

Plant Mars (W.A.W.A.)



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Introduction

Sending humans to Mars for long periods of time creates many challenges, especially when it comes to providing fresh food. Astronauts cannot rely only on packaged meals from Earth because of the limited amount and the lack of nutrients over time. Because of this, scientists are studying how to grow plants in space, specifically Mars. One of the biggest challenges is that Martian soil does not contain the nutrients and organic materials that plants need to grow. It is dry, crusty and lacks nitrogen, which is one of the most important nutrients for plant growth. The purpose of this experiment will help test what type and amount of fertilizers could help plants grow in soil similar to Martian conditions by focusing on comparing organic and synthetic fertilizers. In comparison, synthetic fertilizers are made by humans and usually provide nutrients more quickly and in higher amounts. The experiment tested two different amounts, 25 mL and 50 mL, to see how both the type and amount of fertilizer affected growth.

Green beans (*Phaseolus vulgaris*) were chosen for this experiment because of the several qualities that make them useful for Mars farming. First, green beans are classified as legumes which means they can take nitrogen from the air and turn it into nutrients in the soil through a natural process. This is very important because Martian soil does not have the nitrogen that can be used to support plant life. Green beans also grow relatively fast and do not need a large amount of space, making them reasonable for small growing areas like on a spacecraft or a Mars base. Another reason green beans were chosen is because they are known to grow in difficult environments, including volcanic soils that are similar to Martian soil. Volcanic soil shares some features with Martian soil such as low nutrients and rough texture. This suggests that green beans may be able to adapt to Martian conditions better than other plants.

An important benefit of growing plants like green beans during missions like to Mars is the positive effect on astronauts' mental health. Living in space or on Mars far away from home can be stressful and isolating as they are far from family, surrounded by a small crew, and stuck in a limited space for a long period of time. This can cause the crew to experience loneliness, anxiety and boredom. Taking care of plants can help reduce these feelings by giving astronauts a daily task that makes them feel more at home. Watching plants grow over time can help astronauts feel a sense of progress and accomplishment, which is important for maintaining a positive mindset. The color, smell and even the presence of plants can remind astronauts of Earth.

This experiment is important because it helps show how green beans react to different conditions in a controlled environment that is meant to be similar to Mars. The results showed that the plants grown with organic fertilizer had better growth than those with synthetic fertilizers. The plants with synthetic fertilizers did not grow at all. One possible reason for this is that synthetic fertilizers might have provided too much of certain nutrients, especially nitrogen, which could harm the roots instead of helping them. Since green beans already produce their own nitrogen, adding too much nitrogen may have affected their natural growth negatively. On the other hand, organic fertilizers may have helped the green beans grow by improving the soil slowly and safely. Organic fertilizers often make the soil better at holding water and supporting helpful microorganisms, which are tiny living things that help plants grow. Even though worms were added to improve the soil, most of them did not survive, which suggested that the soil conditions were not good. This shows that more work is needed to create a soil environment that can support both plants and other living organisms on Mars.

In conclusion, this experiment provides useful information about how to grow green beans on Mars. It shows that choosing the right type of fertilizer is very important. The findings could help scientists and engineers design better farming systems for future missions to Mars. In the future, testing different fertilizers, changing the amount given or trying other plants could help improve results even more. This helps successfully grow food on Mars and help support human life on Mars.

Experimental Design

For the PBL Project, the scientists began their experiment in a science lab located in Collins Hill High School. These scientists had to follow very strict protocols not only for their safety but also for others. These protocols were safety procedures such as safety goggles, masks and gloves provided by The Institute of Competition Sciences. Martian regolith or Martian dust is considered very toxic and poisonous to humans. If it makes contact with the eyes, nose and/or mouth, it can cause severe irritation and/or respiratory and internal risks. Also, due to their high toxic components and the fact that Martian dust is very fine, inhalation and ingestion can cause the dust particles to be lodged into the lungs and/or absorbed into the bloodstream. According to PubMed Central, “Toxic components of martian dust include perchlorates, silica, nanophase iron oxides, and gypsum in addition to trace amounts of toxic metals whose abundances are debated: chromium, beryllium, arsenic, and cadmium.”

In addition to their growth advantages, green beans could play an important role in creating a closed-loop life, a lifestyle that is designed to mimic nature, a support system for long term space missions. In environments like a Mars base, waste recycling is essential because resources are extremely limited. Green bean plants can be set up into systems where organic waste, such as plant scraps and safely processed human waste, is broken down and reused as

nutrients for future crops. This reduces the need to transport large amounts of fertilizer from Earth. Also advanced plant growth habitats are designed to carefully control light cycles during LED technology, regulate humidity and recycle water through condensation systems. According to NASA, “Future plant research conducted in these research facilities will help enable exploration by improving our understanding of how plants, their associated microbiomes in leaves and roots, and how they grow in the spaceflight environment.” This shows that growing plants in space is not just about food production, but also understanding the relationship between plants and their microscopic friends. Green beans could be benefitted because they naturally form relationships with bacteria that help them obtain nitrogen and grow in poor soil conditions. By studying the interactions, scientists can design better growing systems for Mars that could help support both plants and beneficial microorganisms. Lastly, studies conducted on the ISS have also shown that tending plants could help improve crew cooperation and provide a responsibility they all share. This helps strengthen team work and trust. These additional benefits show that green beans are not just a food source but also a key part of a sustainable living space on Mars.

Methods

The research conducted before planting explored the differences between organic and synthetic fertilizers, and their effects on both the growth of a plant and the quality of the soil. This was conducted while minding the effects of the Martian soil combined with the potting mix. With this, the hypothesis was then able to be furtherly curated and condensed into one final statement: Different amounts of synthetic and organic fertilizers will affect the growth rates and lengths of green beans when observed. Findings suggested that synthetic fertilizers produced with nutrient boosting chemicals contribute to damaged and dry soil but offered large growth

results (Cherlinka 2024). In contrast, organic fertilizers containing different microbes that shared a symbiotic relationship the soil were suggested to be a healthier alternative for both the plant and the soil (Cherlinka 2024). Given to the researchers by the competition hosts were 5 medium sized pots, black latex gloves, a variety of seeds to choose from, and a large container of Martian soil simulant. Teachers and educators provided other seed options, purified water, potting mix, UV lamps to simulate sunlight, worms, and aluminum trays large enough to fit all 5 pots.

Different variables of influence were controlled by researchers in order to ensure fullest potential success. Independent variables such as the amount and type of fertilizer were never modified during the experiment as it would affect the results of the data. For the synthetic fertilizer, Miracle-Gro LiquaFeed All Purpose Plant Food was used which contained a 12-4-8 ratio of nitrogen, phosphate, and potassium as observed in the manufacturing label. This product was chosen to represent the synthetic fertilizer as it contained chemicals and man-made ingredients that promoted instantaneous growth by feeding the plant. This contrasts the organic fertilizer used, Mykos Pure Mycorrhizal Inoculant, as the microbial activity feeds the soil which then provides nutrients for the plant to grow. As for the dependent variable, the growth of the plant was observed over the course of 8 weeks as the data recorded height in inches, new growths such as leaves, and irregularities caused by environmental stresses such as changes in stem and leaf texture. Controlled environmental elements were crucial in maintaining a stable environment for the legumes to grow. All 5 pots were placed in an aluminum tray to be grouped together and placed on a table two feet away from a UV light source that remained powered on for the entire duration of the experiment. Within the pots was a mixture of 300 milliliters of Martian soil simulant and 300 milliliters of potting mix to create a 50:50 ratio. Each pot was filled with the soil mixture approximately 85% from the top of the pot. No modifications were

made to the amount of potting mix nor the amount of Martian soil simulant. Additionally, one earthworm was administered to each pot and left to maintain sufficient nutritional balance. 50 milliliters of water were added to each pot every day along with light misting from a plastic spray bottle. Approximately 4-5 sprays were used to mist all 5 plants along with the 50 milliliters of water given.

All materials utilized are listed below:

- 5 medium sized pots
- 1 medium sized aluminum tray
- Table/stand
- UV lamp
- Potting mix
- Simulated Martian soil
- Purified water
- 5 green bean seeds
- Miracle-Gro LiquaFeed All Purpose Plant Food
- Mykos Pure Mycorrhizal Inoculant
- Plant stabilizers for stem support
- Graduated cylinder
- Beaker
- Pot labels

Steps in order to replicate experiment:

To begin, gather all ingredients listed above. Using a beaker, measure 300 milliliters of both the potting mix and the Martian soil and mix together. Take all 5 pots and fill each

approximately until 85% full. Dedicate two pots to contain organic fertilizer and another two to contain synthetic fertilizer. The 5th pot will not contain any fertilizer. In the organic fertilizer pots, add 25 milliliters of Mykos Pure Mycorrhizal Inoculant in one pot and 50 milliliters in another. Mix and label accordingly. Repeat the steps for the synthetic fertilizer pots using Miracle-Gro LiquaFeed All Purpose Plant Food. In the middle of the mix, dig a small hole about an inch deep and insert one seed into each pot. Cover the seed with the mix in the pot and lightly pat down the soil and compact it. Gather all labeled pots and place them in an aluminum tray and on a table two feet away from the powered UV light.

Data

On February 10th, the experimental design was put into action as the seeds were placed in soil and observed over the course of 8 weeks. Below is a graph demonstrating the growth of the green beans measured in inches per week.

Figure 4								
Pots	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
25 ml organic	0.5	6	12	0	0	0	0	0
50 ml organic	0.2	4	7.5	11.5	12	14 1	14 2	8 2.5
25 ml synthetic	0	0	0	0	0	0	0	0
50 ml synthetic	0	0	0	0	0	0	0	0
Control	0.7	3.7	8.75	6	6	5 1.5	4.5 2.4	0 3

For the first 3 weeks, it can be observed that the growth of 25 ml organic, 50 ml organic, and the control pot were all growing healthily and exponentially. However, later during the week it was discovered that the experiment had been tampered with and vandalized. The following week showed the effects of that as the 25 ml organic pot had died and been removed from the pot entirely to be replanted. The control pot was showing signs of environmental stress as 2.75 inches broke off when it was touched. The part that had broken off was placed vertically in the pot in hopes that it would continue to grow or establish roots. During week 4, the leaves of the control pot were also showing signs of environmental stress. The leaves had developed brown/yellow spots, puzzling the researchers as they waited to observe further what the possible causes could be. The next week showed similar results as the control pot started shrinking and the texture of the leaves were dry and crusty. The researchers then made a collective decision to add new beans to observe whether the seeds would regrow as easily as they had before. 1 extra bean had been added to the pot labeled 25 ml organic, 2 for the 25 ml synthetic, and another 2 extra beans for the 50 ml synthetic. Week 6 showed new results as there were signs of 2 new growths in the 50 ml organic and 1 new growth in the control pot. The new growths differed from the original observations, as they appeared to be sprouts with two little leaves opposite from each other compared to the original grows which had obviously sprouted from a seed. In the chart, the extra measurements below the original ones are the measurements of the new growths in inches. In the end, the original plant in the control pot had died and only the new growth remained.

Analysis and Results

The final day of observation showed evident differences between all of the plant growths. Although each plant was grown under the same control variable, including a 50:50 mixture of

Martian soil stimulant and Earth soil, daily watering of 50 milliliters, and constant exposure to the ultraviolet light made the final outcomes vary significantly. Because all environmental factors were controlled, the changes in plant growth can be directly associated with the independent factor: the type and quantity of fertilizer used. The observations directly supported the hypothesis that different amounts of synthetic and organic fertilizers would affect the growth rates and lengths of green bean plants. It was seen that the disparity in outcomes followed the idea that the quantity and types of fertilizers played an important role in their development.

In the control group, the pot without any fertilizer indicated stable but measured growth from the beginning to the end of the experiment. By the time the observation period came to an end, the control plant had already reached the height of nearly $8\frac{3}{4}$ inches and demonstrated constant development of the leaves and its sturdiness. This shows that green beans are capable of growing in a Martian soil mixture without any additional nutrients; however the growth is hindered when compared to plants that get further assistance. Therefore, the control group provided a reference point for comparison and revealed that, while the soil mixture could support life, it was still not ideal since it lacks sufficient nutrients to promote optimal growth.

In comparison, the plants that were grown using the organic fertilizer demonstrated the highest level of growth and overall health performance. The plant with 25 milliliter of organic fertilizer achieved the greatest height, reaching approximately 12 inches, and displayed strong stems, flourishing healthy leaves, and a solid firm structure. The organic matter established a helpful growing environment by enhancing nutrient availability and supporting microbial activity. The plant that received 50 milliliter of organic fertilizer also grew efficiently, but it displayed signs of structural imbalance, featuring slight bending in the stems and fragile structure. These results show that organic fertilizer enhances plant growth, but too much may

reduce optimal development and lead to nutrient imbalances or rapid growth, reducing overall structural stability. Overall, the organic fertilizer plants outperformed the control and synthetic ones, highlighting that soil chemicals are crucial for plant growth in nutrient-poor soil.

In contrast, the synthetic fertilizer plants had no measurable growth, given that neither plant achieved successful germination. Because of this, the 12% nitrogen in the synthetic fertilizer caused an excess of nitrogen, stunting the growth of the bean and causing a lack of germination. Comparatively, the organic fertilizer used, Mykos Pure Mycorrhizal Inoculant, contains “*Rhizophagus intraradices*” as an active ingredient. “*Rhizophagus intraradices*” are a type of arbuscular mycorrhizal fungus. According to the University of Wisconsin-Madison Horticulture (2005), “Mycorrhizae are fungi that have a symbiotic relationship with the roots of many plants”. This symbiotic relationship creates a balanced exchange between the fungi and the plants. The plant produces carbon in which the fungi can feed off from, and the fungi act as a sponge to absorb excess nutrients for the plants, to then absorb and use to grow. These fungi are used in fertilizers as it can help promote root growth, expanding water and nutrient intake by wide margins and building stress tolerance. Mycorrhizae in soil is ideal for restoring degraded soil and accelerating growth through improving root structure.

From these findings, it can be concluded that the reason both potted plants containing 25 and 50 milliliters of synthetic fertilizer did not germinate was that they were ruined from the beginning. The excess amount of nitrogen delayed the growth compared to the pots containing organic fertilizer or none at all, producing no results. The control variable plant grew about average and if compared to the plants containing organic fertilizer, they set the standard for how green beans grow with no help other than watering them daily as a basic need. The pot with 25 milliliter of organic fertilizer was the most successful until its unfortunate demise, during an act

of vandalism. When compared to the pot with 50 milliliter of organic fertilizer, the 25 milliliter organic pot had more growth, with a stronger and thicker base connecting to the root. This is not to say that the 50 milliliter organic pot was not also successful, but when compared with the 25 milliliter organic pot, the 50 milliliter organic pot showed that the 25 milliliter of organic fertilizer was a better ratio with the soil. Although all of the pots received the same amount of water, sunlight, and worms, the results show the effects of excess nitrogen and symbiotic fungi in fertilizer when applied to green beans.

Conclusion

The results agree with the hypothesis that different types and amounts of fertilizer are essential for plants to gain nutrients from and would promote beneficial soil activity and growth. The plant receiving 50 milliliters of organic fertilizer grew well and was able to maintain a structure throughout the duration of the experiment despite being tampered with. The control plant exhibited moderate growth, reaching $8\frac{3}{4}$ inches, showing that Martian soil along with the help of earth soil can support survival of the plants but not their optimal growth. In contrast, the synthetic fertilizer group failed to germinate, most likely due to excessive nitrogen interfering with the natural nitrogen fixation process in green beans.

The environmental factors also influenced growth. Overwatering resulted in weak stems and overly mushy soil, leading to changing the tray every time the plants were watered. This factor also led to adding supports such as pencils and rolled papers to keep plants from drowning, and changing the napkin underneath the pots so the moisture wouldn't cause growth of mold. Eventually plant stakes made for pots were added to replace the makeshift ones. These observations show that, in addition to fertilizer, careful management of water, soil structure, and plant support is important for successful growth under extreme conditions like Martian soil.

If the experiment were repeated, specific improvements could enhance the results. Testing additional fertilizer concentrations could identify the most effective nutrient balance. Measuring soil pH, nutrient levels, and root development throughout the experiment would provide deeper insight into how fertilizer affects growth. Protecting the plants from damage and maintaining consistent environmental conditions would further improve the accuracy and reliability of the results. Overall, the results indicate that organic fertilizers combined with careful environmental management are critical for successful plant growth in Martian soil. These findings help understand how cultivating crops in challenging soils can support sustainable food production on long-duration missions.

The observation of this experiment has important significance for future space exploration and long-term missions to Mars. Successfully growing green beans in a Martian soil stimulation demonstrates that, with the right combination of nutrients and environmental management, plants can serve as a reliable food source for astronauts. Organic fertilizers, which improve soil structure and support beneficial bacteria, are essential for maximizing growth in nutrient-poor soils. Continued research in this area can develop sustainable agricultural systems for space, reduce reliance on Earth-based food supplies, and ensure that astronauts have access to fresh nutritious crops during long-duration missions. This experiment confirms that plant growth in outer space environments is achieved, but relies heavily on careful nutrient management, monitoring the environment, and attentive care of the plants.

Photos



Figure 5 (Week 1)

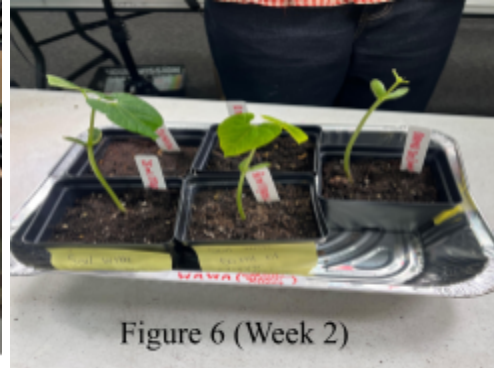


Figure 6 (Week 2)

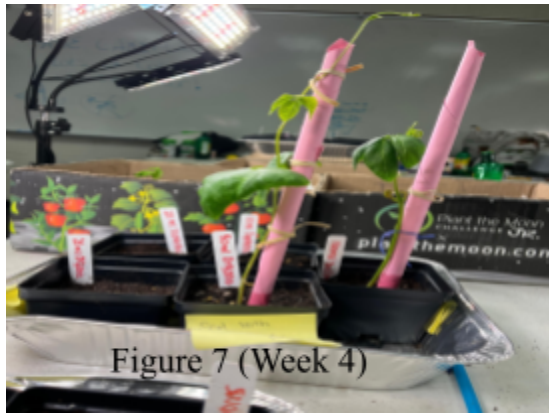


Figure 7 (Week 4)

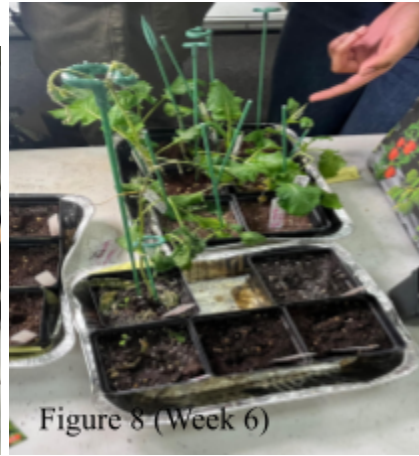


Figure 8 (Week 6)

References

NASA's Curiosity Rover Finds Biologically Useful Nitrogen on Mars - NASA. (2015, March 24).<https://www.nasa.gov/solar-system/nasas-curiosity-rover-finds-biologically-useful-nitrogen-on-mars/>

Wieger Wamelink, & Pouwels, C. (2024). Effect of struvite on the growth of green beans on Mars and Moon regolith simulants. *Open Agriculture*, 9(1).
<https://doi.org/10.1515/opag-2022-0261>

NASA. (2023, June 9). Growing Plants in Space - NASA. NASA; NASA.
<https://www.nasa.gov/exploration-research-and-technology/growing-plants-in-space/>

Searles | How to Grow Green Beans. (2022). Searlesgardening.com.au.

<https://www.searlesgardening.com.au/articles/how-to-grow-green-beans>

The Living Farm. (2025, March 25). 5 Steps to Successfully Starting Green Beans in the Garden.

YouTube. <https://www.youtube.com/watch?v=Cq3PrLVrOf4>

Cherlinka, V. (2024, May 3). Organic Vs. Synthetic Fertilizer: Pros, Cons, And Which To Use.

Eos.com. <https://eos.com/blog/organic-vs-synthetic-fertilizers/>

Tang, J., Li, W., Wei, T., Huang, R., & Zeng, Z. (2024). Patterns and Mechanisms of Legume

Responses to Nitrogen Enrichment: A Global Meta-Analysis. *Plants*, 13(22), 3244.

<https://pmc.ncbi.nlm.nih.gov/articles/PMC11598177/>