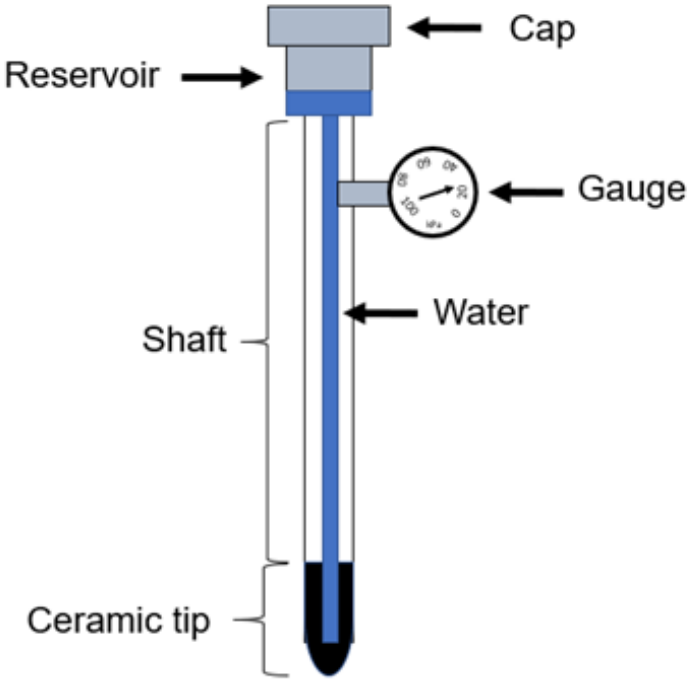
How to Use a Tensiometer

Compiled by
Resource Conservation District of Monterey County

RCDMC
RESOURCE CONSERVATION DISTRICT OF MONTEREY COUNTY

What is a Tensiometer?



A tensiometer is a tool for monitoring soil moisture conditions in agriculture. Tensiometers can be easily read by irrigators in the field and operate without electricity.

Figure 1. Common tensiometer diagram.

What is Tension?

Tensiometers measure soil moisture in units of negative pressure, also known as tension. Tension is a measure of the force that plant roots must exert to pull water from soil pores (Figure 2). Large pores (macropores) hold water with less force than small pores (micropores). As plants extract moisture from the soil, water is first taken from the largest pores. As the soil dries, more force is required to pull water from smaller pores. High tension values mean that the soil is becoming dry, the plant experiences more water stress and growth slows.

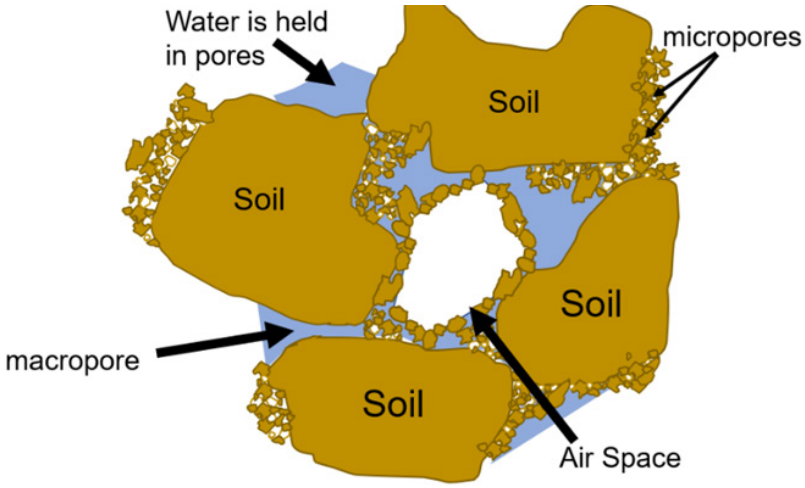


Figure 2. The matrix of a soil holds water by surface tension, just like capillary tubes.

How do Tensiometers Work?

Tensiometers are filled with water (preferably distilled) that has been de-gassed by boiling. A key component of the tensiometer is a porous ceramic tip which allows water in the shaft of the tensiometer to freely pass into the soil without air moving through the small pores in the tip. If the soil is not saturated, water will move from inside the tip to the unfilled soil pores. Because air cannot replace the space vacated by the exiting water, a vacuum (tension) develops in the tensiometer that can be measured with an accurate gauge. Water stops moving from inside the tensiometer to the soil when the internal vacuum pressure of the tensiometer equals the soil tension, or the force needed to pull water from the soil pores. The vacuum gauge measures tension in units of kilopascals (kPa) or centibars (cbars), which are equivalent (1kPa = 1 cbar). [A vacuum gauge may also display units of mmHg (millimeters of mercury). It is important to confirm which values are observed on the gauge (1 cbar = 7.5 mmHg).] Tensiometer readings are not affected by variations in soil texture, temperature or salinity. However, these factors can influence plants' ability to take up sufficient water and must be considered alongside the tensiometer reading. Note: Soil water tension indicates when to irrigate, but not how much water to apply.

Where to Install a Tensiometer?

Tensiometers should be placed in the field at several locations and preferably include the top, middle, and bottom regions of the field. A good rule of thumb is to install the tensiometers in the plant row where roots are concentrated and taking up the most water. In drip-irrigated fields, place the tensiometer slightly inside the plant row, nearer to the wetting zone but not immediately beneath the drip tape. In sprinkler-irrigated fields, place the tensiometers within the sprinkler wetted pattern. At each location, install tensiometers at two or more depths (Figure 3). The shallowest depth should be a third to a half of the depth of the effective root zone. The second depth should be just below or at the effective rooting depth for the crop. For example, tensiometers installed at a 6- and 12-inch depth for strawberries allows for moisture monitoring in the active root zone and below the primary rooting zone.

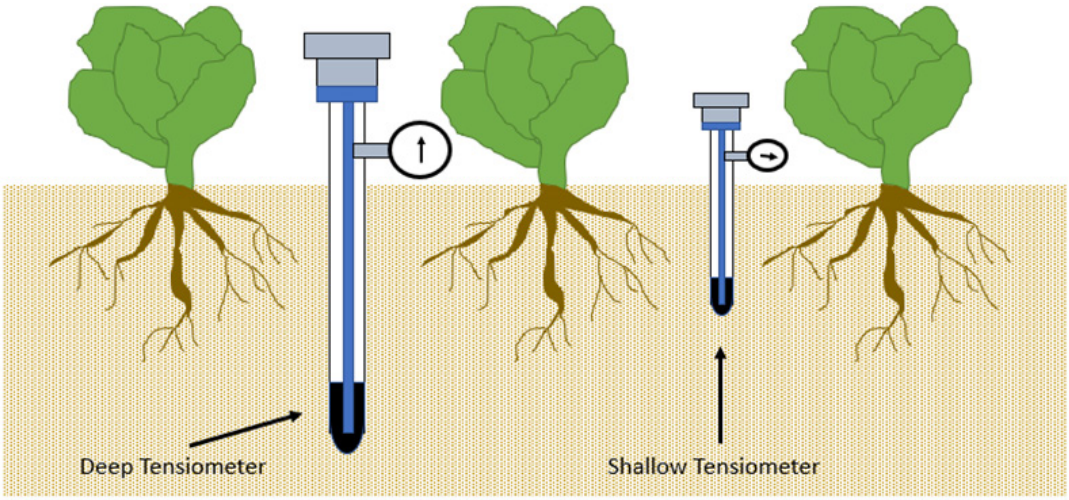


Figure 3. Tensiometers installed at two depths. The tensiometer on the left is installed below the effective rooting depth. Saturated conditions at this depth indicate irrigation in excess of crop requirements. The tensiometer on the right is installed within the effective rooting zone of the plant. This unit should be monitored closely for increasing tension, and irrigation should be scheduled according to the desired maximum tension for the crop.

How to Install a Tensiometer

It is critical that the tensiometer has no air leaks or it will not accurately reflect the true tension of the soil. When installed in soil, water must pass freely from the tensiometer through the ceramic tip into the soil, creating a vacuum in the tensiometer that equals the soil water tension. Proper installation of the tensiometer achieves good contact between the ceramic tip and the soil.

- De-gas distilled water by boiling and then allowing to cool. This water will be used to fill the tensiometer reservoir.
- Fill the tensiometer reservoir fully with de-gassed distilled water and firmly place the cap on the tensiometer, ensuring that air will not leak into the reservoir.
- Soak the water filled tensiometer overnight in a bucket filled with enough water to cover the ceramic tip prior to installation. The water used for soaking the ceramic tip need not be de-gassed.
- Test the tensiometer: Ensure that the vacuum gauge reads 0 when the reservoir is full when the ceramic tip is saturated with water. Remove the tensiometer from the water and use a dry towel to dry the ceramic tip (Figure 4A), or leave it exposed to dry air. Ensure that the tension value rises as water is removed from the reservoir through the drying ceramic tip. The tensiometer should approach 80 cbar of tension after several minutes, depending on humidity. If not, there may be an air leak somewhere in the tensiometer. Check all connections and try again. Re-saturate the tensiometer by placing the ceramic tip in a bucket of water prior to installation.
- Using a soil probe, make a hole of a diameter equal to the tensiometer shaft and to a depth of 1 or 2 inches less than the intended depth (Figure 4B). In gravelly or dense soils, it may be necessary to probe the entire depth as it will be difficult to press the tensiometer further into the soil without causing damage.
- Place soil from the same field where the tensiometer will be installed in a bucket, removing pebbles or rocks. Add water to create a thick slurry.
- Carefully pour the slurry into the hole and insert the tensiometer, pushing it to the desired depth (Figure 4C).
- The soil slurry assures the hydraulic integrity between the ceramic tip and soil (Figure 4D). (Note: formation of air gaps between the ceramic tip and the soil will lessen the accuracy of tensiometer readings). After a day of equilibration, the tension reading should accurately reflect the tension of the soil.

Figure 4. (A) Use a dry towel to wrap around the ceramic tip and test to ensure the tension rises (B) Use of a soil probe to begin installation (C) Pouring a soil slurry into the hole (D) Freshly installed tensiometer. Images B-D by Michael Cahn via UCANR Salinas Valley Agriculture blog.

Interpretation of Tension Readings

Tensiometer gauges commonly range from 0 to 100 cbar (or kPa) where 0 cbar indicates saturation of the soil (Figure 5). Tensiometer gauges can be read daily by an irrigator and some have the option to connect to dataloggers. Measurements taken over time can be used to indicate trends. Shallow tensiometers often reach 0 cbar immediately after an irrigation event, while deeper tensiometers will indicate reduced tension later, as the wetted zone progresses through the soil profile. Depending on the irrigation management strategy, deeper tensiometers may never drop to 0 cbar after installation.

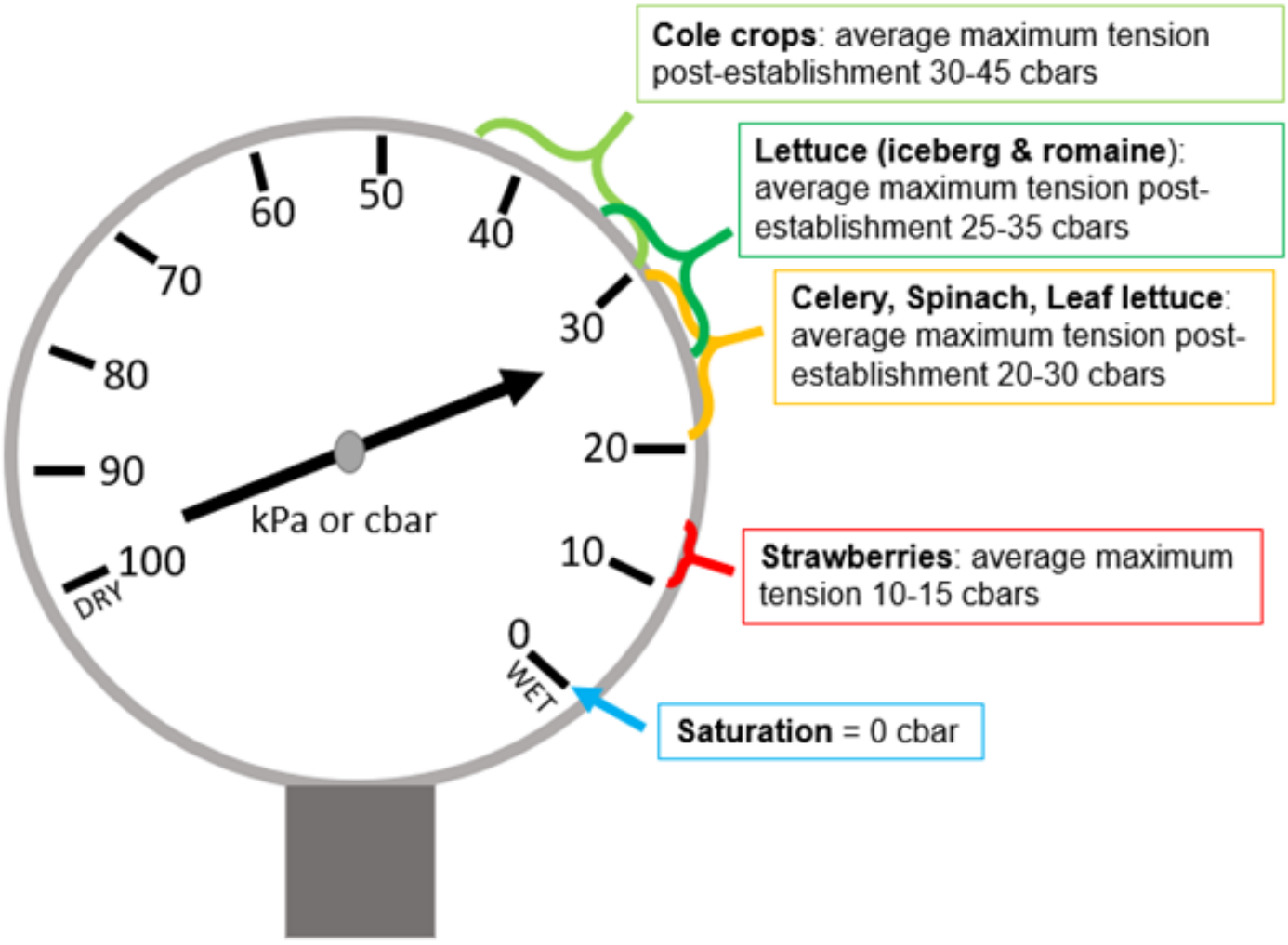


Figure 5. Common tensiometer gauge face reading from 100 to 0 cbars or kPa. The brackets indicate average maximum tension in root zone for various crops.

Monitoring tension with the use of a data logger produces a graph representing soil moisture tension over time (Figure 6). Tension values are low when the soil is wet and increase as it dries. The lines in the graph move upwards as the tension increases and drop again after an irrigation event wets the soil. Then, tension values begin to increase as excess water drains away by gravity to field capacity. Following this, evaporation and crop transpiration remove more water from the soil profile and tension values gradually increase. Tension can be less than 0 cbar or kPa if the soil is supersaturated. This information can be used to reduce over-watering by avoiding application durations that result in supersaturation.

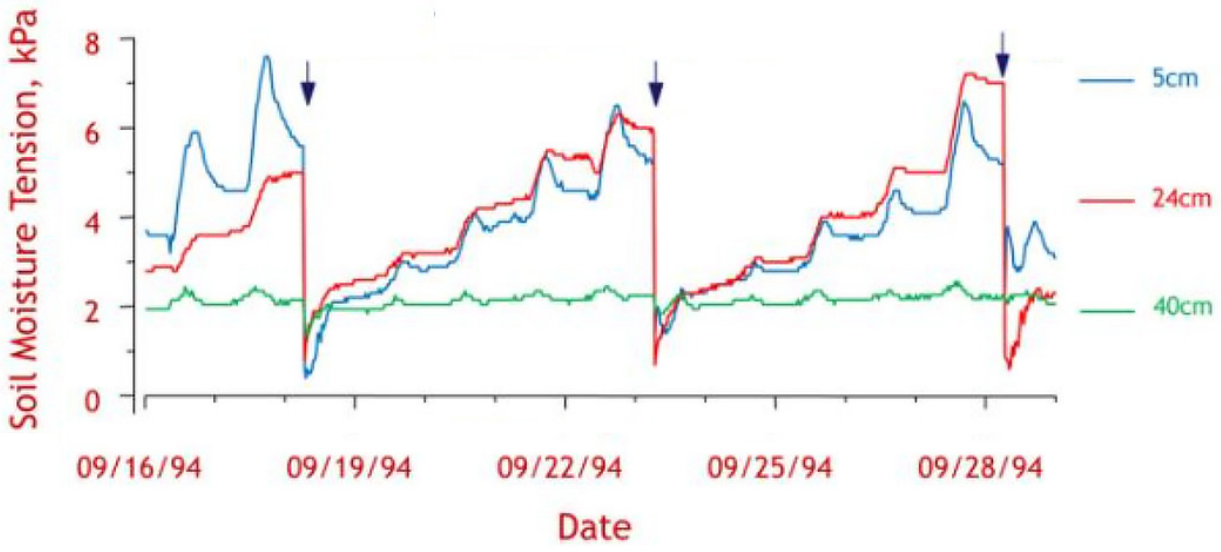


Figure 6. Soil moisture tension (kPa) at 5, 24, and 40 cm depth. The Y-axis reports tension from 0 to 8 kPa (0 kPa is saturated) and the X-axis reports time by date. The black arrows indicate irrigation events and show the shallow tensiometer lines (5 and 24 cm) dropping to 0 kPa.
Image by Loren Oki via UCANR UC Nursery and Floriculture Alliance.

The University of California Cooperative Extension in Monterey County developed a chart of recommended average maximum soil moisture tension values for establishment and post-establishment, as well as recommended depths to insert tensiometers, for various vegetable crops grown in the central coast (Table 1). North Carolina State University Cooperative Extension recommends installing tensiometers at 6- and 12-inch depths for strawberries and starting irrigation when the deeper tensiometer reads 30 cbars. After an irrigation event, the tensiometer should read 5-10 cbars. A tensiometer gauge installed at a 6-inch depth in a strawberry field showing 15 cbars indicates the soil is dry enough to cause crop stress and should be irrigated. It is important to note that soil moisture is expected to vary within a field due to factors such as: variation in the application rate of the irrigation system, leaks in the drip tape and variation in soil properties across the landscape.

Vegetable crop	effective rooting depth[1] at crop maturity	Irrigation criteria: average soil moisture tension in root zone		recommended tensiometer depths
	inches	establishment	post-establishment	inches
		---------- cbars ----------		
Artichokes				
annual	12 to 18	20 to 30	30 to 45	8 and 18
perennial	18 to 24	--	40 to 50	12 and 24
Asparagus	24 to 36	20 to 30	45 to 60	12 and 24
Carrots	12 to 18	15 to 25	25 to 35	8 and 18
Celery	12 to 18	15 to 25	20 to 30	8 and 18
Cole				
broccoli	18 to 24	20 to 30	30 to 45	12 and 24
cauliflower	18 to 24	20 to 30	30 to 45	12 and 24
cabbage (red and green)	18 to 24	20 to 30	30 to 45	12 and 24
brussels sprouts	18 to 24	20 to 30	30 to 45	12 and 24
Lettuce				
iceberg	12 to 18	15 to 25	25 to 35	8 and 18
romaine	12 to 18	15 to 25	25 to 35	8 and 18
leaf	8 to 12	15 to 25	20 to 30	8 and 18
spring mix	8	15 to 20	20 to 30	8
Bell pepper (drip)	12 to 18	15 to 25	25 to 35	8 and 18
Spinach				
bunch	12	15 to 20	20 to 30	8 and 18
baby and teen	8	15 to 20	20 to 30	6 to 8
Fresh market tomato (drip)	18 to 24	20 to 30	45 to 60	8 and 18

1. typical depths that contain 80% of roots in a deep, uniform, well drain soil profile

Table 1. Effective rooting depth, recommended maximum soil moisture tension, and tensiometer depths for coastal vegetables.

Tensiometer Maintenance

The tensiometer reservoir must be maintained with water and closed tightly to keep a vacuum. If the lid is removed, it will release the vacuum and give false low readings. If the tension does not reach high levels, the water in the reservoir should ideally not be depleted. If it dries too much, the reservoir may need to be refilled or the unit may need to be re-installed. Check for air leaks or evaluate the reservoir water level if you suspect the readings are inaccurate. Remove tensiometers at the end of the season by digging them carefully out of the soil and immediately wash the ceramic tip clean and flush out with distilled water to prevent growth of algae and soil drying that may plug the ceramic tip. Store the tensiometer in a protected location to preserve the vacuum gauge and ceramic tips.

Sources:

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