Precision (plant) medicine: Biotech drug delivery system fights diseases pesticides can’t control

A new method developed by engineers at MIT may offer a starting point for delivering life-saving treatments to plants ravaged by such diseases.

These diseases are difficult to detect early and to treat, given the lack of precision tools to access plant vasculature to treat pathogens and to sample biomarkers. The MIT team decided to take some of the principles involved in precision medicine for humans and adapt them to develop plant-specific biomaterials and drug-delivery devices.

The method uses an array of microneedles made of a silk-based biomaterial to deliver nutrients, drugs, or other molecules to specific parts of the plant. The findings are described in the journal Advanced Science, in a paper by MIT professors Benedetto Marelli and Jing-Ke-Weng, graduate student Yunteng Cao, postdoc Eugene Lim at MIT, and postdoc Menglong Xu at the Whitehead Institute for Biomedical Research.

The microneedles, which the researchers call phytoinjectors, can be made in a variety of sizes and shapes, and can deliver material specifically to a plant’s roots, stems, or leaves, or into its xylem (the vascular tissue involved in water transportation from roots to canopy) or phloem (the vascular tissue that circulates metabolites throughout the plant). In lab tests, the team used tomato and tobacco plants, but the system could be adapted to almost any crop, they say. The microneedles can not only deliver targeted payloads of molecules into the plant, but they can also be used to take samples from the plants for lab analysis.

The work started in response to a request from the U.S. Department of Agriculture for ideas on how to address the citrus greening crisis, which is threatening the collapse of a $9 billion industry, Marelli says. The disease is spread by an insect called the Asian citrus psyllid that carries a bacterium into the plant. There is as yet no cure for it, and millions of acres of U.S. orchards have already been devastated. In response, Marelli’s lab swung into gear to develop the novel microneedle technology, led by Cao as his thesis project.

The disease infects the phloem of the whole plant, including roots, which are very difficult to reach with any conventional treatment, Marelli explains. Most pesticides are simply sprayed or painted onto a plant’s leaves or stems, and little if any penetrates to the root system.

Such treatments may appear to work for a short while, but then the bacteria bounce back and do their damage. What is needed is something that can target the phloem circulating through a plant’s tissues, which could carry an antibacterial compound down into the roots. That’s just what some version of the new microneedles could potentially accomplish ….

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Sure enough, they tested the material on their lab tomato and tobacco plants, and were able to observe injected materials, in this case fluorescent molecules, moving all they way through the plant, from roots to leaves.

“We think this is a new tool that can be used by plant biologists and bioengineers to better understand transport phenomena in plants,” Cao says. In addition, it can be used “to deliver payloads into plants, and this can solve several problems. For example, you can think about delivering micronutrients, or you can think about delivering genes, to change the gene expression of the plant or to basically engineer a plant.”

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So far, this is a lab technique using precision equipment, so in its present form it would not be useful for agricultural-scale applications, but the hope is that it can be used, for example, to bioengineer disease-resistant varieties of important crop plants. The team has also done tests using a modified toy dart gun mounted to a small drone, which was able to fire microneedles into plants in the field. Ultimately, such a process might be automated using autonomous vehicles, Marelli says, for agricultural-scale use.

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