DECAGON
2007

Canopy News

Beam Fraction Calculation in the LP-80

The radiation reaching the probe of the LP-80 can come directly from the solar beam, or be scattered from the sky or clouds. These two sources are affected differently by canopy architecture and must, therefore, be treated separately in the computation of leaf area index from canopy transmission measurements. The information needed to make the computation is the beam fraction, or ratio of radiation that comes directly from the solar beam to the total radiation (beam plus scattered or diffuse PAR) incident on the probe. The previous version of AccuPAR (model PAR-80) required the user to measure beam fraction by shading the probe. The AccuPAR (model LP-80) computes it using measurements it has available. The method used is

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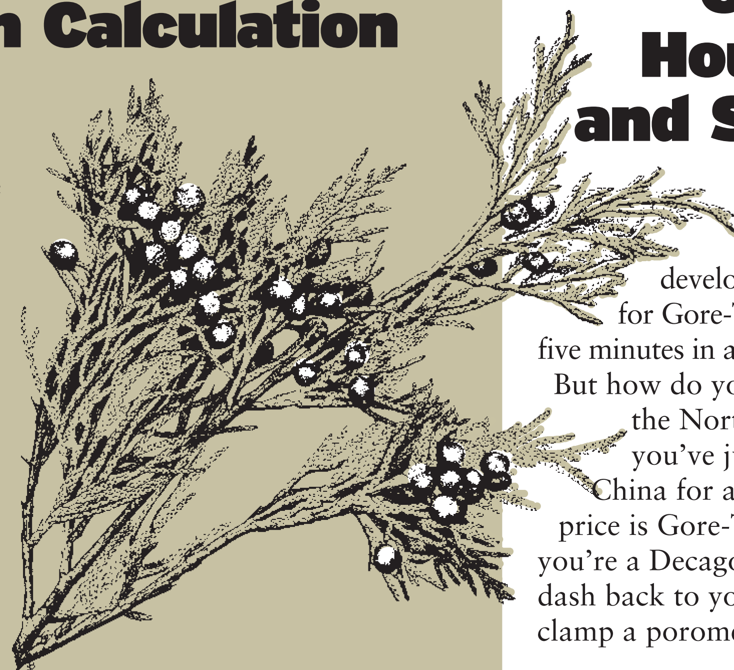

▲ Rocky Mountain Juniper, *Juniperus scopulorum*, is a small tree native to western North America. One particular living specimen, the "Jardine Juniper" is 1500 years old based on a 1950's core sample. The tree is rooted on a high rock protecting it from forest fires.

Do you measure leaf wetness?

If so, do you paint and calibrate your leaf wetness sensor? A significant body of leading researchers in leaf wetness and plant disease suggests you should paint and calibrate them for accurate measurements (e.g. Gillespie and Duan, 1987; Lau et al., 2000; Sentelhas et al., 2004).

With the standard resistance grid leaf wetness sensor, wetness is only sensed when water droplets are large enough to bridge the gap between two fingers in the grid and lower the effective resistance. Researchers recognized this fact long ago, and have tried to devise methods that would allow the sensors to detect small water droplets that are typical of the onset of dew. The methods tried have ranged from laying cloth on top of the sensor to the current standard method: painting the sensor surface with latex paint. Instead of water actually bridging the traces, the

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Gore-Tex, House wrap and Stomates

Want to develop an appreciation for Gore-Tex? All you need is five minutes in a rubber raincoat. But how do you know whether the North Face knock-off you've just purchased in China for a ridiculously low price is Gore-Tex or rubber? If you're a Decagon researcher, you dash back to your hotel room and clamp a porometer onto the fabric.

Decagon's porometer was designed to measure stomatal conductance in leaves. It's typically used by canopy researchers to relate stomatal resistance to canopy attributes like water use, water balance, and uptake rates of herbicides, ozone, and pollutants. It's small, accurate, and perfectly easy to use—you just grab, clamp, and get the reading.

The sensor head for the porometer is a clamp holding two relative humidity sensors mounted along a fixed diffusion path. By measuring the vapor concentration at two different points along this path, it's possible to compute stomatal conductance in leaves (see sidebar)—and measure water loss in a whole range of other materials.

▸ From the very beginning, Dr.

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Stomatal Conductance for

TRADESHOWS 2007

American Society of Enology & Viticulture
June 19-22, 2007
Reno, Nevada

American Society for Horticultural Science
July 16-19, 2007
Scottsdale, Arizona

American Phytopathological Society
July 28-August 1, 2007
San Diego, California

Ecological Society of America
August 5-10, 2007
San Jose, California

American Society of Agronomy
November 4-8, 2007
New Orleans, Louisiana

Campbell, the porometer's designer, saw the possibilities: "Give this to someone with only a passing interest in research, a ten year old kid for example, and they'll go around the garden and come back with some really interesting observations," he said. "There are lots of questions about what loses water and what doesn't that you can answer with this instrument."

Dr. Campbell was probably thinking the questions would be about organic material—but it hasn't always turned out that way. By putting a wet paper towel on one side of an inorganic material and clamping the towel and the material into the porometer head, you can measure how well water vapor diffuses through the material.

Using this strategy, the researcher in China discovered that his raincoat was pretty much impermeable (unlike real Gore-Tex, which is a good vapor conductor). Spotting the fake North Face coat is now a favorite part of Decagon's canopy seminar. And the coat is not the only leafless item that has been tested. "People will clamp the porometer on just about anything," Doug Cobos, a Decagon research scientist, admitted. He himself grabbed it when a local contractor brought in a sample of some supposedly unique house wrap.

Siding is supposed to protect a house from the elements, but most building codes now require that houses be wrapped under the siding. House wraps provide a secondary defense against liquid water and increase energy efficiency by preventing drafts. As with raincoats, high performance house wrap needs to repel water and stop wind while remaining permeable to water vapor.

The practice of applying a sheathing of tar paper under siding is a hundred years old, but in the last fifteen years, hightech house wraps made from polypropylene in combination with a push towards energy efficiency have made the house wrap market big and competitive. Upstart wraps try to gain market share through innovation, and the one brought in by the local contractor came along with an outlandish claim. According to the manufacturer's rep, this plastic wrap would allow water vapor to diffuse out while preventing any from diffusing in. Some builders might have scratched their heads and moved on. Our local man decided to check it out. He brought a sample of the mystical wrap to Decagon. Out came the porometer and a quick scientific study of house wrap was born.

◄ Anise, *Pimpinella anisum*, is a flowering plant of eastern Mediterranea and southwest Asia. The white flowers are produced in dense clusters. The fruit is oblong, dry, and splits into single seeded portions. Anise can make a sweet and very aromatic liquid scent smelling similar to liquorice. It's put on fishing lures to attract fish.

Gore-Tex, House wrap and Stomates

Dr. Cobos tested industry standard Tyvek house wrap along with the great one-way pretender. The results? “The vapor conductance of the new material was basically the same, regardless of which side of the material faced wet filter paper,” Dr. Cobos said. “And, in fact, the material didn’t diffuse well at all-its conductance was similar to cheap perforated plastic. It didn’t come close to the performance of Tyvek.” Ultimately, the newfangled wrap was retested by the manufacturer and taken off the market.

Probably the porometer’s best and highest use is still in canopy research, but its affordability, its portability, and its sheer practicality make it an every day kind of instrument. It gets pulled out to measure whatever seems interesting, organic and inorganic alike. That dovetails with Dr. Campbell’s vision of it as an affordable tool for routine use in canopy studies-and everywhere else. Can you use it on yourself? “Oh sure,” says Dr. Campbell. “People clamp the porometer on their fingers all the time. That’s a quick way to see if it’s working.” He grins. “Maybe you could use it as a lie detector on your kids.” ■

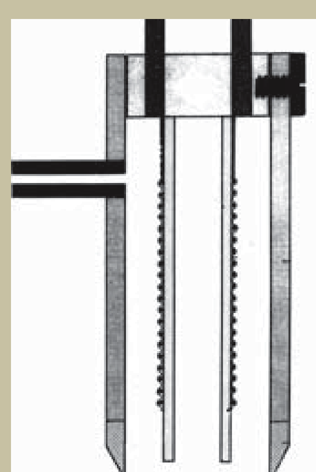
History of the Porometer.

The first work on measuring stomatal openings started in the late 1930’s with scientists like M.C. Desai, F.G. Gregory, and H.L. Pearse. These pioneers would strip the leaf epidermis, make impressions with collodion, look at infiltration with liquids and observe stomata with direct microscopic investigation.

The 1960’s opened new possibilities to make measurements with the advent of the Dunmore electronic humidity sensor. This sensor was not very good in retrospect, but it helped launch the concept of the hand-held porometer with Ellis Wallihan’s research and design.

With the advent of the Vaisala fastresponse capacitance humidity sensor in the 1970’s another leap forward was made. At this point the commercialization of porometers by Licor and Delta-T put the measurement into the hands of researchers that could not build their own equipment. Licor’s design was based on work by C. van Bavel , C. Tanner, and E. Kanemasu. Across the Atlantic, Delta-T used designs based on work by J. Monteith.

As in the past, technology progresses, and now new and improved humidity measurement technology is available, allowing Decagon to provide a new, low cost porometer.



◄ Ellis Wallihan’s porometer design with the Dunmore electronic humidity sensor (circa 1960.)

DECAGON DEVICES

www.decagon.com/canopy

Is it time to recalibrate your AccuPAR LP-80 External Quantum Sensor?

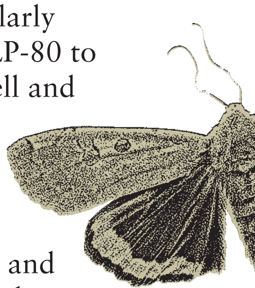
The question of sensor calibration is never far from the mind of an experienced scientist when making measurements in the field. Inaccurate sensor calibrations can cause headaches like hours of data adjustment in the lab, or complete loss of information from an experiment. As it says in the manual, the LP-80 Ceptometer is calibrated by matching the output of its 80 sensors to the external quantum sensor, made by Apogee Instruments Inc., which has been calibrated to a NIST traceable standard. Under standard field conditions, Apogee recommends the quantum sensors be sent in every two years for recalibration. Since the quantum sensor attached to the LP-80 will not experience the same continuous, harsh field conditions, we recommend calibrating the external quantum sensor every three years.

Sending the external quantum sensor in for recalibration is simple and relatively inexpensive. Apogee has agreed to handle the entire calibration procedure so the sensors can be sent directly to them. Please note that you will only need to send your external quantum sensor and not the LP-80 to Apogee for calibration. To get your sensor recalibrated, call Apogee ((435) 792-4700) to obtain a return material authorization (RMA) number and a quote for the calibration.

When you receive your newly recalibrated quantum sensor back from Apogee, you will need to recalibrate your LP-80. This process is explained fully in the manual in Chapter 7: Setup Menu: Calibrate Probe. First you will need to go to the external sensor constant calibration screen in your Setup menu. There you will input the calibration constant. Next, go to the calibration screen in your Setup menu and follow the steps on the screen by leveling your probe and quantum sensors (a flat surface will work too if both quantum sensor and LP-80 are at the same angle), ensuring PAR is over 600 umol m^{-2} s^{-1}, and pressing Enter on the LP-80. Once you have completed these steps, your LP-80 and external sensor are ready to be used again.

Updating LP-80 Firmware and Software

As with any firmware or software, Decagon is regularly updating the code in the LP-80 to ensure it is functioning well and free from bugs. If your LP-80 is running firmware earlier than 1.34 (i.e. 1.33 and older), you need to get an RMA# and send your instrument in to have the latest code loaded on your instrument. You can check your firmware version by moving to the Setup tab using the Menu button, scrolling down to "About", and pressing Enter. The Firmware version will show on the screen along with other information. Please call Decagon's Technical Support Department and they can help you through this process.



▲ *Noctua*

In addition to running the latest LP-80 firmware, please be sure you have the latest data retrieval software program running on your computer. AccuLink version 2.2 is now available and can be downloaded online at http://www.decagon.com/instruments/agdownload.html#AccuPAR. You may also get this program on a CD from Decagon upon request. ■

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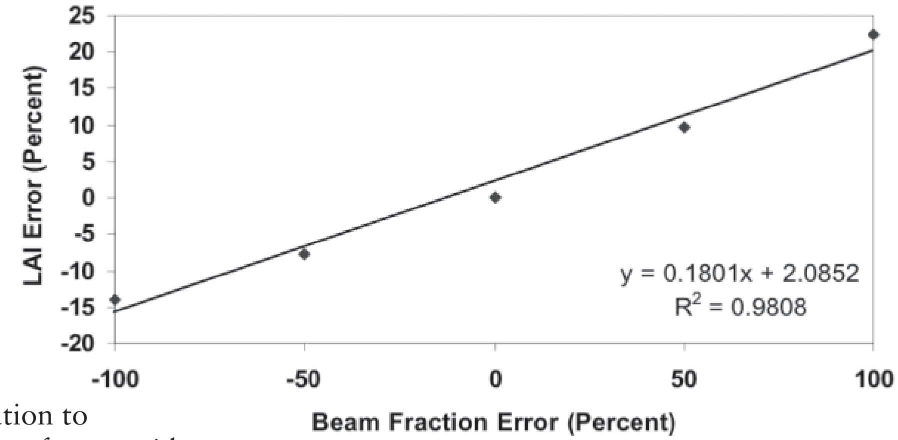
Beam Fraction Calculation in the LP-80



▸ modified from one published by Spitters et al. (1986) to find beam fraction for total radiation. They correlated beam fraction with the ratio of measured total global radiation to potential radiation on a horizontal surface outside the earth's atmosphere.

pronuba moth.

The above canopy measurement of PAR from the LP-80 is the total global PAR value. Since latitude and time of day are known, the potential PAR (PAR on a horizontal surface outside the earth's atmosphere) can be computed. The ratio of these two measurements is related to the fraction of the total PAR in the solar beam just as Spitters et al. did. The method used by the LP-80 is as follows:

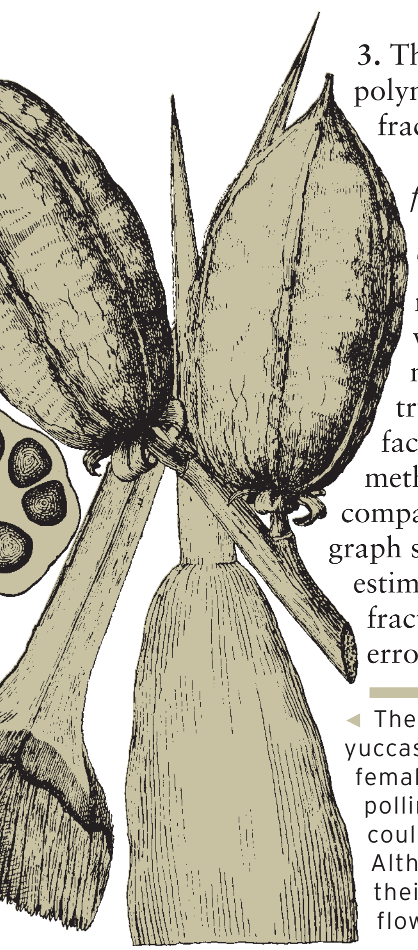
1. Compute the fraction of potential PAR that reaches the probe. This is the PAR "solar constant" times the cosine of the zenith angle, divided into above canopy PAR reading. We assume the PAR "solar constant" to be 2550 mmol/m^2/s.

2. A value of 0.82 or above is set to 0.82, a clear sky; a value of 0.2 or below is set to 0.2, a fully diffuse sky.

3. The fraction *r*, is used in the following empirical polynomial, derived from data, to compute beam fraction:

$$f_b = 1.395+r(-14.43+r(48.57+r(-59.024+r24.835)))$$

This approach is likely less accurate than a direct measurement of f_b, if that measurement were done very carefully, but it is difficult to do direct measurements of f_b on a routine basis while one is trying to measure canopy interception or LAI. In fact, the errors introduced by the approximate method used in the LP-80 are typically small compared to other measurement errors. The above graph shows the error in LAI as a function of error in estimating beam fraction, assuming a constant beam fraction of 0.4 was used for all LAI calculations. This error is independent of LAI. The calculations are for a zenith angle of 30 degrees. Larger zenith angles have smaller errors. The graph shows that the error in LAI is always smaller than ± 20%. For a 10% error in beam fraction the error LAI is around 2%. It is difficult to know how large errors in the LP-80 method for computing beam fraction could be since that depends on conditions, but they are likely in the range 10 to 20%. The error this introduces into the LAI calculation is therefore in the range of 2 to 4%, which is considerably smaller than uncertainties from spatial variability in the measurement of LAI. ■



◂ The Joshua Tree, *Yucca brevifolia*, the largest of the yuccas, grows only in the Mojave Desert and relies on the female Pronuba Moth for pollination. Without the moth's pollination, the Joshua Tree could not reproduce, nor could the moth, whose larvae would have no seeds to eat. Although old Joshua Trees can sprout new plants from their roots, only the seeds produced in pollinated flowers can scatter far enough to establish a new stand.

Reference

Spitters, C. J. T., H. A. J. M Toussaint and J. Goudriaan. 1986. "Separating the diffuse and direct component of global radiation and its implications for modeling canopy photosynthesis. Part I. Components of incoming radiation." Agric. Forest Meteorology 38:217-229.

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Do you measure leaf wetness?

resistance of the latex paint itself changes when wet, causing the output of the probe to change.

There is, however, one major flaw with this method, that many researchers may not be aware of. In order for the latex paint to take up water and achieve a resistance change, it has to be hygroscopic in nature. As with most hygroscopic materials, the latex paint is indifferent to what state the water is in, and will absorb water vapor just as readily as liquid water. Gillespie and Duan (1987) and Sentelhas et al. (2004) have suggested this effect can be minimized by baking the latex paint to remove some of the hygroscopic elements, making the sensor less sensitive to water vapor. However, even this specialized protocol doesn't fully remove the effects of water vapor. We collected field data with a standard resistance grid leaf wetness sensor painted with latex paint and baked according to Gillespie and Duan (1987). The air temperature and relative humidity were measured adjacent to the leaf wetness sensor, and the temperature of the leaf wetness sensor itself was measured with a fine wire thermocouple to allow calculation of the relative humidity of the sensor surface (rh_s). Figure 1 shows the sensor resistance plotted against rh_s. With this particular sensor, the dry resistance is about 7000 kΩ, and any resistance less than that baseline value would generally be considered to indicate a wet sensor. It is clearly apparent from the plot that even the carefully treated and baked sensor begins to give false positive results above about 70% relative humidity. In fact, it is apparent from Figure 1 that at all times when rh_s is above 90%, a false positive is registered by the painted probe.

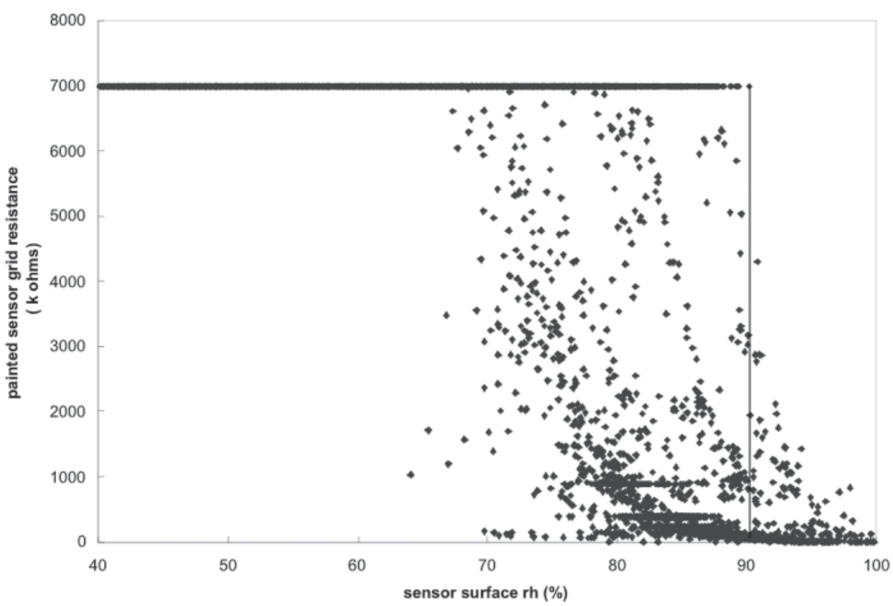

Figure 1. Grid resistance of a painted, baked resistance type leaf wetness sensor as a function of sensor surface relative humidity (rh_s). Data were collected over a 60 day period in the summer and fall of 2005. Periods during and after rainfall and dew events were carefully removed from the data set, so any resistance less than the baseline level of 7000 kΩ are false liquid water events.

Some researchers combat the hygroscopic effects apparent in Figure 1 by individually calibrating each painted sensor. One common calibration method is to seal each sensor in an isothermal container over a pool of water, and record the sensor resistance at equilibrium in the 100% rh conditions that result. This value is then taken to be the new baseline value. As one might imagine, this is a tedious and time consuming activity.

A recently developed leaf wetness sensor (model LWS, Decagon Devices) uses a different method for measuring surface wetness. Instead of measuring the resistance between metal grid fingers, the sensor measures the dielectric constant of the surface of the sensor. With the dielectric method, droplets don't need to be large enough to bridge adjacent traces, so any amount of liquid water on the surface of the probe is measured, no matter what the droplet size. This eliminates the need for painting the sensor. Extensive testing has shown no hygroscopic effects are present below about 98.5% rh_s and that those between 98.5% and saturation aren't large enough to register as false positive values. The dielectric leaf wetness sensors are also individually calibrated before leaving the factory so that each sensor reads exactly the same baseline dryness, thus eliminating any need for user calibration. Figures 2 and 3 show data collected with a painted resistance grid sensor and a dielectric leaf wetness sensor respectively during onset of a typical nighttime dew event. From Figure 2, it is apparent that the hygroscopic response of the painted sensor can lead to significant overestimation

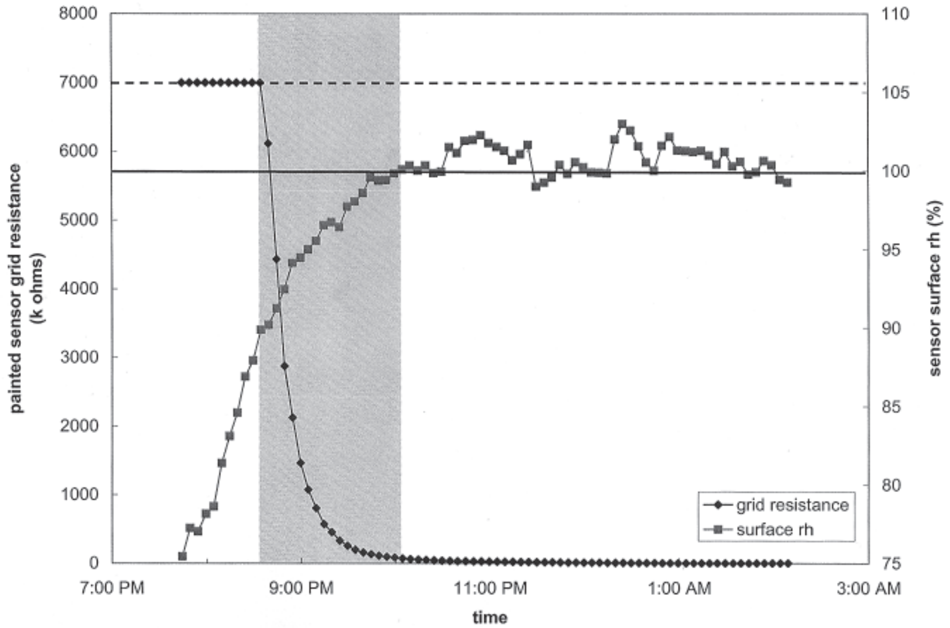

Figure 2. Grid resistance and surface relative humidity of a painted, baked resistance grid leaf wetness sensor over the onset of evening dew. The dashed horizontal line indicates the dry resistance of the sensor, with anything less than that threshold indicating surface wetness. The solid horizontal line indicates 100% rh_s when dew will just begin to form on the sensor surface. The gray zone indicates the time duration when the sensor indicates liquid water, but none is present.

of leaf wetness duration (in this case over 1.5 hours) if the sensor is not individually calibrated after painting. Figure 3 shows data from the same dew event collected with a dielectric leaf wetness sensor with no painting or calibration by the user. The dielectric leaf wetness sensor underestimates leaf wetness duration by 5 minutes.

The data presented above make a convincing argument that the new dielectric leaf wetness sensor will provide more accurate results than an un-painted or painted and un-calibrated resistance grid leaf wetness sensor, with none of the hassles of painting, baking or individual calibration. ■

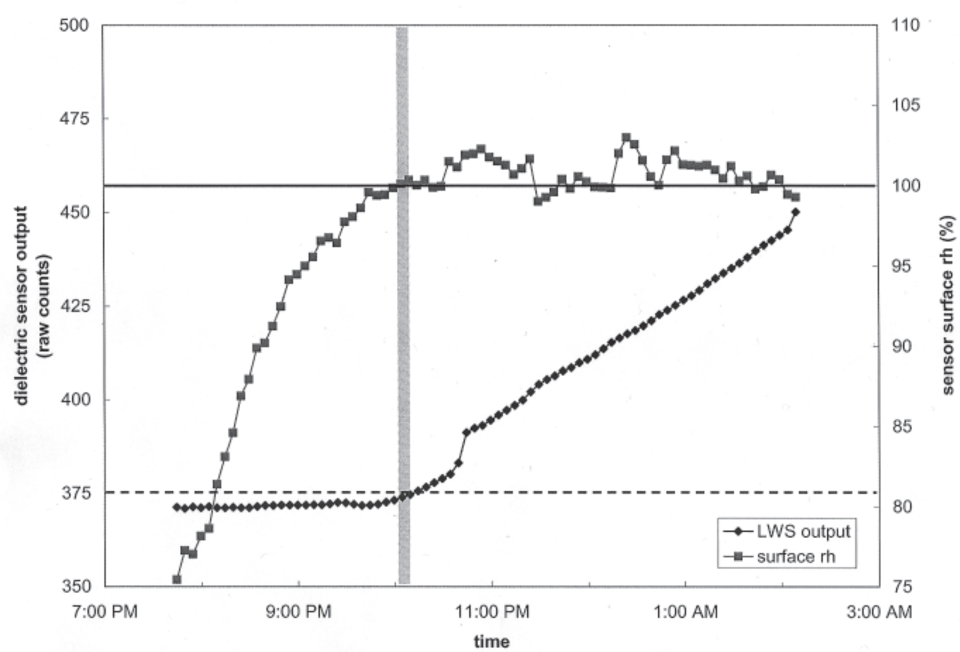

Figure 3. Sensor output and surface relative humidity of an out-of-the-box dielectric leaf wetness sensor over the onset of evening dew. The dashed horizontal line indicates the dry baseline output of the sensor, with anything greater than that threshold indicating surface wetness. The solid horizontal line indicates 100% rh_s when dew will just begin to form on the sensor surface. The gray zone indicates the time duration when the sensor indicates liquid water, but none is present.

References

Gillespie T.J., Duan R.X., 1987. "A comparison of cylindrical and flat plate sensors for surface wetness duration." Agric For Meteorol 40: 61–70.

Lau, Y.F., Gleason, M.L., Zriba, N., Taylor, S.E., Hinz, P.N., 2000. "Effects of coating, deployment angle, and compass orientation on performance of electronic wetness sensors during dew periods." Plant Disease 84:192–197.

Sentelhas, P.C., Monteiro, J.E., Gillespie, T.J., 2004. "Electronic leaf wetness duration sensor: why it should be painted." Int J Biometeorol 48: 202-205.

Greetings from Bryan

EVERY WINTER my plants reach the low ebb in their existence. Some skirt death and others succumb to the shortened days and my lack of interest in gardening. During these gray days, the only time my green thumb starts to twitch is when I enter the R&D Department at Decagon. They have two grow-lights they use for their testing. They grow lush wheat and grass, that would make my yard look bad in the height of summer, for sensor development and testing during the dead of winter.

Now that we have moved into a building with an atrium, the facilities people are busy asking me for suggestions for plants that will flourish in this setting. We can't afford to put in big grow lights so we are going to have to work with what Mother Nature gives us. Time to get out the LP-80 and measure the PAR values, do some conversions and look for plants that will flourish in this environment. If you get a chance to come and visit Decagon you can see if my measurements were correct—or if we have artificial plants.

Regards,

Bryan Wacker

Good news for everyone who owns or wants a leaf wetness sensor!

CAMPBELL SCIENTIFIC INC. (CSI) has begun selling and supporting Decagon's leaf wetness sensor. If you have an interest in measuring leaf wetness and have a CSI data collection system, weather station or are planning to install one, the Decagon leaf wetness sensor (LWS) may be a good solution for you. CSI has incorporated programs for their popular shortcut software to support the LWS with CSI loggers. Contact Decagon or CSI for more information on implementing the leaf wetness sensor with CSI data loggers. ■

◄ Skullcap, *Scutellaria alpina*, is used in traditional medical systems of China, India, Korea, Japan, European countries, and North America. The base of the flowers resemble miniature medieval helmets or English Skullcaps. Above ground plant parts are used as an anti-inflammatory, abortifacient, antispasmodic, slightly astringent, fever reducer, relaxant, sedative, and a strong tonic. It's, also, a potentially toxic antibacterial.

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