Scientists identify a new signaling component important for plant symbiosis

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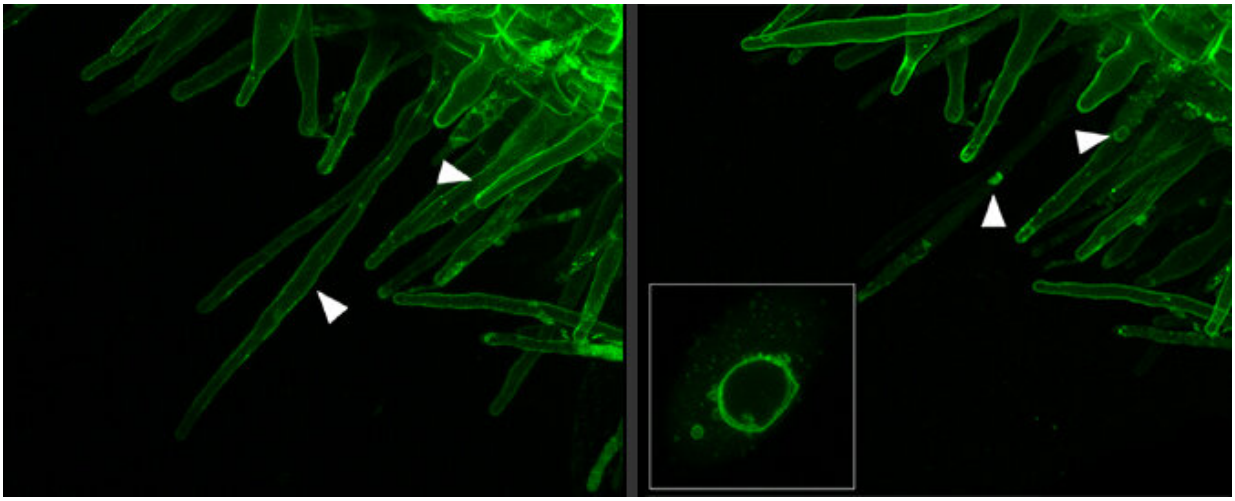

Confocal microscopy images showing NICK4-GFP translocation to the nucleus upon perception of nod factors in Lotus japonicus roots. Credit: Marcin Nadzieja/AU

A proteomics-based protein-protein interaction study has led to the discovery of proteins that interact with a legume receptor that mediates signal transduction from the plasma membrane to the nucleus. This shows how symbiotic signals from symbiotic bacteria are transmitted upon perception, ultimately leading to their accommodation within the host plant.

Legumes are of significant agricultural importance mainly due to their

abilities to establish symbiotic relationship with nitrogen-fixing bacteria known as rhizobia. A deeper understanding of biological nitrogen fixation (BNF) and subsequent transfer of this knowledge to crop plants would allow us to circumvent the use of fertilizers and grow crops sustainably. In addition, the successful transfer of BNF to non-legume crops would especially benefit smallholder farmers who can then increase crop yield without facing cash constraints associated with the purchase of inorganic fertilizers.

To contribute to this goal, members of the Plant Molecular Biology group at Aarhus University directed by Professor Jens Stougaard have dedicated their research to understanding legume-rhizobial symbiosis. In 2003, the group identified the plasma-membrane localized Nodulation (Nod) factor receptors 1 and 5 (NFR1 and NFR5) responsible for the recognition of compatible symbionts; Nod factors are symbiotic signalling molecules that vary in structure depending on the rhizobium species. Using a stringent lock (Nod factor receptors) and key (Nod factor) mechanism, only compatible rhizobia are allowed to enter the plant while incompatible bacteria will not be able to infect and colonize the root nodules.

A breakthrough after 15 years' research

For over 15 years, components involved in directly relaying Nod factor signals downstream of Nod factor receptors have remained elusive, limiting the researchers' understanding of how these Nod factor receptors ultimately lead to changes in root hair structure and formation of new organs (nodules) required for rhizobia entry and accommodation. A breakthrough was finally achieved using an elegant Proteomics approach and by taping on the expertise of colleagues from Cyril Zipfel's research group (The Sainsbury Laboratory, UK) who have constantly unravelled new players in plant defence signalling.

The work published in the *PNAS* journal describes how the researchers fished for interactors using NFR5 as bait. Similar to signalling processes involved in plant defence, vegetative, and reproductive growth, they observed that a receptor-like cytoplasmic kinase is pivotal for transducing signals downstream of receptors after ligand perception in symbiosis signalling. The researchers named this cytoplasmic kinase NFR5-interacting cytoplasmic kinase 4 (NiCK4). They hypothesize that upon Nod factor perception, a phosphorylation cascade involving NiCK4, NFR1 and NFR5 results in NiCK4 localization to the nucleus where several critical legume symbiosis components are present, and subsequently promote the formation of nodules used to house compatible rhizobia.

The Nod factor and Nod factor receptor triggered movement of NiCK4 from the plasma membrane to the nucleus is very exciting data as calcium oscillations in the nucleus is a hallmark of symbiosis signalling in legumes. Following this discovery, the research team hopes to assemble and connect more symbiosis signalling components. A thorough understanding of all components involved in the symbiosis signalling pathway is crucial for successful transfer of BNF to non-legume crops.

More information: Jaslyn E. M. M. Wong et al, ALotus japonicuscytoplasmic kinase connects Nod factor perception by the NFR5 LysM receptor to nodulation, *Proceedings of the National Academy of Sciences* (2019). DOI: 10.1073/pnas.1815425116

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