Study shows dry air drives overlooked changes in how plants drink and breathe

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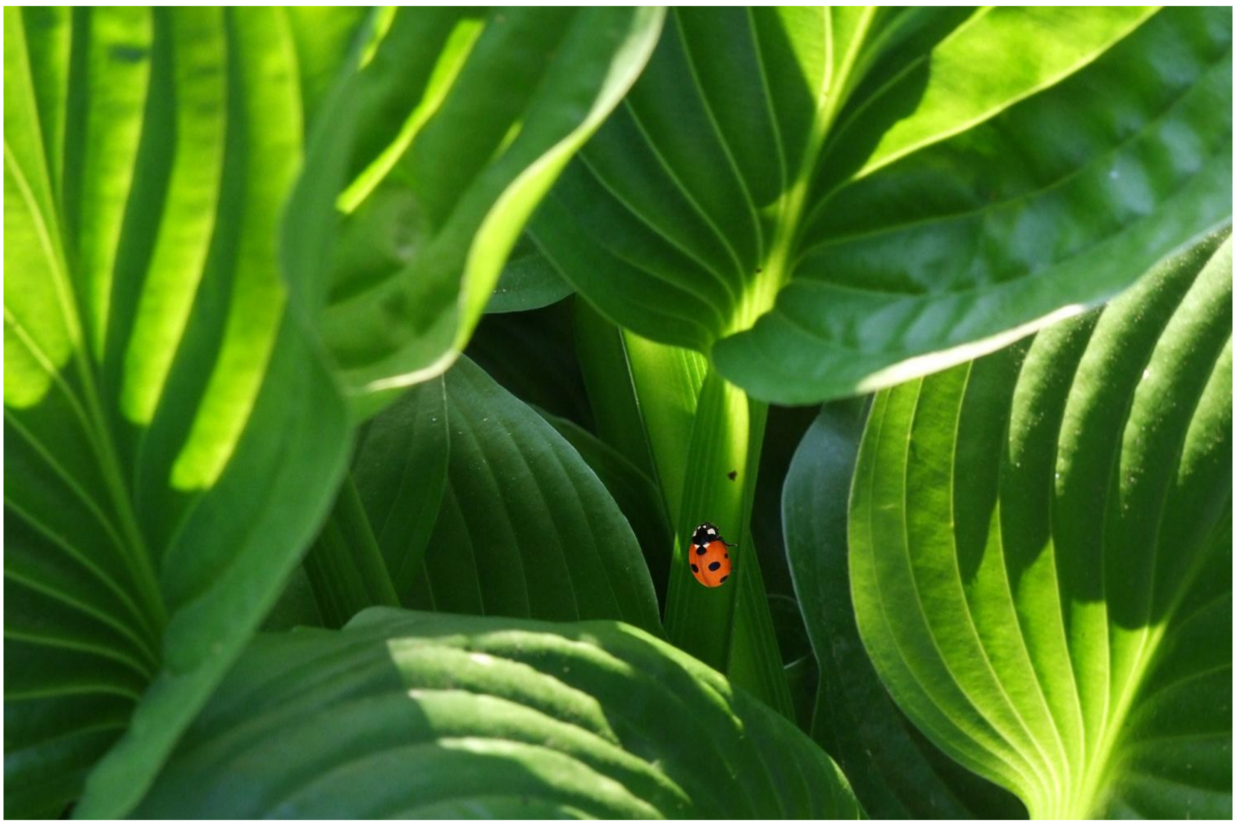

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Plants drink up much of the water that falls to Earth. They take what they need before releasing it through tiny holes on the underside of their leaves, just as people release water vapor with every exhale.

How much a plant drinks and the rate at which it releases water, or transpires, depends partly on moisture levels in the air and soil. Global warming will shift this process more than previously predicted, according to new research from Stanford University.

Published June 1 in *Nature Climate Change*, the paper shows current climate models underestimate how severely plants ration their water use in response to dry air, and overestimate the effect of dry soil. The results suggest plants in many regions will lock away less water than expected during hot droughts in the future, leaving more water available to percolate into reservoirs, underground aquifers, rivers, lakes and streams.

"This is good news," said study co-author Alexandra Konings, an assistant professor of Earth system science at Stanford's School of Earth, Energy & Environmental Sciences (Stanford Earth). Yet there is also a dark side to the findings: While water resources may be less diminished, plant growth and carbon uptake will likely suffer more than most models predict.

"Whether plants will fare better in future droughts is a more complex question," said lead author Yanlan Liu, a postdoctoral scholar in Konings' lab. "But now we know plants will use less water than expected."

For agricultural crops, this means the best available estimates of future water needs, growth and vulnerability are "likely to be incorrect" during periods when the atmosphere is very dry, said another of the study's authors, Mukesh Kumar, who is an associate professor of civil, construction and environmental engineering at University of Alabama.

Atmospheric dryness going 'through the roof'

The scientists looked specifically at a component of climate models that estimates evapotranspiration, which refers to the rate at which Earth's land surface and plants return water to the atmosphere. "So much of the water balance in any given ecosystem goes to evapotranspiration, it has implications for how much water is left over for water resources for people," Konings said. "It also has big effects on weather and climate."

A common modeling approach treats this dynamic process more or less as a function of soil moisture. "That's not realistic because vegetation responds to drought based on the amount of water inside the leaves," Konings said.

Few climate models try to disentangle the effects of dry soil and dry air when predicting changes in evapotranspiration. "The models in use right now work really well if you're averaging wet and dry conditions over multiple years, but not in times of drought," said Konings, who is also a center fellow, by courtesy, at Stanford Woods Institute for the Environment.

This entanglement becomes increasingly problematic under climate change. In some hot spots around the globe, episodes of dangerously humid heat are striking with growing severity and frequency. But as temperatures rise, Konings said, most droughts will be accompanied by relatively dry air. Hotter air can simply hold more water vapor than cooler air, which means the atmosphere becomes less saturated if it heats up without additional water. As a result, while future changes in soil moisture are hard to predict and likely to vary by region, she said, "Atmospheric dryness is going to go through the roof."

Bringing in hydraulics

The researchers modeled the effect of this drying on plants' drinking habits by zooming in on responses in the plant hydraulic system—the pipes and valves inside a plant's roots, stem and leaves. They developed mathematical techniques to derive evapotranspiration rates from a combination of widely available datasets, including records of soil texture, canopy heights, plant types and flows of carbon and water vapor at 40 sites around the world. Then they cross-checked their techniques against limited real-world measurements of evapotranspiration.

The development of a hydraulic model, in itself, is not a first. But the researchers went further, comparing the different model approaches to understand the impact of plant hydraulics under various conditions.

They found the most widely used approaches for estimating evapotranspiration miss about 40 percent of the effect of dry air. This is like a weather forecast that fails to mention wind chill or stifling humidity. The effect is strongest—and current predictions are the most off-base—in places where plants are the least adapted to drought. Konings said, "We were surprised that this had such a big effect."

More information: Plant hydraulics accentuates the effect of atmospheric moisture stress on transpiration, *Nature Climate Change* (2020). DOI: 10.1038/s41558-020-0781-5 , www.nature.com/articles/s41558-020-0781-5

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