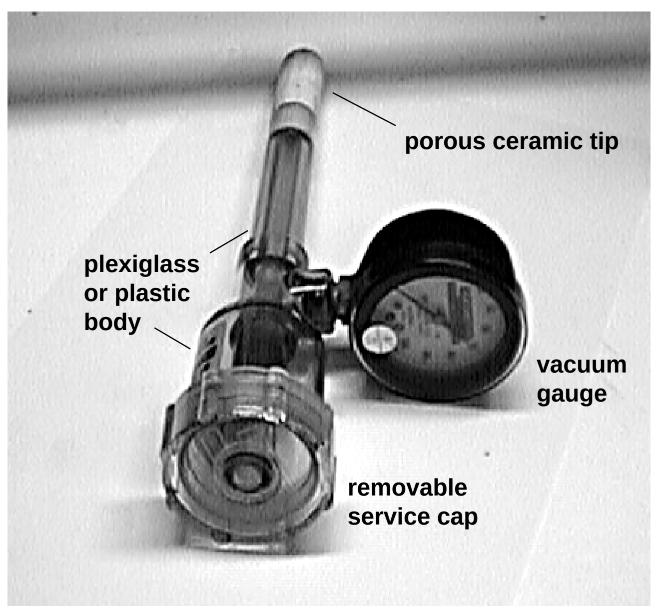
Hawaii's soil and climate often vary a lot from place to place over relatively short distances. Irrigation management for turfgrass and landscape plants must take these differences into account and be planned accordingly. A good irrigation program applies enough water to replenish the soil supply taken up by plant roots or lost by evaporation from the soil surface. A carefully planned program will also conserve water and reduce the potential for leaching of nitrates and pesticides into groundwater supplies. Tensiometers are devices that sense soil moisture and allow us to measure the moisture that is available to plants. They provide useful information for planning irrigation and managing soil moisture levels to best advantage to maintain healthy turf and landscape plants.

Tensiometer operation

A tensiometer consists of a vacuum gauge connected by a tube to a porous ceramic tip. The tube is filled with water and is normally transparent (made of plexiglass) so the water level within it can easily be seen. The ceramic tip is permeable, and the water in the tube saturates it. The tip is placed in contact with the soil in the root zone. Because the soil is normally not saturated, water is drawn from the tip into the soil. As water moves from the tube into the soil, a partial vacuum is created and measured by the gauge. This measurement is not a direct measurement of soil water content. Rather, it is a measurement of *soil water tension* (also called *soil moisture tension*). The level of pressure (tension) in the vacuum is an indication of the amount of energy needed by a plant to counter the strength with which the soil holds moisture and extract water from the soil. If the soil is near saturation, the pull of water into the soil from the tensiometer will not be strong, the reading will be low, and the plants likewise will not need much energy to extract water from the soil. If the soil is dry, it will absorb water strongly through the ceramic tip, creating greater pressure (and higher reading) in the instrument, and, correspondingly, the plant's roots will need more energy to extract water from the soil.

Soil water tension is related to *water potential*. This also is not water content but the potential of the soil to provide water to plants. As the soil dries and soil water tension increases, the water potential decreases. As the soil water content increases due to additions from rainfall or irrigation, the soil-water tension decreases and soil water potential increases. The tensiometer allows us to monitor these fluctuations in soil water potential.

The tensiometer reading is accurate as long as air does not enter the tube—the system must remain hydraulic. Unlike water, air readily expands and contracts



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Tensiometer readings at various soil-water tension (or water potential) levels for turfgrasses and many landscape plants. Gauge readings may be in centibars (cb) or kilopascals (kPa), which are equivalent.

Soil moisture condition	Coarse textured (sandy) soil	Fine textured (clay) soil	
		Aggregated clays[z]	Non-aggregated clays[y]
Saturated	0	0	0
Field capacity[x]	10	10	30–35
Reduced water availability	30	30	70

[z]Clay soils that form aggregates behave very much like sands. They drain rapidly and lose their capacity to conduct water to plant roots. Examples of aggregated clay soils are Oxisols and Ultisols, the reddish soils of Maui, Molokai, Oahu, and Kauai.
[y]Non-aggregated clays have cracks when very dry and become swollen and sticky when saturated with water. On Oahu, the dark-colored soils of Lualualei, the Waianae area, and Waimanalo are of this type. These soils hold water strongly and continue to conduct water even at tensions higher than 70 cb.
[x]Field capacity is the amount of water remaining in a soil after it has been wetted and allowed to drain to the point where free drainage is negligible. It is considered the ideal proportion of soil air content and soil water content for plant growth.

as pressure changes, and air in the tensiometer tube causes inaccurate measurements. Even if the instrument does not have any leaks, air dissolved in the water will accumulate during normal operation. This air must be removed periodically by refilling the tensiometer with water to restore reliable operation.

The price of tensiometers varies with their length and manufacturer. Normally, a 6-inch length is adequate for turfgrass and 12–24-inch lengths are used for landscape plants.

Units of measure

Soil water potential (or soil water tension) is measured either in *centibars* or *kilopascals*. These units are equivalent, and their use depends on the brand of vacuum gauge used for the tensiometer. In this publication, we will refer to centibars (cb). The vacuum gauge dial measures from 0 to 100 cb, and the operational range of the instrument is between 0 and 85 cb. Above 85 cb, water vapor bubbles form in the tube, and the gauge ceases to function. The measurable range is only a fraction of the soil-water potential range normally considered available for plant growth—some plants survive when the soil-water tension is 1500 cb. However, many turfgrasses and landscape plants experience moisture stress and develop drought symptoms when the water potential is in the range of 30–70 cb. Tensiometers, therefore, help us to avoid plant stress and schedule irrigation to conserve water.

Research in Florida has shown that irrigation should be applied when soil water tension reaches 10–20 cb in sandy soil. The exact value depends on the specific site and soil. The Irrometer Company offers the model “LT” Irrometer™, sometimes referred to as the “Florida tensiometer,” that has a gauge reading from 0 to 40 cb instead of the usual 0–100 cb range. This compressed scale is ideal for irrigation scheduling in sandy soils.

Site selection

A tensiometer is affected by only the small volume of soil that immediately surrounds the ceramic tip. The instrument must be placed in the active root zone of the crop or plants for which irrigation is being scheduled.

If the site contains more than one type of soil and the soils have different water-holding characteristics, several tensiometers may be necessary to adequately access the water status. For small sites or those with uniform soils, just one tensiometer may be adequate. The location selected for the tensiometer should be representative of the general condition. Avoid isolated, low, or wet areas or high, dry locations. Place the tensiometer where it will receive the amount of rainfall or irrigation typical of the area. Tensiometer readings are not affected by salts in the soil or by irrigation with brackish or effluent water.

For turf, groundcovers, or bedding plants, place the tensiometer in the center of the root zone but at least 4–6 inches below the surface.

Depth of tensiometer tip for various types of plants.

Plant type	Effective root depth (inches)
Annuals or bedding plants	6
Groundcovers	6
Shrubs	6–12
Trees and palms	12–24
Turfgrasses	6

For a site combining plants in beds and deeper rooted plants such as palms, shrubs, or trees, consider using two tensiometers. Place one 4–6 inches deep and the second 18–24 inches deep. When multiple tensiometers are used, most irrigations will be scheduled to replenish the upper part of the root zone monitored with the shallower instrument. The deeper tensiometer will indicate when the less frequent but greater water applications are needed to replenish the entire root zone.

Installation

Tensiometers must be installed correctly. The instrument must have good contact with the surrounding soil. Read and follow the manufacturer's directions for site preparation and installation. When purchasing tensiometers for the first time, also purchase the small hand vacuum pump that is necessary to test and service the tensiometer.

Before field installation, test each tensiometer to verify that it is operating correctly. Fill the unit with clean water and allow it to stand in a vertical position for at least 30 minutes so the ceramic tip becomes saturated. Deionized water is preferred for use in tensiometers to help prevent growth of algae and bacteria in the tube. Water treatment compounds and dyes are also available from tensiometer manufacturers. The dyes make it easier to observe the water level in the tube. A plastic squeeze bottle with a small outlet tube is useful for filling tensiometers.

When the tip is thoroughly wet, refill the tube and use the vacuum pump to remove air bubbles in the gauge. Refill again and cap the instrument for installation.

The tensiometer is installed in a hole in the soil, preferably made with a soil coring device. Lacking this tool, the hole can be made by hammering a ⅞ inch (outside diameter) metal pipe into the soil. If a rock or other obstacle is encountered when making the hole, move to another spot. Make the hole no deeper than the desired depth of the tip. If the hole is too deep, there will be a pocket of air beneath the tip, making readings inaccurate. Even if the soil is soft, do not push or hammer the tensiometer directly into the soil. After inserting the tensiometer into the hole, the gauge should be 2–3 inches above the soil surface. The tip must be in contact with the soil on all sides. Tamp the soil around the instrument to ensure good contact and prevent surface water from running down around the tube.

After installation, several hours will be required for the tensiometer to come to equilibrium with soil moisture and provide accurate readings.

Tensiometers are delicate instruments that should be handled carefully. They should be installed in locations out of harm's way to reduce likelihood of damage by foot traffic, maintenance equipment, and vandalism.

Servicing tensiometers

Tensiometers must be serviced periodically to ensure accurate readings. Air bubbles will accumulate under normal use. If the area becomes drier than 100 cb, the tube will be drained and require refilling.

Inspect the water level in the tube during each reading. If more than ¼ inch of air has accumulated beneath the cap, remove the cap and refill the tube with water. If the tube is empty, use the vacuum pump to clear the bubbles that remain in the gauge after filling.

Scheduling irrigation with tensiometers

Tensiometers give a continuous indication of soil water status. This information must be calibrated to the landscape. Tensiometers do not indicate how much water should be applied. This decision must be made by the landscape manager.

The decision to irrigate is made when the average tensiometer reading exceeds a given critical value. The specific critical value depends on soil type, the plants involved, the plant quality desired, and the budget. To determine the critical value for the specific location, calibrate the tensiometer reading in relation to drought stress symptoms. Irrigate the site well, then shut off the irrigation system, disabling the automatic timers, and leave it off until the soil is dry enough that the plants show moisture stress. Look for drought symptoms on the turf or plants in the landscape where the tensiometers are located. Turfgrasses will show a dull green or grayish color. Footprints and tire marks will also be visible for some time after they are made, because the leaf blades are losing turgor. Note the reading on the tensiometer when the symptoms first become visible. The critical value for irrigation for the landscape is before the point when drought symptoms were observed. For instance, if the drought symptoms appear when the tensiometer reading is 60 centibars, water should be applied when the reading is 50 or 55 centibars.

The amount of water to be applied must be determined by the manager based on the irrigation system and the soil's infiltration characteristics. The application rate and coverage of the irrigation system should be determined. Check water penetration by operating the system and observing the depth of water penetration by coring or digging a hole. The amount of irrigation water applied should be adequate to restore only the root zone to field capacity. Excess water will be lost as it percolates beyond the root zone, carrying plant nutrients with it.

Automating tensiometers

Tensiometers are available that can switch on an irrigation system when the gauge reaches a preset reading. The irrigation system will operate for a preset period of time. The tensiometer reading will change as the water from the irrigation cycle percolates into the root zone and moves into the tensiometer, reducing the pressure reading. The irrigation system will not run again until the gauge reaches the preset critical value.

Summary

Tensiometers are delicate instruments that must be handled, installed, and maintained correctly. By using the information tensiometers provide about the soil water status and observing the plants under management, we can become more knowledgable about the water-holding characteristics of the soil and the water needs of the plants. Used properly, tensiometers can help us avoid plant drought stress and meet plant water needs without wasting irrigation water supplies.

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