Measuring Soil Moisture in Pecan Orchards

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Esteban Herrerra, NMSU Extension Horticulturist
John White, Dona Ana County Extension Agent

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Adequate soil moisture content is critical to pecan producers in the arid Southwest. Water is essential for normal plant growth and makes up a large percentage of the overall weight of the plant. Irrigation is used to maintain proper soil moisture for achieving optimal yields and nut quality, thus it is essential that growers apply the right amount of water at the right time. Understanding the basic principles of soil moisture storage, measurements, and management is necessary for the efficient use of water in irrigated pecan orchards and to reduce the pollution potential from runoff and deep percolation.

In general, soils are made up of (1) mineral matter, (2) organic matter, (3) water, and (4) air. Mineral and organic matter are the solids in soil, and may occupy 35–75% of the total soil volume. The remaining volume, or pore space, is occupied by air and water.

The size and total volume of pore space are a function of both soil texture and structure. Clay soils can hold a large amount of water because of the large surface areas of the individual clay particles and the large number of very small pore spaces. Sandy soils, on the other hand, have relatively small surface areas on the sand particles and contain a smaller number of pore spaces, which are larger in size, and thus have a much lower water-holding capacity than clay soils. Knowing the water-holding capacity of soils is important in determining both the amount and frequency of irrigation (table 1).

Soil moisture tension is a measurement of the energy or the force by which water is held by the soil. It is expressed in units of pressure. When soil water is at field capacity and soil moisture tension is low, the plant can readily extract water from the soil. As soil moisture is depleted, soil moisture tension increases, and it becomes more and more difficult for the plant to extract water. At the permanent wilting point, the soil contains some moisture but it is held so tightly that the plant cannot use any of it.

Although plants can withdraw water to the permanent wilting point, their growth usually decreases before signs of permanent wilting occur. In order to obtain good yields and growth, soil moisture must be maintained above the wilting point. For many plants, including pecans, irrigation water should be applied before 50–60% of the available water is depleted.

Table 1. Available water capacity of various soil profiles.

Soil type	Soil profile	in/ft (mm/m)
0	Sandy clay loam	2.0 (166.6)
1	Silty clay loam	1.8 (149.9)
2	Clay loam	1.8 (149.9)
3	Loam,very fine sandy loam, or silt loam topsoil. Silty clay loam or silty clay subsoil	2.0 (166.6)
4	Loam, very fine sandy loam, or silt loam topsoil. Medium textured subsoil.	2.5 (208.3)
5	Fine sandy loam	1.8 (149.9)
6	Sandy loam	1.4 (116.6)
7*	Loamy sand	1.1 (91.6)
8*	Fine sands	1.0 (83.3)
9	Silty clay Clay	1.6 (133.3)

*Note: Tensiometers should be used on soil types 7 and 8.

Soil acts as a “bank” to store water for crop use. Rain and irrigation are deposits, water used by the crop and soil evaporation are withdrawals. A daily balance of these deposits and withdrawals will give the amount of water remaining in the soil profile.

The crop root zone is often viewed as a reservoir for these deposits and withdrawals. Irrigation is used to fill the soil reservoir or to bring the soil moisture content up to field capacity in order to store water for crop use. Thus, the depth of the root zone must be known to determine how much irrigation water is needed. Rooting depth is not constant, but increases as a plant grows. In addition, many factors such as high water tables, soil type changes in the soil profile, soil compaction, soil salinity, and soil fertility may restrict root development.

The depth for soil moisture management in irrigation is often referred to as the "effective root zone" or the "effective rooting depth." Generally, the depth containing about 80% of the total root mass is used for estimating effective root zone depth. Of that depth, about 40% of the total water requirement comes from the top one-fourth of the root zone.

Water requirements for pecans are not constant, but increase as the trees grow. When planning for irrigation, both the seasonal and peak water requirements for the crop being irrigated must be determined. In addition to the peak water use period, pecans have stages of growth in which significant yield or quality reductions will occur if adequate soil moisture levels are not maintained. Irrigations not only must be timed to minimize periods of water stress, but also must not exceed the available root zone storage, except as needed for leaching of excess salts.

Pecan growers should measure soil moisture depth after irrigation to learn the water management efficiency in a particular orchard. Ideally, water should penetrate 3 feet. Whenever soil moisture penetrates deeper or shallower than 3 feet, water management practices must be corrected accordingly. Water penetration can be checked after each irrigation with a simple device built with a 1/2" construction rod. The rod should measure around 3 1/2 feet in length and have one end sharpened. A one-foot long rod welded across the other end makes a T-shaped handle. The rod penetrates wet soil easily, but does not penetrate dry soil. This rod can be used to learn the depth of the irrigation water penetration.

Moisture depth should be uniform over the whole field between borders. The best time to measure soil moisture depth in a loamy soil after an irrigation should be about 24 hours, when soil saturation has drained to full capacity. It may take 36 hours in a heavy soil and about 16 hours in a sandy soil. A practical rule of thumb is to measure soil moisture depth whenever a grower can walk safely on the orchard ground.

Soil moisture monitoring is an effective method for determining the amount of water to apply per irrigation. Several monitoring methods and devices are available to measure soil moisture and determine when pecans need water. Many of these devices can be connected to computer-controlled irrigation systems that automatically apply water only when it is needed. The four most common moisture measuring methods are:

The feel test. A very simple test, one that can be fairly accurate for experienced irrigators. In this test, the soil is felt by hand to determine texture and moisture content at one-foot intervals in the effective root-zone area. Printed guides describing this process are available at county Extension offices and many Soil Conservation Service offices (table 2).

Fiberglass and gypsum blocks. Soil electrical resistance varies with soil moisture content; therefore, porous blocks with electrical resistance elements can be used to measure changes in soil moisture content. Either fiberglass or gypsum blocks can be used. Gypsum blocks are gypsum-encased steel electrodes with insulated wire leads of differing lengths that are connected to a meter. This device determines soil moisture by measuring electrical flow through the soil. A set of three gypsum blocks, buried at one-foot intervals to a depth of three feet, should be used for each 40 acres of orchard, providing they comprise similar soil. Gypsum blocks tend to give inaccurate readings in very wet soils; thus they work better with crops that are not irrigated frequently. Because gypsum deteriorates, new blocks need to be installed each season. A resistance meter costs about $250, and each block costs about $5. Fiberglass blocks are not as common as gypsum blocks.

Tensiometers. Tensiometers measure soil moisture tension, which is the amount of water that can be removed by suction in the same way a plant draws water from the soil. A tensiometer is a water-filled tube with a porous tip and a vacuum gauge. A hole is bored or dug in the soil to the desired depth, and the cup located at the bottom is punched firmly into the soil. Additional soil is packed around the cup and around the tube to ensure good contact with the soil. As the soil dries, water is pulled through the porous tip, and a negative pressure registers on the vacuum gauge. The most commonly used tensiometers are 12, 24, and 36" in length and measure soil moisture at one-, two-, and three-foot depths, respectively. Three tensiometers placed at these depths should also be used for 40 acres of orchard providing all acreage has similar soil.

Tensiometers are most accurate in sandy soils when soil moisture is above 40% of field capacity. In clay soils, they are most accurate when soil moisture is below 75% of field capacity. Tensiometers are reusable, simple to install and read, and cost about $50–75 each. However, the instruments must be periodically refilled to replace the water that slowly moves into the surrounding soil.

Neutron probe. A neutron probe uses a radioactive source and an electronic counter system to determine soil moisture by measuring the slowdown of neutrons as they strike water molecules in the soil. Neutron probes are more accurate than other monitoring meth-

Table 2. Soil moisture indicators for the "feel test."

Degree of moisture	Percent useful soil moisture remaining	Soil type			
		Coarse	Light	Medium	Heavy to very heavy
Dry	0	Dry, loose, single-grained; flows through fingers.	Dry, loose; flows through fingers.	Powdery, dry, sometimes slightly crusted but powdery conditions.	Hard, baked, cracked, sometimes has loose crumbs on surface.
Low	50 or less	Still appears to be dry; will not form a ball.	Still appears to be dry; will not form a ball.	Somewhat crumbly, but will hold together from pressure.	Somewhat pliable; will ball under pressure.
Fair	50–75	Same as coarse texture at 50 percent or less useful soil moisture.	Tends to ball under pressure but seldom will hold together.	Forms a ball and is very pliable; sticks readily if relatively high in clay.	Easily ribbons out between fingers; has a slick feeling.
Excellent	75 to field capacity	Tends to stick together slightly; sometimes forms a very weak ball under pressure.	Forms weak ball, breaks easily, will not slick.	Forms a ball and is very pliable; slicks readily if relatively high in clay.	Easily ribbons out between fingers. Has a slick feeling.
Ideal	At field capacity	Upon squeezing, no free water appears on soil but wet outline of ball is left on hand.	Same as coarse.	Same as coarse.	Same as coarse.
Too wet	Above field capacity	Free water appears when soil is bounced in hand.	Free water will be released with kneading.	Can squeeze out free water.	Puddles; free water forms on surface.

ods because they are not affected by temperature and barometric pressure and are only slightly affected by the chemical composition of the soil and other factors. However, because of the extreme caution required when using low-level radioactive source material and the high cost of the equipment (about $4,000), the device is seldom practical for individual irrigators and small orchards.

The neutron probe is used by first digging a hole with a soil auger, then driving a metal tube into the hole. The neutron source and counter are placed in the tube at the desired depth. The reading obtained in a unit of time is proportional to the moisture content of the surrounding soil. Neutron probes are extremely accurate, but calibration is critical.

Other measuring devices. Several new devices have recently entered the market, including metered moisture probes and computerized irrigation-scheduling programs. New portable moisture meters usually consist of a three-foot (or more) probe with a sensor in the tip of the probe. The probe is pushed into the ground to the desired depth, and a meter on the T-shaped handle provides a moisture reading. These devices cost about $500. Devices that measure soil temperature and electrical conductivity (salts) are also available, but they cost up to $1,000. Some moisture meters can be attached to an optional data logger that will store information for later comparisons or for transferring records to a computer.

Computerized irrigation-scheduling programs are based on evapotranspiration and on-site soil and weather data, so they require reliable and accurate weather data and detailed soil chemistry and textural information. These programs can be quite reliable, but the cost of equipment and time for data collection and entry is high; the program alone can cost over $10,000.

To predict soil moisture conditions accurately and to schedule irrigation frequencies and amounts, the irrigator or farm manager must use a combination of these practices and theories. Knowing everything you can learn about your particular orchard’s soil and soil/plant relationships is important. Further information can be obtained from your local county Extension office or the Soil Conservation Service office.

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