PHYS.ORG

Mars will come to fear my botany powers

November 10 2015, by Steven Burgess

Dr. G.W.W. Wamelink

NASA seems to believe that making space habitable will require more finesse than Elon Musk's "let's nuke Mars" plan, and has funded a couple of synbio projects which seek to provide "the means to produce food, medical supplies and building materials on site at distant destinations". Dr Mark Blenner of Clemson University is working on recycling space waste (or 'turning poop into food') and explains that "it is impractical for astronauts to travel with all necessary supplies in future long-term space exploration missions…NASA has long been interested in converting space waste into useful molecules, such as fertilizer and propellant. These processes have typically focused on physical-chemical treatments. NASA's recent interest in synthetic biology, in my opinion, is driven by the complex molecules that biochemistry can make, and by the wide variety of products that can be made."

Although ideas such as terraforming are well known from scifi, NASA has long funded research such as that carried out by Prof. Robert Ferl and Dr. Anna-Lisa Paul at the University of Florida, who study the effects of space travel on gene expression in plants. Professor Ferl states "when we live on Mars we have to take our ecosystems and our agriculture with us".

I wanted to investigate whether there is a hope that this science could pay off, so I thought it would be a good idea to find out more about Martian agriculture from a real life Mark Whatney – Dr. G.W.W.Wamelink of Wageningen University. Dr. Wamelink and colleagues are part of the Mars One Project and published a paper in PloS One last year which investigated the possibility of growing crops on Martian soil.

SJB: Can you describe how the conditions on Mars differ from Earth, and specifically the range of environmental problems that plants would face on Mars?

G.W.W.W: There are many differences; there is almost no air on Mars, so cultivating crops just like that is impossible. This implies that crops will have to be grown indoors. There is a lot of cosmic radiation due to the absence of a protecting magnetic field (like earth has), and also the lack of air causes radiation to reach the surface. To be safe you need a protective layer of sand cover of more than one meter.

There is less light on Mars, about 40% of earth's light, but that would not cause major problems. Though it would make harvest less than on earth, we would be able to grow plants in the sunlight. But since we will have to go belowground, to live in a kind of 'Hobbit' houses with solar panels providing power for led lights the less intense sunlight is a smaller problem.

The cold (-160oC) is also a problem when living on the surface, but then again belowground well isolated, it could be that warmth will be a problem instead of cold. Gravity on Mars is about one third of earth's gravity. We do not know how this will affect plant growth, though the first experiments on the ISS shows that this may not be a problem (under no gravity).

SJB: What about the famous red soil?

G.W.W.W: The Martian soil I work with, the simulant regolith, has its own problems. Most important I think is the presence of heavy metals. At the moment I am 95% sure that the heavy metals did not end up in the crops, because they did not go into solution due to the high soil pH. However, since we have not done the tests yet we can't be sure, so we can't eat the crops yet. Eventually, because of the input of organic matter , soil pH tends to drop, and the lower it gets the higher the chance that heavy metals will go into solution and end up in the plants, and thus in the human Martians causing health problems. The lack of a major amount of reactive nitrogen is a problem as well.

SJB: and Water?

G.W.W.W: Recently confirmed, there is plenty of water on the planet, so it should not be a problem. However, [Martian water] may contain large amounts of perchlorate – not good for plant growth. Happily this can be filtered out of the water quite easily. What came as a surprise to me was all the attention recently of the finding of all that perchlorate in the water and no attention to the positives, that the perchlorate formed ions with magnesium, potassium and calcium, all essential for plant growth, truly good news!

Growth experiments with Martian soil. Credit: Dr. G.W.W.Wamelink.

SJB: Ok, in your experiments you use a simulant of Martian soil, how do you know what the Martian soil is like?

G.W.W.W: We know quite a lot about Martian soils, due to remote sensing, via spectra etc. you can get information about the mineral content of the soil, from earth with telescopes and from orbit around Mars from satellites. Moreover, the rovers have ovens on board and all kind of other instruments to analyse the soils, giving excellent information about the soil content.

SJB: How did you go about creating a Mars soil simulant, and how close was it to the real thing?

G.W.W.W: NASA delivered the regoliths and the Martian one comes from a volcano on Hawaii. The soil there is as close as possible to the Martian soil. It is up to NASA to look at the specs, and make them as close as possible. This all said, you still have to check the quality, especially when you try to do something new. So we did our own analyses on the simulant. We used the standard protocol we also use for earth soils when want to know what chemical compounds go into soil solution and thus become available for plants, something NASA never did. This led to at least one surprise, the amount of carbon in the soil (see also the Plos One publication). This was surprisingly high. We had contact about that with NASA. One of the possibilities is that our detection method failed. Mars soil and the simulant contain a large amount of iron oxides (rust). The detection method for organic matter is quite simple, bake the soil at 500 degrees centigrade. The loss of mass gives the amount of organic matter. However, we found that iron oxide loses oxygen at that temperature clouding the results – An easy way to make oxygen and iron by the way, though for true iron even higher temperatures are necessary.

SJB: Your results (published in PloS One) are very exciting! However, as you highlighted previously, the lack of reactive nitrogen (NO3 and NO4) in the Martian soil is a big potential problem for growing crops. The simulant you used appeared to contained high amounts of ammonium, can you discuss the potential impact of this on your findings?

G.W.W.W: The simulant contains reactive nitrogen, but Martian soil does as well. Both have low amounts, though the simulant concentration may have been higher. The reason the content looks high is because we used river Rhine soil from ten meters deep as a control. This was so poor in nutrient content that it contained almost no reactive nitrogen, also the reason why the plants grew almost as good on the Martian soil simulant as on the earth soil.

SJB: Ah ok, but nitrogen is still a problem?

G.W.W.W: In this year's experiment, not published yet, we compared [growth on Martian soil] with nutrient rich soil, and then differences are huge. However, in this year's experiment we added organic matter to the simulant (mimicking a previous harvest dug under), which releases reactive nitrogen during the experiment.

SJB: Right, so what approaches might be taken to address this issue?

First tomato grown on Martian soil. Credit: Dr. G.W.W.Wamelink

G.W.W.W: To improve the nitrogen content of the soil, I would like to cultivate first a cycle of nitrogen fixing plants. They fix N2 from the air, with bacteria. The plants can then be used as green manure. Plants species as clovers, but also peas and beans can do the job.

SJB: Do you agree using human waste is a good approach to add organic matter?

G.W.W.W: Of course human faeces will be used! It is necessary to build a closed nutrient cycle, so all nutrients will have to be recycled. With urea (pee) this is no problem, but the poop will have to be sterilised first because of the germs in it.

SJB: So, your experiments have started to tackle the soil problem, but as you stated before plants are likely to face additional challenges on Mars. Growing plants indoors could solve some of these, but are there other factors which need to help make Martian agriculture a reality?

G.W.W.W: We are not totally there, we will still have to see if the plants do not take up the heavy metals. Moreover we just grew one generation, and we will need an ongoing cycle. This asks for a small ecosystem with at least pollinators, bacteria (break down organic matter and N-fixation), fungi (improves nutrient take up by plants and breaks down organic matter) and worms (first breakdown of organic matter). They all have to be able to live in the soil and they have to be sustainable. We never made something like this before, an artificial ecosystem, lots about that is still unknown, so this type of research will give us also insight in how (simple) ecosystems functions and what is minimal necessary.

Dr. G.W.W. Wamelink inspiring the next generation of scientists

SJB: Thanks for taking the time to speak to us, it has been fascinating! I just have one final question though – does you work have implications for agriculture back here on earth?

G.W.W.W: Yes it does. We will have to build a very efficient, sustainable agricultural ecosystem where everything is recycled. This is quite different from how we do it on earth, where agricultural practices are totally non sustainable. One of my dreams is that we will have a concept that we can use not only on Mars or on the moon, but also in e.g. the Sahara desert. The only thing we need is energy and that you have plenty in the desert. If we control everything and manage it as a closed cycle crop growth even in a desert this should in principle be possible. This will be tested in the coming years by colleague Tom Dueck, whole bring a container to the South pole and grow crops there in preparation for growing crops in a space ship on its long journey to Mars.

I think that last point is the key issue, and a similar comment was made by both Dr. Zhang in our previous interview, and Dr. Blenner when referring to his project, who stated "production of omega-3 oils from cheap substrates addresses problems such as ocean sustainability, and food security. Whereas production of renewable polymers addresses environmental and sustainability concerns with petroleum derived materials…There are several companies, including Dupont and DSM, working towards and commercializing omega-3 oils from synthetic biology. Similarly, the production of renewable polymers [from waste instead of refined glucose] is also a focus for several companies."

Science needs to be inspiring, something I feel these projects achieve. Space provides its own set of challenges, and addressing these can help with sustainable living in a way that is of genuine commercial interest.

This story is republished courtesy of PLOS Blogs: blogs.plos.org.

Provided by Public Library of Science