A Simple Method for Determining a Partial Soil Water Retention Curve

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Nursery managers can develop their own partial soil water retention curves. Developing these curves can provide nursery managers with a better understanding of the soil moisture relationships for the various soils at their nurseries. (Tree Planters' Notes 36(4):20-23; 1985)

Soil water retention curves can help nursery managers make decisions about irrigating their nursery crops more objectively (1, 3). For various reasons (including the expense of developing the soil water retention curves) many nursery managers have chosen to forego this practice. However, by using a soil tensiometer, a large pot, a known volume of nursery soil, a graduated cylinder, and a scale, nursery managers can develop their own partial soil water retention curves.

Materials and Methods

We developed this system with a tensiometer (Jet Fill Tensiometer, Soilmoisture Equipment Corp., Santa Barbara, CA), a single 3.8-liter plastic pot, and a sample of Norfolk loamy sand soil. The tensiometer was filled, according to the manufacturer's instructions, with a solution containing 1 gram of copper sulfate (an algae inhibitor) for each 3.8 liters of water and then weighed.

The filled tensiometer was held in the center of the pot, with the ceramic tip about 4 to 8 centimeters from the pot's bottom, and soil was poured in until it reached the 15-centimeter level on the tensiometer (figure 1). The soil was packed by gently dropping the pot

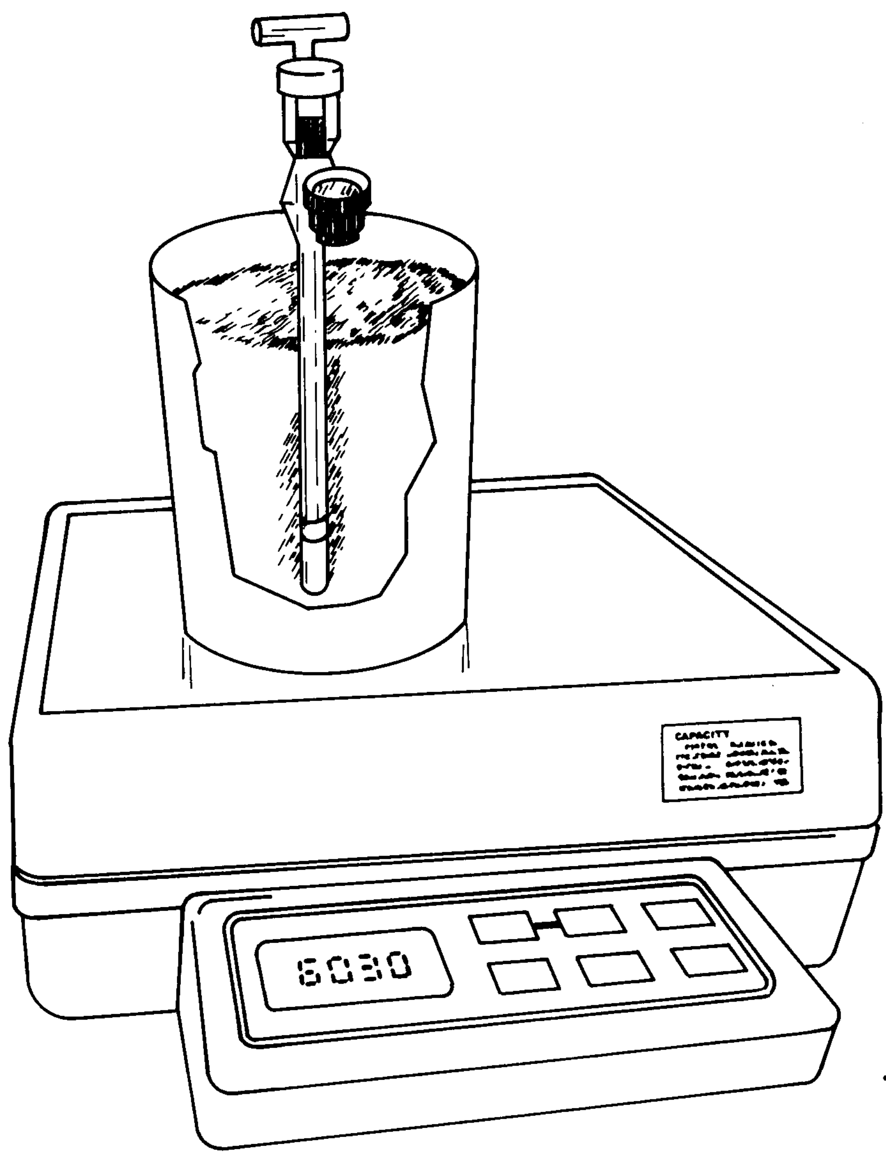

Figure 1—*Weighing the pot and tensiometer.*

several times from a height of about 5 centimeters. More soil was added and the packing and filling process repeated until the soil bulk density approximated that used in the nursery. It is important to ensure good contact between the ceramic tip on the tensiometer and the soil in the pot.

Then the soil in the pot was saturated with tap water; that is, it was filled until water ran freely through the drain holes in the pot bottom. The pot was let stand overnight so that the tensiometer could equilibrate with the soil.

On the following day, the weight of the pot with the tensiometer was recorded to the nearest 0.01 kilogram and the soil moisture tension to the nearest centibar (table 1). This weighing process was continued every day throughout the test period, until the tensiometer readings reached 70 to 80 centibars (1 centibar = 1 kilopascal). Then, the pot was rewatered and the tensiometer re-zeroed. At this time, the tensiometer was kept in place, and the fluid in the reservoir was replenished.

Table 1—*Calculations for the soil moisture tension curve*

Day	Soil moisture tension (centibars)	(A) Weight of wet soil pot, and tensiometer (kg)	(B) Weight of dry soil pot, and tensiometer (kg)	(C*) Weight of water (kg)	(D) Weight of dry soil (kg)	(E) Soil bulk density (g/cm³)	(F†) Volumetric water content (%)
1	4	6.33	5.68	0.65	5.00	1.33	0.17
2	6	6.32	5.68	0.64	5.00	1.33	0.17
3	12	6.26	5.68	0.58	5.00	1.33	0.15
4	20	6.22	5.68	0.54	5.00	1.33	0.14
5	30	6.16	5.68	0.48	5.00	1.33	0.13
6	70	6.00	5.68	0.32	5.00	1.33	0.09
7	0	6.49	5.68	0.81	5.00	1.33	0.22
8	0	6.44	5.68	0.76	5.00	1.33	0.20
9	0	6.41	5.68	0.73	5.00	1.33	0.19
10	8	6.31	5.68	0.63	5.00	1.33	0.17
11	10	6.30	5.68	0.62	5.00	1.33	0.16
12	24	6.16	5.68	0.48	5.00	1.33	0.13
13	72	6.01	5.68	0.33	5.00	1.33	0.09
14	0	6.58	5.68	0.90	5.00	1.33	0.24
15	10	6.27	5.68	0.59	5.00	1.33	0.16
16	16	6.20	5.68	0.52	5.00	1.33	0.14
17	30	6.13	5.68	0.45	5.00	1.33	0.12
18	38	6.05	5.68	0.37	5.00	1.33	0.10
19	60	6.01	5.68	0.33	5.00	1.33	0.09

*C = A − B.
†F = (C/D) × E/(g/cm³).

Each wet-to-dry cycle represented a replication in this experiment. The time required for each drying cycle depends upon several factors, including soil texture, relative humidity, and air temperature. The drying cycles in our study ranged from 10 to 12 days. A nursery manager can also develop a curve with one drying cycle using three or four pots and tensiometers. With one pot and tensiometer, three or four drying cycles are suggested to ensure repeatability. Because soil water retention curves change with different bulk densities and soil textures, a separate curve should be developed for each soil used at the nursery.

At the end of the test period, the tensiometer was removed and the pot and the soil were dried for 48 hours at 105 °C. The dry weight of the soil was recorded. Before the volumetric water contents (VWC) of the soil were calculated, we subtracted the weights of the filled tensiometer and the pot from all weights recorded during the drying cycles. Soil bulk density (BD) was then calculated according to the following formula:

Bulk density = (weight of ovendry soil)/(volume of soil).

To calculate the soil volume, we taped over the drain holes in the pot bottom and then filled the pot with water to the level previously occupied by the soil. The water was then poured into a graduated cylinder and its volume recorded. The volume of space occupied by the tensiometer must also be accounted for. To find this value, we placed the tensiometer (15 centimeters deep) into a graduated cylinder with a known volume of water and recorded the volume of the displaced water (70 milliliters in this case), which represents the volume occupied by the tensiometer. The volume of soil in the pot equals the volume of water in the pot minus the displacement volume of the tensiometer.

After these calculations, the following formula was used for calculating the soil volumetric water content (VWC) at the recorded soil moisture tension (1 gram/cubic centimeter = density of water at 20 °C):

VWC = [(weight of soil wet -- weight of soil dry)/weight of soil dry] x bulk density/ (1 g/cm^3)

Examples of these calculations are listed in table 1. The VWC values were then plotted against their corresponding soil water tensions and a regression line was fitted (figure 2). Although a statistically fitted regression line is recommended, a hand-fitted curve can also be used.

Discussion

Developing a soil moisture curve should provide the nursery manager with a better understanding of water retention in the upper soil

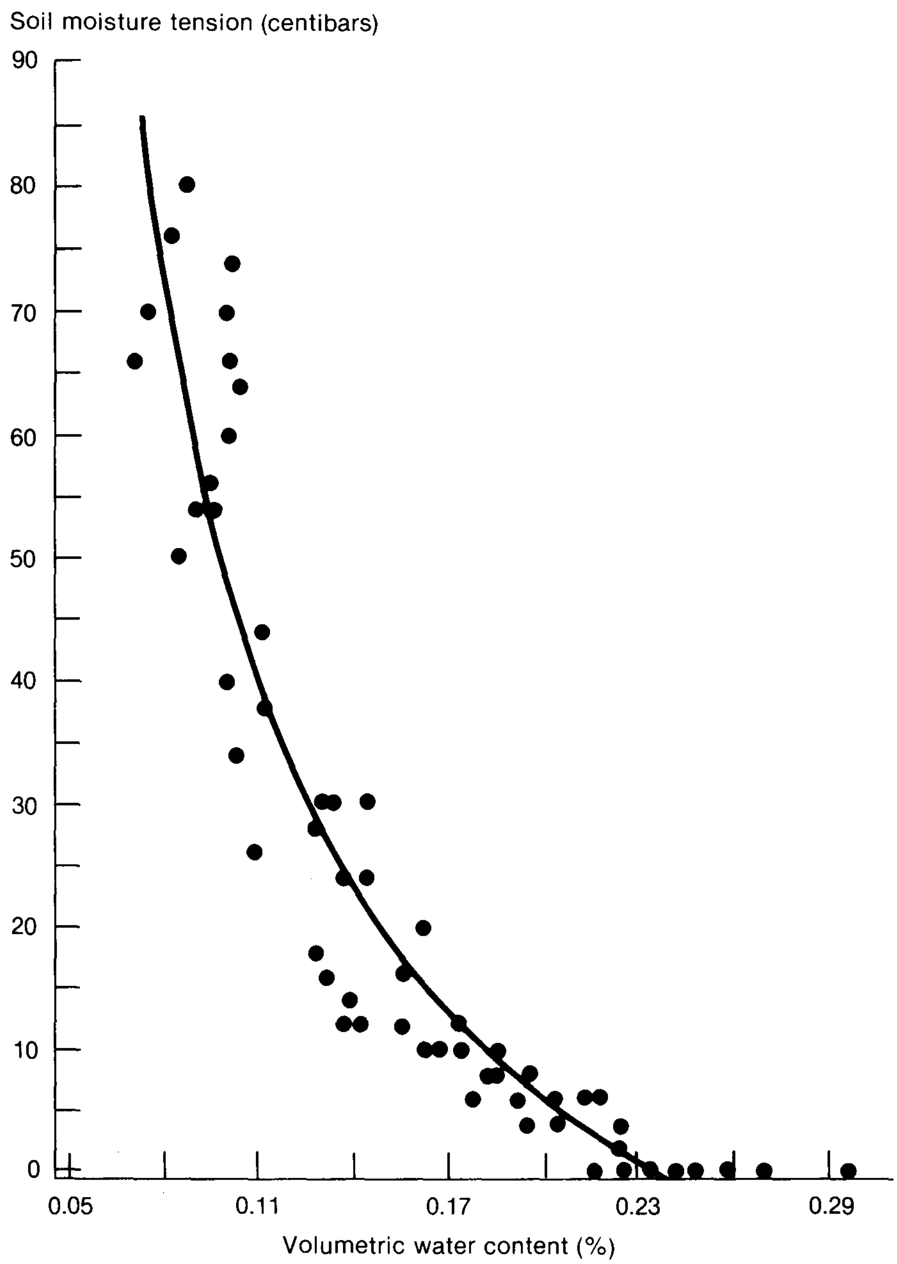

Figure 2—*A soil water retention curve; centibars = (33.5 + 7.9)/volumetric water content.* $R^2 = 0.86$.

profile of the nursery. Of particular interest is the point on the water retention curve where the soil tension begins to rise steeply. To promote seedling growth, irrigation should be applied to maintain the plow layer between field capacity and the point on the curve where the soil tension begins to rise steeply (2). For the curve represented in figure 2, this point is at about 40 centibars.

The curve can also be used to predict how much water should be applied in order to bring the soil tension back to field capacity (1,2). The following information is needed for making this prediction:

1) The average depth of the plow layer in centimeters (conventionally 18 centimeters).

2) The soil water retention curve, with values of VWC at field capacity (10 centibars) and an upper limit of dryness (normally between 30 to 75 centibars).

In the following example, the amount of irrigation water needed to change the soil tension in the top 18 centimeters of soil from 30 to 10 centibars is calculated with the soil water retention curve in figure 2.

a) At field capacity (10 centibars), the water value is 0.18 x 18 = 3.24 centimeters.

b) At the upper limit for irrigation (30 centibars), the water value is 0.13 x 18 = 2.34 centimeters.

c) The irrigation needed would be 3.24 -2.34 = 0.9 centimeters of water.

Although this method can be used to predict the amount of irrigation water needed to correct a soil moisture deficiency, it is not essential that nursery managers actually calculate the amount needed every day. By keeping a daily record of the soil moisture tension and how much irrigation is applied, the nursery manager can eventually learn by trial and error how much irrigation is needed. For example, if 1 centimeter of irrigation lowered the soil moisture tension from 40 centibars to 20 centibars, then the nursery manager would know that next time more irrigation would be needed to lower the tension from 40 centibars to 10 centibars. In time, the nursery manager will gain experience in determining how much irrigation is needed to change the soil tension from an upper limit for dryness back to field capacity. However, developing soil water retention curves provides the nursery manager with a better understanding of the moisture relationships for the nursery soil. Knowing whether to irrigate or not should help nursery managers improve their water use.

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