

Measurement of Soil Moisture

accurate instruments for measuring soil moisture conditions
practical means of determining proper timing of irrigation

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Instruments to measure soil moisture conditions—developed as research tools—eliminate much of the guesswork in the timing of irrigations and can indicate adequate penetration for a particular soil type and crop.

Two types of such instruments—tensiometers and resistance blocks—are available and are practical in both research and commercial use. A new method—neutron thermalizing—has certain advantages in research studies but does not have practical application on farms because of the cost and radiation hazard.

Tensiometer is a general term which applies to an instrument consisting of a porous ceramic cup with a narrow neck joined to a section of tubing. The opposite end of the tubing is connected to a mercury manometer or to a vacuum gauge. When filled with water and installed in soil the tensiometer provides a reading of the soil moisture suction value at the cup contact area.

The mercury manometer type of tensiometer gives precise readings and is useful in soils where water table conditions are present. For practical purposes in most agricultural soils the vacuum gauge tensiometer is useful.

Tensiometers are the only instruments that give a direct reading on soil moisture availability to plants, which is an index of soil wetness. Because tensiometers cease to function at soil suctions above 800 millibars—due to air entering the system—their usefulness is limited in fine textured soils. The useful range of tensiometers compared with the per cent of available moisture to plants would vary for different types of soil. In a sandy soil the useful range of tensiometers would represent about 90% of the available water, while in a clay soil it represents about 50% of the available water. Tensiometers indicate the rate of water use—even in fine textured soils—as well as water penetration after irrigations.

Resistance Blocks

The electrical resistance block method of measuring soil moisture is used in many types of agriculture because of its simplicity and low cost when large numbers of units are needed. Its construction consists of two electrodes embedded in moisture blocks of an inert porous ma-

terial such as fiberglass, nylon, or ceramic—or a slightly soluble electrolyte such as gypsum. When buried in the soil the porous material becomes a part of the soil environment and changes in moisture content with the soil. Wire leads from the electrodes can be located at the soil surface in areas not being disturbed by cultural practices. The changes in electrical resistance of the blocks due to changes in soil moisture are measured by connecting the ends of the block lead to a specially designed meter. Some meters are calibrated to indicate directly needs for irrigations.

The porous material most often used in the construction of resistance blocks is gypsum—plaster of paris. Gypsum blocks are sensitive mainly in the drier range of soil moisture.

When the gypsum block is compared with a tensiometer in the field, the block will not indicate change in soil moisture until the 500 millibars value is reached. This will vary greatly with the construction of the block. The gypsum block

should never be used in soils that are continually wet due to poor drainage conditions. Nylon and fiberglass blocks are not as easily deteriorated by high moisture condition. They are also more sensitive to moisture changes at lower soil suction values than are the gypsum blocks.

Neutron Thermalizing

Radioactive materials have been used to measure soil conditions only in recent years.

Neutrons can be used for measuring soil moisture because they are uncharged particles and have almost the same weight as a hydrogen atom and because most of the hydrogen in soil is in the water form.

When fast neutrons are emitted into the soil they are decelerated to slow neutrons upon collisions with hydrogen atoms. By counting the slow neutrons it is possible to show a good relationship between the number of neutrons counted and the amount of moisture in the soil.

The field equipment shown in the photograph is being used to measure soil moisture in citrus groves. The radioactive source of fast neutrons is attached as a ring to the center of the probe which counts the neutrons after they are slowed down. This unit is lowered into soil through aluminum access tubes placed permanently in the soil. The shield is for protection and standardization. It has a ball of lead around the radioactive source to stop the gamma radiation. Surrounding the lead is paraffin containing a high percentage of hydrogen atoms which slow down the fast neutrons. Because paraffin has the same effect on fast neutrons as water it can be used to adjust the meter to a set value before measuring soil moisture. The meter indicates the number of slow neutrons counted by the probe.

The neutron thermalizing method has several advantages in measuring soil moisture. It measures moisture on a volume basis and thus supplies a number that can be used to convert the moisture value to inches of water per given depth of soil. Results of measuring on a volume basis are not affected by temperature, salts, and soil compaction as is the case

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Portable neutron rate meter mounted at convenient working height on a golf cart. The probe and shield are located at the bottom of the cart.



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with resistance blocks. One calibration curve serves for many soil types and one instrument can be used to make as many moisture measurements as time allows. Also, the access tubes are the only part of the equipment left in the field. Furthermore, this method measures a larger volume of soil.

However, there are some disadvantages in the neutron thermalizing method. The equipment is costly and there are radiation hazards. If moisture content obtained by neutron thermalizing is to be related to soil suction a separate calibration is needed for each soil type. Also, the volume of soil that is measured changes with the moisture content of the soil.

Comparisons of Methods

The three methods of measuring soil moisture—tensiometers, resistance blocks, neutron thermalizing—have been used to study irrigation effects on citrus at Riverside. Some of the data for the irrigation season of 1956 are graphically illustrated for comparative purposes.

The upper graph on this page represents an infrequently irrigated orange plot at Riverside and shows the range of moisture depleted on a volume basis which is approximately 19.5%–8.5%. The first readings on soil moisture conditions were made about two days after the irrigation water was turned off. The field capacity for both methods was at a lower moisture content or a higher suction value for the last two irrigations. This change in field capacity as the irrigation season progresses has been noted in other areas. It could be due to either higher water use during the two days after the irrigation or lack of complete wetting of soil particles. The tensiometer did not respond to changes in soil moisture above 800 millibars. However, by extrapolation, valid information can be obtained up to the one bar soil suction value which is approximately 12% moisture on a volume basis. This extrapolated value represents almost 70% of the available moisture in a Ramona sandy loam.

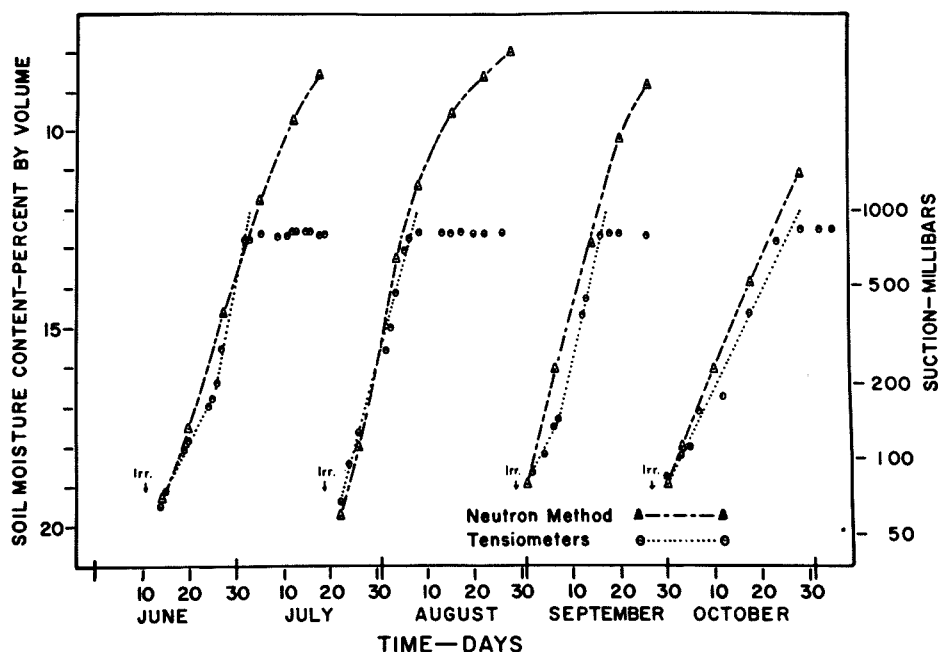
On August 27, soil samples were taken near the place where neutron measurements were made. The soil moisture contents of these samples were at or below the 15 bar soil suction value down to the 24" depth in the soil profile. The 15 bar value is comparable to the permanent wilting percentage. The trees were wilted at this time. The slope of the line indicates the rate of soil moisture depletion. During the month of September the rate of evapo-transpiration was the highest as shown by the slope. This agrees with mean monthly temperature for this pe-

riod. On the other hand, October shows a noticeable decrease in the slope.

The three methods of measuring soil moisture conditions were used in a commercial navel orange grove. Sprinkler irrigation treatments were applied here as a portion of an experiment. Readings were made on a weekly basis. All measurements were made in the soil near the edge of the tree. The tensiometers and resistance blocks were located at the 18" soil depth. Neutron measurements were made at 12" and 24" soil depths and so the average value of the two depths was

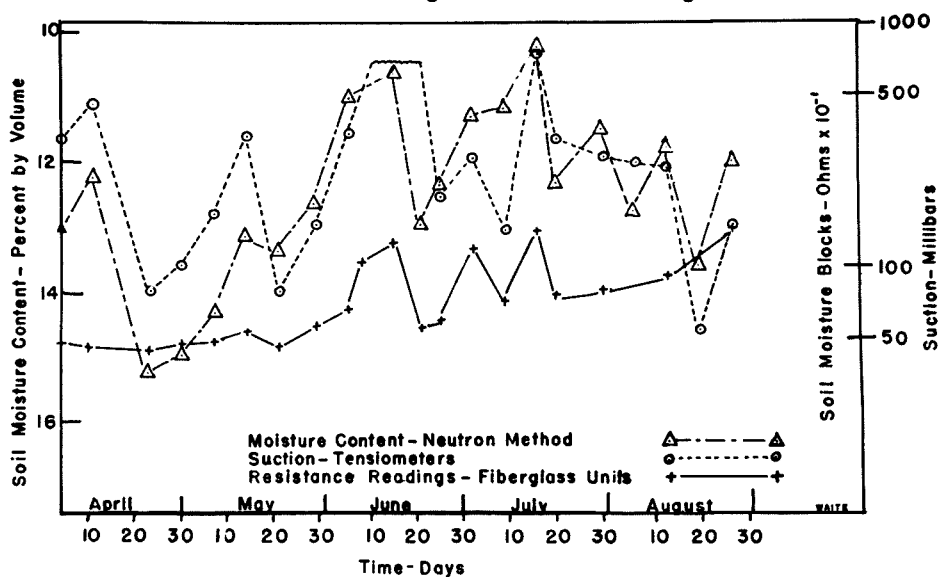
plotted. Because the neutron method measures a bulk volume of soil this moisture content would represent the average moisture condition of the soil profile from about 6"–30". This volume of soil would contain about 80% of the citrus feeder roots. The data taken with the neutron method and with the tensiometers compare well. This means that a tensiometer properly located in the active root zone will register moisture changes that are average for the soil profile. During the months of July and August this

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Comparisons of soil moisture contents measured with neutron equipment and soil suction values measured with tensiometers. The data were obtained at the 1' soil depth in an infrequently irrigated navel orange plot at Riverside.

Comparisons of data for three different methods used in measuring soil moisture conditions. All moisture units were close together in a sprinkler irrigated navel orange plot. Tensiometers and fiberglass units were at the 18" soil depth. Neutron values are averages of 12"–24" readings.



MOVEMENT

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phere suction value—about 75% of the available water has been removed from the Fallbrook soil and approximately 60% from the Holtville soil.

Further studies of moisture extraction from soils are being made under controlled conditions without using plants. Soil columns are positioned horizontally and brought to equilibrium with water at approximately 30 millibars. This is often a value read on tensiometers following an irrigation in the field. A constant suction is then applied at one end of a soil column, by applying a controlled vacuum to one side of a porous ceramic disc the other side of which is in direct contact with the soil. The lower left graph on page 24 shows the accumulated water extracted from soil columns when the suction of 900 millibars was maintained constant. The extracted water was measured in surface inches in relation to the area of the soil column.

In the same length of time, 80% more water was extracted from a column of soil 14" long compared with the same column when it was cut down to 7" in length. This would indicate that, for this Fallbrook sandy loam, root-free portions of the soil 7" away from roots can make substantial contributions to water extracted by roots.

Soils vary greatly in their ability to conduct water. A comparison of three soil types shows that under the same controlled laboratory conditions the water extracted from a Ramona sandy loam soil was approximately twice as much as from a Fallbrook sandy loam and three-fold that from a Yolo loam. The curves comparing various soils were all obtained using 14" soil columns.

For these studies of soil moisture movement, fragmented soil samples were screened and compacted in the columns. Further studies will be made on undisturbed cores.

If only moisture flow rates are measured—to compare the ability of various soils to conduct water—the size and shape of the soil sample and suction equipment would need to be standardized. However, when continuous records of the moisture suction values are obtained at various locations along the soil column, as well as moisture extraction rates, computations can be made expressing the conductivity values of a soil as a function of the moisture suction. These values are characteristic of the soil and independent of the methods of measurement. They can be used to characterize different soils or study the effects of soil management practices on the same soil. Also, when suction values in the field are measured by tensiometers, flow rates can be estimated.

Studies of moisture movement in soils in the liquid phase are made under constant temperature conditions. Thermal gradients within the soil column, which result in water vapor diffusion, can cause significant disturbances to the measured liquid flow.

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In most cases not enough water can be stored in the soil to last throughout the season. Where water penetration is slow, more water can be applied by irrigating more frequently or by increasing the time the water is on the land surface at each irrigation. Both approaches have advantages and limitations. More frequent irrigation may be accomplished without any other change in the system or in practice, but has the disadvantage of higher labor costs. It may be an inadequate measure for the more difficult problems. Prolonged irrigation may require substantial changes such as converting from furrows to basins in which water can be ponded for long periods or using small furrows to insure better coverage of border strips with small streams. Irrigation of crops susceptible to injury or disease under prolonged irrigation can not be managed in this way, and the practice may encourage growth of water-loving weeds. However, such methods may be the only means of increasing the productivity of soils with very slow water penetration even though changes in cropping pattern or farming operations are required.

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ing facility must provide for maximum energy capture, discharge water at a temperature giving maximum rice yields, occupy a minimum land area, with reasonable installation and maintenance costs.

From experience in rice irrigation, water temperature may be expected to influence the growth of other crops. However, it is difficult to predict the influence of water temperature on yields because of its numerous direct and indirect effects on the plant. In addition to the cold water damage reported here, crop injury is sometimes associated with warm water.

As more is learned about its effects on

irrigated crops, water temperature may become a factor of considerable importance in the selection of crops and their management for maximum yield and minimum unit cost.

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grove was on a two week irrigation schedule. The irrigation water applied July 19 and August 3 reached the 12" soil depth but did not wet the soil at the 18" depth to field capacity.

The time and place to use either tensiometers or blocks depends to a large extent on climatic conditions and soil types and to a lesser extent on the nature of the crop. In inland areas of southern California where high water losses may cause stress conditions in plants, timing of irrigations becomes very important. Tensiometers have proved to be valuable tools for timing irrigations in citrus and avocado groves. However, in the more humid areas where irrigations are intermittent, along with rainfall, resistance blocks are used with satisfactory results. Resistance blocks made of gypsum rather than fiberglass or nylon are generally preferred in agricultural soils.

The neutron method is still a research tool although it might be valuable on large agricultural acreages.

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QUALITY

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in the Imperial Valley. Here Colorado River water is used for irrigation and contains large quantities of sulfate, which produces this toxic symptom.

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