Multi-scale research uncovers microbes that affect sorghum drought response

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Drought is one of the greatest threats to agricultural systems, resulting in unpredictable crop yields, declines in farm revenue, and an increase in disease outbreaks. In the United States alone, drought has cost the nation

$249 billion since the 1980s. One potential solution to enhancing crop resilience is the inoculation of seed with bacteria, aka. plant "probiotics" that are known to improve a plant's drought tolerance. While scientists have identified many microbes that show promise in the lab, replicating their efficacy in agricultural field studies proves much more difficult, largely due to complex environmental variation in the real world.

New research spearheaded by Rebecca Bart, Ph.D., Associate Member, Donald Danforth Plant Science Center, and her colleagues tackled the challenge of bridging the gap between lab and field studies related to crop-microbial interactions and their influence on drought tolerance. Their work has the potential to accelerate crop adaptation to drought conditions and streamlines findings from the lab for farmers in the field. Their seminal research was recently published in *The ISME Journal* and *eLife*.

The authors took a systems-level approach to identify microbes that affected drought response in sorghum, work that spanned "sterile, controlled environments" in the lab, to field experiments chock full of complex soil properties, uneven topography, and nonuniform accumulation of water moisture. The team found that at least six microbes that caused root developmental defects in the lab—stunting the height of sorghum seedlings—were also negatively affecting sorghum growth in the field.

"The big advance here," said corresponding author Bart, "is that we observed similar patterns in a controlled environment and in the field. That result tells us that our lab observations are real and relevant to agriculture." Strikingly, the research team also identified a new microbe that promoted root growth, a critical characteristic to improve crop resilience to drought.

The research, which took place over the course of the last five years, was not without its own challenges. "Environmental variation makes the real world a noisy place to conduct science," wrote first author and Danforth Center Senior Data Scientist Jeffrey Berry. The authors needed to develop a model to account for confounding biological variables in field experiments—factors like soil pH and phosphate content, which can vary wildly across a field site.

By combining giant, multivariate datasets from collaborators across several institutions, including at University of Nebraska-Lincoln, Iowa State University, Washington State University, University of North Carolina-Chapel Hill, Colorado State University, and the Joint Genome Institute, Berry was able to use sophisticated computational models to understand and overcome variation in the field.

The result was a first-of-its-kind statistical model that accounted for soil properties that influenced traits in both crops and microbes. The authors could now compare their results between the lab and field without worrying about how environmental variation might be altering their field observations. "Jeff figured out how to connect some really complicated puzzle pieces," concluded Bart.

In addition to tackling complicated statistics and collaborating with scientists across the country, part of the teams' success was having access to the Danforth Center's unparalleled research infrastructure. For example, the authors used The Bellwether Foundation Phenotyping Facility to visualize and quantify how drought and microbe treatments affected sorghum growth and development as part of their controlled lab experiments.

The team is beginning to replicate their methodology in other crops systems like maize, and future research plans for this work will be housed out of the Danforth Center's new Subterranean Influences on Nitrogen and Carbon (SINC) Center, co-directed by Bart and three other

Danforth Center members.

More information: Mingsheng Qi et al, Identification of beneficial and detrimental bacteria impacting sorghum responses to drought using multi-scale and multi-system microbiome comparisons, *The ISME Journal* (2022). DOI: 10.1038/s41396-022-01245-4

Jeffrey C Berry et al, Increased signal-to-noise ratios within experimental field trials by regressing spatially distributed soil properties as principal components, *eLife* (2022). DOI: 10.7554/eLife.70056

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