# Experts apply microbiome research to agricultural science to increase crop yield

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NAU associate professor Greg Caporaso. Credit: Northern Arizona University

The global demand and consumption of agricultural crops is increasing at a rapid pace. According to the 2019 Global Agricultural Productivity Report, global yield needs to increase at an average annual rate of 1.73 percent to sustainably produce food, feed, fiber and bioenergy for 10 billion people in 2050. In the US, however, agricultural productivity is struggling to keep pace with population growth, highlighting the importance of research into traditional practices as well as new ones.

In an effort to increase crop yield, scientists at Northern Arizona University's Pathogen and Microbiome Institute (PMI) are working with Purdue University researchers to study the bacterial and fungal communities in soil to understand how microbiomes are impacting agricultural crops. They believe technological advances in microbiome science will ultimately help farmers around the world grow more food at a lower cost.

Nicholas Bokulich, a PMI assistant research professor, and Greg Caporaso, an associate professor of biological sciences and director of PMI's Center for Applied Microbiome Science (CAMS), have been testing a long-held farming belief that phylogenetics—the study of the evolutionary relationship between organisms—should be used to define crop rotation schedules.

The team recently published its findings regarding microbiome research in agricultural food production in *Evolutionary Applications*. The paper is titled, "Phylogenetic farming: Can evolutionary history predict crop rotation via the soil microbiome?"

Specifically, the traditional approach has been to rotate distantly related crops across different years to maximize plant yield. "One hypothesis for why this may be helpful is that plant pathogens are specific to a single host or to very closely related hosts. If you grow closely related crops in adjacent years, there is a higher chance that pathogens may be lying in wait for their hosts in the second year," Caporaso said. "But this hypothesis has not been directly tested."

The team's experiment, supported by a grant from the USDA National Institute of Food and Agriculture, spanned two outdoor growing seasons. In the first year, Purdue scientists Kathryn Ingerslew and Ian Kaplan grew 36 crops and agricultural weeds that differed in evolutionary divergence from the tomato. The experimental plots ranged from tomato (the same species) to eggplant (the same genus as tomato, but a different species) and sweet peppers (the same family as tomato, but in a different genus and species) through corn, wheat and rye, which are much more distant relatives of the tomato.

In the second season, the researchers only grew tomatoes on all of the plots. They found that in plots where tomatoes were grown in the first season, the year-two tomato yield was lower than in year one, as they expected. However, there were no significant reductions in tomato yield on any of the other plots. "This result suggests that while crop rotation is indeed important for yield, the effect may not extend beyond the species level," Caporaso said.

"This outcome was very surprising because the idea that closely related plants should be avoided in rotations is a widely held rule of thumb across the spectrum from small-scale gardening to large-scale agriculture," said Kaplan, a professor of entomology. "The fact that we cannot detect any signature of relatedness on crop yield—beyond the negative effects of single species monoculture (or tomato after tomato)—suggests that other factors need to be considered in designing crop rotation programs in sustainable farming systems."

Before planting in year two, Caporaso and Bokulich used microbiome sequencing methods to determine the composition of the bacterial and fungal communities in the soil. They found that a microbiome legacy of the year-one crops lived on, although both the soil bacterial and fungal communities were significantly different across the plots of different plants.

"We're now able to explore the role of microbes and the composition of microbiomes in agricultural systems in far greater depth and resolution than has ever been possible before," Caporaso said. "Those technologies can undoubtedly help us optimize agricultural systems to continuously enrich, rather than deplete, soil over time."

Caporaso says his long-term goal with this research direction is to collaborate with organic farmers who are practicing regenerative agriculture techniques. "We can learn how they can use advances in microbiome science to their advantage. I believe that this can help lower their fertilizer costs and water use, and build resiliency and food security in our communities."

## Undergraduate researcher will conduct vermicomposting program to track microbiome of food waste

In a related project funded by the NAU Green Fund as well as through Caporaso's lab, which is focused on software engineering in support of microbiome research, environmental science undergraduate student researcher Christina Osterink plans to prototype a workplace composting program this summer. Her project will involve working with about 10 offices on campus to collect food scraps and deliver them to Roots Micro Farm based in downtown Flagstaff.

While diverting food waste from the landfill to an urban farm, Osterink and her team also will track the microbiome of the collected food waste through its transformation via vermicomposting, a worm-based composting method, into high-quality soil. "This will help us develop a more precise understanding of the role of microbes in the composting process as we bring together efforts from throughout NAU's campus as well as local farmers to improve NAU's sustainability and Flagstaff's soil integrity," she said.

Caporaso is hopeful findings from Osterink's research can be applied to optimize composting systems and reduce farmers' costs.

# Applying microbiome research to agricultural science, a new direction for CAMS

Caporaso notes that the vermicomposting project represents a new research direction for his lab. "Most of our work at CAMS is related to human health," he said, "but there are at least as many opportunities to apply microbiome research in other areas, such as agricultural science."

Meanwhile, the next step in the crop rotation study will be to identify the important factors for plant yield, especially if evolutionary relatedness of species is ruled out.

"Do we want to rotate crops that thrive with similar soil microbiomes, so that the beneficial bacteria and fungi are already in place to support the next growing season?" Caporaso said. "That would be valuable information for both small urban farms and large industrial operations."

**More information:** Ian Kaplan et al, Phylogenetic farming: Can evolutionary history predict crop rotation via the soil microbiome?, *Evolutionary Applications* (2020). DOI: 10.1111/eva.12956

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