Why communication is vital—even among plants and funghi

May 26 2017

Plant scientists at the University of Cambridge have found a plant protein indispensable for communication early in the formation of symbiosis - the mutually beneficial relationship between plants and fungi. Symbiosis significantly enhances a plant's ability to take up vital nutrients like phosphate from the soil, and understanding the processes involved holds great promise for the development of sustainable 'biosolutions' to enhancing food production in order to feed a growing global population.

By analysing a mutant strain of maize (called Zmnope1) that does not form symbiotic associations with fungi, the scientists managed to identify the missing gene - NOPE1 - which codes for a transporter molecule not previously described in plants. The new study, published today in *Nature Plants*, suggests that the plant's NOPE1 gene must be working properly if beneficial fungi in the soil - called arbuscular mycorrhizal (AM) fungi - are to properly respond to signals released by plant roots and begin the process of forming this vital symbiotic relationship.

"The fungus and the plant need each other as symbiotic partners, and communication is vital in finding each other," says study principal investigator and research group leader Dr Uta Paszkowski. "Wild type plants release something that conditions the fungus for symbiosis, but if the plant can't talk to the fungus due to the missing transporter, the fungus won't be able to respond."

The NOPE1 gene codes for a transporter of a molecule called N-acetylglucosamine (GlcNAc), a building block of chitin, which is a major component of the cell walls of most fungi and also of many signalling molecules. It has previously been shown in the fungal pathogen Candida albicans that when GlcNAc is transported into a fungal cell it activates cell signalling. It increases the expression of genes that promote hyphal growth leading to pathogenic interactions with a host plant. In this new study, exposure of AM fungi to the exudate of rice plant roots with functional NOPE1 had a similar effect, causing the fungi to invade the roots of plants, and also to express virulence genes that help them attach to host plant cells.

The Cambridge team's work now provides the first evidence that the previously unknown plant GlcNAc transporter protein also plays a role at the other side of this relationship - in the initiation of plant root colonization by AM fungi. Wild type rice roots were shown to acquire and release GlcNAc, with uptake clearly dependent on NOPE1. The transporter they identified is the first plasma membrane transporter of GlcNAc ever identified in plants.

"This is the first plant protein ever reported to be indispensable for communication between plants and the fungus in the rhizosphere," says Paszkowski. "Symbiosis starts when the plant roots and fungi exchange various types of chemical signal in the soil. Even before the two organisms have made physical contact, signalling molecules are released into the rhizosphere - the region of soil accessible to both fungus and plant root. They form symbiosis for life, so it's an important decision."

Symbiotic interactions between plants and fungi have long been known to exist, but until now knowledge of this process has been limited to the stimulatory effects of plant hormones called strigolactones on fungal metabolism and development. Through clever association with arbuscular mycorrhizal (AM) fungi, plants significantly extend their reach by increasing the surface area of their roots. The fungus establishes itself in the plant root and grows long, branching extensions underground called hyphae that facilitate the uptake of minerals from the soil. The relationship is termed symbiotic because both parties benefit: the plant gains minerals important for its growth through the fungus, and the fungus gains nutrients it needs to survive from the plant.

Symbiosis can profoundly influence plant performance in both wild and cultivated systems. Being fixed to the spot, plants can't relocate once they've used up the minerals in the soil beneath them. That's why farmers rely on large quantities of expensive fertilizers to ensure their crops grow well. Understanding how plants and fungi communicate to form these symbiotic relationships could lead to the development of cheaper, environmentally-friendly ways to ensure crops get all the nutrients they need.

"By better understanding this early communication process we can find ways to manage the establishment of symbiosis, for example to achieve a faster delivery of nutrients to crops from the soil," says Paszkowski. "In crops with a short growing season, speeding up symbiosis development could reduce the amount of phosphate fertiliser needed. It would be a cheaper and more sustainable way of growing crops."

Managing this natural process to biofertilise crops could be one approach to help feed the world's growing population sustainably. The current high levels of chemical fertiliser used to pump minerals into the soil are not only damaging to the environment, but are expensive. The potential now exists to develop new strains of crop that work better in low-input agricultural systems. Smallholder farmers in the poorer countries of the world could better afford these biosolutions, leading to good crop yields and a good income for their families to help raise them out of poverty.

With the global population estimated to reach nine billion people by

2050, producing enough food will be one of this century's greatest challenges. Paszkowski and her team are members of the Cambridge Global Food Security Initiative at Cambridge, which is involved in addressing the issues surrounding food security at local, national and international scales.

More information: An N-acetylglucosamine transporter required for arbuscular mycorrhizal symbioses in rice and maize, *Nature Plants* (2017). nature.com/articles/doi:10.1038/nplants.2017.73

Provided by University of Cambridge