SOIL MOISTURE STATUS & INSTRUMENTATION

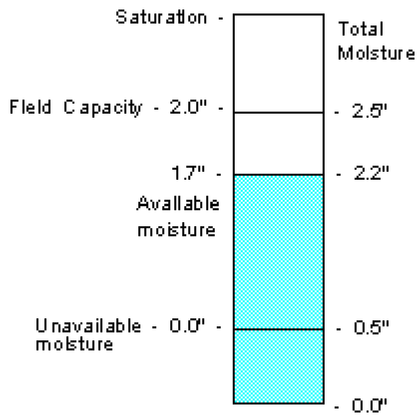
CONTENT vs. DEPLETION vs. TENSION

Descriptions of soil moisture can often times be confusing. Sometimes soil moisture is described in terms of actual or total soil moisture content. That is, how much total water is actually in the soil. Other times, soil moisture will be described in terms of available water. This is soil moisture that is above the permanent wilting point, available to the crop.

Another way to describe soil moisture is to talk in terms of the "soil moisture depletion" or "soil moisture deficit". Remember that the upper limit of available soil moisture is field capacity. Adding water to the soil in excess of field capacity will just result in deep percolation. The amount of water required to take the soil from its current soil moisture to field capacity is termed the soil moisture depletion (or deficit), the SMD.

The figures below will help to explain. For example, assume that a soil has a field capacity of 2.0 inches/foot. The permanent wilting point is at .5 inches/foot. The current soil moisture reading is 1.7 inches/foot total water. Thus, . . .

There are 1.7 inches/foot total water in the soil. There are 1.2 inches/foot available water in the soil, 1.7 total minus the .5 inches below permanent wilting point which won't be used by the crop. The soil moisture deficit is .3 inches/foot, that is, adding .3 inches/foot to the current 1.7 inches/foot will take the soil to its 2.0 inches/foot field capacity.



All of the above describe soil moisture "volumetrically". They are "volumetric" measurements of soil water. The measure the actual soil water content (or what it takes to refill the soil to field capacity). The measurement standard of "inches of water held per foot of soil" is a standard for volumetric measure.

There is another way to describe soil moisture. This is in terms of the soil's water-holding forces, termed "soil moisture tension."

Related Links:

- Soil Moisture Sensors-MicroIrrigation Forum (http://www.microirrigationforum.com/new/sensors/)
- Soil Water Content Sensors & Measurement (http://www.sowacs.com/)

SOIL MOISTURE TENSION

We have been talking of soil moisture in volumetric terms. That is, how much water is physically in the soil, the inches of water held per foot of soil.

However, the plant doesn't really care about the actual amount of water in the soil. It cares about the soil's water-holding forces, how hard the soil is holding on to that water. For example, a clay loam may have an available water content of 1.2 inches/foot. And a sandy loam may have the same available water content of 1.2 inches/foot. A plant in the clay loam is probably feeling much more stress than the plant in the sandy loam. Finer soils will hold more water than coarse soils. But they will also hold on to it much tighter for any given water level.

The term used for describing the water-holding force is "soil moisture tension". Soil (or plant) moisture "tension" is another way that moisture can be measured and described.

Soil/plant moisture tension is measured in terms of pressure, most commonly as centibars (1 bar = 100 centibars = 1 atmosphere = 14.7 PSI for agricultural work.

To a plant, all other things being equal, it doesn't care if it is growing in beach sand or black clay. If the moisture tension is equal, it feels the same amount of stress, regardless of the actual amount of water present. And it will develop at the same rate.

METHODS OF MEASURING SOIL MOISTURE

There are three main ways of measuring soil moisture volumetrically, that is, in terms of inches/foot. One well-known method is the neutron probe. The neutron probe consists of a small cylinder, usually about 2" x 8" that is connected to a control box by 6-8 feet of electrical cable. The radioactive material (the source of the neutrons) is contained in the cylinder. When not in use the cylinder is stored within the control box, which is lined with paraffin wax and lead for safety.

Access holes are drilled and PVC or aluminum pipe inserted at appropriate places in a field. To measure soil water the neutron probe cylinder is lowered into the hole to pre-determined depths (dependent on the crop and soil). When turned on, the source within the cylinder will emit fast, low-energy neutron particles in about a 6" ball around it. When these fast-moving particles strike a hydrogen molecule (present in water, H_2O) they are slowed down. The instrument detects and counts these slowed particles. The total number of slowed particles is calibrated to read out in terms of total soil moisture.

The neutron probe is an expensive instrument (although costs, size, and weight are coming down) and requires special training, licensing, and storage procedures. Also, the required access tubes and time to take a reading, realistically restrict its use to one or two spots in a field. Usually it is used by scientists, consultants, and larger farms. Please click the following link for photos and additional information.

http://www.sowacs.com/sensors/index.html

Another way to measure soil moisture is to take a soil sample of a known volume, weigh it, dry it thoroughly, then weigh it again. The difference in weight between the wet and dry soil is the total water content. This method, known as the "gravimetric" method, is slow and not used in production agriculture except to calibrate other methods.

MEASURING SOIL MOISTURE BY HAND PROBING, THE "FEEL" METHOD

One of the easiest, cheapest, and most flexible methods is by "feel". That is, using a soil sampler or soil auger to take samples of soil from varying depths of the root zone and judging the water content by the feel and appearance of the sample. It is easy because anyone can do it. It is cheap because all it takes is an inexpensive soil sampler (see the Additional Resources section of the Appendix for places to obtain soil samplers). And it is flexible because you can go any place in the field, at any time.

This flexibility is one of its great strengths. With neutron probes, tensiometers, and gypsum blocks, you can only measure soil water at the point of installation of the access tube or instrument. If using tools like leaf pressure chambers or infrared thermometers, you are restricted as to time of day (and in the case of the infrared "gun", whether it is cloudy or not, and windy or not).

With practice, it is easy to become fairly accurate. The following two links help relate the feel and appearance of soil samples to the water content, the "feel method." The first has some good color photos and presents the depletion in percentage. The second presents a table that relates appearance to the depletion in inches.

http://www.ianr.unl.edu/pubs/irrigation/g690.htm
http://cati.csufresno.edu/cit/rese/90/900607/

Additionally, NRCS has similar information.

Following is an example of estimating the SMD for a preirrigation using inch values from the table on the second link.

1. The purpose of the irrigation is to take a 6 foot profile to field capacity. Effective root zone = 6 feet.
2. Soil samples are withdrawn from .5 feet, 1.5 feet, 2.5 feet, 3.5 feet, 4.5 feet, and 5.5 feet.
3. The field is layered so that samples 1 through 3 are classified as medium loams and samples 4 through 6 are heavy loams. Noting the headings on the four columns of descriptions, you want to match the feel of each sample to a description in the appropriate column. Then read the indicated soil moisture deficit to the right or left.
4. Sample 1 (a medium loam from .5 feet) is dark, will slick, but will not ribbon. This indicates a SMD for the top foot of .4-.5 inches. Sample 2 (from 1.5 feet) is dark and forms a ball but will not slick or ribbon, indicating a SMD for the second foot of .7 inches. The remaining samples are then examined.
5. The total of the SMDs for the 6 samples is 3.5 inches. This gives you an idea of the net irrigation water to apply. Remember, effective, efficient irrigations are the result of knowing WHEN, HOW MUCH, and HOW to irrigate. The soil moisture depletion is the HOW MUCH to irrigate.
6. Note that if you need to satisfy a leaching requirement (explained in both the Irrigation Scheduling and Salts and Drainage chapters), the leaching depth should be added to the estimate of the soil moisture depletion to determine the total to irrigate.

Probing is cheap enough that it can be used both before and after an irrigation. Use it before an irrigation to both time the irrigation and estimate the correct amount of water to apply. Sample the soil after an irrigation to make sure that you got enough water into the root zone. If the after-irrigation sampling indicates too much or too little water in, adjust the next irrigation's management as required.

MEASURING SOIL/PLANT MOISTURE TENSION

Measuring water volumetrically, that is, in terms of actual water content is important. It gives us an idea of how much water to replace at an irrigation. Remember though, the plant does not care how much water is actually in the soil. It only cares how hard that water is being held by the soil. Thus, to prevent stress you would like to be able to measure this water-holding force, the soil moisture tension.

The most well known methods are the tensiometer and gypsum blocks. Both are in wide-spread use. The are relatively inexpensive and easy to use. However, like a neutron probe access tube, once installed they can only measure soil moisture tension at that one spot. Care must be taken in choosing the measuring site and the depths of installation.

Also, for complete water management there should be a way to relate a relative soil moisture tension reading to the soil moisture depletion to allow for efficient irrigations.

This is a very important point. The measurement of soil moisture tension provides an indicator for WHEN to irrigate. We want to irrigate before excessive stress on the plant, to provide for optimum plant development. The measurement of soil moisture content provides the estimate of HOW MUCH to irrigate. This is how much water to apply when we do irrigate.

The tensiometer tries to mimic the root as closely as possible. There are three main parts to the instrument, illustrated in link below. They are a water-filled tube (of varying lengths depending on what depth of soil is to be measured), a vacuum gauge on the above ground end of the tube, and a porous, ceramic tip on the other.

The tensiometer is inserted into the soil to the desired depth. As the soil moisture level decreases at that depth, the soil will try to draw water out of the tube through the porous tip. This creates a vacuum in the tube which is read on the gauge. It is a direct reading on the stress that the plant roots must overcome. If irrigation (or rain) water is added, the vacuum in the tube will draw water back into the tube, decreasing the vacuum and reducing the gauge reading.

Tensiometers will generally read a range of from 0 to 70-80 centibars. Above 70-80 centibars, the water flow between the soil and the ceramic tip breaks and suction (and thus, the vacuum in the tube) is lost. The reading will go to zero.

This is an important point, especially with deep tensiometers. A zero reading on a tensiometer can either mean a very wet soil, or a very dry soil.

"Gypsum block" is a generic term. Modern blocks may be made of fiberglass and other porous materials. They consist of a cylinder of porous material, about 1 inch in diameter and two inches long, with two wires embedded in it but not touching.

The block is buried at the desired depth with the electric leads extending above ground. When measuring tension, an electric voltage is sent through the wires. The resulting current flow is read with a sensitive instrument. The porous block will contain more or less water as the soil dries or wets. The wetter the block, the more current will flow. Instruments used are commonly calibrated so that the current flow is read as centibars.

An advantage of gypsum blocks are that they can be used to read very high soil moisture tensions.

Another instrument that may be called a gypsum block (because they are very much alike in appearance) is the thermal dissipation sensor. Wires are again embedded in a porous ceramic block. When wet, the block will dissipate (throw off) heat rapidly. When dry it dissipates heat much slower. An electric circuit is used to quantify this change as the soil wets or dries.

With a neutron probe, the access tube allows you to measure at any depth or depths desired. But once buried, the gypsum block or tensiometer is in one place. Thus, tensiometers and any form of "gypsum block" are usually used in "banks". That is, two or more of the instruments will be installed at the same field site but at different depths.

MEASURING PLANT MOISTURE TENSION

Measurements of moisture tension can be soil-based or plant-based. Soil-based measurements measure the tension in the soil, as with a tensiometer or gypsum block. This is a direct reading on the tension that the plant must overcome. There is an instrument that measures the moisture tension within the plant directly, the plant leaf pressure chamber (also called the "pressure bomb").

This device consists of a pressure chamber with a special removable cover, pressure gauge, and pressure source. When using the pressure chamber, a leaf/petiole sample is cut. The petiole is inserted through a self sealing hole in the pressure chamber cover. The cover is then screwed on the chamber with the leaf inside the chamber and the cut end of the petiole left out. Then pressure is slowly introduced to the chamber. At some point, sap will be seen to bubble from the petiole. The pressure gauge is read in centibars of pressure. The reading is a direct measurement of the plant moisture tension and thus, the stress in the plant.

Leaf chambers have been very effective in scheduling irrigations (particularly the first seasonal) for cotton. The UC Extension has done much testing to develop specific recommendations. They can suggest desirable pressure readings at the first seasonal and following irrigations in different varieties.

Pressure chambers are flexible in that you can go anywhere in the field to cut petiole samples. However they are restricted to 2-3 hours of sampling time a day, usually around solar noon (when the sun is highest).

Again, tension measurements are essential to prevent stress from lack of soil moisture. However there must still be some way of knowing how much water to apply during an irrigation. Effective, efficient irrigation management combines tension measurements with volumetric soil moisture measurements.

THE THERMAL INFRARED THERMOMETER

Another instrument in use is the thermal infrared thermometer (sometimes called the "infrared gun" because of its appearance). This instrument is a thermometer that measures temperature by reading infrared radiation. The instrument is aimed at whatever you wish to measure the temperature of.

In use the thermometer is aimed at the crop canopy so that the average temperature of the crop's leaf surfaces is measured. At the same time a measurement of the ambient air temperature is taken. The difference between the two temperatures indicates the amount of stress on the crop. The basic theory being that if ETc is normal, the leaf temperatures will be lower (as water evaporates through the surfaces).

The thermometer is very fast and easy to use. You can point it anywhere in the field. However, it should be used at about the same time every day, it should be used on a full canopy (so that bare soil is not read), and also in low wind.

One of the keys for effective use of any form of soil or plant moisture measurement is picking the correct field site and depth in the root zone to sample. Do you want to irrigate to the driest part of the field, or the wettest? Do you irrigate to the sand streak, or the rest of the field. This is again an example of the art and science of irrigation management. Science has provided the tools for measuring soil moisture. You have to decide where best to measure and interpret the results.

SALT AND IRRIGATED AGRICULTURE

All of the ideas discussed in this chapter are affected by the amount and relative balance of salts in the soil and water. High or out of balanced salts in the soil can reduce effective available water holding capacities, restrict water infiltration, require more irrigations, and/or alter soil moisture tension readings, among other effects. The Westlands Water District is affected by high water tables in some areas and by high salts in groundwater in most areas. Please read the chapter on Salts and Drainage or see this link to a United Nations soil and water training manual that covers this same material, but describes things in metric units. .

SUMMARY

In summary, there is a body of science that has created a model of how water moves into the soil, through the soil, into the plant, and back out into the atmosphere.

We know that soil will only hold so much water, it does no good to irrigate over this maximum field capacity. We know that the water-holding forces in the soil go up as the level of soil moisture goes down. This leads to two ways of describing soil moisture- in terms of the actual water content (inches of water held per foot of soil), and in terms of the water-holding forces (centibars of tension).

We act in terms of the actual water content (inches of water per foot of soil), we need to know how much water to replace at an irrigation. The crop doesn't care how much water is in the soil. It cares how hard that water is being held by the soil (the soil moisture tension in centibars). Crops extract water at a measurable and predictable rate, evapotranspiration, ETc, measured in terms of inches/day. We do not let the crop use all the available water in the soil. As the soil moisture goes down, the forces holding water in the soil go up. It becomes harder for the plant to extract the water it needs.

We can describe the rate at which water enters the soil as an infiltration rate, measured in inches/hour. We can also describe the rate at which we apply water during an irrigation, the application rate, also measured in terms of inches/hour. If the application rate is greater than the infiltration rate, runoff will occur.

There are many ways of measuring water, both in terms of volume and in terms on tension. Each has its own strengths and weaknesses. Which is chosen depends on the specific situation.

The available water holding capacity of soils, the rate at which water soaks into and through soil, the level of stress on a plant at any soil moisture level, are all affected by excessive or imbalance salts in the soil. See other pages on Salinity for further information on these effects.