Researchers make discovery that could increase plant yield in wake of looming phosph

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Credit: Mick Lissone/public domain

Scientists at the University of North Carolina at Chapel Hill have pinpointed a key genetic switch that helps soil bacteria living on and inside a plant's roots harvest a vital nutrient with limited global supply. The nutrient, phosphate, makes it to the plant's roots, helping the plant increase its yield.

The work, published in the March 15 issue of *Nature*, raises the possibility of probiotic, microbe treatments for plants to increase their efficient use of phosphate. The form of phosphate plants can use is in danger of reaching its peak - when supply fails to keep up with demand - in just 30 years, potentially decreasing the rate of crop yield as the as the world population continues to climb and global warming stresses crop yields, which could have damaging effects on the global food supply.

"We show precisely how a key 'switch protein',PHR1, controls the response to low levels of phosphate, a big stress for the plant, and also controls the plant immune system," said Jeff Dangl, John N. Couch Distinguished Professor and Howard Hughes Medical Institute Investigator. "When the plant is stressed for this important nutrient, it turns down its immune system so it can focus on harvesting phosphate from the soil. Essentially, the plant sets its priorities on the cellular level."

Dangl, who worked with lead authors, postdoctoral researchers Gabriel Castrillo and Paulo José Pereira Lima Teixeira, graduate student Sur Herrera Paredes and research analyst Theresa F. Law, found evidence that soil bacteria can make use of this tradeoff between nutrient-seeking and immune defense, potentially to help establish symbiotic relationships with plants. Bacteria seem to enhance this phosphate stress response, in part simply by competing for phosphate but also by actively 'telling' the plant to turn on its phosphate stress response.

In recent plant biology studies, there have been hints of a relationship between plant phosphate levels and immune system activity - a relationship that some microbes can manipulate. In the new study, Dangl and colleagues delved more deeply into this relationship, using mutant versions of Arabidopsis thaliana, a weed that has long been the standard "lab rat" of plant biology research.

In one experiment, Dangl's team found that Arabidopsis plants with mutant versions of the PHR1 gene not only had impaired phosphate stress responses, but also developed different communities of microbes in and around their roots when grown in a local native North Carolina soil. This was the case even in an environment of plentiful phosphate - where phosphate competition wouldn't have been a factor - hinting that something else was happening in the plants to trigger the growth of different microbial communities. The researchers found similar results studying PHL1, a protein closely related to PHR1 with similar but weaker functions.

In another experiment, in lab-dish conditions, the researchers colonized roots of sterile-grown normal Arabidopsis plants with a set of 35 bacterial species isolated from roots of plants grown previously in the same native soil. In these re-colonized plants, the phosphate stress response increased when exposed to a low-phosphate condition.

Investigating further, the team showed that PHR1 - and probably to a lesser extent PHL1 - not only activates the phosphate stress response but also triggers a pattern of gene expression that reduces immune activity, and thus makes it easier for resident microbes to survive.

The findings suggest that soil-dwelling microbes have figured out how to get along with their plant hosts, at least in part by activating PHR1/PHL1 to suppress immune responses to them. Dangl's team also thinks these microbes may even be necessary for plants to respond normally to low-phosphate conditions. It could be possible, then, to harness this relationship - via probiotic or related crop treatments - to enable plants to make do with less phosphate.

"Phosphate is a limited resource and we don't use it very efficiently," said Dangl, who is also an adjunct professor of microbiology and immunology at the UNC School of Medicine. "As part of fertilizer, phosphate runs off into waterways where it can adversely affect river and marine ecosystems. It would be better if we could use phosphate in a way that's more efficient."

More information: Root microbiota drive direct integration of phosphate stress and immunity, *Nature*, nature.com/articles/doi:10.1038/nature21417

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