A new way to grow crops in marginal soils could help feed the world

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The global population is expected to reach 9.7 billion in 2050—but how will we feed all these people? Roughly one-third of the world's arable land suffers from lack of accessible iron, rendering it inhospitable to staple crops like maize and soybeans.

Last year, a Stanford research team led by associate professor of chemical engineering Elizabeth Sattely discovered a genetic adaptation that allows one hardy plant to thrive on these marginal soils. Now, her lab has revealed more about the genetic mechanisms behind this survival trait. Although more studies are needed, Sattely believes this avenue of research will one day enable scientists to splice this adaptive mechanism into the genomes of staple crops, thus opening up more farmland for food production and leading to a new, eco-friendly form of plant genetic engineering. "We may be able to take traits developed through natural selection and move them where we need them," Sattely says.

Sattely's lab studies soil microbiomes—the community of bacteria that live around the roots of plants to help them process nutrients in much the same way gut bacteria help people digest food. Her research in this area focuses on one form of plant indigestion: an inability to absorb enough iron, which stunts crop growth and depresses yields.

Scientists have long known why such iron deficiencies occur. Many arid regions of the world, including the western United States, have alkaline soils, and this alkalinity acts like a chemical lock that traps iron in the ground. But after studying this problem for years, Sattely's lab discovered how a plant known as *Arabidopsis thaliana*, a relative of cabbage and mustard, overcomes this iron deficiency thanks to the way its roots interact with alkaline soils. The researchers showed how *Arabidopsis* roots secrete a molecule in the coumarin family that exerts a chemical pull that helps yank iron into the plant, overcoming the countervailing tug exerted by the alkalinity of the soil.

In their most recent experiments, Sattely's lab found another way that coumarin may help *Arabidopsis* acclimate to alkaline conditions: The coumarin molecules that the plant's roots secrete into the soil drive off certain bacteria. Since bacteria also need iron to grow, the researchers surmise that the plant is trying to protect its access to a vital mineral. "Arabidopsis has evolved a metabolic pathway that chemically alters the surrounding soil and its root microbiome when its iron supply is limited," said Mathias Voges, the graduate student in Sattely's lab who led this new work.

To study all these chemical interactions, which typically occur underground and out of sight, Sattely's lab developed an experimental process based on hydroponics. Voges grew *Arabidopsis* plants in water that had a chemical and mineral content similar to that of alkaline soils. To this environment he added the various types of bacteria that normally compose the *Arabidopsis* root microbiome. In the future, researchers can use this hydroponic platform to create different pseudo-soil environments to test how plants react to other adversities—for instance, can plants tune their microbiomes to improve mineral uptake in nitrogen-starved soils?

In the short term, Sattely's lab will try to better understand how the coumarin adaptation works so they can eventually bioengineer wheat, corn or other crops to grow in alkaline soils. Meanwhile, as researchers use the hydroponic technique to discover other root microbiome adaptions, she believes this will lead to a second generation of plant genetic engineering. Instead of engineering manmade traits into plants, scientists will gain the ability to move naturally evolved traits from one plant to another.

"What we envision is a new type of ecologically savvy crop science," Sattely said.

More information: Mathias J. E. E. E. Voges et al. Plant-derived coumarins shape the composition of an Arabidopsis synthetic root microbiome, *Proceedings of the National Academy of Sciences* (2019). DOI: 10.1073/pnas.1820691116

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