DECAGON 2006 Soils News www.decagon.com/soils/

SOIL • PLANT • WATER • SEED

DECAGON DEVICES

Measuring Specific Surface of Soil with the WP4

THE SPECIFIC SURFACE AREA of a soil sample is the total surface area contained in a unit mass of soil. Soils with high specific surface areas have high water holding capacities, more adsorption of contaminants, and greater swell potentials. Specific surface is therefore an important parameter.

Smaller Particles, Greater Surface Area

Specific surface is closely tied to particle size distribution. This can be seen with a simple thought experiment. A cube, 1 cm on a side, with a density of 1 g/cm^3 has a surface area of 6 cm^2/g. If the cube were divided into smaller cubes 1 mm on a side, the resulting 1000 cubes would have the same mass of material, but a surface area ten times that of the single cube, or 60 cm^2/g. If the cube were divided into 10^{12} cubes 1 µm on a side, the surface area would be 6×10^4 cm^2/g. Thus, the smaller the particles, the greater the surface area per unit mass of soil.

Two-Day Measurements

Various approaches have been used to measure specific surface area, including adsorption of nitrogen and other gases on the soil. The most commonly used method at present uses the adsorption of ethylene glycol monoethyl ether (EGME). This involves saturating prepared soil samples, equilibrating them in a vacuum over a $CaCl_2$-EGME solvate, and weighing to find the

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Improving ECH_2O Field Performance

■ ECH_2O probes can be buried at any depth, even below the root zone.

Decagon introduced the ECH_2O-20 cm soil moisture probe in the spring of 2001. Since that time, the probe has been continually tested and modified to improve its performance in the field. Issues that have received considerable attention recently are the ECH_2O probe's sensitivity to differences in electrical conductivity (EC), soil texture, and temperature.

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INSIDE ▸

Improving ECH_2O Field Performance

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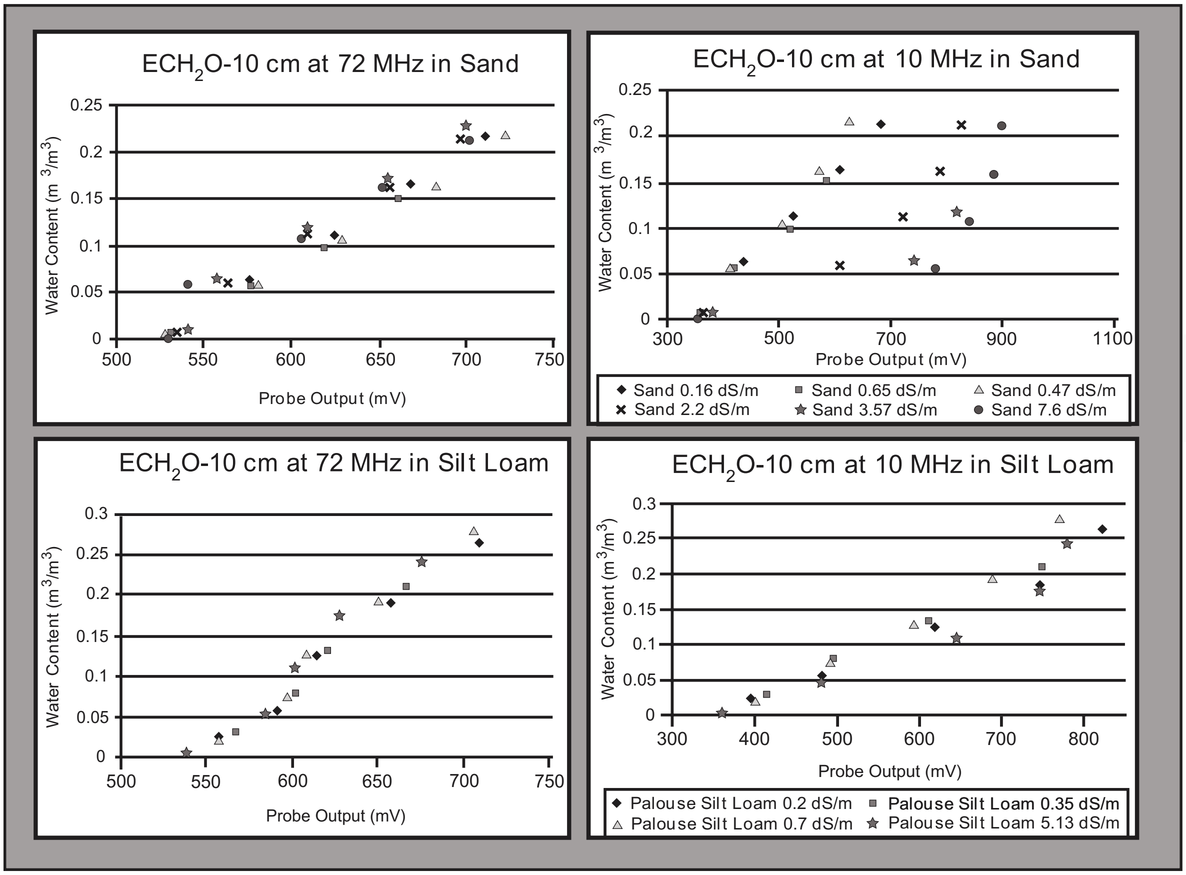
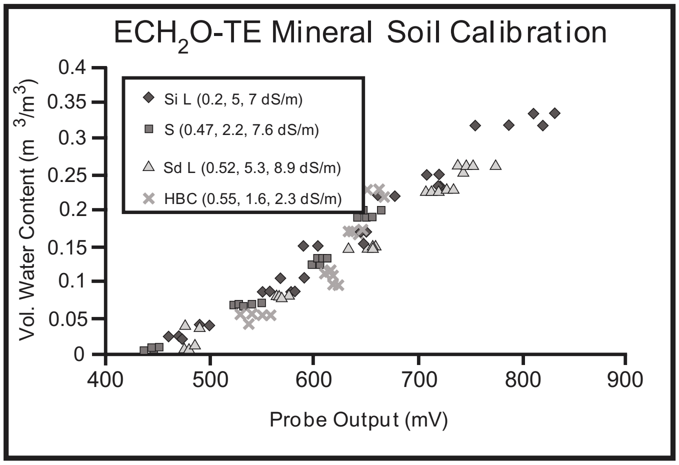
Electrical Conductivity, Soil Texture, and Temperature

While the current ECH_2O-20 and 10 cm probes are adequate for most field applications, some research and commercial project needs are not being met because of these issues. Thus, there has been considerable interest in developing a probe that has lower sensitivity to variations in electrical conductivity, soil texture, and temperature while maintaining the qualities that have made the ECH_2O probe so widely accepted.



▲ Fig. 1. ECH2O-10 probe output running at two frequencies in sand and silt loam at several solution electrical conductivities and water contents.

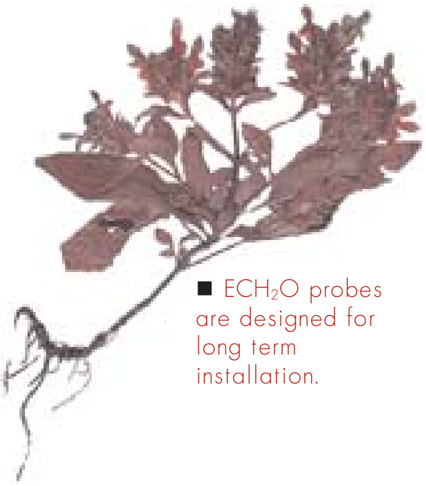


◄ Fig. 2. Two ECH2O-TE probes calibrated in four soil types at varying salinities up to 8.9 dS/m (S - sand, Sd L - sandy loam, Si L - silt loam, HBC - Houston black clay)

Increasing Measurement Frequency

There has been considerable discussion in the scientific literature regarding how increasing measurement frequency improves the salinity, soil texture, and temperature response of soil moisture sensors. With this in mind, we changed the measurement frequency of one of our current probes, (ECH_2O-10cm) and two new 5 cm-long ECH_2O probes (ECH_2O-TE and ECH_2O-5) to see if we could improve the response of the probes.

Figure 1 illustrates the improvement that increasing the measurement frequency has made in the ECH_2O-10 sensor. The performance of the two new sensors (ECH_2O-TE and ECH_2O-5) is similar to that of the ECH_2O-10 (Fig. 2). ■

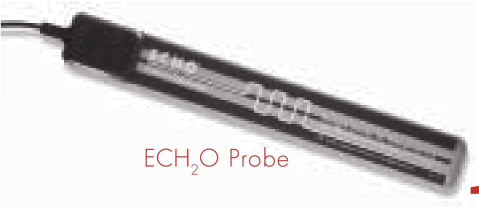


■ ECH_2O probes are designed for long term installation.

Precision and accuracy of three alternative instruments for measuring soil water content in two forest soils of the Pacific Northwest.

Canadian Journal of Forest Research, #35, August 2005

Nicole M. Czarnomski, Georgianne W. Moore, Tom G. Pypker, Julian Licata, and Barbara J. Bond



ECH$_2$O Probe

ABSTRACT: We compared the accuracy and precision of three devices for measuring soil water content in both natural and repacked soils and evaluated their temperature sensitivity. Calibrations were developed for a capacitance instrument (ECH$_2$O), a time domain reflectometry cable tester (CT), and a water content reflectometer (WCR) in soils collected from the Wind River and H.J. Andrews Experimental Forests. We compared these calibrations with equations suggested by manufacturers or commonly used in the literature and found the standard equations predicted soil moisture content 0%–11.5% lower ($p < 0.0001$) than new calibrations. Each new calibration equation adequately predicted soil moisture from the output for each instrument regardless of location or soil type. Prediction intervals varied, with errors of 4.5%, 3.5%, and 7.1% for the ECH$_2$O, CT, and WCR, respectively. Only the ECH$_2$O system was significantly influenced by temperature for the range sampled: as temperature increased by 1°C, the soil moisture estimate decreased by 0.1%. Overall, the ECH$_2$O performed nearly as well as the CT, and thanks to its lower cost, small differences in performance might be offset by deployment of a greater number of probes in field sampling. Despite its higher cost, the WCR did not perform as well as the other two systems. ■

Overall, the ECH$_2$O performed nearly as well as the CT, and thanks to its lower cost, small differences in performance might be offset by deployment of a greater number of probes in field sampling.

To receive a free reprint of this paper, please contact kristy@decagon.com or 800-755-2751.

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2 Workshops Announced

SEMINAR COMMENTS

"Organisers/presenters understand the stuff; highly qualified and have updated materials for the subject."

"Good refresher if you've had a soils course or are 'rusty' on measurement technique. I noticed a number of soils 'experts' among class participants."

Decagon is offering a short course for soil scientists on measuring water content, water potential, and water flow in soils.

These workshops will be held at the following conferences:

For more info contact pat@decagon.com

■ 18th World Congress of Soil Science
July 8–15, 2006
Philadelphia, PA
July 8th, 2006

■ American Society of Agronomy
November 12–16, 2006
Indianapolis, IN
November 11, 2006

DECAGON DEVICES

Measuring Specific Surface of Soil with the WP4

	Hygrometric Surface Area (m²/g)	EGME Surface Area (m²/g)
L-soil	24	25
Royal	58	45
Walla Walla	71	70
Milville	72	73
Salkum	84	51
Palouse B	181	203
Ca-montmorillonite	597	760

Table 1. Tuller and Or (2005) specific surface calculations compared to EGME

continued from pg 1—

point when equilibrium is reached. The specific surface is then determined from the mass of retained EGME in comparison to the amount retained by pure montmorillonite clay, which is assumed to have a surface area of 810 m²/g (Carter et al. 1985). The measurement typically takes around 2 days to complete.

All Properties Are Closely Linked

Soil is typically in a hydrated state, and surface area measurements should apply to that state. It would therefore be ideal if water could be used as the probe to determine the specific surface area. Quirk (1955) reviewed such measurements and concluded that water clusters around cation sites, and can therefore lead to errors in the measurements. Recent work, however, using more modern methods for measuring the energy state of the water in the soil, show promise as simple methods for determining specific surface of soil samples. Campbell and Shiozawa (1990) correlated specific surface of six soils with measurements of the slope of a moisture release curve and found excellent correlation. Figure 1 shows the data for the six soils, along with an additional point for Ca-montmorillonite. The slope (x axis value) is equal to the water content of the sample at a water potential of -123 MPa, and is the inverse of the slope used by McKeen (1992) to quantify expansive soils, so it is clear that all these properties are closely linked.

A recent paper by Tuller and Or (2005) obtained the following equation relating surface area and the moisture characteristic:

$$w = \left(\frac{k}{6\pi\rho_w\psi}\right)^{1/3} \rho_w S$$

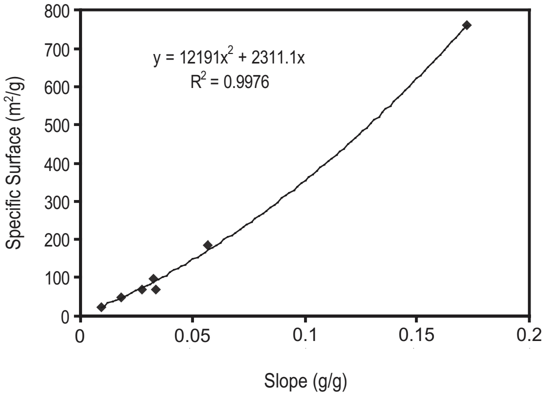
Where w is water content (g/g), ρ_w is the density of water (1000 kg/m^3), ψ is the water potential (J/kg), S is the specific surface (m^2/kg), and k is the Hamaker constant, which they took as -6×10^{-20} J.

Tuller and Or used the WP4 to obtain water potentials for samples at low water content. These, along with the measured water contents, were used to estimate surface area for the same samples shown in Fig. 1 plus one additional soil. The results are shown in Table 1.

Preliminary Findings

The agreement between the two methods is generally good. The low point here, as well as in Fig. 1 is the Salkum soil. Its area may have been underestimated by the EGME method due to the pretreatment. The montmorillonite area is also low, but that value was taken from the literature, and not re-measured in this study.

These results are preliminary, but indicate that the WP4 may be a useful instrument for determining specific surface of soils. ■



◄ Figure 1. Correlation of specific surface with slope of a log-transformed moisture release curve for six soils and Ca-montmorillonite.

REFERENCE

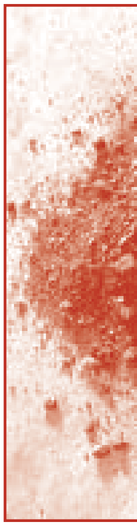
Campbell, G. S. and S. Shiozawa. 1992. Prediction of hydraulic properties of soils using particle size distribution and bulk density data. in Proceedings of the International Workshop on Indirect Methods for Estimating Hydraulic Properties of Unsaturated Soils. M. T. van Genuchten et al. eds. p. 317-328. Univ. of Calif., Riverside.

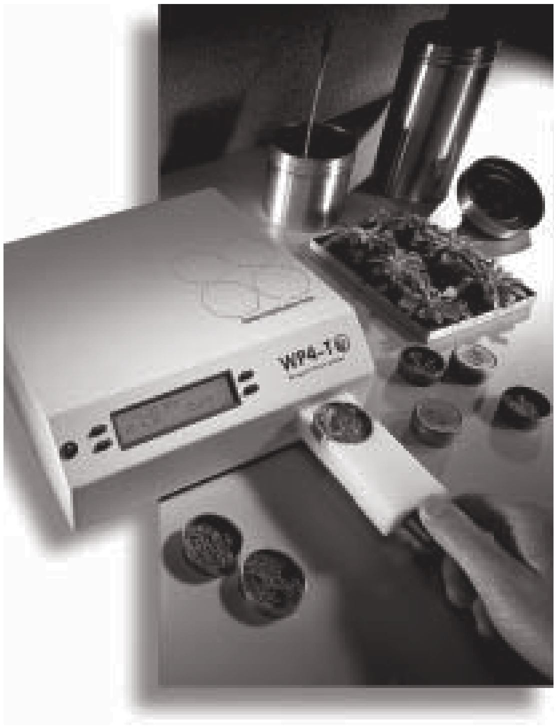
Carter, D. L., M. M. Mortland, and W. D. Kemper. 1986. Specific Surface. In A. Klute (ed), Methods of Soil Analysis, Part 1, 2nd. Ed. Agronomy 9:413-423.

McKeen, R. G. 1992. A model for predicting expansive soil behavior. 7th International Conference on Expansive Soils, Dallas, Vol. 1, p. 1-6.

Quirk, J. P. 1955. Significance of surface areas calculated from water vapor sorption isotherms by use of the B. E. T. equation. Soil Sci. 80:423-430

Tuller, M., and D. Or. 2005. Water films and scaling of soil characteristic curves at low water contents. Water Resour. Res. 41:W09403

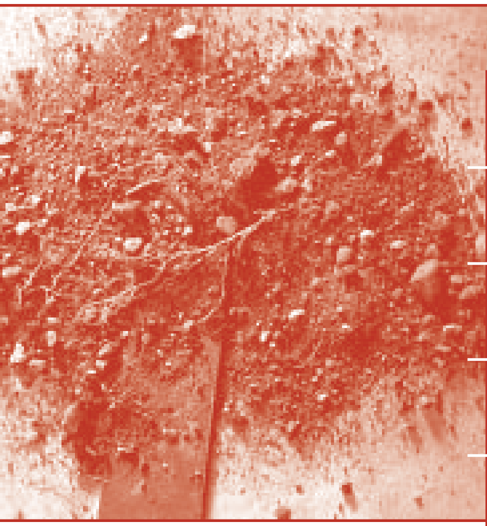




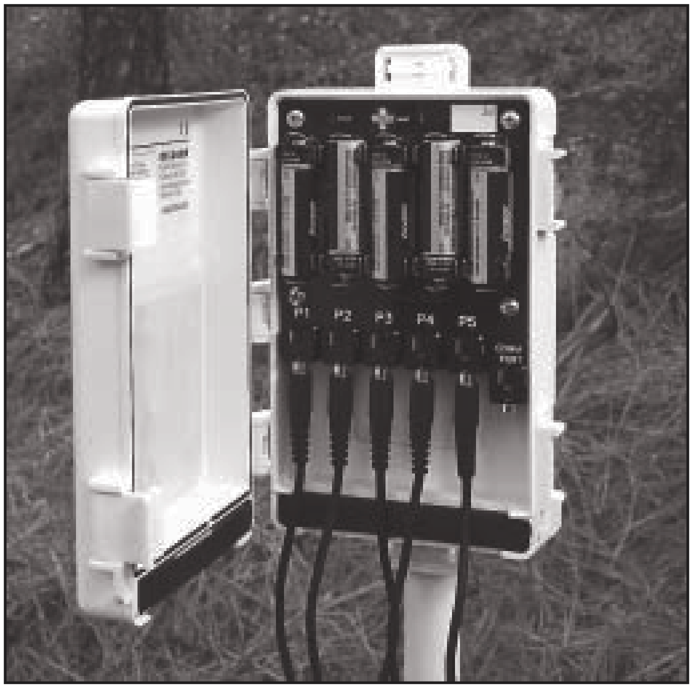
New ECH_2O Calibration Service

OUR EVALUATIONS show that the generic factory supplied calibration for ECH_2O probes results in modest (±3%) accuracy in volumetric water content measurements in most medium- to fine-textured mineral soils. However, the accuracy can be much worse (±10%) in coarse textured soils and soils with abnormally high salt content or organic matter content.

Recent tests by independent researchers (see abstract from Czarnomski et al. on page 3) indicate that soil-specific calibration of ECH_2O probes results in performance similar to that achieved with TDR at a fraction of the price. Decagon recommends that our customers perform a soil-specific calibration if absolute accuracy is desired in volumetric water content measurements. Since some users don't have the time or equipment necessary to conduct a soil-specific calibration, Decagon is now offering a service where ECH_2O probe users can send in a soil sample, and Decagon will perform a soil-specific calibration. This calibration will increase the accuracy to ±1% to ±2% for the soil tested. Additionally, calibration functions can be developed for non-soil materials (e.g. compost, potting materials). Contact tjay@decagon.com for information on this service. ■



ECH_2O Calibration	Accuracy with Factory Calibration	Accuracy with Soil Specific Calibration
Fine to Medium Textured Soil	±3%	±1% to ±2%
Sand	±5% to ±10%	±1% to ±2%
High EC (salty) Soil	±5% to ±10%	±1% to ±2%
Other Material—(compost, organic soil, potting soil, etc.)	No Factory Calibration Available	±2% to ±3%



Mars Update

FOR THE PAST TWO YEARS Decagon has been developing the Thermal and Electrical Conductivity Probe (TECP) that will fly to Mars aboard the 2007 Phoenix Scout mission. TECP combines into a single package many measurements that Decagon's sensors measure on Earth. It will measure Martian soil thermal conductivity and volumetric heat capacity (KD2 and KD2 pro), volumetric water content (ECH$_2$O probes), electrical conductivity (ECH$_2$O TE), atmospheric humidity (Safe Store), and wind speed.

Rigorous NASA Standards

At this point, nearly all the engineering of the TECP has been completed and tested to rigorous NASA standards under demanding Martian conditions. Now we have the task of calibrating the instrument functions and understanding exactly how the sensors behave under varying conditions. On Earth it is relatively simple to investigate the causes of unexpected data. However, with interplanetary sensors it is impossible to elucidate anomalous data once the sensor is sent into space. So, understanding exactly how the sensor behaves under different conditions is imperative to the scientific integrity of the data returned. This task should keep us busy for quite some time. ■

◂ The conical needles ensure good contact between the soil and the sensor.

"The nation that destroys its soil, destroys itself." —Franklin D. Roosevelt

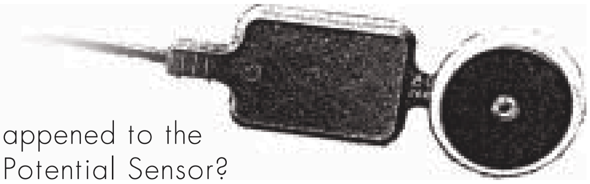
Impressions

- "Decagon has such a good reputation in our lab, always helpful and informative: I certainly will be purchasing Decagon equipment in the future!"
—Shelly Cole
University of California, Santa Barbara

- "We have very much been enjoying our ECH$_2$O Probes for application in the Panama jungle. No equipment has been doing well in Panama. But our Decagon equipment has exceeded all of our expectations."
—Justin Niedzialek
University of Connecticut

- "Thanks so much for your prompt response to my inquiry about the heat-shrink wrap. You are terrific at your job and make me feel very inclined to continue ordering products through Decagon. I really do appreciate your personal concern."
—Linda Martin
University of Kentucky

SOIL MATRIC POTENTIAL SENSOR UPDATE



What happened to the Matric Potential Sensor?

In our efforts to provide a low-cost solution for your research needs, we found improvements in electronics allowing us to decrease temperature and salt sensitivity of the probes.

Because we are putting the final developments in the probes, we must continue to delay their release. When they are released, the Matric Potential Sensor will be a superior product and well worth the wait. You will not be disappointed.

If you'd like to be added to the notification list, just let us know. 1-800-755-2751

DECAGON DEVICES

Tradeshows & Exhibits for 2006

- **The 4th International Conference on Unsaturated Soils**
April 2–6, 2006, Carefree, Arizona
- **European Geosciences Union**
April 2–7, 2006, Vienna, Austria
- **American Society for Enology and Viticulture**
June 28–30, 2006, Sacramento, California
- **18th World Congress of Soil Science**
July 9–15, 2006, Philadelphia, Pennsylvania
- **American Society for Horticultural Science**
July 27–30, 2006, New Orleans, Louisiana
- **Ecological Society of America**
August 6–11, 2006, Memphis, Tennessee
- **American Society of Agronomy**
November 12–16, 2006, Indianapolis, Indiana

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WORKING on my red 1946 Willys with my son reminds me of a "take-apart" car I had as a youth. It's easy and simple to replace things. My son and I converted the electrical system from 6 volts to 12 volts without too much trouble.

I like new gadgets, but I also like the simplicity I often find in older designs. Reducing complexity in the modern world requires better engineering and greater effort. Every instrument Decagon produces takes complex measurements in an uncomplicated way. This lowers the initial cost, reduces the number of parts, and improves long-term maintenance.

We hope you will consider Decagon for your research needs.

Bryan Wacker
Research Agriculture

VISIT DECAGON ONLINE
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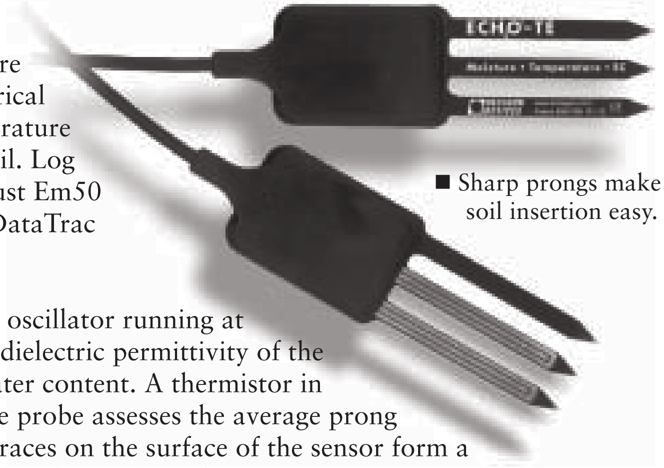
Advertisement

New ECH$_2$O-TE sensor measures water content, electrical conductivity, and temperature—all in one.

Features
- Get 3 readings per Em50 port.
- The higher frequency reduces texture and electrical conductivity effects.
- Digital measurement of soil moisture provides high accuracy readings.
- Serial communication.
- Fewer cables.

Applications
- Moisture and salinity monitoring in engineered media or artificial soil.
- Closely monitor fertigation and its results over time.
- Monitor temperature and water use over time.
- Measure temperature, water content and electrical conductivity.

THE new ECH$_2$O-TE is designed to measure the water content, electrical conductivity, and temperature of growth media and soil. Log your data with our robust Em50 logger and easy to use DataTrac software.



- Sharp prongs make soil insertion easy.

The ECH$_2$O-TE uses an oscillator running at 70MHz to measure the dielectric permittivity of the soil to determine the water content. A thermistor in thermal contact with the probe assesses the average prong temperature. The gold traces on the surface of the sensor form a four-pole array to measure electrical conductivity.

DECAGON DEVICES

Visit www.decagon.com/echo-te
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