Microbes facilitate the persistence and spread of invasive plant species by changing soil chemistry

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This is remnant tallgrass prairie in North Central Texas, showing the "invasion front" of Sorghum that first prompted the research in Rout et al's study. Credit: Marnie Rout, University of North Texas Health Science Center.

Invasive species are among the world's greatest threats to native species and biodiversity. Once invasive plants become established, they can alter soil chemistry and shift nutrient cycling in an ecosystem. This can have important impacts not only on plant composition, diversity, and succession within a community, but also in the cycling of critical elements like carbon and nitrogen on a larger, potentially even global, scale. Clearly, both native and exotic plants form intimate relationships with bacteria in the soil that facilitate the extraction and conversion of elements to biologically usable forms. Yet an unanswered question with regard to plant invasions remains: could the changes in soil biogeochemistry be due to an advantage that invasive plants get from interacting with their microbiome?

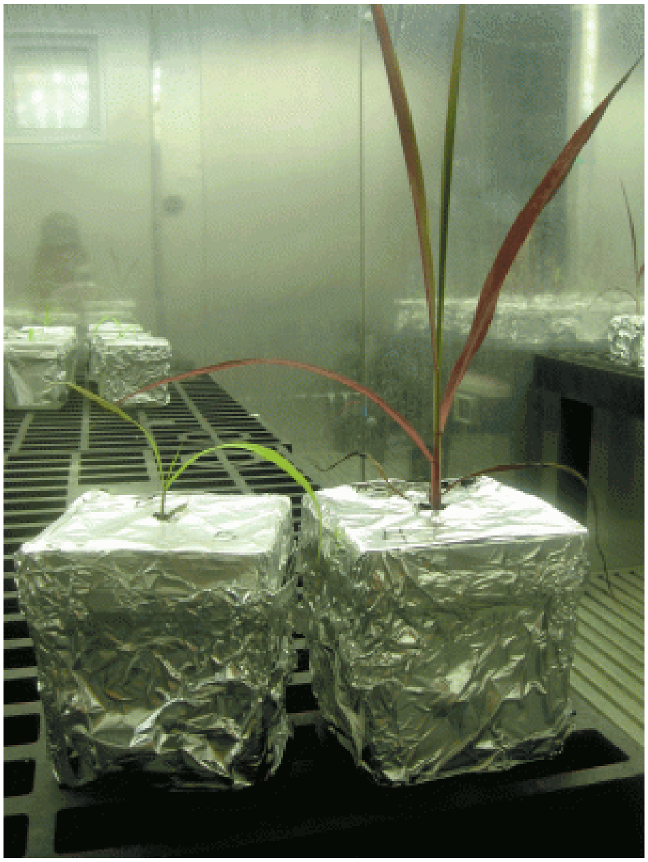
When alien species invade and take over communities, they may not come alone—many plant species are host to a whole suite of microorganisms that not only live in plant cells, but also in the soil surrounding the plants' roots. These microbes form close, often mutualistic, associations with their plant hosts. Some convert atmospheric nitrogen into bioavailable forms that are then exchanged for carbon from the plant. Bioavailable nitrogen is frequently limiting in soils, yet many invaded ecosystems have more carbon and nitrogen in plant tissues and soils compared with systems dominated by native plants . Since changes in the soil nitrogen cycle are driven by microbes, could bacteria associated with invasive species not only be responsible for the observed changes in soil nutrient concentrations, but also for enabling the continued growth and persistence of the invader species?

These were the kinds of questions that started percolating for Marnie Rout (University of North Texas Health Science Center) after she drove by a remnant tallgrass prairie in North Central Texas as a beginning graduate student. She was particularly struck by the obvious and drastic changes the native prairie was undergoing due to the invasion of an exotic grass.

"It literally looked like someone had drawn a line down the field," Rout explained. "On one side was the native prairie, the other side had this towering monoculture of invasive *Sorghum*. The plant looked like it was invading in a military fashion, forming this distinct line that was clearly visible."

Subsequent literature searches led to the discovery that sugar cane, an agriculturally important crop, is a nitrogen fixer that contains bacterial endophytes, and Rout became curious if the microbes she and her colleague Tom Chrzanowski (The University of Texas Arlington) discovered in invasive *Sorghum* might be providing similar benefits to this invasive plant.

Rout combined forces with colleagues from The University of Montana, The University of Texas Arlington, and University of Washington to investigate whether the differences in soil nutrient concentrations found in an invaded prairie could be due to metabolic processes of the bacterial microbiome associated with the invasive grass, and to determine whether these microbial agents facilitate the perpetuation and spread of this invasive grass. They published their findings in a Special Section in the *American Journal of Botany* on Rhizosphere Interactions: The Root Biome.



An experiment with invasive grass found that the biomass and rhizome production was severely stunted without bacteria. The larger, red-striped plant on the right had the bacteria and high rates of nitrogen fixation, whereas the plant on the left is smaller because bacteria were inhibited and was not fixing nitrogen. The tin foil wrapping protects the substrate from light. These were grown from sterilized seeds in a growth chamber at the University of Montana. Credit: Marnie Rout, University of North Texas Health Science Center.

"Things attributed to plant-plant interactions like competition and facilitation are likely under more microbial regulation than we have been giving them credit," Rout commented. "Studying disruptions to ecosystems like those seen in plant invasions provides a window into something—specifically the process of co-evolution—that we normally don't get to observe in a single human lifetime."

Indeed, the alarming rate—almost 0.5 meters a year—at which the invasive grass *Sorghum halepense* has invaded the tallgrass prairie, formerly dominated by the native little bluestem *(Schizachyrium scoparium)*, over the last 25 years, and the complete dominance of that invasive was the ideal situation in which Rout could test her ideas.

Rout and colleagues first confirmed that the invaded soils of the prairie did indeed have higher levels of nitrogen, phosphorous, and iron-derived chemicals compared with the non-invaded prairie soils still dominated by native plants. They then tested whether the interactions between the dominant invasive grass and the soil biota could be responsible for the observed changes in the soil nutrient concentrations.

By isolating five bacterial strains of endophytes found inside *S. halepense* rhizomes (subterranean stems used for storage and vegetative reproduction) and growing them in the lab in different mixtures of substrates, the authors determined that these microbes were able to fix and mobilize nitrogen, phosphorus, and iron. All three are important elements associated with plant growth; however, some were produced in excess of what would be needed for plant growth. Indeed, perhaps somewhat alarmingly, the amount of iron that was produced reached levels that are toxic to many crops—and may even inhibit establishment of native species.

Furthermore, the authors were able to show that not only can this invasive plant acquire microbes from the environment, but that it is also capable of passing them on to the next generation via seeds. Using a sophisticated series of intricate experiments involving growing seedlings from surface sterilized seeds in nitrogen- deprived or nitrogen-augmented soils and slurries with different suites of soil microbes, Rout and colleagues showed that these microbes enabled the grass to produce 5-fold increases in rhizomes, a primary mechanism driving invasions of this species.

These findings give us a new understanding of how an invasive plant can acquisition soil biota to its own advantage, altering the environment and changing the ecosystem in the process. By acquiring soil bacteria, *S. halepense* increases the bioavailable nitrogen and phosphorus in the soil, and has increased rhizome production and aboveground biomass, which in turn facilitates its spread and establishment. Moreover, these changes to the soil chemistry not only increase the competitive edge of this invasive species, but also can inhibit or eliminate the existing native species.

"This research shows that macro-scale observations, such as plant trait expression, and ecosystem functions like nutrient cycling, are more intimately connected to micro-scale influences than we might expect," summarizes Rout.

Rout's fascination with bacterial endophytes continues; she is currently exploring them from a genetic perspective to better understand the complex communication between the microbiome and the plant.

"With the growing human population and concerns for meeting the global food crisis in the coming decades, invasive plants and their microbiomes might turn out to be useful for enhancing crop yields."

"The root microbiome is as important to plant health and agricultural productivity," she concludes, "as the human microbiome is to human health."

More information: Rout, Marnie E., Thomas H. Chrzanowski, Tara K. Westlie, Thomas H. DeLuca, Ragan M. Callaway, and William E. Holben. 2013. Bacterial endophytes enhance competition by invasive plants. *American Journal of Botany* 100(9): 1726-1737. DOI: 10.3732/ajb.1200577

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