



# What will it take to grow food on Mars?

By Megan Sever

| December 29, 2021

*What Will It Take to Grow Food on Mars? CSA News*

We think farmers on Earth have it tough—how about trying to farm on Mars? There are myriad of challenges to overcome, but if we are to ever explore the Red Planet, it's a necessity. Understanding the soil—actually, regolith—will be very important, but we don't have Mars soils samples yet, and so researchers have been relying on simulated soils. While all the minerals and nutrients you would need for a productive soil have been detected on Mars, it remains to be seen whether they are bioavailable or in high enough amounts for food production. Among the soil (regolith)-based challenges on Mars are perchlorates (toxic to humans and detrimental to plant growth) and compaction and crusting issues. These challenges, though, are solvable with enough research and ingenuity.

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*Photo by NASA.*

We think farmers on Earth have it tough—how about trying to farm on Mars? There, the average temperature is about  $-80^{\circ}\text{F}$ , the atmosphere is about 100 times thinner than Earth's so solar radiation blasts the surface, and there's no readily available water. Oh yeah: And the soil—actually, regolith, which is inorganic unconsolidated broken-down bedrock—is full of toxic salts called perchlorates. These salts get absorbed by plants that grow in them and are toxic to humans who might eat those plants.

Farming on Mars—or growing anything—may seem quixotic. But if humans are to ever explore the Red Planet, it's a necessity. They cannot rely on food brought from Earth. So, astrobiologists, geologists, soil scientists, and others are putting their brains together to come up with ways to grow life-sustaining food on Mars.

### **How Do You Study Martian Soil?**

It's important to note that we don't know with 100% certainty the makeup of Martian soil. That's because we don't have any samples of the Mars regolith. None of the rovers or spacecraft sent to Mars thus far have been capable of collecting and returning samples to Earth. (NASA and the European Space Agency are working on a 2026–2028 mission to collect and return samples.) So for now, scientists are creating simulated soils using Earth-based materials, carefully mixed based on minute details collected by rovers about the Martian regolith's chemistry, mineralogy, and texture.

Using data from rovers, “we are able to match the chemistry, mineralogy, and the texture of the soils really, really well,” says Christopher Oze, an applied geologist at Occidental College in Los Angeles. What we can’t match very well, he says, is what the billions of years of solar radiation have done to the soils and what that radiation means for their reactivity.



*Artist's conception of a potential outpost on Mars, complete with a greenhouse. NASA image courtesy of Clouds AO.*

The first simulated Mars soil was created in 1998 by scientists at NASA’s Johnson Space Center using tephra from Pu’u Nene cinder cone on the Big Island of Hawaii. That recipe was used for almost two decades. Meanwhile, in 2007, scientists at NASA’s Jet Propulsion Laboratory created another recipe with a texture and performance closer to Martian regolith. That recipe was based on basalt

from the Mojave Desert in California. A few others have also been developed, predominantly to help with engineering, like determining how to make rovers and landers land or move safely around the Red Planet. In 2018, armed with new data from the Curiosity rover, scientists at the University of Central Florida created the first Mars Global Simulant soil based on what’s considered the “global soil” of Mars.

The problem with all of these soils, though, is that each of them lacks characteristics important and relevant for agricultural experiments, says Laura Fackrell, a planetary scientist and geomicrobiologist now at Northern Illinois University. Since Fackrell wanted to experiment with growing plants in Martian soils during her doctoral work at the University of Georgia, she decided she’d just have to create her own. She and her colleagues described their five regolith and bedrock simulants in a [2021 paper in](#)

[Icarus](#). These simulants, the team noted, better represent the mineralogical and chemical characteristics of Martian soils that are most important for “establishing the potential and limitations” of simulants for agricultural experiments.

Meanwhile, Oze and his colleagues also developed simulated soils for their agricultural experiments, which they described in a [2021 Soil Systems paper](#).

### **What Does Martian Soil Have that We Can Use?**

Although the Mars global soil can broadly be found all over the planet, there’s also heterogeneity in Martian soils. It’s important to experiment with different types of Martian soils because if plants grow better in one than another, soil alone might be enough of a reason for the first humans to land where a better growing medium is, Oze says. (Think about landing in a sandy desert versus a rich volcanic soil.)



*Outside HI-SEAS, a moon/Mars simulation habitat on Mauna Loa Volcano in Hawaii, researchers don spacesuits for every excursion outside. Source: HI-SEAS.*

At the core, Martian regolith is basaltic. It's dusty and altered from heavy bombardment, Fackrell says, and its thickness varies around the planet. The bedrock and regolith haven't been heavily weathered by water, which means that many of the primary minerals are still there, Fackrell says. The regolith also all comes from the same basaltic parent material and has been exposed to similar conditions.

All the minerals and nutrients you would need for a productive soil have been detected on Mars, Fackrell says. "But whether or not they're bioavailable or in high enough amounts is something we're still exploring."

Take nitrogen. The good news is that there is nitrogen, and at least some of it is in the form of nitrates, which are usually bioavailable, she says. The bad news is, there isn't nearly

enough to support plants. The other of the "big three" nutrients—phosphorus and potassium—are both plentiful on Mars. In fact, there's a lot more phosphorus on Mars than on Earth. But phosphorus is "tricky," Fackrell says. It chemically fixes so quickly that only a part of it remains available to plants—and we don't even know how much of it is bioavailable to start with, she says. But it's good that there's plenty of it. There's likely a bit less potassium on Mars, but it's probably enough to work with, and at least it

doesn't have the complicated interactions that phosphorus has, "so we probably don't need to bring it with us," she says.

Calcium sulfates, also important for plants, are also found on Mars, as are magnesium sulfates, which provide important nutrients in the right amounts. (They can also be toxic if there's too much though.)

"Most beneficial is the actual soil, the fact that you have a heavy physical substrate that you don't have to bring with you from Earth," Fackrell says. Process it properly, combine it with recycled waste like leftover plant material, and we should be able to use it to grow food, she says.

### **What Does Martian Soil Have that Poses a Problem?**

In a word? Perchlorates. These chlorinated salts are abundant on Mars, possibly everywhere, at concentrations of up to 2% (by weight) in the regolith. Although perchlorates show varying rates of toxicity to plants, Oze and his colleagues' experiments showed in the Mars soils that perchlorates were detrimental to growth at even 0.5% concentrations. Perchlorates are toxic to humans.

In their study, Oze and his colleagues compared growth of the grain amaranth (*Amaranthus cruentus*) and the common bean (*Phaseolus vulgaris*) in their regolith simulant to growth in a standard potting soil treated with perchlorates. They planted seeds in the regolith simulant and potting soil with no perchlorates and 0.5 and 1% perchlorates by weight. Even with no perchlorates, the amaranth did not germinate in the Martian regolith simulant, but the bean did. However, with any amount of added perchlorate, the bean also failed to germinate. In the potting soil, seeds of both species germinated to varying degrees, even with the perchlorates. But the perchlorates significantly reduced their biomass, especially the leaf area. The findings aren't good. Due to perchlorate prevalence in the Martian substrate, Oze and his team state: "Developing effective methods for perchlorate removal prior to using Martian regolith as a planting substrate" will be "instrumental to successful Martian agriculture."

What's more, Oze says, his team's study also found that perchlorates enhance metal release from soils, creating soils that have too



*Rocks on Mars, as viewed by the Perseverance rover. Source: NASA/JPL-Caltech.*

much metal for plants. The perchlorates appear to have modified the geochemistry of the regolith. The other major problem Oze found is that the simulant soil significantly compacts with the addition of water. In fact, his team suggests that the amaranth probably didn't grow in the simulant soil even without perchlorates due to the soil compaction, which both limits water infiltration and root penetration.

Fackrell says crusting creates yet another issue for plants, related to compaction. When the regolith—which contains calcium salts, magnesium salts, and perchlorates—interacts with water, it can form a hard mineral crust called a “duricrust,” she says. “That cements things together,” further limiting water infiltration and plant growth.

### **How Can We Overcome the Challenges?**

All of these challenges are solvable with enough research and ingenuity. There are ways to deal with perchlorates though most come with their own sets of challenges. Phytoremediation is an option, but the question then is what do you do with all the now-possibly-toxic plant waste since those plants are not likely edible? Heat treatment to volatilize the perchlorates is another option, but tests have suggested it's not a viable method on these simulant soils, Oze says. Biochar or another additive—perhaps even perchlorate-reducing bacteria—are possibilities too and should be investigated further, he says.

But research so far seems to suggest water treatment is the best option. Perchlorates are highly soluble, so rinsing the soils in water effectively removes the salts. Two challenges persist with that solution though: How do you get enough water on Mars to actually remove the perchlorates—slow flow rates are not enough to remove perchlorates, Oze's research showed—and then what do you do with the now-toxic water afterward? “Water is going to be such a precious resource” on Mars that finding

other viable ways to reduce the perchlorates is really important, Oze says.

In terms of cementation, compaction, and crusting, further research is needed on how the addition of organic matter or bacteria may change the regolith's texture as well.

One thing to note though, Fackrell says, is that although they're bad for plants, perchlorates may also provide a very important resource on Mars: oxygen. Certain bacteria degrade perchlorates down to chloride, producing oxygen in the process. So in figuring out how to rid the regolith of the toxic salts, we also need to figure out how to harness the process to create oxygen, she says.

To solve all of these problems, Fackrell says, creating recycling systems will be vital—using perchlorates to get oxygen, for example. Using nitrogen-rich human waste like astronaut Mark Watney did in the movie *The Martian*—growing potatoes using just human waste—to get the nitrogen fertilizer needed for plants is another example. Plant waste (like stalks) also could provide additional nitrogen plus the necessary organic material for soils. “We don't have to bring everything [to solve these problems] with us as much as just figure out how to properly reuse everything and create a closed system,” Fackrell says.

### **Is Growing Plants on Mars Even Possible?**

“Absolutely” we can figure out how to grow food on Mars, Oze says. What's needed now, he adds, is investment in studying the long-range plans for human habitation on Mars. There's such a focus on getting there, but “what's next? What happens once you get people there?” Plus, he says, we don't want to be on Mars facing an emergency food situation like Watney. “We should be planning for this.”



*Artist's conception of a different style of a potential greenhouse on Mars. Source: NASA.*

Fackrell is hoping for more direct measurements of soil properties like pH and salinity from future Mars missions, so scientists don't have to infer these properties from minerals.

And we need more experiments growing all kinds of different plants. It's just going to take trial and error. "We need to know how the plants are going to respond" to life on Mars,

Fackrell says. She wonders: How does the atmosphere fit in? How does gravity fit in? How does radiation change things? How do we deal with the cold temperatures? How do we get enough water? How do we eliminate the things we don't want, like the salts? How will microbes change the situation? And then, once we grow food, how do we cook it? Pick-and-eat crops like lettuce or tomatoes are easy since they don't need cooking, but they also don't provide the caloric benefits that will be necessary to sustain humans on Mars, she says. Foods like wheat, soy, and rice are really important for sustaining humans, but they require a lot of energy to cook. So there are a lot of important questions on the food science side of this problem too, she notes.



*On Mars, a greenhouse like this prototype might not only be used to grow food, but also to provide oxygen and recycle human waste.*

Source: University of Arizona.

Ultimately, “the solution to growing plants on Mars is going to be a combination of a lot of techniques,” Fackrell says. We might start with hydroponics-based systems like they use on the International Space Station, she says, but then we’d want to extend into soil-based systems to expand the number of crops since not everything can grow well in hydroponics systems. Things like root vegetables (including potatoes), corn, vine vegetables and fruits, and many cereal grains struggle in such systems. These need soil and room to grow, so there will have to be some sort of soil-based system.

Fackrell says humans on Mars will need backup plans, fail-safes, for all of our systems, food included. We’ll need “more than one avenue for producing plants,” so if one fails, we’re not destitute. Having a variety of ways to grow things creates food security.

### **Dig deeper**

View Laura Fackrell’s presentation at the 2020 Annual Meeting of ASA, CSSA, and SSSA on this topic at <https://bit.ly/3pOYTCR>.

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