Long Duration Martian-Soil Based Agriculture Experiment Technical Report

Kush Jani

Virginia Aerospace Science and Technology Scholars

Abstract

Regarding the need for an understanding of the effects of Mars’ environment on agriculture, this report proposes a long duration experiment and its design in order to gain an understanding of differences between organisms over multiple generations. In using fast growing plants, crew members shall collect information about the necessary nutrients and species for optimal growth in Martian soil and track potential mutation derived changes, both negative and positive, to primarily understand the needs of terrestrial plants for ideal growth on Martian soil. The report also recognizes the specifics of the experiment, which come with requirements for a long duration manned mission, as well as the resource, power, and time requirements associated with the phases of the experiment. Through the proposed experiment, scientists will be provided comprehensive links that potentially allow for better research into the past geological, climatic, and biological status of Mars while also preparing for human habitation of Mars.

Long Duration Martian-Soil Based Agriculture Experiment Technical Report

With incredible ingenuity and technological advances, humanity has taken its first steps towards the stars by landing on the Moon, and is primed to make Mars the next frontier for our species and terrestrial life itself. Yet, any attempt at establishing a permanent human settlement must be preceded by a sustainable presence of crops and thus requires experimentation and investigations to further our understanding of agricultural practices in the unique characteristics of the harsh Martian environment. Over the past few decades, a Green Revolution has supported the exponential boom in human population through technological advances in the science of growing crops and the techniques of agriculture like synthetic agriculture and genetic engineering respectively (Pingali, n.d.). As humanity becomes a multiplanetary species, a goal of achieving such a radical realization of agricultural opportunities on Mars shall be critical, and having experiments on Mars for the development of agricultural techniques will accordingly be as necessary on manned investigative missions. With the proposed mission design, these necessities will be met through the delegation of crew time and resources towards the objective of both achieving and optimizing Martian agriculture in Martian soil over the course of a long duration mission to allow for preliminary findings that ensue humanity’s presence on Mars will be sustainable.

Any mission to Mars comes with sustainable constraints and costs that promotes any experimentation to maximize its applicability to the needs of researchers as set out by the Mars Exploration Program Analysis Group (MEPAG). An analytical group, MEPAG operates in conjunction with NASA to provide four primary goals for research regarding the past biological, atmospheric, and climactic conditions and potential future human endeavors (Mars Science Goals, n.d.). The proposed experiment will be able to meet the goals set by MEPAG since, by understanding how the growth of terrestrial plants is affected by the Martian environment, insight into the geological and atmospheric signs of past plants can be better estimated while simultaneously preparing for true human habitation on the Martian planet. Specifically, in the experiment, astronauts will operate through multiple phases designed to test a variety of factors including plant varieties and soil nutrient levels in order to best optimize terrestrial plants for the Martian soil. In the primary phase of the experiment, the crew of the manned mission will construct and organize the necessary resources for the growth of the plants in a greenhouse module, which will be located to specifically and optimally provide sunlight for the specific angle of the sun experienced on landing sight during the duration of the stay. Furthermore, to efficiently use the limited space, plants will be placed on racks with potted Martian soil and connected to automatic watering systems to minimize wasted crew time. Following the setup, astronauts will take Wisconsin Fast Plants, which have a full life cycle of 40 days, and other fast-growing edible seeds and plant them into Martian soil (Wisconsin fast plants, 2022). Unlike astronauts on the international space station, the crew will plant seeds in different orientations to test the viability of gravitropism on Mars, which allows seedlings to root downwards in the presence of gravity, and to potentially find an optimal orientation (Plants in space, 2022). In twenty-four hours, astronauts will be able to take samples of germinated seeds out of the soil for preliminary analysis of gravitropism in Mars gravity. Over the course of the remaining first cycle, astronauts will provide varying amounts of fertilizer through the use of organic waste, such as sewage from the crew, in order to discover the necessary nutrient balance for plant growth while tracking characteristics of the plants (Candanosa, n.d.). Following the primary cycle, astronauts will sample resulting seeds from the first generation and analyze the seeds for defects or abnormalities from terrestrial seeds that potentially were caused by the microgravity or radiation of Mars. Astronauts will also replant seeds in new soil and used soil to identify correlations between certain species of plants and subsequent species’ growth since certain species may be able to vitalize the Martian soil by providing biomass for biofertilization of other, potentially more beneficial, crops (Kasiviswanathan et al., n.d.). Through the experimentation of terrestrial plants coupled with Martian soil, astronauts will be able to understand the effects of the Martian environment on biological species over a sample of generations which will provide valuable insight into Mars’ history. Discovering the altered characteristics of plants will enable speculative investigations regarding the atmospheric conditions likely in the past and allow an understanding of potential past biomass’ influence on the atmosphere and geology of the planet.

Through the proposed experimentation, astronauts will be able to provide scientists with valuable insight into the behavior of biological organisms and their life cycles in a distinctive and exclusive way. However, the experiment will come with its own set of requirements due to its nature. In particular, due to the need for plant growth observations to be made with the radiation and gravity unique to Mars’ surface, the experiment will be fully reliant on the time spent on the Martian surface, without the ability to make use of the transit times between Earth and Mars. Moreover, the necessity of examining the effect of the Martian soil and environment on the growth and health of offspring is a primary cause of obstacles to agricultural experimentation. The offspring must be analyzed for defects and alterations since, without observing multiple generations of growth, scientists cannot ensure the true viability of agriculture in Martian soil as being sustainable due to the potential for accumulating detrimental mutations (Mohanta et al., 2021). As a result, agricultural experimentation inherently entails long duration crewed missions to fully guarantee factual observations. However, as a result of the reliance on long term missions, the experiment gains opportunities in findings of rapid improvement and specialization of the plant as the plants have, over enough generations, the potential to evolve to better succeed in the space environment. By being selected for positive traits, crew members could utilize the increased mutation rates caused by Mars’ radiation to differentiate plants with competitive abilities specific to the Martian environment (Mohanta et al., 2021). Therefore, unlike experiments utilizing plants grown in the International Space Station, the plants of the proposed experiment could be optimized uniquely for the Martian environment beyond the increased radiation and include adaptations for the lower gravity of Mars, which would further allow speculative observations about potential past life on Mars to be made. As a result of these variables, estimated results of the experiment become more ineffective as the duration of the experiment increases since the factors of radiation and evolutionary selection become more important. However, even the first three months of the experiment will have variability which will set the course for the remainder of the experiment as the plants may suffer greatly from the environmental challenges. Martian plant growth in a low-gravity simulation on Earth have show significantly less issues than those grown in microgravity simulations, potentially indicating a reduced amount of challenges for plant growth and a likelihood of similar results as plants on Earth after three months (Manzano et al., 2018). However, simulations are not always accurate, and factors of the soil may have a greater role over plant health. Shown by one study, simulants of lunar dust were inaccurate in demonstrating the poor plant growth of plants in real lunar dust samples, potentially indicating that soil quality could make the result of the experiments nonexistent, with no plant growth (Keeter, 2022). Following six months of the experiment, plant growth and results may have improved due to the biofertilization of previous plants being utilized to better the soil for growth. Furthermore, the plants may be more adjusted to the environment as the plants will have had four generations of establishment in the Martian soil. However, defects and mutations may also have accumulated in the seeds of the plants over the generations and resulted in detrimental traits being accumulated. As a result, by the twelfth month, the duration of the experiment will likely play a role in the potential for two results where the plants would have either adapted over generations to their environment, or accumulated too many detrimental mutations and defects to continue growing.

With the results of the agricultural experiment being so distinctly different by the end of the duration, the importance and meaning behind the results become more significant and emphasized as any findings will have extraordinary weight on the future long-term possibility of human settlement and habitation on Mars. The great significance of the experiment will accordingly be the result of certain costs on the mission associated with the time and resource requirements placed on the crew and mission respectively. For the greenhouse itself, the mission resource requirements must hence include the supplies necessary for the construction of the well-insulated module as well as the specific requirements of plant growth lights for use inside the greenhouse. Furthermore, microscopes and DNA extraction tools will be utilized to identify changes and properties of the seeds in an efficient manner by the crew throughout the experiment as visual defects can be linked to certain unique traits (Lee et al., 2019). The plants themselves may also require additional nutrients and fertilizers depending on the ability of terrestrial plants to adapt to Mars’ conditions. Alongside fertilizer, the plants will require the mission to bring additional oxygen and water for the pressurization of the greenhouse and watering of plants, although water requirements may be lessened due to Martian gravity affecting the soil’s ability to drain (Candanosa, n.d.). In order to operate the pumps and growth lights, the experiment will also increase the power demands of the mission, although lights will only need to operate during the normal circadian cycle of plants and could utilize efficient LEDs designed to emit only necessary wavelengths for plants (Hall, 2021). Additionally, since the plants will only need light during a circadian cycle, solar panels could be used to operate the necessary electronics for the plants without the need for batteries to store energy over nights and release excess energy in the form of heat to prepare the greenhouse for the colder nightly temperatures. Aside from the physical and power resources of the experiment, the time factor for the crew will be relatively little as the automatic distribution of water and nutrients will allow crew to only measure the plants and their various characteristics routinely. Furthermore, astronauts report finding gardening relaxing and enjoy spending their free time with the plants, while also gaining a boosted morale from the fresh produce, allowed by the cultivated plants, in their diet (Guzman, 2021). With all of the psychological benefits, the time spent by the crew on the experimentation will essentially be negligible, as the likely few hours weekly will only serve to help with the crew’s mood.

The importance of discovering the viability and ideal methods for agriculture on Mars will pave the way for the dramatic step humanity will take as an interplanetary species. Through the sustainability of agriculture on Mars, humanity will be able to permanently live on Mars and experience significant benefits with new resources and land being opened for the ever-increasing population to take advantage of. With the proposed experiment, the astronauts of the mission will be able to discover and unlock a bounty of opportunity for understanding of the Martian past, from its geological to its biological roots, and prepare humanity for colonization by providing scientists and researchers an unprecedented view into the response of terrestrial organisms on a new world. Just as humanity did thousands of years ago in discovering the agricultural lifestyle will the actions of the crew for the proposed experiment prime humanity for a decisive turning point in the future.

References:

Candanosa, R. (n.d.). *Growing green on the Red Planet*. American Chemical Society. Retrieved March 18, 2023, from https://www.acs.org/education/resources/highschool/chemmatters/past-issues/2016-2017/april-2017/growing-green-on-the-red-planet.html

Guzman, A. (2021, April 6). *Seven ways the ISS helps study plant growth*. Retrieved March 18, 2023, from https://www.nasa.gov/mission\_pages/station/research/news/Seven-Ways-the-ISS-Helps-Study-Plant-Growth

Hall, L. (2021, December 16). *NASA research boosts LED lamps for home and garden*. NASA. Retrieved March 18, 2023, from https://www.nasa.gov/directorates/spacetech/spinoff/NASA\_Research\_Boosts\_LED\_Lamps\_for\_Home\_and\_Garden

Kasiviswanathan, P., Swanner, E. D., Halverson, L. J., & Vijayapalani, P. (n.d.). *Farming on mars: Treatment of basaltic regolith soil and briny water simulants sustains plant growth*. PLOS ONE. Retrieved March 18, 2023, from https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0272209

Keeter, B. (2022, May 12). *Scientists grow plants in lunar soil*. NASA. Retrieved March 18, 2023, from https://www.nasa.gov/feature/biological-physical/scientists-grow-plants-in-soil-from-the-moon

Lee, C.-L., Huang, Y.-H., Hsu, I. C., & Lee, H. C. (2019, June 10). *Evaluation of plant seed DNA and botanical evidence for potential forensic applications*. Forensic sciences research. Retrieved March 18, 2023, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7241509/

Manzano, A., Herranz, R., den Toom, L. A., te Slaa, S., Borst, G., Visser, M., Medina, F. J., & van Loon, J. J. W. A. (2018, April 4). *Novel, Moon and Mars, partial gravity simulation paradigms and their effects on the balance between cell growth and cell proliferation during early plant development*. Nature News. Retrieved March 18, 2023, from https://www.nature.com/articles/s41526-018-0041-4

*Mars science goals, objectives, - NASA*. (n.d.). Retrieved March 18, 2023, from https://mepag.jpl.nasa.gov/reports/MEPAGGoals\_2020\_MainText\_Final.pdf

Mohanta, T. K., Mishra, A. K., Mohanta, Y. K., & Al-Harrasi, A. (2021, October 4). *Space breeding: The next-generation crops*. Frontiers. Retrieved March 18, 2023, from https://www.frontiersin.org/articles/10.3389/fpls.2021.771985/full

*Plants in space - national space biomedical research institute*. (n.d.). Retrieved March 18, 2023, from http://nsbri.org/wp-content/uploads/2015/06/Plants-in-Space.pdf

Pingali, P. (n.d.). *Green revolution: Impacts, limits, and the path ahead | pnas*. Retrieved March 18, 2023, from https://www.pnas.org/doi/10.1073/pnas.0912953109

*Wisconsin fast plants of the University of Wisconsin: Homepage*. Wisconsin Fast Plants®. (2020, June 23). Retrieved March 18, 2023, from https://fastplants.org/