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SOILS NEWS
2002
DECAGON

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Sacramento,CA

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August 4–9
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ASA-CSSA-SSSA
November 11–14
Indianapolis, IN

American Society for Enology and Viticulture
June 26–27
Portland. OR

17th World Congress of Soil Science
August 14-20
Bangkok, Thailand

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Inexpensive & versatile water content probe commands ±3% accuracy.

RESEARCHERS familiar with commercial water content probes will often ask three questions when approached with a newly developed dielectric sensor: what is the accuracy of the instrument, how does it react to differing soil textures, and electrical conductivity, and how much does it cost? In fact, the first two questions are closely related, as often the properties of a soil can determine the accuracy of volumetric water content reading from a dielectric probe. Poor results from probes that measure dielectric in soils with high electrical conductivity and salinity are well documented.

Soil texture and salinity effects on calibration stability.

The third question has considerable importance as well because the cost of water content sensors can limit the number of sites where water content is monitored.

A new inexpensive dielectric sensor *(trade name: ECH$_2$O)* developed by Decagon Devices, Inc. uses specialized circuitry to measure the dielectric of media surrounding a thin, fiberglass-enclosed probe. The objective of the experiment was to determine the calibration of several dielectric probes with respect to soil water content and examine the effects of soil texture and salinity on the stability of that calibration.

Methods

Six soils with differing textures were collected and allowed to dry in air for several weeks. Soil textures included loamy sand, sandy loam, loam,

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Table 1. Textural and salinity analysis for soils used in soil water content analysis.

Soil Type	Sand (%)	Silt (%)	Clay (%)	EC (mmho cm^{-1})
Loamy Sand	87	3	10	0.04
Sandy Loam	79	9	12	0.34
Loam	47	29	24	0.09
Silt Loam	*	*	*	0.20
Silt Loam	3	71	26	0.12
Silty Clay Loam	3	68	29	0.09
Silty Clay	17	41	42	1.48

* Data unavailable.

Response of the ECH_2O Soil Moisture Probe to Variation in Water Content, Soil Type, Solution Electrical Conductivity, and Temperature

Continued from page 1

silt loam, silty clay loam, and silty clay *(artificially mixed) (Table 1)*. We manually crushed each sample to break up large peds and allow uniform packing.

TO TEST the dielectric probe's response to changing water contents, tap water *(electrical conductivity (EC) < 0.1 mmho cm*$^{-1}$*)* was mixed with soil to make at least four different water contents for each soil type. Soil was then packed around the dielectric probe in a 30 cm x 15 cm x 15 cm container. Although bulk densities often increased with increased volumetric water content (θ), care was taken to standardize packing densities. Voltage outputs of probes packed in soil were recorded at each water content.

Salinity effects on probe output were also considered. To test the effect of higher EC, we made solutions of approximately 3.3 mmho cm^{-1} and 12.9 mmho cm^{-1} EC by adding 2 and 8 g, respectively, of NaCl to 1 liter of distilled water.

These solutions were added to each soil type and measurements of θ and probe output were recorded for several water contents.

Soils with high sand content may require soil-specific calibration for accuracy.

Seven dielectric probes were tested on each soil type and θ to determine the stability of calibration between probes. An ECH_2O sensor requires a fixed excitation voltage that produces an output voltage proportional to the dielectric of the medium surrounding it. A 20 ms excitation voltage was supplied to each sensor and the output voltage recorded. Four different excitation voltages, 2.5 V, 3 V, 4 V, and 5 V, were used to determine the effect of input voltage on probe output.

ACTUAL θ WAS calculated for each soil/water mix. Volumetric soil samples were collected using a hollow cylinder *(16.3 cm*^{3}*)* and dried using a microwave oven for 10 min. Volumetric water content was determined using the difference in weight before and after drying, the soil weight, and the volume of the soil sample. Three samples were taken for each soil to evaluate θ.

Water content versus probe output data was plotted for each probe and soil type. Ideally, a standard calibration would apply to all soil types and salinities, so a single regression was plotted and any large deviations considered. In addition, differing input voltages were compared to consider bias in probe output based on excitation voltage.

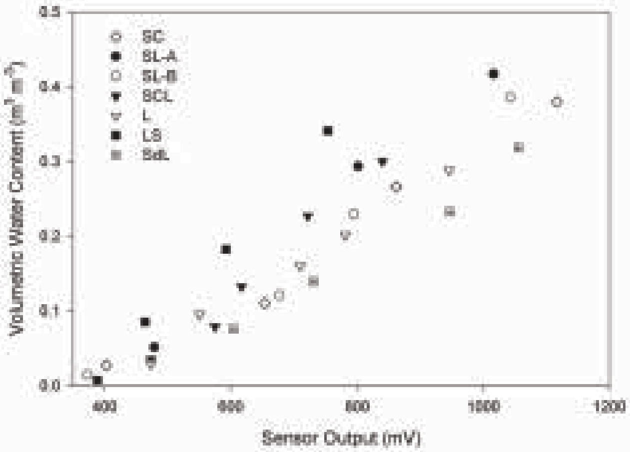

Fig. 1. Comparison of volumetric water content with probe output for a single probe in seven soil types, silty clay (SC), silt loam (SL-A and SL-B), silty clay loam (SCL), loam (L), sandy loam (SdL), and loamy sand (LS).

Results and Discussion

Dielectric probes were found to have a near linear relationship to θ for all soils tested *(Fig.1)*. Some scatter can be seen in the data, which is due, in part, to difficulties obtaining accurate measurements of θ. Dielectric sensors have a limited volume of measurement that decreases considerably with distance from the surface of the probe. Because it was likely that there were differences in bulk density between soil adjacent to the probe and at the soil surface, our inability to

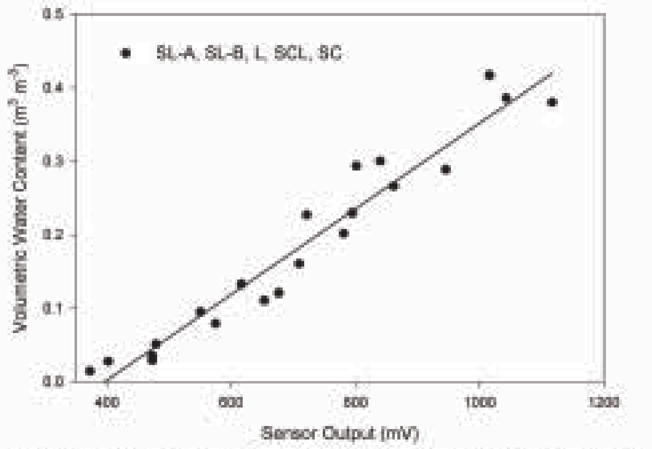

Fig. 2. Linear regression of soils with low to moderate sand content. Regression R^2 was 0.94.

measure water content directly at the surface of the probe may have lead to errors in actual θ.

A REGRESSION line through data for soil types with low to moderate sand content shows good correlation between θ and sensor output *(Fig. 2)*. However, the trend of the data from sandy loam and loamy sand both exhibits regular bias in probe output that is separate from the random variation above and below the mean exhibited by other soils *(Fig. 3)*. While the output of the sensor remains linear with θ, these data suggest soils with high sand content would benefit from individual calibration. Soils with high clay contents are also of interest because they have been shown to cause large errors in some dielectric sensor measurements. Our data show very little dependence of the ECH_2O sensor on soil textures with moderate percentages of clay *(Fig. 1)*.

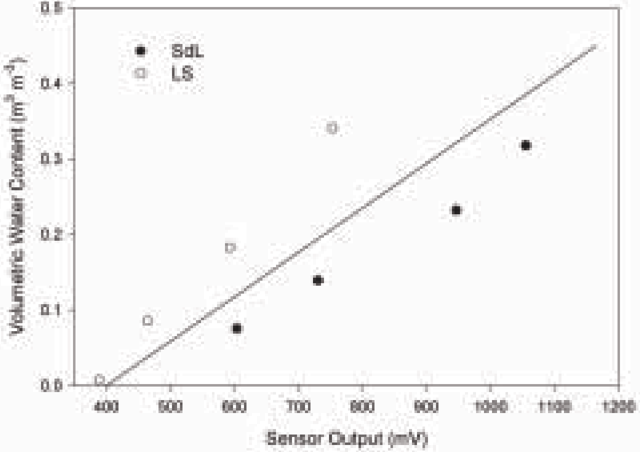

Fig. 3. Sensor output for soils with high sand content. Line indicates overall calibration line for soils with low to moderate sand content.

APPLYING a 3.3 mmho cm-1 solution to soils did very little to shift the overall calibration line *(Fig. 4)* for soils with low to moderate sand contents. Figure 4 indicates the increased electrical conductivity of the soil solution did not shift the majority of the data outside the scatter of the tap water θ.

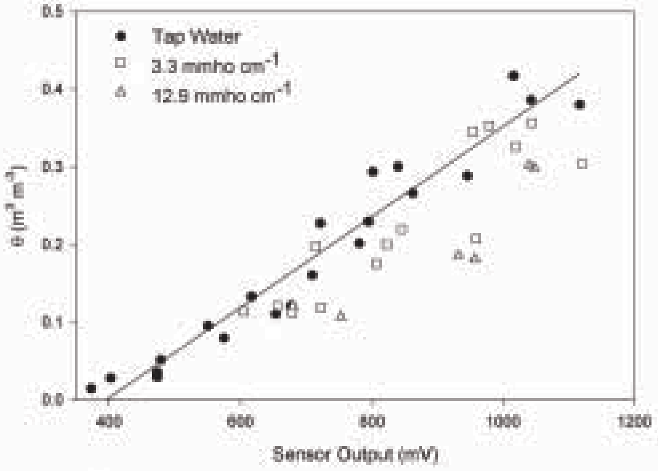

Fig. 4. Change in θ versus sensor output for increased bulk solution electrical conductivity. Data points for 12.9 mmho cm^{-1} solution were limited.

Differences in individual probes do not bias sensor output.

However, when solution EC was increased to 12.9 mmho cm^{-1}, deviations from the standard calibration are much more apparent. A calibration shift was more evident in the measurements on sandy loam and loamy sand *(Fig. 5)*.

Bias in individual sensor output was insignificant for all probes tested. Using recorded outputs at each soil water content, scatter plots were made to compare individual probe output at a given θ with all other sensor outputs at the same θ. Figure 6 shows an example of sensor versus sensor plot and regression. Regression

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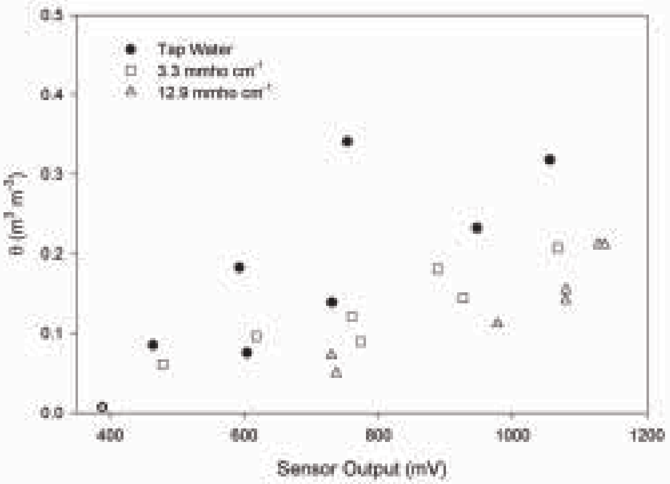


Fig. 5. Calibration of sandy soils with increasing solution electrical conductivity

lines for all probes showed a maximum of < 4% deviation from unity, suggesting that calibration is not probe specific. This result is important as it allows standard calibration functions to be applied to multiple probe outputs when multiplexed.

A universal calibration is transferrable to all probes.

Excitation voltage had no affect on the linearity of probe output. However, increased excitation voltage did reduce the sensitivity *(Δθ per unit mV)* of the probe 10, 16, and 21% for 3, 4, and 5 V excitation, respectively, compared to the 2.5 V input. Often, data recording devices are limited the range of input voltages that can be provided, so the flexibility of probe excitation is a common concern. These results suggest that higher excitation voltages can be supplied to the probe with only a small loss of sensitivity.

Summary

Probe output was shown to be linear with θ for all soil tested, but soils with high sand content had regressions that were considerably different from those of other soil types.

▶

DECAGON'S AQUALAB CX-2T water activity meter is being used by Drs. Ellis & Murdoch for pioneering work on water activity's effect in storage environments and controlling seed viability. Research is being done at the University of Reading-Seed Science Laboratory, UK.

(L. to R. Dr. Alistair Murdoch; Bryan Wacker, Decagon; Matt Galloway, Decagon; Dr. Richard Ellis)

Note: Donation to science by Decagon Devices, Inc.

Probe linear with all tested soil, except high sand content.

Combining probe readings and θ for all soils, we found that a standard calibration curve could be used to evaluate water contents to within ± 3% θ for soils with low to moderate sand content. For soils with high sand content, soil-specific calibrations would be required for accurate measurements. Increasing soil solution EC had a small effect on probe output. Again, for soils with high sand content, that effect was much more pronounced, especially at solution electrical conductivities of 12.9 mmho cm^{-1}. Differences in individual probes did not bias sensor output for the variety of soils we tested, suggesting a standard calibration can be developed for any probe and then transferred to all other probes. ◆

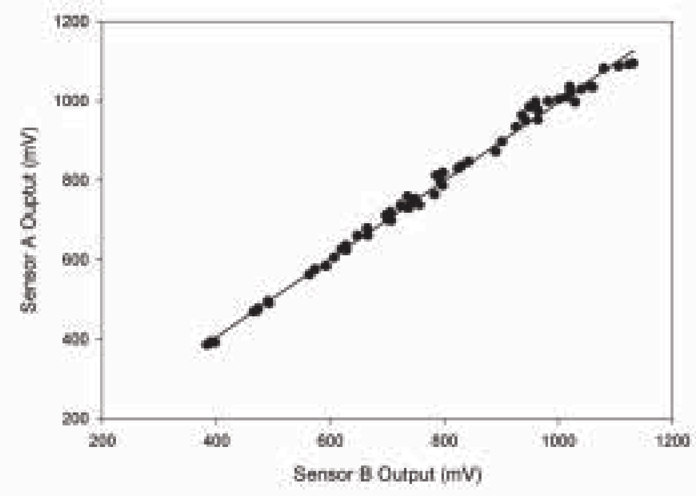


Fig. 6 Example of sensor comparison to determine calibration bias of individual probes. Regression line shows a slope of .987 and intercept of 11.4 with an R^2 = .994.

◂ ECHO Probe Specifications

Range: Zero to saturated volumetric water content.
Measurement time: 10ms.
Accuracy: ±3% typical. ±1% with soil specific calibration.
Resolution: 0.002 m/m.
Output range: Dry soil 375 to 1000mV, Air 255 to 260mV proportional to volumetric water content.
Power requirement: 2.5VDC @ 3mA.
Operating temperature: 0–50°C.
Dimensions: 10" L x 1.25" W.
Datalogger option: see NanoLogger on page 8.

◂ ECHO Check Specifications

Measurement speed: Less than 1s.
Resolution: 1mV, 0.1%, 0.01 in/ft. Adjustable calibration.
Meter accuracy: Better than 1%.
Power: 3.6 volt lithium battery.
Battery life: 3 to 4 years.
Case: Stainless steel with silicone elastomer spacer.
Case dimensions: 3.5 x 4 inches (oval).
Weight: 115 g (4oz).
Operating environment: 0 to 40°C.
Carrying case: Black 400 Denier holster with belt clip.

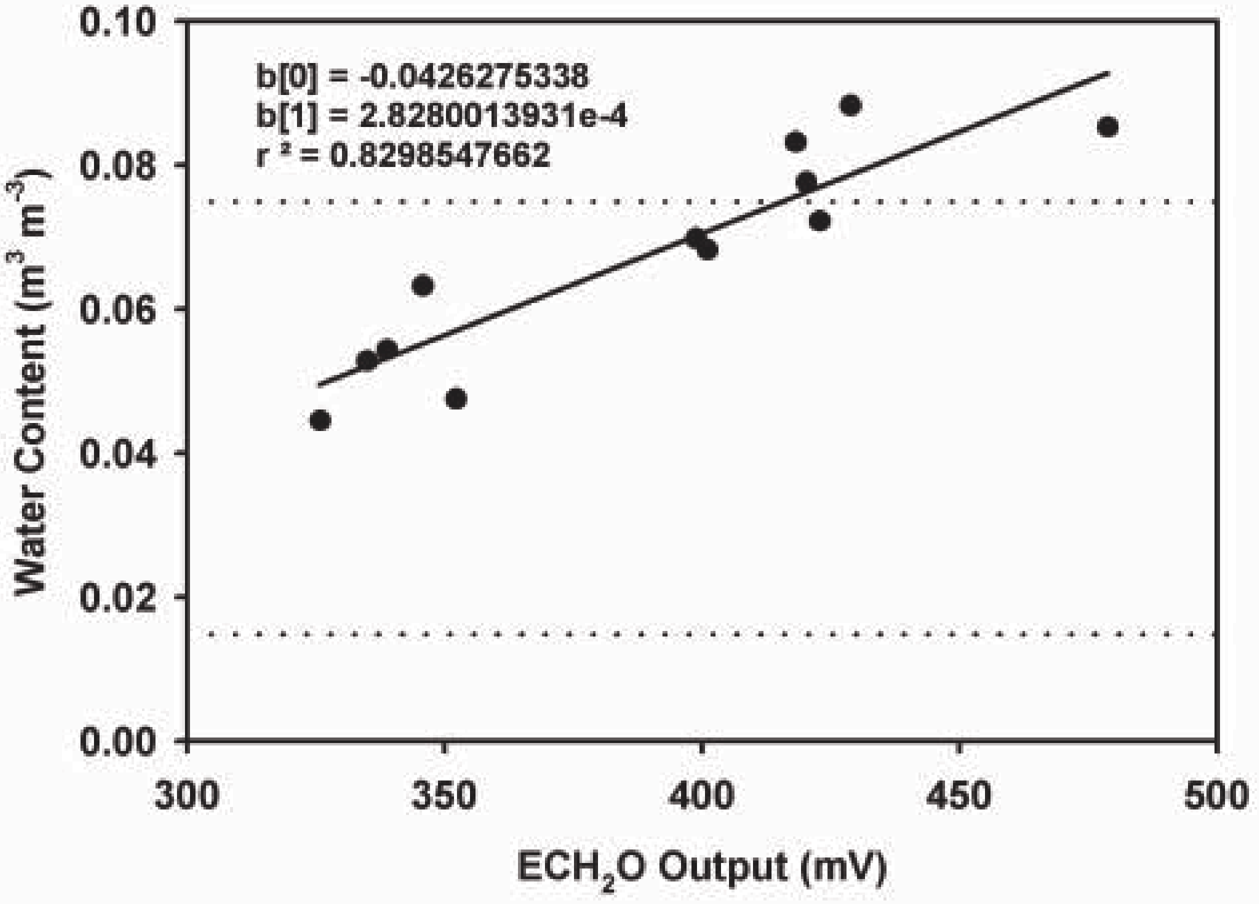
Dr. Colin Campbell and Ph.D. student Nu Nu Wai working in the WSU Soil Physics Lab.

During the spring of 2000, Decagon hired Colin Campbell, a recent graduate of Texas A&M University with a Ph.D. in Soil Science (Environmental Biophysics). Decagon offered a portion of Dr. Campbell's work time to teach Environmental Biophysics in the Department of Crop & Soil Sciences at Washington State University in Pullman.

Through this synergistic relationship, Decagon gleans new ideas for Decagon research instrumentation and also assists WSU with their teaching load. Dr. Campbell is an Adjunct Assistant Professor in the department and began teaching in the spring of 2001.

Letters

Scheduled irrigation for citrus.



Upper and lower dotted lines represent field capacity and permanent wilting point, respecitively, in the sand soil.

FOR THE SOIL used in [our] calibration, Field Capacity is approximately 7.5 % volumetrically. Wilting point is assumed to be approximately 1% volume but could be as high as 1.5%.

This is an extremely narrow range of values, making a very low value for plant-available soil water. This is why, although Florida gets a large (>50 inches) amount of average annual rainfall, we need probes that offer a high degree of accuracy in this narrow range during our dry season of October –June.

Thank you for the opportunity to work with your product. The [ECH_2O] sensors respond very well in our sand soils. They would make great sensors for scheduling irrigation and monitoring soil moisture.

I have attached a file containing the field calibration data and a plot of my data and the linear calibration provided. The calibration provided extremely low values and good linear fit was made which will make [ECH_2O] sensors very useful in our soils.

Kelly T. Morgan
University of Florida
Citrus Research and Education Center
Lake Alfred, FL

LETTERS from Customers

2

Customer service.

Thanks for everything. The nanovoltmeter arrived and is working fine, and the shallow cups make me very happy. I’m glad I got your help just in time. Again, thanks for everything.

Your attention to detail was obvious ... and level of assistance unprecidented.

Eric Graham
Smithsonian Tropical Research Institute
Panama City, Republic of Panama

For more information visit our website:
www.decagon.com/soils

3

Testing Thermal Properties of Native Soils in Australia— A Letter.

WE ARE up and running using using the KD2 Thermal Properties Analyzer to test the native soil along the route.

The Murraylink Project is a privately funded electricity transmission project, which will be owned by the Murraylink Transmission Company. MTC has been recently formed by Transenergie Australia (a division of Tranenegie US) and SNC Lavalin.

MTC has let the design, engineering and procurement contract to ABB, and ABB have let the civil contract (i.e. trench and install the cable) to PIHA.

The transmission will link the South Australian and Victorian electricity grids using dual underground high voltage, direct current cables.

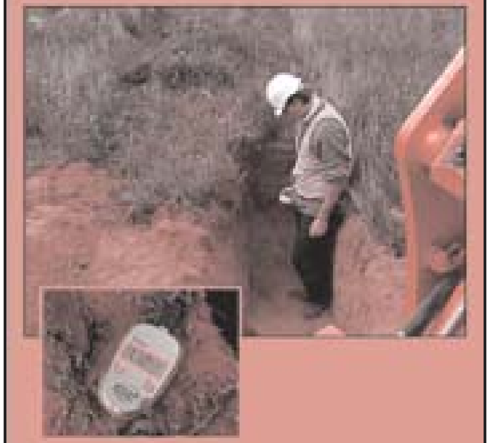
The connection points will be at Red Cliffs in Victoria and Berri in S.A.

The cable will be buried in between at 1200mm cover, for a distance of 180 kilometres.

I have attached some digital photographs taken today on site, I hope they are useful to you,

Regards,
Robert Mc Donald
PIHA Project Manager

Worker uses KD2 in Australian trench to measure thermal resistance.



Application Note List

Seed Longevity in Storage is Enhanced by controlling Water activity
Educational piece on seed duration in storage.

Measurement of Leaf Water Potential using the WP4
Recommended procedure and example results.

Field Portability for WP4 Dew Point PotentiaMeter
Setting up a car battery/inverter for remote operation.

Water Potential: The Key to Successful Seed Priming
Primer on priming.

Generating a Soil Characteristic using the WP4
Moisture release curve procedure- Our most popular "how-to" application note.

Measuring Soil Hydraulic Conductivity with a Disk Infiltrometer
Theory, serves as manual for Mini Disk Infiltrometers.

Response of the Echo Soil Moisture probe to Variation in Water Content, Soil Type, Solution, and Electrical Conductivity.
ECHO performance under varying environmental parameters.

Changing the Calibration of the ECHO Check Hand-held Reader
How to fine tune your meter for sandy soils.

Measuring Water Content in Organic Soils using ECHO Probes
Calibrating for potted plant and greenhouse applications.

Response of ECHO Soil Moisture Sensor to Temperature Variation
Analysis of temperature effects and recommendations.

" … and we can save 700 lira by not taking soil tests."

Low-cost Echo Probe Datalogger

▲ Advance product announcement.

Model: EM5 Nano Logger.

Channels: 5.

Storage: 25,000 measurements.

Communication: RS232 and spread spectrum radio *(5 miles line-of-sight)*.

Resolution: 12-bit analog-to-digital conversion.

Power: 4 AAA alkaline batteries.

Instrumentation Progress

Six years ago Decagon's soils instrumentation consisted of only one instrument for measuring water potential. Today we have broadened our instrumentation significantly. The newest instruments available in 2001 are the ECH_2O probes and the soon-to-be released EM5 Nano Logger.

All this progress cannot be attributed to a single individual; it is a group effort of many talented and dedicated individuals. In the future, we hope to continue to serve your soil research needs with innovative soils instrumentation.

Bryan Wacker
Soils Product Manager

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