Asteroid soil could fertilise farms in space

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IF YOU want to start a space farm, head for an asteroid. It seems there's enough fertiliser zipping around the solar system to grow veg for generations of space colonisers – and researchers are already beginning to grow viable, edible plants in space.

Asteroids are a hot topic with the 3 December launch of Japan's Hayabusa 2 spacecraft, which aims to return a sample from carbon-rich asteroid 1999 JU3. And astronauts are spending longer and longer in space, with the first crew to spend a full year aboard the International Space Station due to launch in 2015.

"Longer human missions will require the company of plants, in terms of providing both food and psychological comfort," says Bratislav Stankovic at the University of Information Science and Technology in Ohrid, Macedonia. His team is one of many running experimental mini farms on the ISS, and one of the first to grow plants successfully.

Space farmers have had a tough row to hoe. Nearly every space shuttle flight through the 1980s and 1990s carried experimental plant payloads. But just as human bodies seem to need Earth-like gravity to function, so plants seemed to struggle in microgravity.

"It appears to influence cell biochemistry," says Stankovic. The plants displayed strange genetic mutations, grew in unpredictable and undesirable shapes, and seeds did not germinate or grow well. They also had trouble producing a second generation of fertile seeds, a key milestone for sustainable space farming.

But now, Stankovic and his colleagues from the University of Wisconsin-Madison have made a capsule that enabled two generations of seeds to successfully grow on the ISS (*Astrobiology*, doi.org/xpz).

The capsule tightly controlled soil moisture, light, air temperature, humidity, and levels of carbon dioxide and ethylene – a hormone plants release into the air when they begin to ripen. A mesh held down a base of fertilised gravel in which the plants could spread their roots.

Once astronauts installed the system, it was remote-controlled and monitored from the University of Wisconsin. They grew *Arabidopsis thaliana*, a small, edible flowering plant that is often used as a model species.

Not only did the plants produce seeds, but 92 per cent then germinated successfully. Some were grown on the ISS and others back on Earth. There was little difference between the two, the team found. The space seeds had their protein stores packed a little differently and the plants' branches grew in slightly different directions. But these are small details, Stankovic says. "It is likely that the previous failed attempts had to do with inadequate control of the growth environment," he says. "Microgravity per se is not a limiting factor."

No gravity required

Other would-be space farmers have focused on characterising differences more precisely. Robert Ferl at the University of Florida in Gainesville and his colleagues also grew *A. thaliana* on the ISS.

They found that plants used adaptive strategies to deal with not having gravity, such as increasing their expression of genes associated with light perception in the leaves and remodelling root cell walls.

Understanding those strategies could help engineer plants that grow even better in space than they do here, says Ferl. Still, that might not even be necessary, he says, since plants seem to find solutions themselves.

"I remain optimistic that before the end of the decade we will obtain seeds from plants grown on the moon," Stankovic says. But that raises an important question: will lunar soil support plants?

Plants grown on spacecraft will need soils we bring with us and will be able to use human waste as fertiliser. Ongoing extraterrestrial colonies are another story, though. If off-Earth colonies want to grow, or if they can't recycle every last atom of waste, we will need additional nutrients. "Get to Mars or the moon and, yes, plants will pull minerals from whatever soils we give them," says Ferl. "Any atoms that plants pull, we don't have to pack."

Although the Apollo missions carried out plant experiments using lunar regolith, which is mainly composed of basaltic and other volcanic material, there were not enough experiments to get an idea of whether it would be suitable, Ferl says (*Astrobiology*, doi.org/c52fbn).

Other groups have tried growing plants in simulated lunar and Martian soil, whose mineral composition is similar to volcanic Earth soils. Wieger Wamelink and colleagues at the Alterra research institute, part of the University of Wageningen in the Netherlands, reported this year that they grew a veritable salad – wheat, tomato, cress and mustard – for 50 days with no added nutrients (*PLoS One*, doi.org/xp3). The plants even grew better in the simulated space soil than controls grown in poor quality Earth soil.

Looking even further forward, others have pondered how large human populations might sustain themselves in space. That's where asteroids come in, specifically carbonaceous or "c-type" asteroids, which are known to be packed with organic compounds.

They are highly nutritious for plants, according to Michael Mautner of Lincoln University in New Zealand. He has grown edible plants directly in material from c-type asteroids, which fell to Earth in meteorites. He simply ground up the meteorite and added water.

He has also analysed the nutrient content of these meteorites and extrapolated to asteroids. He calculated that a 200-kilometre-wide space rock could provide enough fertiliser to sustain 10,000 people for a billion years (*Planetary and Space Science*, doi.org/xp6).

You'd need to control the air pressure and provide water, but the nutrients are there, he says. If we grabbed all the carbonaceous asteroids in the solar system, it could sustain a population of a billion for a billion years, according to his estimates.

Both Stankovic and Ferl say Mautner's work is useful, quantifying the long-term vision of nutrients availability for space farming. "There are great resources in space that can yield immense human populations in this solar system, and much more in billions of solar systems in the galaxy, for billions of future aeons," Mautner says.

But we can't count our space lettuces before they germinate, Maunter warns. This vision relies on the success of the home planet. "For this future, we must make secure our human survival on Earth first, so that we can spread life in space."

This article appeared in print under the headline "Down on the space farm"

How does your garden grow?

All sorts of plants and seeds have already been to space and back. Here are a few highlights.

• In the first space walk by an American, Ed White carried mustard seeds as a sign of his Christian faith.

• Stuart Roosa took 500 seeds of various kinds on Apollo 14, which orbited the moon. On return, the seeds were grown alongside controls. No differences were seen.

• Seeds were kept for 72 days aboard the first space station, the Russian Salyut 1 in the early 1970s, providing the first observations of seed germination after space flight.

• In the early 1980s, the Russians grew lettuce on Salyut 7.

• Dozens of plant species have been grown on space shuttle flights. Potatoes grew the same in space as they do on Earth.

• Other space shuttle plants include sunflowers, cress, oats, pine and mung beans. Some plants' roots grow in the wrong direction without gravity but others don't.

• A second generation of canola seeds was grown aboard the International Space Station, but they were not very healthy.

• In what may be a prelude to astronauts eating fresh-grown space produce, Chinese cabbage, Swiss chard, lettuce, snow pea and radish are currently growing aboard the ISS.