How to measure leaf transpiration

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CONTRIBUTORS

Occasionally, researchers learning how to measure leaf transpiration ask us if they can estimate the transpiration from a single leaf by simply measuring its stomatal conductance. Unfortunately, the answer is no. This article illustrates why that's true and what you'll need to do to estimate the total conductance, and therefore, the evaporation from a leaf.

*E*The calculation of transpiration () from a leaf is given by Equation 1

$$E = g_v(C_{vs} - C_{va})$$

Equation 1

where g_v is the total conductance of vapor from inside the leaf into the air, C_{vs} is the concentration of vapor inside the leaf and C_{va} is the concentration of vapor in the air.

The conductance term (g_v) is needed to solve for transpiration, but it is actually the combination of two variables. To move water vapor from inside the air into the atmosphere requires moving water through not only the stomates and the waxy cuticle of the leaf, but also through the air itself (see Figure 1).

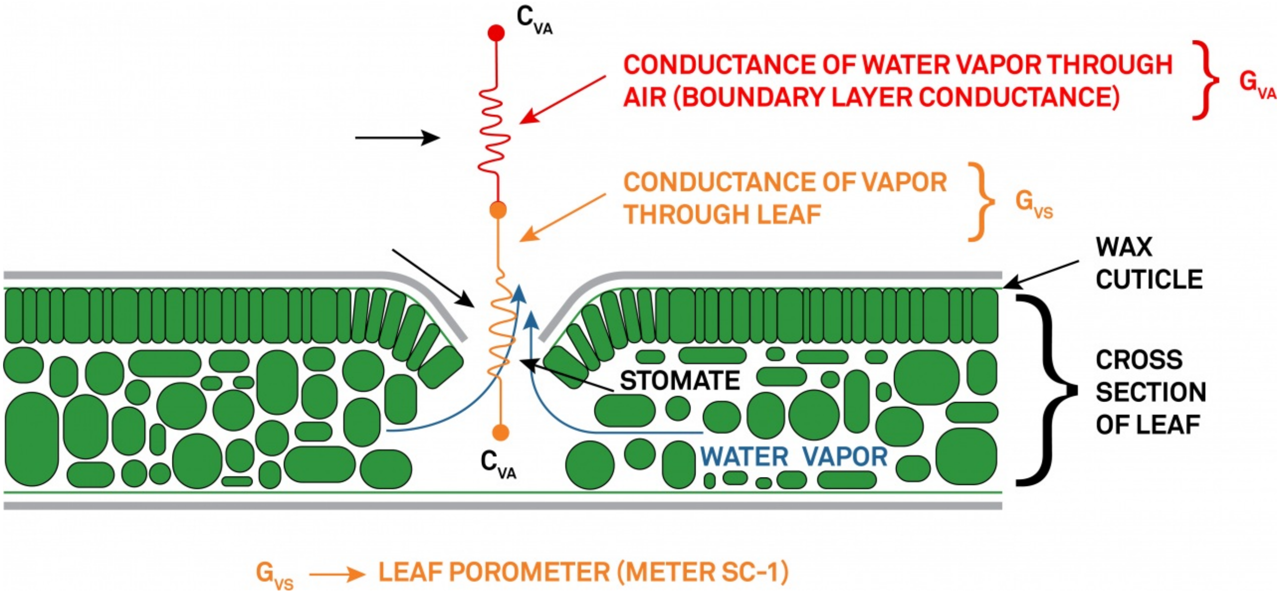

Figure 1. Simplified diagram of a single leaf stomate

Figure 1 shows an enlarged diagram of a single stomate on a leaf. The water vapor is shown in blue. Palisade parenchyma cells and spongy mesophyll cells are shown in green. The water vapor inside the leaf can move to the outside of a leaf through the stomates and also across the waxy cuticle. But most of the time (when the stomates are open), the water moves through the stomates into the atmosphere. This is called conductance of vapor through the leaf stomatal conductance (g_{vs}).

The stomates and waxy cuticle are not the only limitations for moving water vapor from inside the leaf into the bulk air. The air outside the leaf also resists the movement of water vapor. This is called the conductance of water vapor of the air, or the boundary layer conductance (g_{va}). Both g_{vs} and g_{va} act like resistances in an electrical circuit. They resist the movement of water vapor, and they act in combination (called a series resistance) to limit water from moving inside the leaf into the bulk air.

Stomatal conductance

To calculate transpiration, you'll need to know the conductances g_{vs} and g_{va}. To get the conductance of the stomates (or the stomatal conductance) g_{vs}, use a leaf porometer, such as the METER SC-1 leaf porometer.

SC-1 leaf porometerThe METER measures stomatal conductance

There are not a lot of choices when measuring stomatal conductance. You can't calculate it. Estimating it is possible but not a good method, so a device is used to measure it.

Boundary layer conductance

To get the next conductance value, g_{va}, use a simplified engineering equation (Equation 2).

$$g_{va} = 0.135\sqrt{\frac{u}{d}}$$

Equation 2

In Equation 2, the conductance of vapor of the air (g_{va}) is equal to a constant (0.135) times the square root of the wind speed over the leaf (*u*) divided by the characteristic dimension of the leaf (*d*).

- *u* = wind speed across a leaf
- *dw* = characteristic dimension of the leaf (0.72 w) where is the width of the leaf

To get these values, first measure the wind speed across the leaf with an anemometer,*d.* which provides the value of In this case, it would have to be a small anemometer, but it is possible. Next, find the characteristic dimension of the leaf (Figure 2). Do this by measuring the width of the leaf in the direction of the wind and multiplying by a constant 0.72.

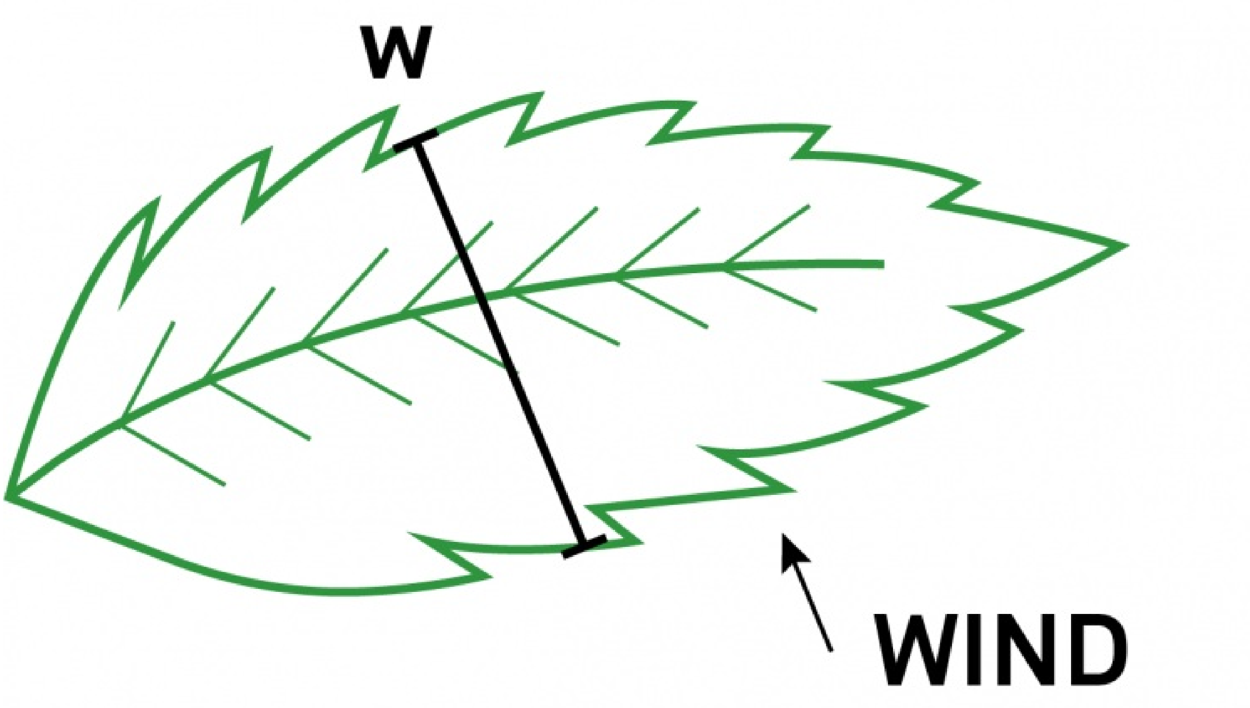

Figure 2. Diagram of a leaf where w is the width of the leaf in the direction of the wind.

g_{va}Once you obtain these two variables, you can then use them to estimate the conductance of vapor to the air ().

Conductance of the system

Once you obtain g_{va} and g_{vs}, you can combine these conductances to get an actual value for the conductance of the system (g_v). Equation 3 shows how to combine series conductances

$$g_v = \frac{1}{\frac{1}{g_{vs}} + \frac{1}{g_{va}}} = \frac{g_{vs}\, g_{va}}{g_{vs} + g_{va}}$$

Equation 3 (simplified for two resistors in a series)

Concentration of vapor at the surface

Now that you have g_v, you'll need to calculate the two vapor concentrations shown in Equation 1.

The concentration of vapor at the surface is equal to the saturation vapor pressure at the temperature of the leaf divided by the pressure of the air (Equation 4).

It’s easy to calculate both of these values. The saturation vapor pressure at the leaf temperature is given by Tetens Formula (Equation 5).

$$C_{vs} = \frac{e_s(T_L)}{P_a}$$

Equation 4

$$e_s(T_L) = 0.611 \text{ kPa} \exp\left(\frac{bT_L}{c+T_L}\right)$$

Equation 5

where *b* is 17.502 and *c* is 240.97 °C and *T* is the leaf temperature. In this video, you can see how to do this calculation in a little more detail. Equation 6 shows how to get P_a or the pressure of the air

$$P_a = 101.3 \text{ kPa} \exp\left(\frac{-A}{8200}\right)$$

Equation 6

where A is the altitude of the leaf location.

Concentration of vapor in the air

The other value you need is C_{va} (Equation 7)

$$C_{va} = \frac{e_s(T_a)(h_r)}{P_a}$$

Equation 7

*e*where (*sT*) is the saturation vapor pressure at the air temperature ($_a$) found using Equation 5 and *Th* is now the air temperature and $_r$*C* is the relative humidity. The relative humidity, air temperature, and leaf temperature must be measured. Once you measure and calculate all these things, just plug them into Equation 4 ($_{vs}$*C*) and Equation 7 ($_{va}$).

$C_{vs}C_{va}E$Once you have and , you can plug them into Equation 1 and solve for : the transpiration from the leaf.

How to measure leaf transpiration: a summary

So to estimate leaf transpiration, you'll need to measure quite a few variables, even though the formula ($E = g_v (C_{vs} - C_{va}$) is simple.

- G_{vs} – stomatal conductance (use a leaf porometer SC-1)
- T_L – leaf temperature (use an infrared thermometer IRT)
- T_a – air temperature (use a weather station ATMOS 41)
- h_r – relative humidity (use a weather station ATMOS 41)
- *A* – altitude (look up on the internet)
- *u* – wind speed* (m/s) (use a weather station ATMOS 41)
- *w* – leaf width (use a small ruler)

***NOTE:** weather stationFor the wind speed, you can use the ATMOS 41 , but it depends on where the leaf is located. If the leaf is near the ground, and the ATMOS 41 is at 2 m, you will have to correct for height. There is an equation to estimate the wind speed down to the location you're measuring. It falls off exponentially as you get toward the surface.

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Questions?

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