Cultivating salad plants that can be grown on the Moon

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These cellulose-based cubes are more advanced than they may appear. They will make it possible to grow food plants on the moon. Photo: Galina Simonsen/SINTEF

NASA has finished its planning and is ready to go. Humans will soon be returning to the Moon—this time in a manned base. But, if this project is to succeed, astronauts must be able to grow their own food. Norwegian researchers are in the process of making this possible.

The lunar "soil," or regolith as geologists call it, is essentially a powder in which it is difficult to grow plants. As if this wasn't enough, the moon is characterized by temperatures that can reach 200 degrees during the day and fall to as low as minus 183 degrees at night.

So says SINTEF researcher Galina Simonsen. However, in spite of this, Simonsen and her colleagues working as part of the international project LunarPlant, which is being headed by NTNU Social Research and the Center for Interdisciplinary Research in Space (CIRiS), believe that it will be possible to grow food plants on the moon.

Meeting this challenge requires a rational utilization of available resources, combined with sufficient light and an artificial atmosphere. There is also a need to find a replacement for fertile soil.

"You may already have heard of hydroponics," says Simonsen. "This is a method of growing plants in water, which is entirely possible if the water contains sufficient nutrients. The use of this method is essential to the success of this project," she explains.

How much water is there on the moon?

"Radar data indicates that the moon's polar regions hold more than 600 billion kilograms of ice," says Simonsen, "This is enough to fill about 240,000 Olympic-sized swimming pools. It is much less than we have on Earth, but will be enough to enable humans to maintain some level of activity. The ice will be melted to form water which will be used to cultivate food plants," she explains.

However, growing plants in water requires that the water contains sufficient nutrients. The "fertilizer" that will be utilized on the moon will in fact be provided by the astronauts themselves in the form of human waste—their urine. Because this project is based on the circular use of resources.

This is where the term "liquid gold" makes its entrance. Gardening enthusiasts among Gemini readers will know that this is the name given to urine diluted in water. Many a flower bed has been brought into bloom thanks to more than a few drops of "liquid gold." However, it is normally not recommended to use urine as a fertilizer for plants intended for human consumption. One of the challenges in this project is to find out how we can use this resource safely.

"Barriers linked to the use of urine as a fertilizer include the strict regulations governing the use of human waste in food plant cultivation," explains Simonsen. "In addition, the handling of human urine is generally unpleasant, combined with the odor and the fact that it releases long-lived organic environmental toxins and trace metals," she says.

Plants grown in "liquid gold" must be analyzed carefully and accurately so that we can identify safe threshold values with a view to approving their use as a food source. Moreover, the plants themselves have to contain sufficient nutrients.

"It may be possible to extract some nutrients for plant growth from the lunar regolith (the lunar soil)", says Simonsen. "But these are somewhat meager. Urine can provide nitrogen, potassium and phosphorous. If you are cultivating salad plants, you can also grow other edible plants that can assist with the regulation of both the water quality and nutrient balance in the system," she says.

Soil? We only find true soils on Earth

Another aspect of the LunarPlant project is focusing on soil. Or, to be more precise in the case of the moon, the lack of soil. Soil on Earth not only provides nutrients—it is also the habitat in which the plants "live."

"We're trying to find out how we can get the plants to grow without collapsing," says Simonsen. "This involves identifying a growing medium that enables plants to develop a root system that gives them adequate support," she says.

In order to stand upright, plants prefer to have something solid in which to drive their roots. Currently, rockwool is used by some hydroponic horticulturalists. But rockwool is not a sustainable material, at least not on the moon.

"Sending rockwool to the moon could cost up to NOK 20 million per kilo," explains Simonsen. "For this reason, it is important that we can use a material that is entirely circular. It has to be light and multifunctional. In other words, a material that can first be used for a purpose other than that as a growing medium," she says.

So, in collaboration with the VTT technical research center in Finland, the researchers have developed a substrate that functions as a supportive collar for the growing plants.

The substrate is in fact a cellulose-based alternative to soil and rockwool. The cellulose is produced by plants or, more precisely, from plant waste. The substrate can first be used as insulation material for the secure transport of vital and sensitive equipment that has to be carried from Earth to the moon. On its arrival, it can be reused as a growing medium.

So far, the results have been promising.

"We observe that the substrate doesn't break up in the aqueous growing

medium. Its components are also plant-friendly and free from any chemicals that may have a negative impact on plant growth or food safety," says Simonsen.

But does the system have any limitations?

"Yes," replies Simonsen. "Its application is limited to only certain types of plants. Only a few plants can be cultivated hydroponically, such as tomatoes, cucumbers, strawberries and salad vegetables. Others, such as root vegetables, cannot be grown using this method," she explains.

Learning from the oil industry

The substrate is thus essential, but it is also important to know how the water it contains behaves. For example, some plants do not like "getting their feet too wet."

"The water must not be allowed to stagnate," says Simonsen. "There must always be adequate water flow. Both air and water have to be transported efficiently through the material in order to ensure healthy plant growth. The substrate must be sufficiently robust to support a fully developed plant and at the same time enable the roots to grow unobstructed," she says.

In order to find out how this happens, the researchers have obtained know-how from the oil industry, and multiphase flow modeling has been shown to be a very useful tool.

"Technologies used for oil and gas transport have proved to be transferable," says Simonsen. "The methods we apply for fluid hydrocarbon transport in major installations can be transferred to the mechanisms working in minute structures such as these plant substrates," she says

"Our aim is to construct a digital model that simulates the different factors that influence the behavior of the substrate," explains Simonsen. "This will enable us to run simulations under conditions that are identical to those on the moon, including the effect of weightlessness," she says.

Can we also use this technology to grow plants in hostile regions on Earth?

"Absolutely," says Simonsen. "This method of cultivation can be applied anywhere, and is particularly important in the context of resource utilization. Urine contains phosphorous, which is a non-renewable resource, and rockwool, which is currently used in a number of situations, is not biodegradable," she says.

Provided by Norwegian University of Science and Technology

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