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Nano Science, Technology and Industry Scoreboard

Nanoscale Nutrients Can Protect Plants from Fungal Diseases

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Researchers are fortifying crops with nutrients fashioned into nanosized packages, which boost plants’ innate immunity against pathogenic fungi more efficiently than traditional plant feeding.

Chances are, most — if not all — of the produce in your kitchen is threatened by fungal diseases. The threat looms large for food staples of the world such as rice, wheat, potatoes and maize (SN: 9/22/05). Pathogenic fungi are also coming for our coffee, sugarcane, bananas and other economically important crops. Annually, fungal diseases destroy a third of all harvests and pose a dire threat to global food security.

To stop the spread of fungal diseases, farmers fumigate the soil with toxic chemicals that lay waste to the land, sparing not even the beneficial microbes teeming in the earth. Or they ply plants with fungicides. But fungicide use is effective only in the short run — until the pathogenic fungi evolve resistance against these synthetic chemicals.

Now, a new idea is taking root: Help plants stand their ground by giving them the tools to fight their own battles. A team led by Jason White, an environmental toxicologist at the Connecticut Agricultural Experiment Station in New Haven, is fortifying crops with nutrients fashioned into nanosized packages, which boost plants’ innate immunity against pathogenic fungi more efficiently than traditional plant feeding. Over the past few years, the researchers have devised various nanonutrient concoctions that boost the fungal resistance of soybeans, tomatoes, watermelons and, recently, eggplants, as reported in the April Plant Disease.

The concept “tackles the challenge at the origin rather than trying to put a Band-Aid on the [problem],” says Leanne Gilbertson, an environmental engineer at the University of Pittsburgh who was not involved in the research. White’s strategy provides plants with the nutrients they need to trigger enzyme production to guard against pathogenic attack. Without any synthetic chemicals introduced, the strategy sidesteps any opportunity for malignant fungi to develop resistances, she says.

The researchers’ nanomaterials approach is inspired by their earlier discovery that nanoparticles transported up from the roots of maize can loop back down from the leaves. The researchers dipped half of the root fibers of a single maize plant in a copper nanoparticle formulation and the other half in pure water. The copper showed up in the water-dipped roots, pointing to a roots-to-shoot-to-roots roundtrip, White and his colleagues reported in 2012 in Environmental Science & Technology. That finding suggested that nanoparticles can be applied directly to the leaves in the first place, even when the target destination was the roots.

Using the leaves as an entrance point gets around a perennial problem: Delivering dissolved nutrients through the soil is hardly efficient. Chemicals may break down in the soil, vaporize into the atmosphere or leach away. Only about 20 percent of watered nutrients eventually reach the target areas in a plant. “By using the nanoscale form, we can actually more effectively deliver [nutrients] where we want it and where the plant needs it,” White says.

To see if this approach could deliver nutrients specifically needed in defense against hostile fungi, White and colleagues carried out tests in eggplants and tomatoes. The team sprayed metallic nanoparticles onto the leaves and shoots of young plants, then infected the plants with pathogenic fungi. The nanoparticle-treated plants had elevated levels of nutritional metals in the roots and higher produce yields compared with the plants fed readily dissolved nutrients, the team reported in 2016 in Environmental Science: Nano.

The nanoparticles weren’t harming the fungi, the researchers found: The fungi still thrived amidst nanoparticles in the environment without the host plant present. Instead, the nanoparticles’ antifungal properties stem from providing plant nourishment — equivalent to humans taking nutritional supplements — that allows plants to mount an appropriate defense on demand.

What makes nanonutrients more potent than common fertilizers is the sweet spot in their sizes, which control how fast they dissolve, says Fabienne Schwab, an environmental chemist not involved in the research. Nanonutrients are thousands of times smaller than the diameter of human hair and thousands of times larger than readily dissolved nutrient salts. They have a large, exposed surface, so they dissolve more quickly than a heftier chunk of the same nutrient. Yet nanonutrients are big enough that that they don't dissolve all at once: They can gradually release the nutrients over weeks. In contrast, readily dissolved nutrients give plants a temporary nutrient spike, akin to a sugar rush.

"When you use [nutrients] at the nanoscale, you can tune the solubility pretty much the way you like," says Schwab, of the Adolphe Merkle Institute in Fribourg, Switzerland.

It's not just the size that can be tuned — the shape, composition and surface chemistries can be modified to stimulate different levels of a plant's responses. For instance, White and his collaborators found that nanometer-thin copper oxide sheets were better than spherical copper nanoparticles at preventing Fusarium virguliforme infection in soybeans. The key to their effectiveness lay in the nanosheets' quicker release of charged copper atoms and stronger adhesion to leaf surfaces. The copper nanomaterials restored the soybean's masses and photosynthesis rates to the levels of disease-free plants, the team reported in Nature Nanotechnology in 2020.

"It's a very promising technology," says Schwab, but she adds that there are other aspects to consider before its implementation. If agricultural nanotechnology is to achieve widespread use, it needs to observe environmental and safety regulations, as well as — perhaps even more challengingly — overcome consumer wariness. So far, White and his collaborators found no residual nanonutrients in their produce that would end up on the dining table of consumers. But other implications, such as the nanomaterials' persistence in the environment and hazards posed to human handlers, have yet to be fully understood.

"People in general get nervous when you talk about nanotechnology and food," says White. But he says his group isn't using any exotic materials, whose health impacts remain complete enigmas. Instead "we're using nutrients the plants need [that] they just can't get enough of."

White says he has eaten the eggplants, tomatoes and watermelons he's grown for his research. And perhaps that's the best reassurance consumers can get: a toxicologist trying the literal fruit of his labor.

Read the original article on Science News.