Drought fighter found in soil

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Professor Yan Jin (left) and postdoctoral researcher Wenjuan Zheng hope to develop new technologies to increase food production using drought-fighting microbes that naturally live in soil. Credit: Evan Krape

Some discoveries happen by accident. Consider how Sept. 28, 1928, unfolded: Alexander Fleming, back in the lab after a vacation with the family, was sorting through dirty Petri dishes that hadn't been cleaned before he went away. A mold growing on one of the dishes caught his attention—and so began the story of the world's first antibiotic: penicillin.

Recently, at the University of Delaware, the plants didn't get watered one long weekend during a small botany experiment. That has now led to an intriguing finding, especially for areas of the globe hit hard by drought—the American West, Europe, Australia, portions of Africa, Southeast Asia and South America, among them.

Climate scientists say we should expect more frequent and severe droughts in the years ahead, while population experts predict about a 30 percent increase in world population, to more than 9 billion by 2050. How will we grow enough food for everyone under such pressures, and do so sustainably? According to this UD research, the answer may lie right under our feet.

Discovering a drought fighter

Back to that UD experiment. Returning to the lab that following Monday morning, the postdoctoral associate found one tray of seedlings a wilted, scraggly mess, while the other tray of seedlings stood at attention. The only difference between the trays: the soil of the thriving specimens had been sprayed with Bacillus subtilis (UD1022), a strain of bacteria discovered several years ago at UD by a research team led by Professor Harsh Bais in the Department of Plant and Soil Sciences.

Bais's team determined that these microbes, which live on the surface of roots and in the surrounding soil, trigger pore-like openings on the leaves, called stomata, to shut tight to keep pathogens out and to protect the plants from dehydrating.

After the Bais lab published on the work, Professor Yan Jin, a soil physicist in the department, approached Bais about looking deeper to see if the microbes may impact the actual soil they inhabit.

"There's a big gap in our understanding of how benign microbes may affect so-called 'green water'—the water in soil that's available to plants," Jin explained.

She wanted to know if UD1022 may modify the soil's properties—its structure, chemistry, how soil pores are distributed and how their sizes change—in relation to the green water supply. She wanted to know exactly what was happening in the soil and set out to find the answer.

In an article published recently in *Water Resources Research*, Jin and her team from UD, along with colleagues at the National Institute of Standards and Technology (NIST), confirm that the beneficial microbe UD1022 reduces evaporation and increases the soil's ability to hold water. Using state-of-the-art techniques, the study provides detailed analyses of how microbes interact with soil particles to physically change the underground ecosystem and help plants tolerate drought.

How microbes hold on to water

Experiments were done in both the lab at UD, and using high-powered neutron imaging at NIST to peer into the soil and record what was happening.

In a closed environment chamber at the UD College of Agriculture and Natural Resources, postdoctoral researcher Wenjuan Zheng and master's student Saiqi Zeng worked with two soil samples at a time—a control sample and a sample treated with the UD1022 microbes—and continuously measured the water retention characteristics of the soil and the water evaporation rate as the soil was dried in the chamber. The experiments were done for different textured soils: sand, sandy soil and clay-rich soil samples, taken from the UD farm and from an agricultural experiment station in Georgetown, Delaware.

To determine what was happening in the soil samples, the team relied on the neutron radiography imaging capabilities at NIST.

"Neutrons can 'see' water," Jin said. "Because they interact strongly with hydrogen, they provide an ideal non-destructive technique for examining the distribution of water in delicate materials like our soil samples containing microbes, in real time."

"We felt very lucky that we found NIST and could use their imaging facilities," Jin added. "This collaboration was critical to our work."

Tiny columns were packed with soil—one column was treated with the UD1022 microbes and the other column was not treated. Then the columns were saturated with water, and neutron imaging recorded the evaporation process. A total of 1,500 individual images were taken of each sample over about a nine-hour period. They provided a detailed look at the distribution of water in the samples, as well as real-time evaporation dynamics. A high-powered scanning electron microscope (SEM) helped uncover what the microbes were doing in the samples.

And just how do these tiny organisms (UD1022) help the soil hold on to water?

"This effect is caused by the microbes' ability to form a gelatinous network, a biofilm from a complex mixture of polysaccharides, proteins, lipid, vitamins and sugars," said Zheng, the first author on the paper. She was a postdoctoral associate at the time and is now a senior researcher in the Department of Mechanics and Aerospace Engineering at Southern University of Science and Technology, China.

"It's as if the bacteria build these little houses for themselves," Zheng said.

The biofilm the bacteria generate acts like a glue to form "soil aggregates" that can retain more water in their pores.

These microorganisms and their gluey matrix can more than carry their own weight. "They've been shown to hold water like a sponge, absorbing 10 times as much water as their dry weight," Zheng noted. "This natural biofilm changes the soil properties, leading to slower evaporation. This can make more water available to plants, as well as increase the time available for plants to metabolically adjust to stress from drought."

While much of the U.S. East Coast has had a water-logged summer and early fall, other areas of the country and many other nations are suffering from relentless, and in some cases, life-threatening, droughts. Jin hopes that UD1022 can play a positive role in agriculture in these parched regions as global population creeps higher.

"What can we do to ensure food security?" Jin asked. "Plants could be genetically modified, but that takes a long time. Lots of companies are selling biofertilizers to overcome these problems—sometimes they work, but more often they don't. That's why more basic research is critical to help us understand the mechanisms at work. By understanding the interactions among plant roots and the soil microbiome—a largely untapped underground resource—we hope to develop new technologies that will increase food production and at the same time reduce the use of chemical fertilizer."

More information: Wenjuan Zheng et al. Plant Growth-Promoting Rhizobacteria (PGPR) Reduce Evaporation and Increase Soil Water Retention, *Water Resources Research* (2018). DOI: 10.1029/2018WR022656

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