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Lifeblood of Leaves: Vein Networks Control Plant Patterns

New University of Arizona research indicates that leaf vein patterns correlate with functions such as carbon intake and water use -- knowledge that could help scientists better understand the complex carbon cycle that is at the heart of global climate warming.

"Leaves have very different networks of veins. They have different shapes, different sizes, different thicknesses," said Benjamin Blonder, a doctoral student in the department of ecology and evolutionary biology. "The really interesting question is how a leaf with a certain form produces a certain function?"

Blonder developed a mathematical model to predict the functions of leaves based on three properties of the vein network: density, distance between veins and number of loops, or enclosed regions of smaller veins much like capillaries in humans.

Vein density reflects how much energy and resources the leaf has invested in the network, while distance between veins shows, how well the veins are supplying resources to the leaf? The number of loops is a measure of the leaf's resilience and plays a role in determining its lifespan. If the veins reconnect often and part of the leaf becomes damaged, resources can be circulated through different pathways.

"It's like in a city where there's a roadblock somewhere," said Blonder. "If the city was designed well, you can still take another road to get to where you want to be."

Blonder won the UA Graduate and Professional Student Showcase President's Award for his work, which was published this week online in the journal of Ecology Letters.

The vein network inside of a leaf is like most of the important organ systems in a person, Blonder said.

"It's like the skeleton because it holds the whole leaf up and lets it capture sunlight and not get blown over in a windstorm. It's like the circulatory system because it's distributing water from the roots up to all the cells within the leaf, and it's also bringing resources from the leaf back to the rest of the plant after photosynthesis has happened. It's also like a nervous system because there are chemical signals that are transmitted to the leaves from other parts of the plant through the liquid in the veins," he said.

"This is important for the function of the leaf because when this one structure is implicated in so many different patterns, clearly there're going to be tradeoffs between being able to do all of these different functions well," said Blonder. For example, a leaf with a very loopy network of veins might live longer, but it will also cost a lot of carbon, which plants absorb from carbon dioxide in the atmosphere, to develop that vein network.

Blonder's model successfully predicted relationships among photosynthetic rate, lifespan, carbon cost and nitrogen cost for more than 2,500 species worldwide based on global data. But that doesn't mean, it will work on a local scale.

To find out, the team tested leaves from 25 plant species on the UA campus. While initial results appear to show that the model will work, the team hasn't tested enough samples to know if, it successfully predicts relationships in leaf function on a case-specific basis. More extensive studies will include leaves from species at the Rocky Mountain Biological Laboratory in Colorado.

"If it's successful, we hopefully have a really satisfying way of understanding why leaves look different in different environments -- also a useful way of understanding how leaves are functioning in different environments that can be used for climate modeling or for reconstructing past climates from fossils of leaves," said Blonder.

So, how do relationships among plant leaf functions impact global carbon levels?

"Carbon can only get into leaves through little pores on the leaf surface, and when carbon comes in, which is something good for the plant, water also comes out," said Blonder. "There's this incredibly tricky tradeoff for all plants where they need to gain carbon to make energy, but to gain that carbon they lose a lot of water in the process. So if you want to gain more carbon, you have to lose more water."

Plants with denser vein networks -- veins that are closer together -- are able to withstand higher levels of water loss and absorb more carbon. Unfortunately, that doesn't mean you should plant trees with dense leaf vein networks if you want to save the planet.

"It becomes a little bit more difficult to scale up beyond there because a plant is not only just its leaves: It's also the trunk and the roots and so on," said Blonder. "The important thing to think about is that other parts of the plant are going to be contributing to the carbon cycle also in terms of decomposition or other large-scale environmental effects."

"Carbon flux from plants is critical to understanding global change and the global carbon cycle," said Blonder. "What we're hoping to be able to do is understand the leaf side of the picture, but there's clearly a lot more to plants and the environment than that. So this is not the answer to every environmental question but it's a good start because leaves are the site of photosynthesis and carbon flux, and it's certainly necessary to understand those before you can understand plants in general."

Blonder hopes to use his model to develop more comprehensive climate models that take plants into account and to better understand past climates. Blonder's model could play an important role in understanding plant ecology, global carbon cycling and other environmental processes in the future.

Blonder is a Biosphere 2, 2010-11 Science and Society Fellow and keeps a blog about his research (http://bblonder.wordpress.com/). Undergraduate students Lindsey Parker, Jackie Bezinson and David Cahler assisted Blonder with his research.