METER
ENVIRONMENT

WHY WE SHOULD REEXAMINE THE -1.5 MPA STANDARD FOR PERMANENT WILTING POINT

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A primary function of soil in natural environments is to store water from rain and irrigation and to make the stored water available to plant roots for uptake and transpiration. Not all of the water stored in the soil, however, is available to the plants. In some clay soils, half the pore space may be filled with water unavailable to plants. For water-budget analyses and irrigation management, it is important to know how much water the soil can store.

A BREAKTHROUGH PLANT WATER REQUIREMENT STUDY

In 1912, L. J. Briggs and H. L. Shantz published an amazingly-complete study of the water requirements of plants. Briggs, at the time, was a soil physicist for the USDA Bureau of Plant Industry. He later transferred to the Bureau of Standards (now National Institute of Standards and Technology; NIST), becoming its director in 1933. In that post, he was given the responsibility to oversee the early stages of the Manhattan Project, which developed the first nuclear weapons in World War II. After his retirement, he went back to the soil physics questions from his early career. He sought to measure the limiting tension in a column of water and was able to produce tensions as high as 300 bars. Shantz also went on to a distinguished career, becoming president of the University of Arizona.

Briggs and Shantz measured the wilting coefficient of plants, which is the soil water content below which plants wilt and do not recover when placed in a humid atmosphere. This measurement was made for a wide range of soil textures. The wilting coefficient was then correlated with a number of measurements on the soil itself including the “hygroscopic coefficient” and the “moisture equivalent.” The hygroscopic coefficient is the water content of soil “equilibrated” through the vapor phase with pure water, and the moisture equivalent is the water content of the soil after it is centrifuged at 1000g for 40 minutes in a screen-bottom tube. Both correlations were amazingly good.

WATER POTENTIAL IS INTRODUCED AS A CRITICAL NEW CONCEPT

We know that the wilting coefficient is best described in terms of a water potential, and one might wonder why Briggs and Shantz used hygroscopic coefficient or moisture equivalent. They used these measures because no means existed, at that time, for measuring water potential. The concept of capillary (or matric) potential had just been applied to soils by Briggs' colleague, Edgar Buckingham. Buckingham was a soil physicist with the Bureau of Soils and worked under Briggs for a few years around the turn of the century. He and Briggs had a long association, later working together again in the Bureau of Standards. Briggs was therefore well-acquainted with the concept of water potential, but methods had not yet been invented for measuring it.

In the 1930s, L. A. Richards developed a method for bringing soil to a known water potential. He used a ceramic plate which had pores sufficiently fine enough to pass water and solutes through but retain soil and air. Wet soil samples were placed on these plates inside a chamber where air pressure could be applied to the soil and water in the sample. The bottom of the plate was open to atmospheric pressure. When air pressure was applied to the samples, the water potential of the soil water increased, and water flowed out through the plate, allowing the sample to approach equilibrium. If equilibrium was attained, the matric potential of the sample was equal to the pressure applied to the sample.

THE -1.5 MPA PERMANENT WILTING POINT VALUE WAS BASED ON FLAWED DATA

With the invention of the pressure plate, thousands of samples were run to determine relationships between water content and water potential. As this body of data became available, correlations were made between the wilting coefficient and water contents at various potentials. From these, the water content at -15 bars, or -1.5 MPa correlated best. Briggs and Shantz found that soils varied enormously in their wilting point water contents, but the wilting water potential for all soils was near -1.5 Mpa.

This enormous amount of work to obtain pressure plate moisture release data had one serious flaw: until quite recently, no independent method existed to determine that the samples were, in fact, equilibrated (a requirement for correct determination of matric potential). A recent paper by Gee et al. (2002) examines the assumption of sample equilibrium on a pressure plate and concludes that hydraulic conductivities of samples at -1.5 MPa are so low that they never equilibrate, even after many days on a plate. Measurements with thermocouple psychrometers showed that actual sample water potentials ranged from 0.66 to 0.99 MPa after 10 days on a pressure plate at 1.5 MPa pressure. Simulations confirmed that hydraulic conductivity is too low for equilibration in any reasonable amount of time at these low potentials. Amazingly, Briggs actually understood and discussed the problem of low unsaturated conductivity and non-equilibrium over short distances, in relation to the measurement of the wilting coefficient in his 1912 paper.

RESPONSE TO LEARNING THOUSANDS OF 15 BAR MEASUREMENTS ON SOIL ARE WRONG

What has been the response of the soils community to the revelation that the thousands of 15 bar measurements on soil are wrong? Surprisingly, there doesn't appear to have been much response. Certainly, there is a reluctance to redo all that work, but wishing doesn't change the facts. Fortunately, the practical consequences of these errors may not be great. The moisture release curve for soils tends to be quite steep around the wilting point (a large change of water potential for a small change of water content). Thus, even when there are quite large errors in the permanent wilt water potential, the permanent wilt water content is still nearly correct. Consequently, calculations of moisture-holding capacity and available water are not affected to any great degree. All of this suggests the need for a new Briggs and Shantz study where water potential, rather than the water content, of the soils at wilting is measured. Hopefully, someone will accomplish that before the centennial of their important contribution is reached.

LEARN MORE ABOUT PERMANENT WILTING POINT

Soil moisture is more than just knowing the amount of water in soil. Learn basic principles you need to know *before* deciding how to measure it. In this 20-minute webinar, discover:

- Why soil moisture is more than just an amount

- Water content: what it is, how it's measured, and why you need it

- Water potential: what it is, how it's different from water content, and why you need it

- Whether you should measure water content, water potential, or both

- Which sensors measure each type of parameter

UNDERSTAND PLANT AVAILABLE WATER

Learn everything you need to know to measure and predict soil water availability and soil water movement—all in one place.

Download the "Researcher's complete guide to water potential"

Download the "Researcher's complete guide to soil moisture"

REFERENCES:

Briggs, Lyman James, and Homer LeRoy Shantz. *The wilting coefficient for different plants: and its indirect determination.* No. 230. Govt. Print. Off., 1912. Article link.

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