Apollo-14 Moon Trees and more Space Plants

> *Pollution, pests, wind, drought - Germany's forests are suffering. According to current figures, only 21% of the trees in this country are really healthy. The conversion of the vulnerable monocultures into a sustainable forest has the highest priority.*
>
> *(Der Spiegel, Nr.16/April 1, 2023)*

With the growing activities for re-engineering the forests in Europe to adapt and make them more resilient to the changing climate, I was wondering what the many space-based biology experiments could contribute. One of the earliest and most popular experiments – but long forgotten now, was the "Apollo-14 Moon trees" seeds experiment.
I asked chatGPT to compose the story of the Apollo-14 moon trees, which I verified and augmented accordingly.

It began with a man named Stuart Roosa. Roosa was a former U.S. Forest Service smokejumper and one of the three crew members on the Apollo-14 mission, which launched on January 31, 1971 on a Saturn V rocket. The Apollo-14 mission was the third successful Moon landing, and is mostly remembered for astronaut Allan Shepard hitting golf balls on the lunar surface. [1]
During the Apollo-14 mission Roosa spent 33 hours in solo orbit around the Moon in the lunar orbiter module (CSM) called "Kitty Hawk", while waiting for his fellow astronauts to return from the Moon surface, he was conducting an extensive series of experiments. Roosa carried seeds from loblolly pine, sycamore, sweet gum, redwood, and Douglas fir trees as part of a joint NASA/U.S. Forest Service experiment. The plan was for the seeds to be carried around the moon and then returned to Earth, where they would be planted and studied to see if exposure to the lunar environment had any effect on their growth. The seeds were sealed and stowed in a small cylindrical metal canister stored in Roosa's personal baggage, the pilot's preference kit (PPK).
Upon return to Earth, the seed canister burst after having been exposed to a vacuum, scattering and mixing up the seeds. Nonetheless, the seeds were recollected and sent off to two research facilities: the Southern Forest Research Station in Gulfport, Mississippi, and the Western Research Station in Placerville, California. The seeds proved viable, giving the Forest Service more than 400 Moon Tree seedlings. The seeds were germinated and planted throughout the United States, becoming known as the "Moon Trees".[2] Mostly forgotten, many of the trees can still be found today if you know where to look. Dave Williams, a curator at NASA's National Space Science Data Center maintains an online list of the known Moon Tree locations. [4]

The first official Moon Tree planting ceremony was held in Philadelphia's Washington Square Park on May 6, 1975. Stuart Roosa, Forest Service Chief John McGuire, and many others were on hand as a sycamore seedling was planted in the northeast corner of the park. Following the Philadelphia planting, many other Moon Trees were given away and planted all over the country as part of U.S. bicentennial celebrations during 1975 and 1976. A Douglas fir Moon Tree seedling was planted also at the White House. [3]

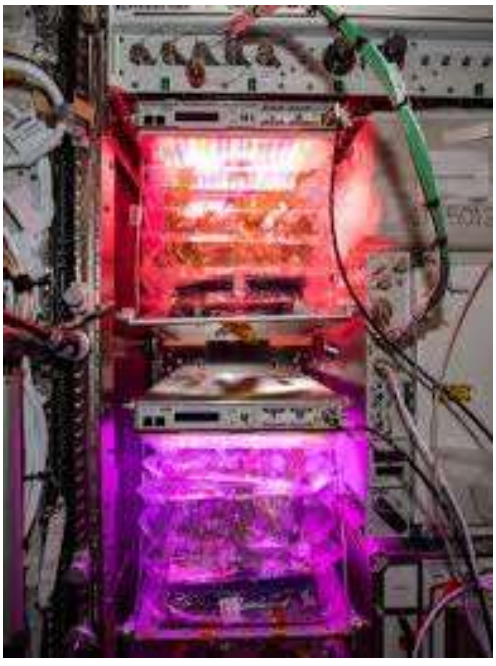
Seedlings were also sent to other countries, including Brazil, and France. Switzerland. Japan are also mentioned by other resources but could not be verified by the official NASA list. [4]
You can also still buy your own Moon Tree seeds from the American Forests organization's Historic Trees Program. [5]

Food-Plants beyond our Planet?

The development of technologies for growing food plants beyond our planet in a sheltered environment is extremely important for answering a fundamental question: will we ever be able to leave the vicinity of the Earth at all? Without plants, this idea will never come true.
Innumerable astro-biological experiments have been carried out since the beginning of spaceflight on sounding rockets, satellites, and onboard orbiting crewed stations. To illustrate where we stand, the following state-of-the-art examples shall be presented.

As of October 2022 two practical institutional developments to improve the cultivation of plants in space were developed, which may well help in creating a base on the Moon and already allow solving everyday problems on Earth. As mentioned in the introduction, with climate changes, increasing chemical pollution of ecosystems, global soil erosion processes — growing plants in difficult conditions becomes an important joint task of both terrestrial and space botany.

One active program is *ADVA SC* (Advanced Astro-culture), which is led by Weijia Zhou, Ph.D., of the Wisconsin Center for Space Automation and Robotics. The task of this program is to determine the conditions under which plant mortality will be lower, and the yield will be significantly higher.
For example, green bananas imported from tropical countries are treated with ethylene to turn them yellow as quickly as possible. But in the conditions of a lunar station devoid of light breezes of wind carrying extraneous gases away, the ethylene will accumulate in the air, causing plants to age faster, and the harvest will spoil.
A device developed by scientists allows eliminating these annoyances. In the device, air is constantly passed through tubes covered with thin layers of titanium dioxide. The insides of the tubes are exposed to ultraviolet radiation, which triggers a simple chemical reaction to convert ethylene to water and carbon dioxide. From these two simple ingredients, any plant can easily “prepare” its simplest and most favorite dish — glucose.



The latest experiment on the ISS is called VEG-5 started in Dec. 2022. The experiment is designed to provide healthy and nutritious diets for astronauts on long-duration exploration missions. It will focus on several factors, including fertilizer and light spectrum on fruit production, microbial food safety, and the overall behavioral health benefits of having plants and fresh food in space. In initial ground testing, the dwarf cherry tomato variety grew well in Profile’s products and produced a large crop. [7]
The astronauts successfully grew the dwarf tomatoes aboard the ISS in a miniature greenhouse, Three harvests were performed after 90, 97, and 104 days. The tomatoes were returned to Earth on April 15, 2023 on SpaceX's CRS-27, a cargo resupply spacecraft. The tomatoes were frozen and examined for nutritional value. Some fresh tomatoes could be tasted by the crew directly. [8]
<Tomatoes as grown inside the ISS (Photo: Nasa)

A second industrial influenced activity is to eliminate disease causing agents. For this purpose *KES Science & Technology* Inc. and *Akida Holdings* sold their *Airocide* technology to NASA.
Since “free passengers” in the form of pests and disease-causing agents are not welcome at a space station or a lunar base, an air purifier was created that completely destroys bacteria, fungal spores and toxins, viruses, volatile organic compounds. The device has no filters that need to be replaced, and it does not create harmful by-products (such as ozone). *Airocide* is already welcomed by flower shop workers, because in just 24 hours of operation, the device reduces the number of fungal spores in the air by 92% and bacteria — by 58%. [6]

As recently as January 2023, the China Manned Space Program shared a detailed list of plant seed and microbial species selected for use in space biology research and sent into space on the Shenzhou 14 and Shenzhou 15 rockets. China’s plant space-biology research is of great importance for the future of space studies and humanity’s extraterrestrial colonization goals. As a source of oxygen and nutrients, plants will play a key role in establishing sustainable artificial ecosystems in long-term space missions. In addition to direct plant biology-oriented studies, it is necessary to deal with plant-related microorganisms in this direction. [9]

Plants for the Moon

The extent to which plants can enhance human life support on other worlds depends on the ability of plants to thrive in extraterrestrial environments using in-situ resources. Using regolith samples from Apollo 11, 12, and 17, it was shown that the terrestrial plant *Arabidopsis thaliana* germinates and grows in diverse lunar regolith types.
However, the results also showed that growth is challenging; the lunar regolith plants were slow to develop and many showed severe stress morphologies. Moreover, all plants grown in lunar soils differentially expressed genes indicating ionic stresses, similar to plant reactions to salt, metal and reactive oxygen species. Therefore, although in situ lunar regoliths can be useful for plant production in lunar habitats, they are not benign substrates. The interaction between plants and lunar regolith will need to be further elucidated, and likely mitigated, to best enable efficient use of lunar regolith for life support within lunar stations. [10]

Artemis-1 Moon Trees

The Artemis Moon Trees project harks back to 1971 when Stuart Roosa, the command module pilot for the Apollo 14 mission, orbited the moon with tree seeds tucked into his personal kit. Roosa carried five species of tree: loblolly pine, sycamore, sweetgum, redwood, and Douglas fir at the request of the Forest Service Chief. Forest Service employees then grew these seeds into seedlings and distributed them across the country. Many so-called "Moon Trees" survive today.

The Artemis-1 "next generation" of Moon trees builds upon the Apollo-14 legacy but traveled much deeper into space than their predecessors. Kasten Dumroese, research plant physiologist and national nursery specialist with the Forest Service's Rocky Mountain Research Station explained. "For this [Artemis-1] mission, scientists included additional seed sources for species having large natural ranges: American sycamore and Douglas-fir. These additional seed sources will help the Moon Trees team match the genetics of the species with planting sites to help ensure the long-term health of the trees."

The project flew approximately 1,200 seeds from five tree species — loblolly pine, American sycamore, sweetgum, Douglas fir, and giant sequoia — aboard Orion. The seeds, which left the Earth on Nov. 16, 2022, orbited the moon, and traveled 270,000 miles from Earth before splashing down on Dec. 11. 2022. [12]

Apollo-14 Moon redwood in Sacramento, California, standing tall in 2023. [11]
An impressive proof that the long trip to the Moon and back did not harm the seeds at all.

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