New discoveries offer critical information for improving crop yield

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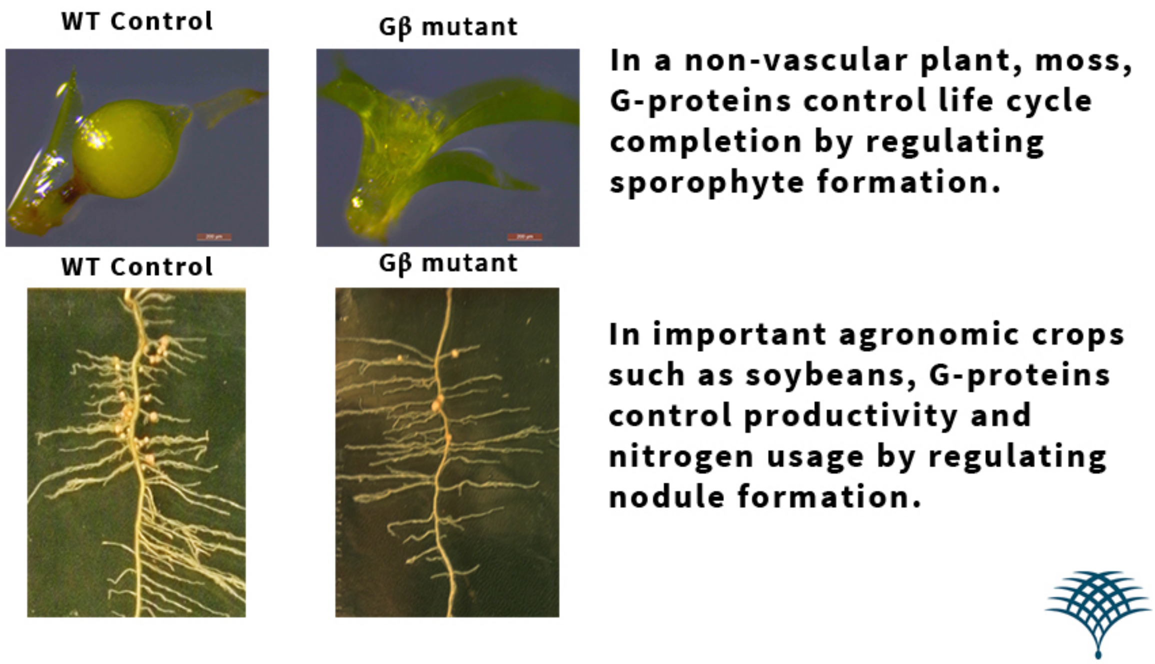

G protein discoveries are important because they play critical roles in plants' development. Credit: Donald Danforth Plant Science Center

In recent years, scientists at the Donald Danforth Plant Science Center, one of the world's largest independent plant science institutes, have made several scientific discoveries demonstrating the significant roles of Heterotrimeric G proteins in plant development, stress tolerance and yield improvement. In recent months, Sona Pandey, Ph.D., principal investigator at the Danforth Center and her collaborators have published a series of new papers on their research which is funded by the National Science Foundation (NSF) and the National Institute of Food and Agriculture (NIFA). The recent publications reveal more information about how G proteins evolved and provide clues to their role in regulating plant growth and abiotic stress response.

Heterotrimeric G-proteins are present in all eukaryotic organisms from simple fungi to humans and plants. The proteins regulate critical growth and development processes in these organisms by acting as molecular switches. While extensively studied in humans due to their involvement in a multitude of diseases and neurotransmission, the knowledge of G-protein signaling mechanisms and their significance in plants remains relatively scarce. Pandey and colleagues were first to discover G-protein in green algae, confirming that the proteins existed early on during plant evolution. In their recent work in collaboration with Dr. Ralph Quatrano's group at Washington University in St. Louis, they discovered that G proteins are essential for the life cycle completion in moss, a non-vascular plant of basal plant lineage. Moss, which has a predominant gametophytic life style, interspersed with a short sporophytic phase, failed to form sporophytes (the only diploid stage in its life cycle) when specific G-protein subunits were genetically removed. This is significant because prior to this work, the plant G-proteins were thought to be non-essential and modulatory in nature. Results of this research were published in the journal, *Plant Physiology* titled "Sporophyte formation and life cycle completion in moss requires heterotrimeric G-proteins" Aug 22. pii: pp.01088.2016.

One of the key focus areas of the Pandey lab research is to uncover both conserved and unique signaling mechanisms and components of heterotrimeric G-proteins in plants. To address some of the questions related to the proposed loss of one of the key regulatory proteins of the

G-protein complex, the Regulator of G-protein Signaling (RGS) protein in the monocot lineage, they performed a large evolutionary and structure/function analysis in collaboration with Dr. Toby Kellogg's lab at the Danforth Center and Dr. Joe Jez's lab at Washington University. Their results challenged the current dogma in the field and confirmed that the RGS proteins are wide-spread in the monocot lineage, despite their frequent loss. This research also showed that the functional interface between the G-protein α subunit and the RGS proteins is conserved across all organisms including between plants and humans. This research is recently published in the journal, New Phytologist, titled "Gα and Regulator of G-protein Signaling (RGS) protein pairs maintain functional compatibility and conserved interaction interfaces throughout evolution despite frequent loss of RGS proteins in plants."

In an attempt to identify additional proteins that possess similar biochemical activities as the RGS proteins, the Pandey lab also identified the role of a type of lipid hydrolyzing proteins, the phospholipase Dα1 (PLD α1) in regulating G-protein cycle. This research provided clues to additional proteins that are involved in the regulation of G-protein signaling pathways in plants, and added significantly to the diversity that may exist in plants' regulatory mechanisms. This research also demonstrated that the same G-protein subunits and their modulators exhibit distinct physiological and genetic interactions depending on specific signaling and a developmental pathway which helps to fine tune the plants' responses to constantly changing environments. These findings were recently published in *The Plant Journal* in an article titled "The role of PLDα1 in providing specificity to signal-response coupling by heterotrimeric G-protein components in *Arabidopsis*" 86(1):50-61. DOI: 10.1111/tpj.13151.

Additional, more directly applied aspects of research in the Pandey lab are related to the regulation of nodule formation in legumes such as soybeans and yield enhancement by controlling seed size and seed number. They recently discovered the role of G-proteins in regulation of nodule formation in soybean and uncovered a signaling pathway where the receptors of Nod factor perception interact with and phosphorylate G-protein components to control nodule number in plants. This research was published in *The Plant Cell* titled "Phosphorylation-Dependent Regulation of G-Protein Cycle during Nodule Formation in Soybean" 27(11):3260-76. DOI: 10.1105/tpc.15.00517.

The research related to yield improvement in crops is related to a newly discovered subunit of G proteins, the type III Gγ. The Pandey lab was first to discover it in soybeans and it was simultaneously reported in *Arabidopsis* from two additional groups. The research from Pandey's lab and others' has confirmed the role of type III Gγ proteins in improved yield, nitrogen use efficiency and stress responses. This work has led to important hypothesis development about several unanswered questions related to the action mechanism of these proteins, for which Pandey has been recently awarded a grant from the National Science Foundation.

"G proteins, alpha, beta and gamma and their modulators are important because they play critical roles in plants' development, including fruit and seed size and production, defense against pests and pathogens and response to abiotic stresses such as drought and ozone," Pandey said. "Understanding their function at the very basic level is an important step in the process of developing products that can be applied to improve crop yield and address environmental issues related to production agriculture."

Ongoing research in the Pandey lab seeks to improve crops that require less nitrogen-containing fertilizer and limit stress factors to increase yield by understanding the regulatory mechanisms and structure/function relationships of important signaling proteins in plants.

Provided by Donald Danforth Plant Science Center