A First Look at Decagon's New Porometer: Understanding the Four Methods to Measuring Stomatal Conductance

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I'm looking at a desk full of scientific equipment, an array of commercially available porometers. It looks like a setup for the game "One of these Things is Not Like the Other One," and Decagon's new offering is the odd one out. Among larger instruments sprouting hoses and cables, the sleek little unit, about the size of a pocket dictionary, looks remarkably simple. Just one cable connects to a sturdy sensor head. Decagon's Research Products Manager, Bryan Wacker, worries that it might be a little too much of a good thing. "I can just hear people saying, 'No air tubes, no dessicant, no motor, no fan? How can this be a porometer?' " he explains.

I'm trying to listen, but I already have the instrument in my hand and I've clamped it onto his office plant, which is giving me a very low reading. He waves me off. "It's been a while since I've watered. Here, come try Kristi's plants. She's one of those daily waterers." I soon discover the fascination of this porometer – it's like getting a new pair of glasses. Suddenly I'm seeing a new dimension to the world. I want to test every leaf in sight. It's the kind of instrument even a kid could love – intuitively easy to both use and understand. In fact, a beta tester wrote, "Thanks for sending the instructions. I don't need them."

It's clearly a very cool thing, but does it work? Is it really possible to measure stomatal conductance without drying and blowing any air? For the answer, I go talk to Dr. Gaylon Campbell, the brains behind this new technology. He explains that up until now, porometry has pretty much been about pumping air into and around leaves. Early "Mass Flow" porometers used a blood pressure bulb and valve in combination with a medical clamp and hose to force air through a leaf. By pressurizing air on one side of the leaf and timing pressure drop, researchers hoped to measure flow through the stomates. These porometers could indicate whether stomates were open or closed, but did little else.

Forcing air through the leaf was physiologically unsound – it forced stomates to open and the readings taken were not very useful. Crude "Null Balance" porometers were built and used by researchers in the 70's. Using equipment ranging from an air mattress pump to a weed sprayer, they pumped just enough desiccated air around a leaf surface to maintain a constant humidity in an enclosed chamber. By measuring the leaf area, air flow rate, and humidity in the chamber, researchers could calculate the stomatal resistance.

Later, this concept was used to design sophisticated and effective commercial porometers. "Dynamic" porometers work by sealing a small chamber containing a fast response humidity sensor to the leaf. After pumping dry air through the chamber to achieve some pre-set humidity, the researcher determines stomatal conductance by measuring the time required for the chamber humidity to rise to some other preset value. All this air pumping and desiccating makes for a clunky, complicated instrument – the fans, motors, and hoses everyone expects from a porometer. They work well, they measure what they're supposed to, but they aren't very elegant, and worse, they're expensive.

Inspired by the ideas of Scandinavian researchers measuring skin conductance in burn patients, Dr. Campbell started thinking about a completely different way to measure stomatal conductance – a way that doesn't require moving any air. It relies on a set of equations (shown in the side bar) that allow vapor concentration to be determined from relative humidity measurements in combination with other known values. 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.

It was no doubt a complex problem, but now that it has been solved, it looks simple—a small sensor head, a few electronics, and voila: a porometer about a quarter of the size and price of previous instruments. Porometers have been a big money investment – something you had to plan a serious study around. Stomatal conductance data have more general interest, though. They can add significant insight—detailing water use, water balance, and uptake rates of herbicides, ozone, and pollutants as well as indicating water stress. The size and price of this new porometer should make it a tool many canopy researchers routinely use.

To Dr. Campbell, it's all that – solid science, accurate readings, reliable instrument – and a bit more. You could call it educational possibilities. Or you could just call it the magic of discovery. "Give this to someone with only a passing interest in research, a ten-year-old boy, for example, and he'll go around the garden and come back with some really interesting observations. We gave an instrument to some staff at an in-house demonstration, and they came back having examined variegated leaves. They compared the white to green and discovered that the white areas didn't transpire. Do flower petals transpire? There are lots of questions about what loses water and what doesn't that you can answer with this instrument."

Mathematics of the Steady State Porometer

Decagon's Steady State porometer measures stomatal conductance using a sensor head with a fixed diffusion path to the leaf. It measures the vapor concentration at two different locations in the diffusion path. It computes flux and gradient from the vapor pressure measurements and the known conductance of the diffusion path using the following equation:

$$\frac{C_{vL} - C_{v1}}{R_{vs} - R_1} = \frac{C_{v1} - C_{v2}}{R_2}$$

Where C_{vL} is the vapor concentration at the leaf, C_{v1} and C_{v2} are the concentrations at the two sensor locations, R_{vs} is the stomatal resistance, and R_1 and R_2 are the resistances at the two sensors. If the temperatures of the two sensors are the same, conductance can be replaced with relative humidity, giving

$$R_{vs} = \frac{1 - h_1}{h_2 - h_1} R_2 - R$$

Conductance is the reciprocal of resistance, so $g_{vs} = 1/R_{vs}$.

Doing the Math: Dynamic and Null Balance Porometers

Dynamic porometers measure how long it takes for the humidity to rise from one specified value to another in an enclosed chamber clamped to a leaf. The resistance R is then determined from the following equation:

$$\Delta t = \frac{(R, A) l \Delta h}{1 - h}$$

where Δt is the time required for the cup humidity to change by Δh, h is the cup humidity, l is the cup "length," and A is an offset constant. Null balance porometers maintain a constant humidity in an enclosed chamber by regulating the flow of dry air through the chamber and find stomatal resistance from the following equation:

$$R_{vs} = \frac{A}{f}\left(\frac{1}{h} - 1\right) - R_{va}$$

where R_{vs} is the stomatal resistance, R_{va} is the boundary layer resistance, A is the leaf area, f is the flow rate of dry air, and h is the chamber humidity. The resistance values found by these equations are typically converted to conductance values.

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