Auburn University
Southern Forest Nursery
Management Cooperative

RESEARCH REPORT 15-02

A MODIFIED METHOD FOR CALCULATING A PARTIAL SOIL WATER RETENTION CURVE TO HELP IN IRRIGATION DURING THE GROWING SEASON

by
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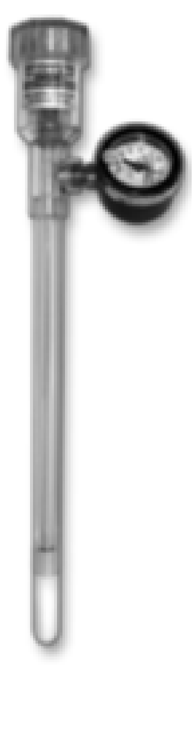
INTRODUCTION

The number of nursery managers using the subjective (qualitative) visual/tactile method to determine irrigation needs in their nursery increased from 18% in1980 (Boyer and South, 1984) to 75% in 2012 (Starkey et.al. 2012). Only 8 percent of responding managers in 2012 used more objective (quantitative) methods such as using either a tensiometer or an electronic soil moisture device (Starkey et.al. 2012). The trend toward subjective (qualitative) methods probably stems from nursery managers learning from, and repeating the methodology of the previous manager rather than using a more objective (quantitative) method.

The visual/tactile method is an indirect method of determining irrigation needs and is subject to significant error unless used by a person with considerable skill (Day, 1984). For example, what is the value of using the visual/tactile method of the soil surface when the seedling's irrigation needs are at the bottom of the plough layer – 4" to 6" below the surface. However, when used properly, and by and experienced person, a reasonable estimate of available soil moisture content may be possible (Day, 1984).



One of several more objective methods for determining seedling irrigation needs involves the use of a tensiometer. Hensley (1999) describes a tensiometer and its basic operation:

"A tensiometer consists of a vacuum gauge connected by a tube to a porous ceramic tip. The tube (made of plexiglass), is filled with water so that the water level within it can 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.

Soil water tension is related to water potential. This 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."

As far as their usefulness in soil moisture determination, Day (1984) indicates that tensiometers are ideal for monitoring irrigation requirements in forest seedling nurseries because they cover the critical soil-moisture range up to 80 centibars.

Retzlaff and South (1985) described a laboratory method for determining partial soil water retention curves using a tensiometer. However, in an attempt to calculate a retention curve using their methodology we found it difficult to replicate nursery soil bulk density in the laboratory, and thus, soil moisture curves could not be determined.

As part of the Nursery Cooperative's goal of increasing seedling productivity through research, one area that could use more quantification (objective) than qualification (subjective) would be seedling irrigation needs. In this study, a change in methodology allowed the duplication of nursery soil bulk densities in the laboratory and allowed calculation of a partial soil water retention curve for soils from three nurseries. Once determined for each individual nursery, one would only need to install a few tensiometers within the nursery and the touch and feel process would have more objective values.

METHODOLGY

To get a range of soil moisture curves, soils were collected from three nurseries in August, 2013: Arborgen Supertree Nursery in Shellman, GA; Georgia Forestry Commission Nursery in Flint River, GA and Plum Creek Nursery in Jesup GA. The soil texture of each nursery sample is presented in Table 1.

Table 1. Soil texture of nurseries used in study

	Soil Texture			
Nursery	**% Sand**	**% Silt**	**% Clay**	**Classification**
Arborgen Shellman, GA	91	6	3	Sand
GFC Flint River, GA	86	11	3	Loamy Sand
Plum Creek, Jesup, GA	77	15	8	Sandy Loam

To collect nursery soils without appreciably altering the soil bulk density ½ cm light blue PVC sewer pipe (SDR35) (15 cm ID) was cut into 25.5 cm length. One edge of the pipe was ground to a 45 degree angle allowing easier penetration into the soil. Within each nursery, a nursery bed without seedlings (generally where the seedlot changed) was identified. The PVC pipe was pushed down into the soil 24 cm and then the soil on the outside of the pipe was removed. Then, a piece of thin plywood was placed next to the bottom of the pipe soil core and pipe was slid onto the plywood board. The soil core, pipe and plywood bottom was then returned undisturbed to the greenhouse at Auburn University. A piece of water permeable landscape ground cloth replaced the plywood and was secured to the bottom of the PVC pipe using an adjustable hose clamp (Figure 1).

Figure 1. PVC pipe with nursery soil

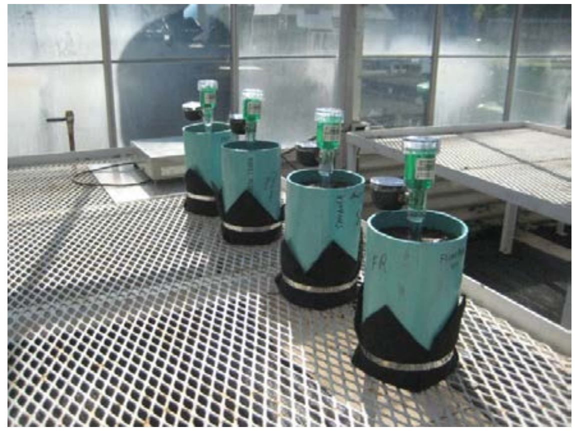


Figure 2. PVC pipe with nursery soil and inserted tensiometers

A 22 mm x13 cm hole was inserted in the center of each sample and then a prepared tensiometer (#106-Irrometer Model R, The Irrometer Company, Riverside CA) was inserted into the hole. Each soil sample core was then saturated with water and allowed to freely drain through the landscape cloth. No further water was added to the soil.

At the same time each day, the centibar reading was recorded on each soil sample and then the soil sample (including the tensiometer) was weighed and recorded. After 10 to 14 days when the tensiometer reading no longer changed from one day to the next, the experimental study was ended. The number of days for a study such as this will vary depending upon the ambient temperatures. The weight of the various components used in this study including the dry weight of the soil and the bulk density were calculated. The methodology described by Retzlaff and South (1985) was then used to determine the volumetric water content of the sample at the various soil moisture tension readings and then a graph drawn representing this data using Excel. Excel was also used to generate a regression equation for each curve.

RESULTS & DISCUSSION

The following graph shows the soil moisture retention curve for all three nursery soils (Figure 3). If an individual nursery had several fields in which the soil texture differed, a side-by-side comparison as shown below would be valuable. However, if multiple fields had similar soil textures each soil moisture retention curve should be individually graphed to avoid clutter.

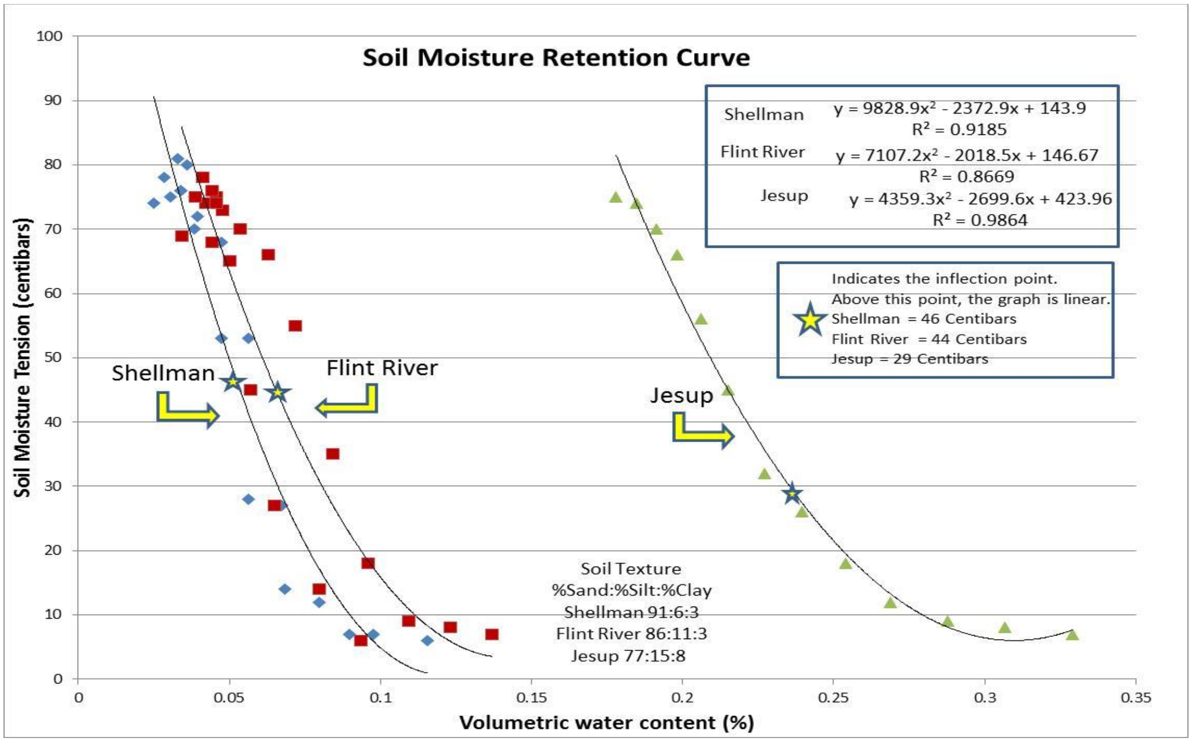


Figure 3. Partial soil water retention curve for 3 different soil textures.

There are several points to make from this graph of soil water retention curves developed from these three different nursery soils.

How to interpret the graph:

1. The lower a point on the graph (closer to X-axis) indicates more moisture in the soil (volumetric water content) and low soil moisture tension (centibars).
2. The lowest part of each nursery soil curves reflects field capacity of that soil.
3. The graph for each of the soil textures is curvilinear at the lower end (high moisture content, low soil moisture tension) and becomes linear further up the Y-axis of the graph reflecting drier soils and increasing soil moisture tension.
4. Following irrigation or rainfall as the soil moisture increases the soil moisture tension would decrease. Once field capacity is reached, the soil moisture tension would be less than 10 centibars
5. The point on the graph where the line changes from a curvilinear to a linear is the inflection point. The inflection point for Flint River, GA is 44 centibars; Shellman, Ga is 46 centibars; and Jesup, GA is 29 centibars.
6. The point of the most rapid decrease in soil moisture availability and increase in soil tension is the linear segment, above the inflection point.

Nursery application suggestions:

7. The tensiometers numbers will fluctuate throughout the day and should be done at the same time each day (early AM reading are generally the most accurate).
8. Tensiometer readings are an indication of the amount of energy roots need to pull water from the soil. The higher the centibar, the more energy is required by the seedling.

9. To promote seedling growth, the area of root growth (top 6 inches) needs to be maintained between field capacity and the inflection point. For Shellman and Flint River the boundaries would between 10 and 45 centibars. For Jesup, which has a much finer texture soil, the boundaries would be 10 and 30 centibars.
10. Delaying irrigation as the soil moisture tension curve approaches the inflection point helps to stress the seedling and grow a better root system.
11. Using foliar wilting as an indication of irrigation needs is a poor decision since the roots wilt before the foliage (Irrometer, 2012) which can either stop or hinder seedling growth if severe.
12. The use of tensiometers in seedling production will not indicate how much water should be applied to your fields, but once developed and using the partial soil curve one can calculate how much water is required to bring the soil tension back to field capacity, thus avoid overwatering, or waiting too long to water.
13. In a nursery environment, an important soil moisture tensiometer reading is the difference between today's reading and that of 3 to 5 days ago. In other words, how quickly is the reading going up (increasing centibar reading)? A slow increase means the soil is drying out slowly and a big jump means the soil is losing water very rapidly and irrigation may be needed.

In this study, the tip of one tensiometer was placed at the same depth in each sample – about 5" deep. In a nursery application, two sensors at different depths will provide more valuable information as to the amount of irrigation that is required. Using sensors, at two depths in the soil profile (for example at 4" and 6"), you can determine how much irrigation to apply. If the shallow sensor shows a rapidly increasing centibar reading (indicating rapid drying), but the deep sensor shows adequate moisture, you only need a short irrigation cycle to replenish the shallow soil profile. However, if the deep sensor also shows a dry condition, then a longer irrigation cycle is needed to fully re-wet the entire root zone. Observing the tensiometer reading after an irrigation or rainfall event will show you exactly how effective that water application was.

MANAGEMENT IMPLICATIONS

In a preliminary survey to a study by Retzlaff and South (1984) they observed that many nursery managers were keeping their soil too moist by irrigating when soil tensions reached 20 centibars. They concluded that using a more objective method of determining when to irrigate could reduce excessive irrigation and in some cases improve seedling growth. Developing a soil moisture curve using an objective method should provide the nursery manager with a better understanding of water retention in the plough layer. Any nursery can calculate a partial soil moisture retention curve using a tensiometer, a digital scale and appropriate size PVC pipe. Although the graph could be generated by hand, Excel makes this task much easier. This is also a much more objective method for training new personnel at your nursery why and when to irrigate.

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