How plants interact with beneficial microbes in the soil

January 12 2016

Credit: Mick Lissone/public domain

Scientists have wondered for years how legumes such as soybeans, whose roots host nitrogen-fixing bacteria that produce essential plant nutrients out of thin air, are able to recognize these bacteria as both friendly and distinct from their own cells, and how the host plant's specialized proteins find the bacteria and use the nutritional windfall.

Now a team of molecular biologists led by Dong Wang at the University of Massachusetts Amherst, working with the alfalfa-clover Medicago truncatula, has found how a gene in the host plant encodes a protein that recognizes the cell membrane surrounding the symbiotic bacteria, then directs other proteins to harvest the nutrients. Details appear online in the January edition of *Nature Plants*.

As Wang explains, plants often recruit microbes to help them satisfy their nutritional needs, offering the products of photosynthesis as a reward. A process used by most land plants depends on a symbiotic relationship with mycorrhizal fungi. These form structures known as arbuscules that help plants capture phosphorus, sulfur, nitrogen and other micronutrients from the soil. This method is akin to scavenging, Wang says, because the amount of nitrogen available in soil is quite limited.

By contrast, the less common process, found mostly in legumes, goes one giant step further: it uses bacteria called rhizobia, which live in root nodules and fix nitrogen from the air and make it into ammonia, a plant fertilizer. Symbiosis with rhizobia means legumes can make ammonia by fixing nitrogen in the air, which at 78 percent of the atmosphere, is "essentially limitless," the biochemist adds.

Thanks to this feat, legume plants can get as much nitrogen fertilizer as they need, rather than relying on often scarce nitrogen in the soil. This is why beans are so nutritious, Wang notes. "The next time you eat your tasty tofu or edamame, you have those little bacteria, and their 'marriage' with legumes to thank."

"Talk to anyone in our field, and the dream is to make it possible for our crops that can't fix nitrogen to get that ability," Wang suggests. "This discovery moves us one step closer. Beans are special, but what our result says is they are not that special because some of the basic infrastructure is already there in plants that use arbuscular mycorrhizal fungi instead of nitrogen-fixing bacteria, which no one understood before."

The researchers led by Wang with postdoctoral researcher Huairong Pan and doctoral students Onur Oztas and Christina Stonoha at UMass Amherst plus others in China, discovered that in both processes bacteria and fungi exchange nutrients with the plant across a cell membrane recognized by a specially encoded protein made by the host plant that defines its borders. "It's as if the plant has discovered how to create a sort of free trade zone," Wang says.

To explore how this trade works, the team, supported by a grant from UMass Amherst, investigated activities of the gene SYNTAXIN 132, which encodes receptors (SYP132) that identify cell membranes and interact with secretory vesicles. They found that the gene usually makes one sort of transcript that always seeks out the plant cell's surface membrane. But if rhizobia are present in the host, that same gene will make a second type of protein that is able to find the membrane surrounding the bacteria. Surprisingly, symbiosis with arbuscular mycorrhizal fungi shares the same SYP132 receptor. Scientists now understand that the host membrane - both in legumes and beyond - around the fungal arbuscule has a lot in common with the membrane around the nitrogen-fixing bacteria.

He adds, "The gene somehow knows the bacteria are present and makes the alternative type of protein, which finds the membrane around the bacteria. This means that the host can tell the two membranes apart, can sort them out."

"Our discovery is that the two SYP132 proteins are not the same, even though they come from the same gene. The gene makes two transcripts, which involves an unusual process near the end of the gene, like a movie with two different endings. Nobody knew there exist two proteins," Wang explains. "So the answer is that one gene can use alternative terminal exons to make two proteins with different sequences at the end. And it's the ends that determine where in a cell the protein ends up."

He says the new knowledge he and colleagues uncovered is important to future agricultural advances because the same process works similarly in most plants, nitrogen fixing or not.

More information: Huairong Pan et al. A symbiotic SNARE protein generated by alternative termination of transcription, *Nature Plants* (2016). DOI: 10.1038/nplants.2015.197

Provided by University of Massachusetts Amherst