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Michigan State University Extension Service
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February 2007
6 pages

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Extension Bulletin E2977, New, February 2007

Using Tensiometers for Scheduling Irrigation of Fraser fir in Christmas Tree Production

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Why Irrigate Fraser fir in Michigan?

Fraser fir (*Abies fraseri*) has become the dominant Christmas tree species in Michigan because of its increasing popularity among consumers and its substantially higher wholesale and retail prices. The species is not native to Michigan, however, and comes from a quite different environment. According to Sylvics of North America, Fraser fir grows naturally in a cool, moist climate characterized as a cool-temperate (microthermal) rain forest with well-distributed mean annual precipitation of 75 to 100 inches and average summer temperatures of 60 degrees F or lower. Michigan receives much less rainfall, and summer temperatures are much higher. Fig. 1 clearly indicates that average precipitation is much higher throughout the summer in Boone, N.C. (one of the native areas for Fraser fir), than in East Lansing, Mich. As a result, water requirements for optimal growth of Fraser fir are likely not met under normal conditions in Michigan. Some Christmas tree growers use various systems to irrigate Fraser fir fields, and many more are interested in installing new irrigation systems to supplement natural rainfall for optimal growth of the trees.

Decisions on when and for how long to irrigate are still entirely based on empirical knowledge and personal experience with water needs of trees in the field. The Department of Forestry is currently investigating several methods, including tensiometers and infrared thermometry, for scheduling irrigation of Fraser fir in Christmas tree production.

The **goal** of this bulletin is to provide growers with basic information about tensiometers — how they work, where to buy them, where and how to install and service them, and how to interpret the readings for irrigation scheduling.

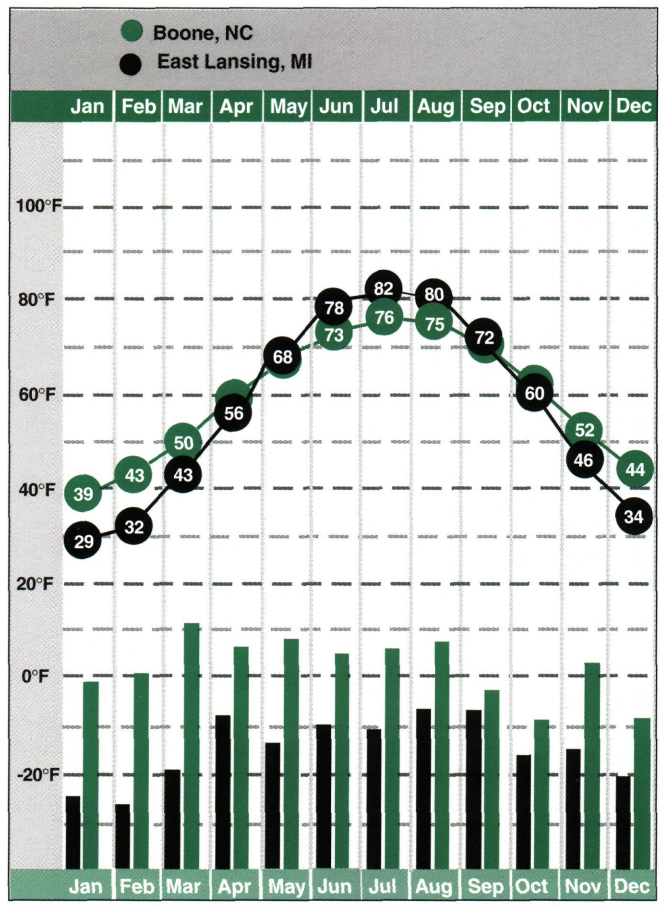


Fig. 1. Average rainfall and average high temperatures for Boone, N.C., and East Lansing, Mich. (source: averages from www.weather.com).

What is a Tensiometer?

A tensiometer is a device made of a sealed plastic or glass tube with a porous ceramic tip on one end and a screw-on cover and a vacuum gauge on the other end (Fig. 2). The vacuum gauge is calibrated in

centibars (cb) and graduated from 0 to 93 cb (this can vary with the brand or tensiometer type). Tensiometers are sold in various lengths — 12 inches, 18 inches and 24 inches.

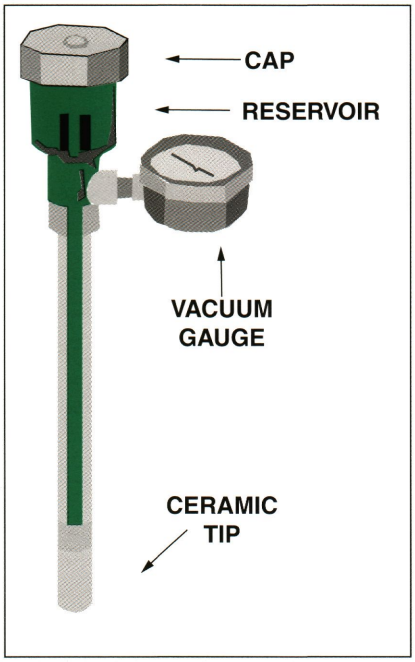


Fig. 2. A tensiometer (adapted from photo courtesy of Jamieson et al., 2002).

The tube is airtight and water-filled and under vacuum when in operation. When the tensiometer is installed in the ground, water moves freely from the ceramic tip into the surrounding soil as the ground dries or from the soil into the tube as the moisture content in the surrounding soil increases. Tensiometers measure the soil water matric potential, which is defined by the Soil Science Society of America (SSSA, 1997) as "the amount of work that must be done per specific quantity of pure water from a specified source to a specified destination." You should consider it a measure of how hard it is for your crop roots to draw water from the soil.

As soil dries with warm weather and no or little rainfall, water is drawn out of the instrument, reducing the water volume in the tube and creating a partial vacuum that is registered on the gauge. Consequently, the drier the soil, the greater the force per unit area holding the remaining water in the soil and the higher the reading. Conversely, when rain moistens the soil, the vacuum created inside the tube will suck water back into the tube and lower the gauge reading. For example, a reading of 25 cb indicates that there is more moisture in the soil than a reading of 50 cb. Properly installed tensiometers are, therefore, good tools to help growers decide when to turn on the water.

Where to buy Tensiometers?

The first place to look for tensiometers is your local irrigation vendor or consultant. He/she probably has some for sale or could order them for you. If you want to order them directly, several companies manufacture and sell tensiometers. The major tensiometer vendors are:

1. Dynamax
10808 Fallstone, Ste. 350
Houston, TX 77099

Phone: 800-727-3570
Fax: 281-561-5200
Web site: www.dynamax.com

2. Earth Systems Solutions
P.O. Box 568
Lompoc, CA 93438

Phone: 800-964-1200
Web site: http://www.earthsystemssolutions.com

3. Irrometer Co.
P.O. Box 2424
Riverside, CA 92516

Phone: 951-689-1701
Fax: 951-689-3706
Web site: www.irrometer.com

4. Soil Moisture Equipment Corp.
801 S. Kellogg Ave.
Goleta, CA 93117

Phone: 805-964-3525
Fax: 805-683-2189
Web site: www.soilmoisture.com

5. Soil Moisture Measurements Systems
7090 N. Oracle Road, #178-170
Tucson, AZ 85704

Phone: 520-742-4471
Fax: 520-544-2192
Web site: www.soilmeasurement.com

Note: Providing the addresses above for Extension and information purposes does not represent an endorsement of these products. Growers are advised to talk to a sales representative and gather all the technical information needed before deciding to buy.

Installing and Servicing Tensiometers

The number and size of tensiometers necessary for an efficient assessment of your system will depend on your soil variability and crops. If you are irrigating seedlings, 12-inch tensiometers are probably the right size for you. However, if you are irrigating trees that are 3 feet or taller, it may be more appropriate to use a combination of 12-inch and 24-inch tensiometers to monitor soil moisture in both the topsoil and deeper in the root zone. It is normally recommended to install one or two tensiometers for each major soil type in your farm. You should try to pick an area you believe is representative of each field. Avoid low areas, which could have poor drainage and be susceptible to water-logging.

Tensiometers should be installed at the beginning of the growing season, shortly after bud break but surely before the beginning of your irrigation season. It is recommended to put tensiometers in the ground sometime in late April or early May after you are done with your planting operations and first pesticide applications. The vendor will normally send you written instructions on how to prepare and install tensiometers. Below is a short summary of the procedures:

Preparation

For accurate measurement of soil moisture, it is necessary to prepare your tensiometer units properly. The unit will probably be shipped to you in pieces. You need to screw the ceramic tip to the tube. While doing this, maintain the plastic cover on the tip and avoid touching the tip with your hands — it will absorb grease, which could affect the permeability of the tip.

Fill the tube with water or the solution sent to you by the vendor. The vendor solution is made up of water, a colorant (to make it easier to see the water level through the clear tube) and some sort of disinfectant (to prevent fungal growth inside the tube). If you did not receive any solution from your vendor, water is fine. If you are using water, add some bleach (10 to 15 percent) to the water to sterilize the solution. Use a pin to push the water through the return holder of the reservoir (Fig. 3).

Place the tubes (ceramic tip down) in a bucket full of water for several days with the caps left off until you're ready to install them (Fig. 4).

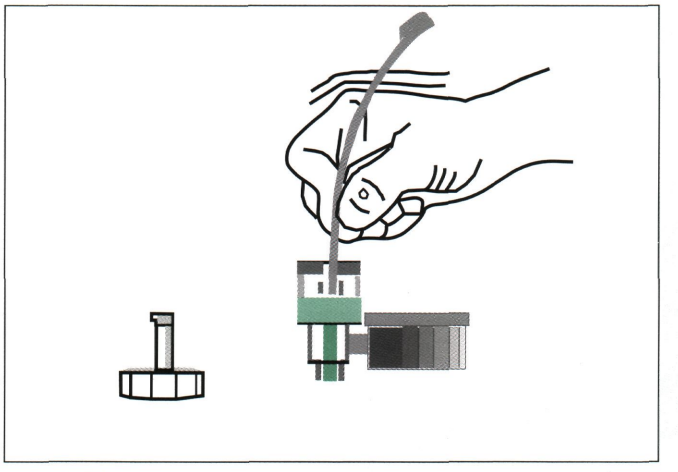


Fig. 3. Filling the tensiometer (source: Irrigation Management Using Tensiometers. III — Maintenance and Troubleshooting, 2006).

Fig. 4. Bucket containing water with prepared tensiometers (photo by Pascal Nzokou, 2006).

For the vacuum system to work properly, your tube should be pumped two or three times during storage to remove air bubbles from the column. This is done using a hand pump, which is also sold by tensiometer vendors. Place the pump on top of the reservoir (Fig. 5), and pump until the gauge reads 70 to 80 cb. Gently tap the tube with your hand, and you will see the air bubble rising up the tube. Slowly release the vacuum by pushing the vacuum release notch. Repeat this process two or three times until you are comfortable that there is no air bubble left in the tube. The ceramic tip should be immersed in water when you do this for the first time to avoid sucking air into the tube.

Fig. 5. MSU forestry graduate student Nick Gooch pumping a 24-inch tensiometer at one of our research locations in Michigan (photo by Pascal Nzokou, 2006).

Installation

Transport your tensiometer to the field in your water bucket and keep the ceramic tip wet until it's installed in the ground. It is better to install your tensiometer when the soil has adequate moisture. If the soil is too dry, there is a risk that your ceramic tip may lose water too quickly and break the vacuum between the tip and the gauge (Fig. 6).

You need to make a hole in the ground to the desired depth using a tensiometer insertion tool (from vendor) or a steel rod or galvanized pipe with the same diameter as your tensiometer body (typically 5/8 inch). A soil auger will also work fine. Mark the desired depth on your tool, hammer it down to the mark and remove it. It is important that your hole be straight, because tensiometers are fragile and could be damaged if forced into the ground. Pour water or a slurry (mixture of water and soil) into the hole to help establish good contact between the porous tip and the soil.

Gently force the ceramic tip into the ground to the base of the hole. Your gauge should be at least 2 inches above the ground. Backfill the hole for good contact and tamp the soil around the tube firmly with your boots or a half-inch dowel.

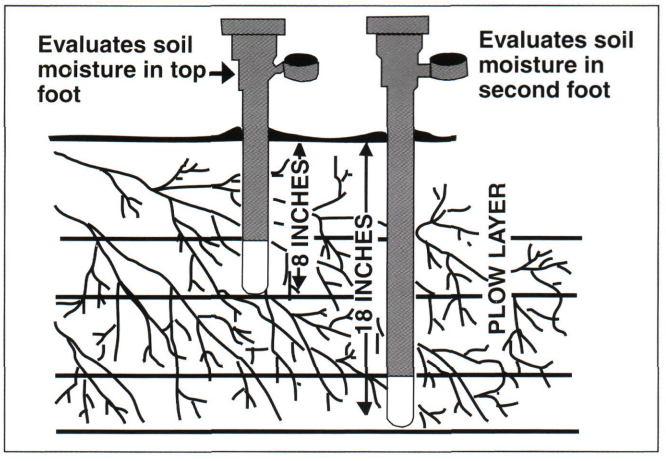


Fig. 6. Depending on your individual situation, you may want to install both a 12-inch and a 24-inch tensiometer to monitor soil moisture in the top foot and the second foot of soil (source: Irrigation Scheduling with Tensiometers, 1998).

Allow the tensiometer to equilibrate with the surrounding soil overnight before starting your readings. Pump out the air as described above two or three times, if necessary.

Maintenance

A properly installed tensiometer should normally be maintenance-free throughout the summer. It may be necessary to refill the column with water occasionally, however. If that need arises, the best time to add water is after an irrigation event or rainfall, when the vacuum is low. Open the reservoir cover, refill the column and pump the tensiometer to remove air bubbles.

We found two common problems with our tensiometers and solved them as follows:

1. **Gauge always reads zero:** There is a break in the vacuum and no communication between the ceramic tip and the vacuum gauge. To solve the problem, check the water level in the tube, and refill with clean water if the level is low. If this does not solve the problem, then there is a leaking connection. Check the ceramic tip, the "O" ring and the gauge connections and make sure they are firm. Replace the ring, if necessary, and mount all the pieces firmly. Make sure the cap is screwed in tightly. If the problem persists, then the gauge may be faulty. Check it and replace, if necessary.

2. **Tensiometer does not record the true soil moisture content:** If your readings do not reflect the true soil moisture content, there is probably poor contact between the ceramic tip and the soil. Change your spot and reinstall the tensiometer following the correct procedure. Always check for air bubbles and pump your tensiometer, if necessary.

Because of Michigan's freezing conditions over the winter, it is recommended to remove tensiometers from the ground to avoid damage to the ceramic tip and vacuum gauge. Freezing could cause the ceramic tip to crack, or water contained in the tensiometer's column may freeze and expand, causing irreparable cracks in the structure.

Store your tensiometers for the winter by putting them in a bucket full of water in a warm room with the reservoir cover opened as shown in Fig. 4. It is not a problem if the water in the reservoir and column evaporates, but make sure that the ceramic tip remains under water throughout the winter.

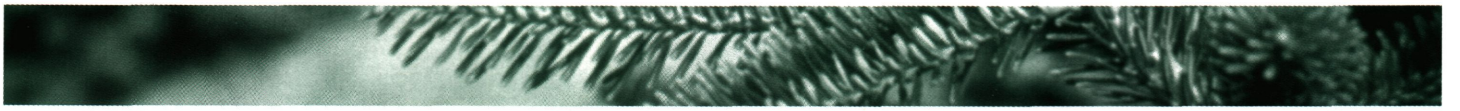
Interpreting Readings

Good irrigation scheduling starts with good record keeping. Create a table with tensiometers numbered 1-x, coded as your situation demands, and record the tensiometer readings every day. The reading should be performed at the same time each day. For example, one grower who already uses this system records his reading every day between 4 and 6 p.m. and makes his decision to start his irrigation run the following day on the basis of the weather forecast for his area.

Tensiometer readings are related to soil water content according to the following table:

Readings	Interpretation
0 to 5 cb	Your soil is **nearly saturated**. This will occur immediately following a rainfall event or in waterlogged areas of your field. If this condition lasts too long, plant roots will suffer from lack of oxygen.
5 to 20 cb	This is the **field capacity** range, the optimal range for plants. Do not irrigate at this level — you will be wasting water and could promote the leaching of your nutrients below the root zone into the water table.
20 to 60 cb	Depending on your soil and plant age, this is the range at which to **turn on your irrigation system**. If your trees are bigger with a deep root system, they will probably not suffer from water stress before your readings are over 30 to 40 cb. If your plants are seedlings, it is probably wise to irrigate with tensiometer readings over 20 cb. You should also adopt a conservative approach if you have sandy and well-drained soils.
Higher than 70 cb	If you are reading over 70 cb, your trees are probably under water stress. If readings stay at this level for a few days, you will probably observe serious seedling and tree damage.

Source: Based on Jamieson et al., 2002.



Conclusion

Tensiometers are simple tools to help you schedule irrigation. We recommend starting slowly and not dramatically changing your current approaches. Start by installing a few tensiometers in a specific section of your field, monitor and record your readings throughout the season and become comfortable with them as you go through a cycle, and progressively adapt your scheduling method to your tensiometers. You will certainly increase your water use efficiency, save money by avoiding unnecessary use of labor and equipment, and maintain the quality of your trees.

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