Soil microbes help plants cope with drought, but not how scientists thought

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There's a complex world beneath our feet, teeming with diverse and interdependent life. Plants call out with chemical signals in times of stress, summoning microbes that can unlock bound nutrients and find water in soil pores too small for the finest roots. In return, microbes get a safe place to live or a sugary drink.

It's a classic you-scratch-my-back-I'll-scratch-yours scenario. Except when it's not. New research from the University of Illinois Urbana-Champaign challenges conventional wisdom to show free-living soil microbes are just looking out for themselves.

The findings are published in the journal *Proceedings of the Royal Society B: Biological Sciences*.

In a multi-generation experiment, researchers from the College of Agricultural, Consumer and Environmental Sciences (ACES) found microbes helped plants cope with drought, but not in response to plants' cries for help. Instead, the environment itself selected for drought-tolerant microbes. And while those hardy microbes were doing their thing, they just happened to make plants more drought-tolerant, too.

"It was a surprise because I expected to see evidence of coevolution and mutualism between the microbes and plants. I think people, myself included, forget that just because microbes do something adaptive or beneficial to the plant, it doesn't necessarily mean they're doing it for the plant," said Kevin Ricks, who completed the project as part of his doctoral degree in the Program for Ecology, Evolution, and Conservation Biology at Illinois. Ricks is now a postdoctoral researcher at the University of Toronto.

To learn how microbes help plants deal with drought, Ricks established live soil communities in pots with or without plants. He watered half of the pots well and imposed drought conditions in the other half, then repeated these treatments for three generations. The idea was to allow time for selection to occur—potentially for plants to signal their need for help and select for microbes that came to their aid.

In phase two of the experiment, Ricks mixed everything up. He again grew plants in soil from phase one and kept the same watering treatments, but some plants were now experiencing drought in soils that had been well-watered for generations, and vice versa. He expected soil microbes from historically dry pots would have adapted to those conditions, helping plants withstand drought more than microbes from historically wet pots. And that is what he found: Plants experiencing drought were bigger when grown with drought-adapted microbes.

But—and this is key—that was true for soils grown with or without plants in phase one. In other words, microbes adapted to drought over time even without plants selecting for them through chemical signals. Yet they still provided benefits when grown with plants generations later. It was proof these microbes were doing their own thing, only helping plants incidentally.

No previous studies on the topic had included a no-plant control, leaving the research community to conclude plants and microbes were communicating in a co-evolutionary dialogue.

"Our results challenge classical thinking about what counts as a mutual benefit. Mycorrhizae and nitrogen-fixing bacteria are kind of model systems, things that people study when they talk about mutualism. But then there's this fuzzier set of interactions that we don't understand yet, but could still wind up having a mutual benefit, or at least a one-way benefit to the plant. I think our approach brings this system into the spotlight," said co-author Tony Yannarell, associate professor in the Department of Natural Resources and Environmental Sciences, part of the College of ACES at Illinois.

The researchers also sterilized some phase-one soils before imposing treatments in phase two. In those pots, plants in historically dry soils were no better off when experiencing drought.

"Some previous studies didn't actually compare soil with and without microbes, so it's hard to really implicate the microbes as the driver of the benefit," Yannarell said. "There are a lot of things that could have been different in the soil, but when we sterilized the microbes away in our experiment, we lost the benefit of the drought adaptation."

The researchers didn't identify the microbes in their experiment, so they can't be sure exactly how they were benefiting plants. But Ricks said soil microbes are involved in many processes that could help plants withstand stress.

"Microbes are responsible for nutrient and carbon cycling, so whether or not they're actually facilitating plant access to water, they could still be freeing up nutrients that make the plant healthier and more resilient to stress," he said.

Ricks hesitated to claim his study will shift paradigms in ecological research, especially considering it was a greenhouse experiment focused on free-living soil microbes and a single type of environmental stress. But he hopes it will encourage other scientists to consider no-microbe and no-plant controls in future studies. They might just reveal what's really going on beneath our feet.

More information: Kevin D. Ricks et al, Soil moisture incidentally selects for microbes that facilitate locally adaptive plant response, *Proceedings of the Royal Society B: Biological Sciences* (2023). DOI: 10.1098/rspb.2023.0469

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