A different kind of green movement: Seedling growth in space

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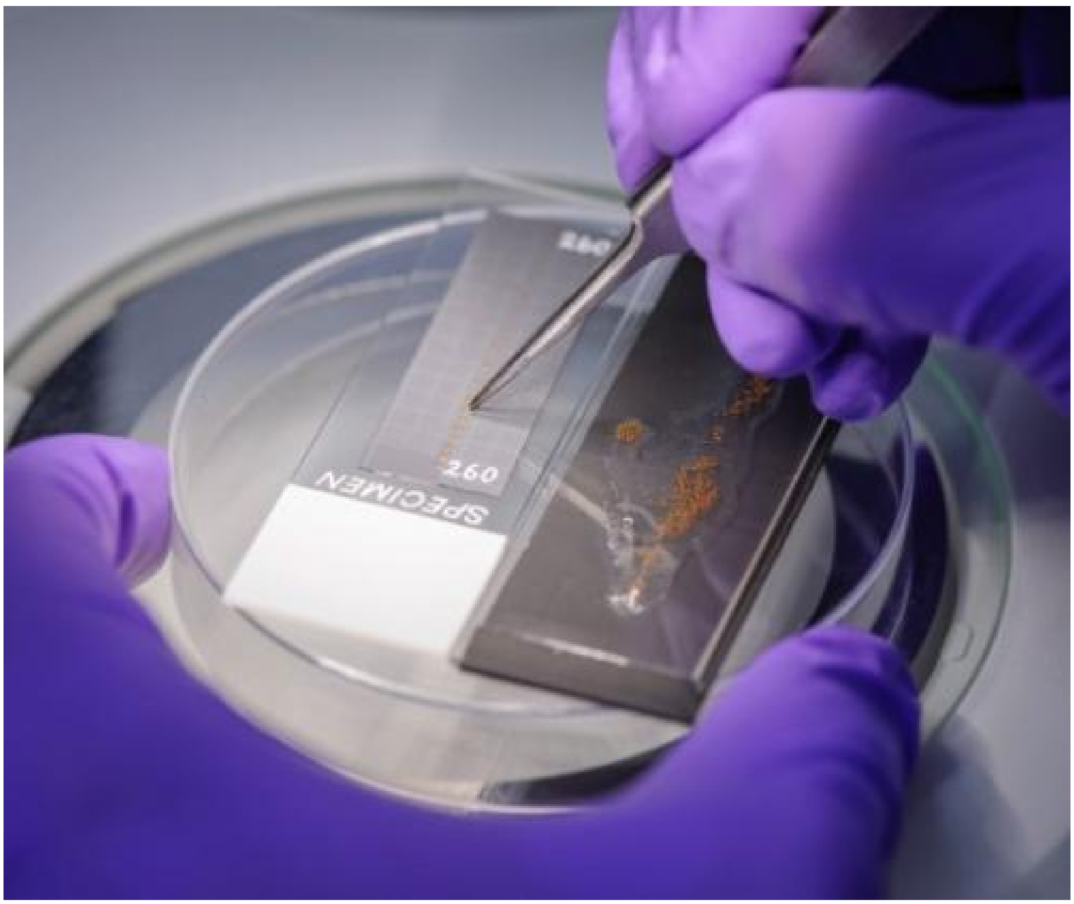

Arabidopsis thaliana seeds are mounted in a specific orientation onto supportive membranes for the Seedling Growth-2 mission. Credit: NASA / Dominic Hart

Plants—literally rooted in Earth—lack locomotion. And although plants may appear static, even the tiniest seedlings are sophisticated organisms that sense and respond to their environment. Seedlings may not travel, but they do move.

An international team of NASA and European Space Agency (ESA) researchers are studying the growth and development of *Arabidopsis thaliana* seedlings - also known as "thale cress" - aboard the International Space Station to gain a better understanding of how plants adapt to weightless and low-gravity environments. Scientists appreciate *Arabidopsis thaliana* more for its small, fully sequenced genome than for what it may add to a salad. It is a widely studied biological research model.

The Seedling Growth-2 mission is the second in a series of NASA-ESA collaborative plant biology experiments using the European Modular Cultivation System (EMCS) facility aboard the space station. The investigation launched to the station aboard a SpaceX Falcon 9 rocket on Sept. 21, 2014. Station crew will start the first experimental run of the study on October 17.

Plants are essential to support life on Earth; they provide food and recycle carbon dioxide into breathable oxygen. This latter ability may prove critical for astronauts who will undertake long-duration deep space missions. A better understanding of how spaceflight affects plants will help researchers determine if plants can provide a complete, sustainable, dependable and economical means to support humans in space.

Plants adjust their growth and behavior in response to changing environmental conditions such as light exposure, temperature and humidity. Like all life on Earth, plants evolved under the constant force of gravity. Plants sense gravity, and gravity influences plant growth.

"We are studying the interaction between gravity and light in plant development. More specifically, we want to better understand the role of red light signaling in phototropism—the directed growth of plants in response to light," said John Z. Kiss, Ph.D., professor of biology at the University of Mississippi, and NASA's principal investigator for the Seedling Growth-2 investigation.

Plants sense and respond to different colors of light. A seedling growing beneath another plant detects that it is in the shade by sensing that certain colors of sunlight are missing; those colors of light are screened out as sunlight passes through the canopy of leaves above. As a survival response, the seedling grows sideways rather than straight up in an effort to get out of the shade and receive direct sunlight. This is one example of phototropism.

Tiny *Arabidopsis thaliana* seeds are visible as a dotted line across the membrane that is sealed inside of an experiment cassette. Credit: NASA / Dominic Hart

This also is an example of plant signaling. Cellular sensors in one part of the seedling detected light. Subsequently, a signal traveled to cells in other parts of the seedling. These cells responded to the signal and changed the seedling's direction of growth.

In the Seedling Growth-2 study, Kiss is studying three genetic strains of *Arabidopsis thaliana* seeds. One is a wild type or "normal" strain. The other two have genetic mutations and lack certain red light sensors called phytochromes.

"By studying the mutants and wild type seedlings, we can better understand the role of specific phytochromes in plant signaling in microgravity and in Earth's gravity," said Kiss. "In the long term, these studies will aid in growing plants on space missions as well as on developing better crop species on Earth."

Because light and gravity sensing are limiting factors for crop plant growth and development, understanding these factors may help researchers to develop ways to optimize light sensing in plants and improve crop production. The findings also may help researchers develop new ways to reduce environmental impacts and increase long-term sustainability of agricultural practices on Earth.

For each run of the experiment, crew aboard the space station will place the equipment inside the EMCS. A team in Norway will control the system remotely from ESA's Norwegian User Support and Operations Centre.

During the Seedling Growth-2 study, *Arabidopsis thaliana* seeds will germinate and grow for six days into tiny seedlings. Images of the seedlings downlinked to Earth will reveal the behavior of the seedlings as they grow under varying conditions of gravity and light.

Hardware integration engineer Stephen Martin places experiment cassettes that contain *Arabidopsis thaliana* seeds into a unique Ames equipment assembly for Seedling Growth-2. The assembly's hardware and electronics will support the study inside the EMCS facility aboard the space station. Credit: NASA / Dominic Hart

Molecular biological analysis of the seedlings will be done in the laboratory of ESA principal investigator F. Javier Medina of the Spanish National Research Council in Madrid. The analysis that Medina's team will perform on the plant tissues will help researchers shed light on the cellular signaling mechanisms involved in plant movement and growth.

As each experiment run completes, the station crew will freeze the seedlings and keep them in the Minus Eighty-Degree Laboratory Freezer for the International Space Station (MELFI). The crew then will transfer the seedlings into the SpaceX Dragon spacecraft for a return trip to

Earth. The still-frozen seedlings will arrive at NASA's Ames Research Center in Moffett Field, California, where a team of plant biologists will chemically treat the seedlings to stabilize the plant tissue for a room temperature shipment to Europe.

"This project serves as a fine example of cooperation within NASA as well a collaboration between NASA and ESA," said Kiss. "Medina and I jointly serve as principal investigators for the Seedling Growth series of spaceflight investigations. By combining our technical and scientific efforts, the potential science return from this project is much greater than if we were both to work singly with our respective space agencies."

While the Seedling Growth-2 mission is in progress, researchers also are preparing for the third part of this investigation—Seedling Growth-3—that is planned to launch to the station in 2015. Kiss expects these studies will yield comprehensive new knowledge about the cell cycle, light signaling and development of plants in space.

"This type of research is vital to enable future long-range space travel and cultivation of plants on Mars for the purpose of human life support," said Kiss.

Some of the most well-traveled seedlings in history are revealing fundamental information about how plants sense and respond to light and gravity, and whether they will be able to accompany us as we travel deeper into space.

Provided by NASA

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