Space Life Sciences Research Highlights

# Growing Plants in Spaceflight Could Help Reveal How They Sense Their World

*Plants may lack a brain and nervous system, but they know and respond when their environment changes. NASA-funded researcher Simon Gilroy of the University of Wisconsin-Madison is working to better understand how they do this by growing a thousand* Arabidopsis thaliana *plants on the International Space Station. He and his team have discovered an "information highway" that can quickly send a signal from root to tip. And their work should provide molecular targets that will let scientists tailor plants to grow better in space and on Earth, even in a flood.*

When a plant grows up inside a greenhouse, safe from the wind and rain, it is more susceptible to pathogens than one raised fully outdoors. Gardeners know that to grow stronger plants, they need to provide some kind of stimulation for their seedlings, such as regularly shaking them or placing a fan nearby. But how does that shaking or gentle breeze signal to the plant that it needs to change the way it grows?

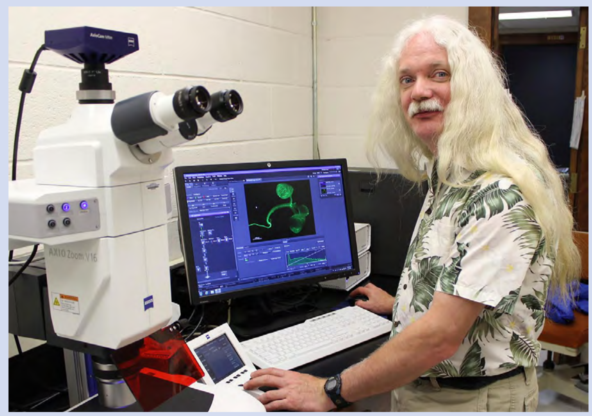
Plants don't have a brain or nervous system, notes Simon Gilroy, a professor of botany at the University of Wisconsin-Madison. But they can sense changes to their environment, such as lower oxygen levels caused by flooding, the munching of insects, or when they have been given a shake. Gilroy would like to know how plants gain that knowledge and spread it throughout the plant.

As part of his research, Gilroy and his colleagues have sent tiny plants of a well-studied species called *Arabidopsis thaliana*, or mouse-ear cress, on spaceflight missions. "Going into space allows you to ask questions that are impossible to do on Earth," Gilroy says, such as how plants know up from down. But his research is important for another reason: "If we're going to spend any real time in space, we have to take plants with us." Astronauts are already growing lettuce aboard the International Space Station (ISS). But if future space travelers want to grow food or flowers on Mars, we will need a better understanding of how plants respond to the spaceflight environment, Gilroy says.

### A Plant's Information Highway

Plants may not have a nervous system, but as in many organisms, their cells can communicate through the movement of calcium ions. Calcium signaling "is ubiquitous in biology," Gilroy notes. "It's making your heart beat. It's making your nerves fire."

Before he sent any experiments into spaceflight, Gilroy needed to better understand how calcium signals move through plant cells. He and his colleagues engineered *Arabidopsis* plants so that cells would glow green when calcium levels were low and red when they increased. The researchers placed a drop of salty water on a plant's root—those cells turned red. Then cells nearby changed color, and soon the researchers could see a wave of calcium traveling through certain layers of the plant's cells all the way to its top.



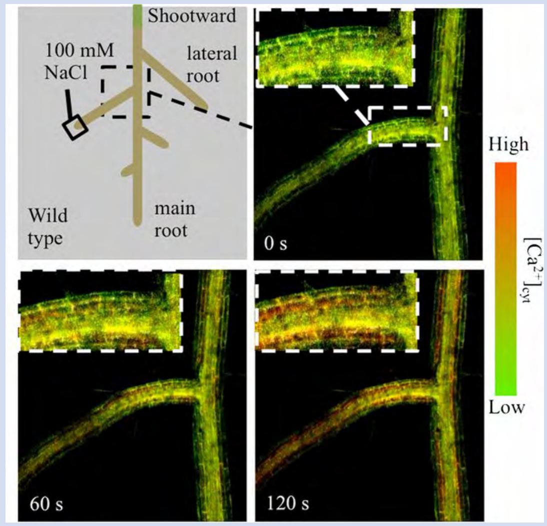
*Simon Gilroy has sent tiny* Arabidopsis *seedlings to the International Space Station as part of an effort to discover how plants sense the world around them.*
Credit: Courtesy of S. Gilroy

This was the first time scientists could see such a calcium signal moving through a plant; it traveled at a speed of about eight cells, or a few millimeters, per second. "That's not as fast as nerve conduction, but at a biological level, that is a really rapid communication," Gilroy says. "It's almost like there's an information highway that's plumbed into the plant." His team reported their finding in 2014 in the *Proceedings of the National Academy of Sciences.*

Calcium signaling is thought to be important to how plants respond to many different stressors, including hypoxia. For his first spaceflight experiment in March 2013, Gilroy and his team wanted to examine how *Arabidopsis* plants respond to a low-oxygen environment. On the ground, hypoxia is a frequent condition, occurring, for example, when plants get flooded. But it also is thought to develop around the roots of plants grown in space, because there is no gravity there to aid gas convection.

The researchers had to pack their experiment into a small cylinder called a BRIC (for Biological Research in Canisters). Each BRIC held five or six Petri dishes full of *Arabidopsis* seeds. On the ISS, the cylinder was warmed up so that the plants would start growing. And after eight days, an astronaut added a chemical that stopped the growth process, "fixing" the plants at that point in their development.

After the plants returned to Wisconsin, Gilroy and his team extracted RNA from the small seedlings and from controls on the ground. The RNA will tell them which genes were turned on inside a plant and to what degree. The researchers are now analyzing the RNA patterns and will determine the differences between plants grown during spaceflight and on the ground.




*After sodium chloride solution was applied to a plant's root tip, a wave of calcium signals (red) emanated through the root.* Credit: W.-G. Choi et al. Proc Natl Acad Sci U S A, 2014

"We're looking for the patterns of which things go up and which things go down in space," Gilroy says. That is a complicated task because there are around 40,000 data points and there are many aspects of spaceflight that can affect a plant's growth on the ISS.

The team sent several different types of *Arabidopsis* into spaceflight. One is a "wild-type" strain, meaning that its genes haven't been altered in any way. Two others had mutations in a gene involved in calcium transport. By studying the three different types of *Arabidopsis*, Gilroy hopes not only to learn more about calcium signaling but also to find molecular targets for designing plants that are more tolerant to flooding and other low-oxygen conditions.

## Data for New Discoveries

Spaceflight also provides a unique opportunity to examine why plants respond to mechanical stimulation, such as a gardener's shake. In the weightlessness of space, plants grow in what Gilroy calls "a mechanically silent environment." With no gravity to weigh plants down, "they get lazy," he says. Plants tend to grow long, thin, and spindly stems, and they can be more susceptible to a pathogen attack than a plant grown on Earth.

To better understand the molecular changes behind this response and illuminate the effect of gravity on plant growth, Gilroy sent a second BRIC experiment to the ISS in September 2014. This time his team loaded up the Petri dishes with wild-type *Arabidopsis* plants as well as plants that had mutations in a gene called TCH-2 that appears to be a central player in how plants respond to stimuli such as being touched. In some plants the gene was always "on"; in others, it was always "off." A second set of control plants was raised in similar conditions on the ground. As with the hypoxia experiment, the RNA of these plants is now being analyzed to see how gene expression is altered by spaceflight and what can be learned from that about the role of gravity on plant growth and development.

"The learning curve for doing space science is really steep," Gilroy notes, and "opportunities for putting experiments into space are fantastically limited." So Gilroy's second BRIC experiment had another component that was part of NASA's GeneLab project. This project is gathering datasets from spaceflight—such as protein expression and genomic data—and releasing them to the public via an online repository (*http://genelab.nasa.gov/data*).

For Gilroy's contribution to GeneLab, his team included in their BRIC containers several ecotypes of *Arabidopsis*. Each ecotype represents a well-studied population of plants from a different geographic location. Similar to Gilroy's other experiments, these plants will have their gene expression data analyzed.

The open-source data "should spawn a bunch of new experiments," Gilroy says. Or theoretically, he says, "your grandmother sitting in front of her laptop can download the data and work out what happened in space."

## Further Reading


Jayaraman D, Gilroy S, Ané J-M. Staying in touch: mechanical signals in plant-microbe interactions. Current Opin Plant Biol. 2014 Aug;20:104-9.

Choi W-G, Toyota M, Kim SH, Hilleary R, Gilroy S. Salt stress-induced Ca2+ waves are associated with rapid, long-distance root-to-shoot signaling in plants. Proc Natl Acad Sci U S A. 2014 Apr 29;111(17):6497-502.

Toyota M, Ikeda N, Sawai-Toyota S, Kato T, Gilroy S, Tasaka M, Morita MT. Amyloplast displacement is necessary for gravisensing in *Arabidopsis* shoots as revealed by a centrifuge microscope. Plant J. 2013 Nov;76(4):648-60.



**For additional information, contact:** Space Life and Physical Sciences Research and Applications Division, National Aeronautics and Space Administration *http://www.nasa.gov/directorates/heo/slpsra/*

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