DECAGON DEVICES

Application Note

Do you measure leaf wetness?

Date: April 3, 2007

If so, do you paint and calibrate your leaf wetness sensor? A significant body of research by leaders in leaf wetness and plant disease research 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 range 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 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 sensors itself was measured with a fine wire thermocouple to allow calculation of the relative humidity of the sensor surface (rhs). Figure 1 shows the sensor resistance plotted against rhs. 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 rhs is above 90%, a false positive is registered by the painted probe.

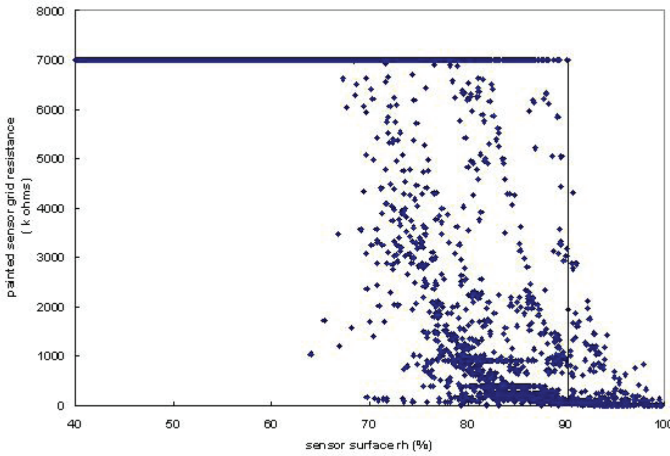

Figure 1. Grid resistance of a painted, baked resistance type leaf wetness sensor as a function of sensor surface relative humidity (rhs). Data were collected over a 60 day period in the summer and fall of 2005. Periods during and after rainfall and dew events were carefully removed from the data set, 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% rhs 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 tuned before leaving the factory so that each sensor reads exactly the same, 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 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.

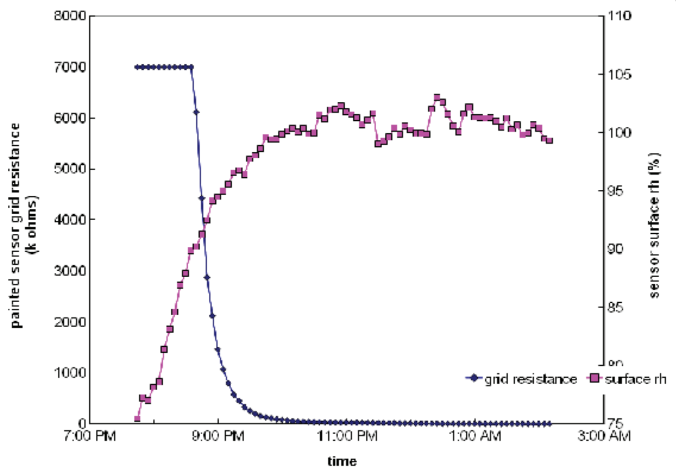

Figure 2. Grid resistance and surface relative humidity of a painted, baked resistance grid leaf wetness sensor over the onset of evening dew. The dashed horizontal line indicates the dry resistance of the sensor, with anything less than that threshold indicating surface wetness. The solid horizontal line indicates 100% rhs 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.

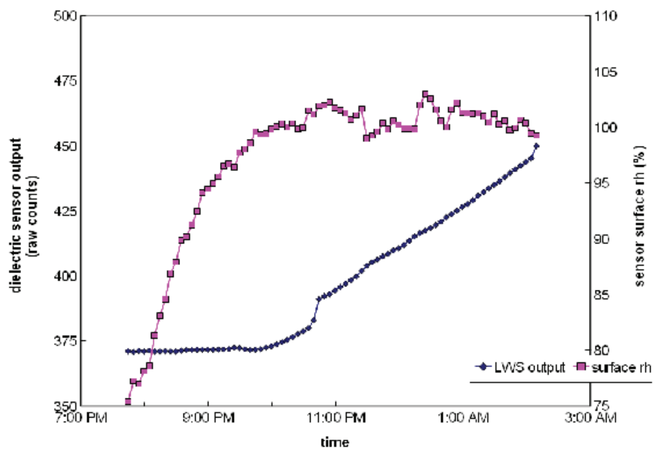

Figure 3. Sensor output and surface relative humidity of an out-of-the-box dielectric leaf wetness sensor over the onset of evening dew. The dashed horizontal line indicates the dry baseline output of the sensor, with anything greater than that threshold indicating surface wetness. The solid horizontal line indicates 100% rhs 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.

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 and baking or individual calibration.

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.