How mold on space station flowers is helping get us to Mars

January 19 2016, by Rachel Hobson

The zinnia plants began to exhibit guttation and epinasty, both signs of plant stress. Credit: NASA

When Scott Kelly tweeted a picture of moldy leaves on the current crop of zinnia flowers aboard the International Space Station, it could have

looked like the science was doomed. In fact, science was blooming stronger than ever. What may seem like a failure in systems is actually an exceptional opportunity for scientists back on Earth to better understand how plants grow in microgravity, and for astronauts to practice doing what they'll be tasked with on a deep space mission: autonomous gardening.

"While the plants haven't grown perfectly," said Dr. Gioia Massa, NASA science team lead for Veggie, "I think we have gained a lot from this, and we are learning both more about plants and fluids and also how better to operate between ground and station. Regardless of final flowering outcome we will have gained a lot."

From drought to flood: when problems are a learning opportunity

The Veggie plant growth facility was installed on the orbiting laboratory in early May of 2014, and the first crop - 'Outredgrous' red romaine lettuce - was activated for growth. The first growth cycle faced some issues.

"We lost two plants due to drought stress in the first grow out and thus were very vigilant with respect to the second crop," said Trent Smith, Veggie project manager.

The second crop of the same lettuce was activated in early July by NASA astronaut Scott Kelly, and thanks to lessons learned from the first run, adjustments to watering and collecting imagery of the plants were made. The leafy greens grew according to schedule, with only one plant pillow not producing. This time the crew was able to eat the lettuce when it was ready to be harvested a month later.

Mold growth initially grew on the plant in pillow E in the bottom left corner of the plant mat. Credit: NASA

The next crop on the docket was a batch of zinnia flowers, but they weren't selected for their beauty. They were chosen because they can help scientists understand how plants flower and grow in microgravity.

"The zinnia plant is very different from lettuce, said Trent Smith, Veggie project manager. "It is more sensitive to environmental parameters and light characteristics. It has a longer growth duration between 60 and 80 days. Thus, it is a more difficult plant to grow, and allowing it to flower, along with the longer growth duration, makes it a good precursor to a tomato plant.

Just more than two weeks into their growth period, though, NASA astronaut Kjell Lindgren noted that water was seeping out of some of the wicks - the white flaps that contain the seeds and stick out of the tops of the plant pillows. The water partially engulfed three of the plants. Within 10 days, scientists noted guttation on the leaves of some of the plants. Guttation is when internal pressure builds and forces excess water out of the tips of the leaves. It occurs when a plant is experiencing high humidity. Additionally, the zinnia leaves started to bend down and curl drastically. This condition, called epinasty, can indicate flooding in the roots. The anomalies all pointed to inhibited air flow in the plant growth facility that, when coupled with the excess water, could lead to big problems for the crop.

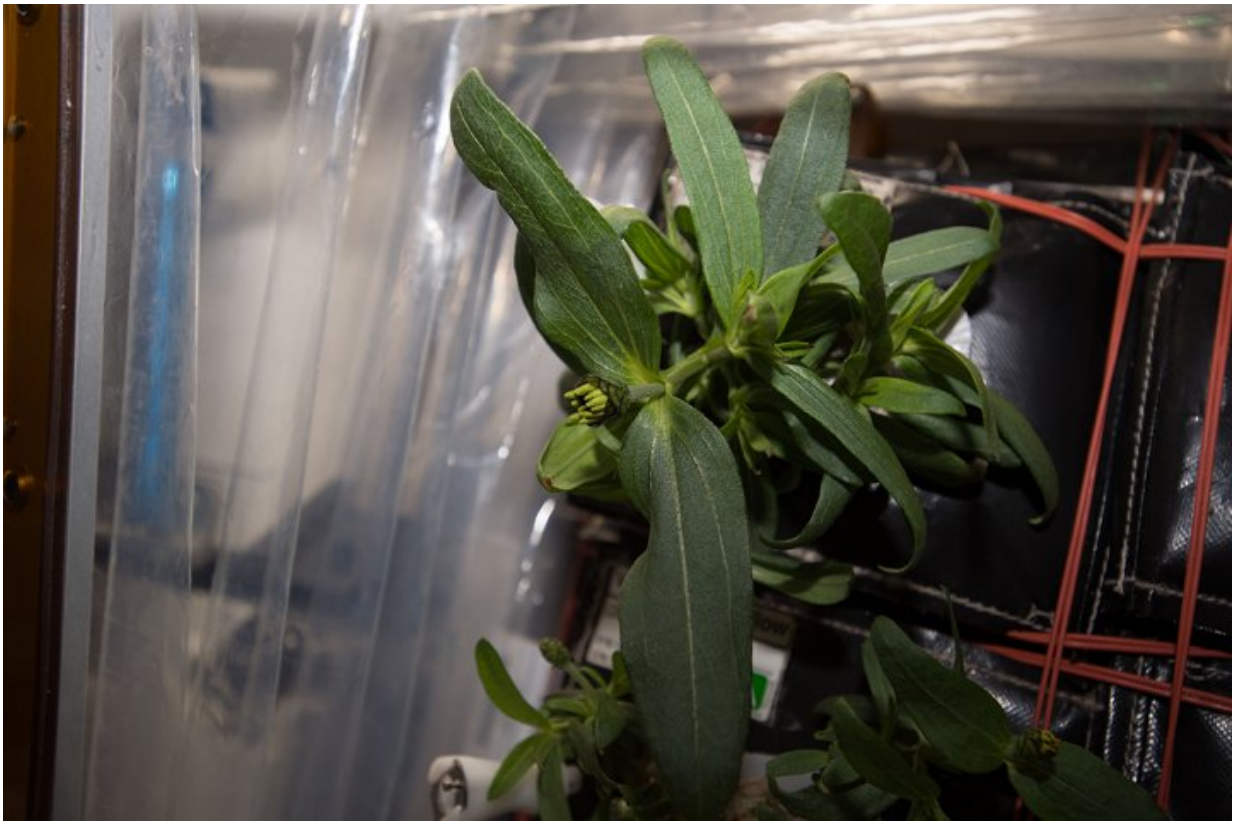
"After observing the guttation and more significant amounts of free water we decided to see about toggling the Veggie fan from low to high," said Smith. "We had evidence indicating reduced air flow through the internal Veggie facility volume, and needed to toggle the fan to high to dry things out."

The fix had to be postponed, though, due to an unplanned spacewalk in mid-December. By that time, tissue in the leaves of some of the plants began to die. On Dec. 22, Smith received a phone call at 3:45 in the morning. Trouble was brewing in the space garden.

"When you have high humidity and wet surfaces," he said, "leaves start dying, and become prime real estate for mold to grow."

The mold issue had Smith out of bed and the Veggie team on the phone by 4 a.m. Within four hours, new procedures were written and communicated to NASA astronaut Scott Kelly, who took over care of the zinnias after Lindgren returned to Earth on Dec. 18. Kelly donned a dust mask as a safety measure, and cut away the affected, moldy plant tissue, which was then stowed in the minus eighty degree laboratory

freezer (MELFI) so it could be returned to Earth and studied. The plant surfaces and plant pillow surfaces were sanitized with cleaning wipes, and the fans continued at a high speed in hopes of keeping the Veggie chamber dried out and mold growth abated.



A picture from Jan. 12 shows new petals beginning to emerge from some of the buds on the remaining plants. Credit: NASA

By Christmas Eve, though, Kelly called down to the ground support team to report new problems with the plants. It seemed the high fan speed was drying out the crop too much, and Kelly said he thought they needed more water. He was told, though, that the next scheduled watering was not until Dec. 27.

"I think that would be too late," Kelly told the ground team. "You know, I think if we're going to Mars, and we were growing stuff, we would be responsible for deciding when the stuff needed water. Kind of like in my backyard, I look at it and say 'Oh, maybe I should water the grass today.' I think this is how this should be handled."

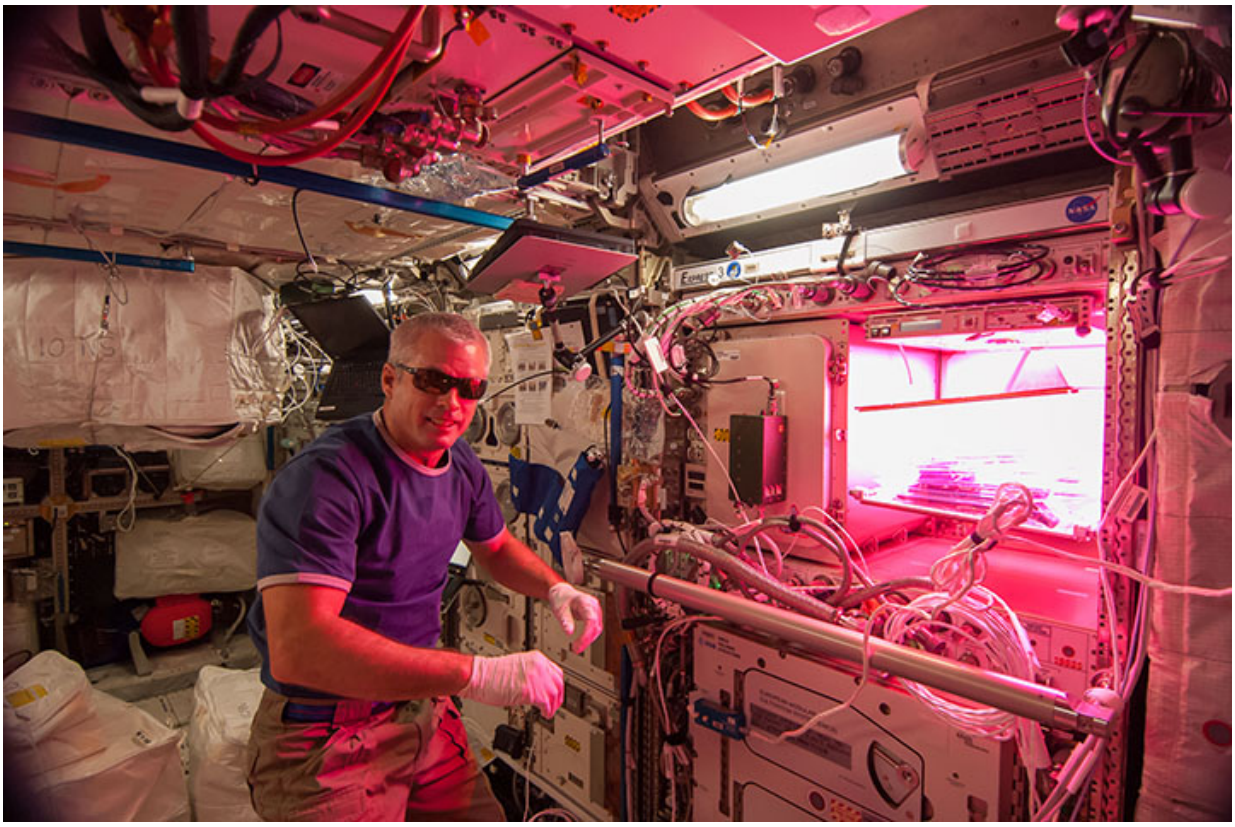
News of the mold didn't dampen Smith's Christmas spirit, though.

"We'd been planning on figuring out how to garden autonomously and his request was just perfect," Smith said. "Christmas Eve 2015 was our gift!"

Taking on the role of autonomous gardener

And so, Kelly became an autonomous gardener aboard the space station.

"This is perfect - he has the helm," Smith said. "We turned over care to Scott. He's seen the lettuce, he's got all the tools he needs, so we just provided him quick guidelines to understand the zinnias."



NASA astronaut Steve Swanson of Expedition 39 activated the red, blue and green LED lights of the Veggie plant growth system on May 7, 2014. Credit: NASA

What the Veggie team created was dubbed "The Zinnia Care Guide for the On-Orbit Gardener," and gave basic guidelines for care while putting judgment capabilities into the hands of the astronaut who had the plants right in front of him. Rather than pages and pages of detailed procedures that most science operations follow, the care guide was a one-page, streamlined resource to support Kelly as an autonomous gardener. Kelly tweeted a picture of the flowers in distress, noting that he'd have to channel a character from the movie, "The Martian."

Contrary to seeming like a dead end for the crop, the issues faced by the

zinnias offered a multitude of learning opportunities for scientists back on Earth. In fact, Smith said, the experience drives home what science experiments are all about: finding out what doesn't work, and figuring out how to solve it. For crews on the way to Mars, Smith said, scientists need to know what would happen if crops experienced drought, flooding, mold growth or other challenges. Would the practices of cutting away dead tissue and sanitizing plants work? How does changing the watering schedule affect the growth? How can crew members be given more opportunities to take charge in the gardening process?

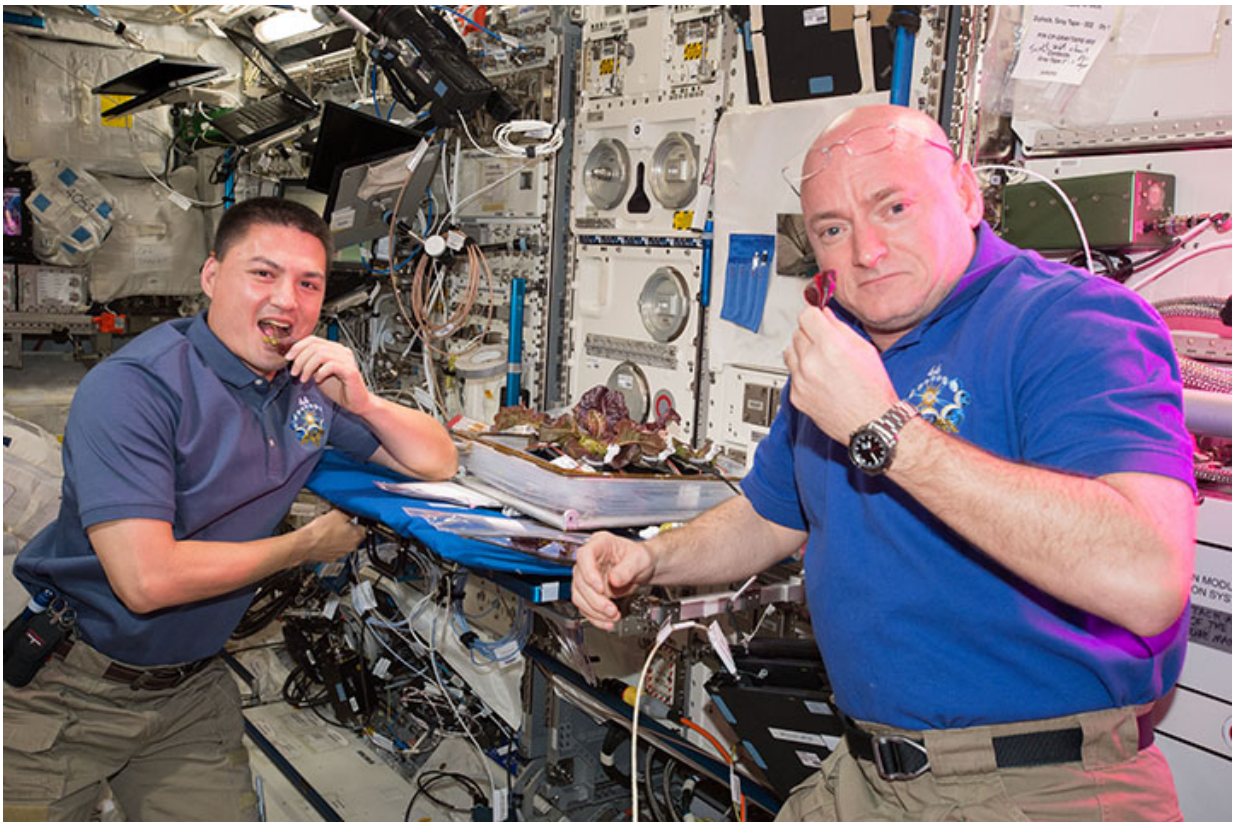
"All these things are so rich in information, my head kind of spins to think about what to focus on," Smith said. "This is perfect. This is really getting us down the road for other crops."

Smith said the Veggie team had hoped to move toward autonomous gardening, and Kelly's willingness to jump in and care for the plants independent of the ground support team was key.

Triumph, not trouble

Shortly after Kelly's heroic holiday gardening efforts, two of the plants that displayed stress died off and were clipped and stowed in the freezer to be returned to Earth for studying. Not all hope was lost, though. The remaining two plants have continued to thrive, and have even had new offshoots of buds forming.

"We see them growing out of their stressed states as seen by the new growth not showing leaf curling," Smith said. "We see that we can use our fan to adjust the conditions. We don't see guttation or free water. So, lots of things and better understanding of our tools for the on-orbit autonomous gardener."



NASA astronauts Scott Kelly and Kjell Lindgren take a bite of plants harvested for the VEG-01 investigation. Credit: NASA

On Jan. 8, Kelly tweeted a picture of the plants' progress.

On Jan. 12, pictures from Kelly showed the first peeks of petals beginning to sprout on a few buds. The bud-to-petal-to-full-flower process can take about 7 to 10 days, Smith said, so flowers could be present by next week.

If the flowers do blossom, chances are it will be an exciting opportunity for the entire crew, and not just Kelly. Previous astronauts who have conducted plant experiments on orbit have noted that it is an experience that brings crew members together. When NASA astronaut Shannon

Lucid grew wheat stalks on the Russian Mir space station in 1996, she called the entire crew over to inspect new seed heads on the tips of the stalks. When the first batch of lettuce was harvested in June of 2014 on the ISS, several crew members joined in the event. When the second batch of lettuce was harvested in August, and astronauts were allowed to eat the fruits of their labor, they gathered and shared the produce with international partners on the station.

"Plants can indeed enhance long duration missions in isolated, confined and extreme environments - environments that are artificial and deprived of nature," said Alexandra Whitmire, deputy element scientist for the Behavioral Health and Performance (BHP) element in the NASA Human Research Program (HRP). "While not all crew members may enjoy taking care of plants, for many, having this option is beneficial."

Though most evidence of the psychological benefits of growing plants in space is anecdotal, Whitmire said efforts like Veggie will yield important information in preparation for a Mars mission.

"In future missions, the importance of plants will likely increase given the crews' limited connection to Earth," Whitmire said. "Studies from other isolated and confined environments, such as Antarctic stations, demonstrate the importance of plants in confinement, and how much more salient fresh food becomes psychologically, when there is little stimuli around."

The implications of plant life for future spaceflight, Whitmire said, is very significant.

More crops for Veggie are heading to the orbiting laboratory aboard SpaceX-8. The Veg-03 run will include two sets of Chinese cabbage, and one set of red romaine lettuce. In 2018, there are plans to launch dwarf tomato seeds to the space station. Smith said the lessons learned from

growing zinnia flowers will be critical in the process of growing tomatoes, a fellow flowering plant. Studies are also in progress to see how adjusting the lighting in the Veggie plant growth facility can affect plan mineral composition. There will be preflight testing to determine what "light recipe" to use aboard the station.

For now, scientists continue to closely monitor the zinnia crop and are following Kelly's lead for care based on his observations. The unexpected turns experienced during this Veggie run have actually offered bountiful opportunities for new learning and better understanding of one of the critical components to future journeys to Mars.

Smith understands, though, that a space garden is like any other garden - sometimes, things just don't grow. The Veggie team is hopeful that the newly-emerging petals will fully bloom soon.

"I'm an eternal optimist," Smith said.

Provided by NASA