Root discovery may lead to crops that need less fertilizer

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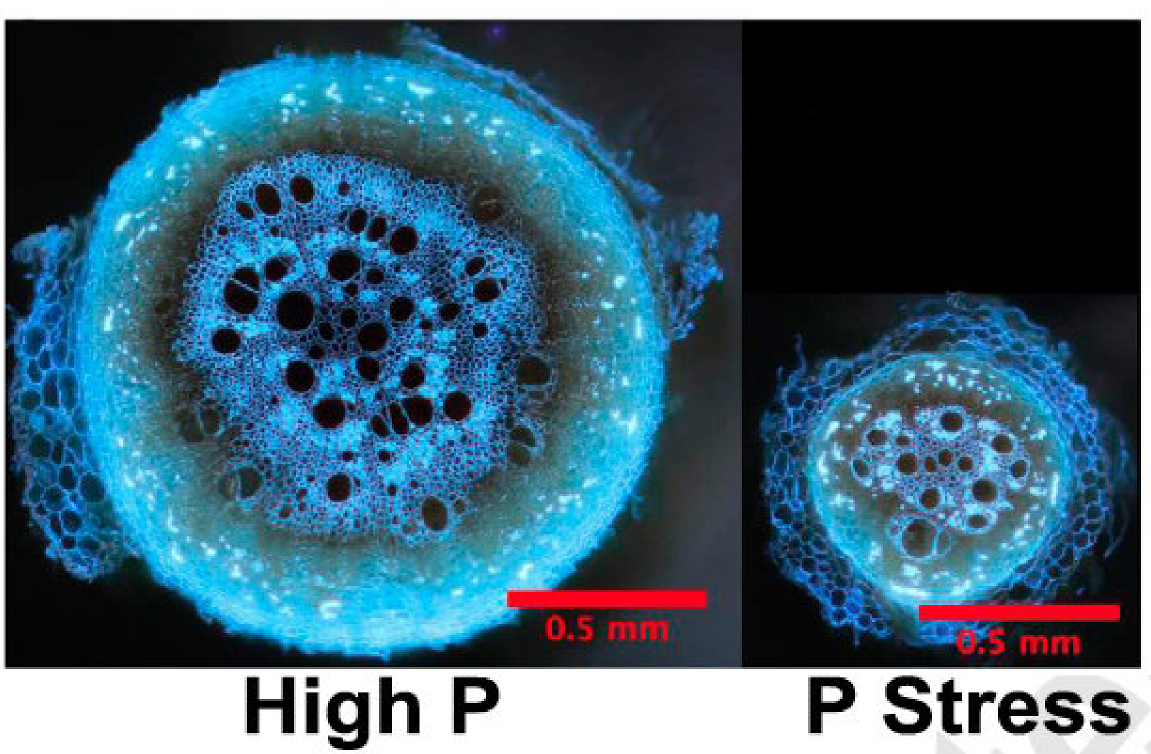
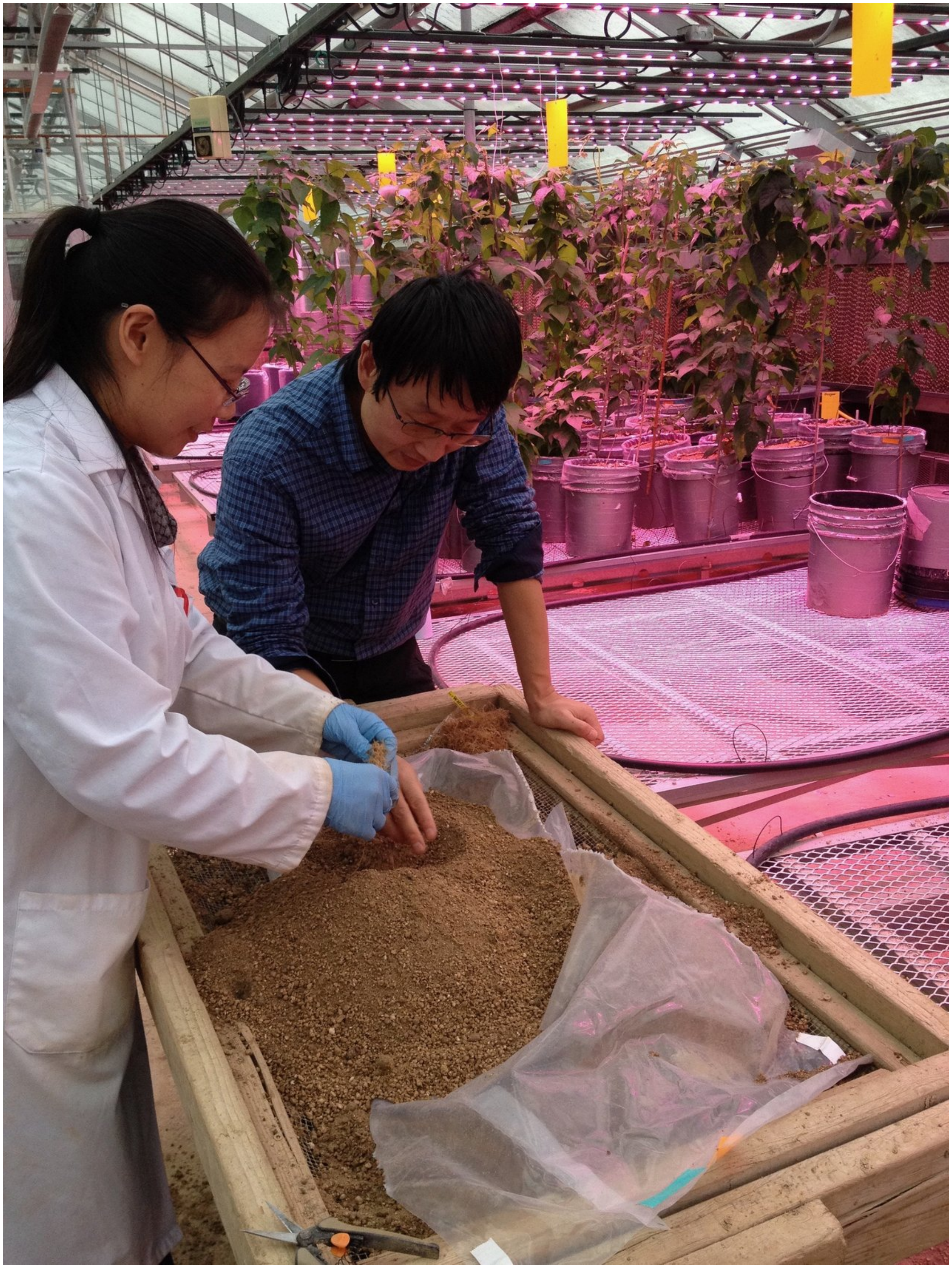


Differences in bean plant growth observed by researchers were striking. In the phosphorus stress treatment, the genotypes with greater reduction of their secondary root growth had increased root length, took up more phosphorus, and had larger shoots than genotypes with greater secondary root growth, which had thicker, less efficient roots. Credit: Jonathan Lynch Lab/Penn State

Bean plants that suppress secondary root growth in favor of boosting primary root growth forage greater soil volume to acquire phosphorus, according to Penn State researchers, who say their recent findings have implications for plant breeders and improving crop productivity in nutrient-poor soils. The increase in the length of the root is referred to as primary growth, while secondary growth is the increase in thickness or girth of the root. Because root growth confers a metabolic cost to the plant, bean plants growing in phosphorus-depleted soils that send out longer, thinner roots have an advantage in exploring a greater volume of soil and acquiring more phosphorus.

"As a natural strategy for plants to deal with phosphorus stress, it's a winner," said lead researcher Christopher Strock, a plant biology doctoral student in the College of Agricultural Sciences. "That's important because most soils throughout the world are phosphorus deficient, and root traits that improve phosphorus acquisition not only can help to improve the efficiency of fertilizer uptake for farmers here in the U.S., but also benefit farmers in developing countries who do not have access to phosphate fertilizers."

Researchers used the common bean as a model for this research because it is one of the most fundamental crops contributing to food security, with greater volume for direct human consumption than any other grain legume. It is especially important throughout the developing world in sub-Saharan Africa and Central and South America, where people don't have wide access to animal protein. In those regions, beans are a primary source of protein and nutrition. Despite the significance of this crop, yields throughout much of the world are constrained by soils that are acidic and extremely depleted in phosphate, one of the main nutrients that plants need to grow.



Research team members are shown here excavating common bean plant roots during the greenhouse experiment. Using laser ablation tomography, they were then able to section and measure root anatomy in hundreds of samples. Credit: Jonathan Lynch Lab/Penn State

"If we can identify root traits that improve foraging efficiency, we can develop new cultivars that have greater ability to take up phosphorus, and have improved yields in these environments," Strock said.

In conducting the study, which was published in this month's issue of *Plant Physiology*, researchers used computer-modeling techniques and grew recombinant, inbred lines of common bean to understand how plants allocate resources to primary and secondary root growth under phosphorus stress. Plants were grown in both greenhouse conditions—at Penn State's University Park campus—and in select fields at the University's Russell E. Larson Agricultural Research Center at Rock Springs.

Normally, Pennsylvania soils would contain too much phosphorus to allow for field experiments on phosphorus stress, but University Distinguished Professor of Plant Science Jonathan Lynch's research group developed a technique to create experimental plots that replicate the phosphorus-depleted conditions of tropical oxisol soils at the Larson facility. This was accomplished by adding truckloads of aluminum oxide pellets to the fields, which binds phosphorus in the soil, making it unavailable to plants.

Normally, Pennsylvania soils would contain too much phosphorus to allow for field experiments on phosphorus stress. But Lynch's research group has developed a technique to create experimental plots that replicate the phosphorus-depleted conditions of tropical oxisol soils at the University's Russell E. Larson Agricultural Research Center at Rock Springs. Credit: Jonathan Lynch Lab/Penn State

Also unique to the Lynch lab is its use of laser ablation tomography to section and measure root anatomy. This revolutionary technique, invented by the Lynch lab, not only allows for greater precision in observations of root anatomy, but also affords researchers the ability to rapidly sample hundreds of root samples per day—a task that would necessitate an impractical amount of labor and time using traditional methods.

Differences in bean plant growth observed by researchers were striking. In the phosphorus stress treatment, the genotypes with greater reduction of their secondary root growth had increased root length, took up more phosphorus, and had larger shoots than genotypes with greater secondary root growth. "All of the genotypes we looked at suppressed their secondary root growth under phosphorus stress, but some showed this response much more strongly than others," said Strock. "And those that suppressed their secondary growth the most, performed better under phosphorus stress because they were able to take the resources they would be putting into secondary growth and increasing root length to forage for more phosphorus."

Lynch noted that his research group collaborates directly with plant breeders at the U.S. Department of Agriculture and agricultural centers in Columbia, Honduras, Mozambique, Zambia and Malawi. Breeders are currently incorporating other discoveries from his lab and are releasing several new varieties of bean with improved root traits for phosphorus acquisition to farmers in Mozambique and Zambia.

"Our goal in this lab is to identify traits like reduced secondary root growth that we can pass along to breeders so that they can incorporate them into their breeding programs," Lynch said. "Working with our breeding partners, varieties of common bean can be developed that have reduced secondary root growth and therefore better yield in poor soils, which will be a huge benefit for small-holder farmers, who rely on beans for food and income."

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