

Plant the Moon Plant Mars

Team Saiph
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Soil Development, Worm Survivability and Growth of Plants in Lava Rock and Regolith

Plant Mars and Plant the Moon Challenges
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Table of contents

Introduction	3
Theory	3
Regolith	3
Lava rock and volcanic ash	4
Worms, recycled organic material, fungi & bacteria	4
What we are testing	4
Visuals: Plants and volcanoes on Earth (1)	5
Visuals: Plants and volcanoes on Earth (2)	6
Visuals: Ash and lava rock on the Moon	7
Visuals: Ash and lava rock on Mars	8
Study Methodology	9
Pots and grow station setup	9
Pot and regolith preparation	9
Planting and plant care	9
Measurement methods	9
Study Visuals	10
Moon pot set up	10
Mars pot set up	11
3D printed pot	12
Moon and Mars growth charts	13
Final Moon plants and soil	14
Final Mars plants and soil	15
Discussion	16
Findings	16
Conclusion	17
Limitations	17
Future questions and ideas	17
Work Cited	18
Appendix	21
Moon plant growth visual timeline	21
Mars plant growth visual timeline	22
Moon observations / water and fertilization schedule	23
Mars observations / water and fertilization schedule	29

Introduction

Living amongst the stars is developing into an attainable reality rather than a faraway dream. Space is becoming more accessible with technological advancements and new players transforming the industry; bringing down exorbitant costs and opening up opportunities to those outside of government space agencies. Space tourism, exploration, habitation, mining, and manufacturing all lie in our not too distant future. Even considering the technological advancements over the last centuries, those who venture into space will share many challenges of the old day explorers. Health, shelter, and food all will be paramount as space explorers confront inhospitable environments far from home.

The next steps on our journey to off Earth settlements are the Moon and Mars. Due to the distance from Earth, high cost of transport, and time needed to deliver additional supplies utilization of as many in-situ resources as possible will be required. It will not be feasible for a continuous supply of food to be brought from Earth. Food will need to be grown.

Space habitats will have temperature regulation, water, oxygen, carbon dioxide, and nitrogen. Plants grown in the habitats will also need soil, grow lights, and grow pots. Grow pots may be 3D printed using in-situ regolith. Fertilizer and grow lights will need to be brought from Earth. We can start to create soil using vesicular basalt, referred to as lava rock in the rest of this study, and regolith. Both lava rock and regolith are available in-situ. Worms, recycled organic matter, fungi, and bacteria that can be generated locally will also help to transform the regolith. As the regolith sees more growth cycles and develops into something more similar to fertile Earth soil, the hope is only recycled local organic matter and in-situ fertilizer, from volcanic ash or another local source, should be needed as an amendment.

Theory

Regolith

The soil on Earth has many differences from the regolith on the Moon and Mars, partly because they do not have the same processes that Earth continuously cycles through. It does not rain, which erodes and transforms Earth's soil. The nitrogen cycle is very different on the Moon and Mars due to the absence of organic matter. The regolith has also been exposed to different forces than we see on Earth, as both the Moon and Mars are exposed to more radiation, have less dense, differently composed atmospheres¹, and have lower gravity.

There are however commonalities shared with the soil on Earth. Besides reactive nitrogen, which is a component of the nitrogen cycle and essential for most if not all life on Earth², all minerals needed for plant growth are likely present in both Martian and Moon regolith (Wamelink et al. pg 1). Plants were able to germinate and grow in simulated Mars and Moon regolith without addition of nutrients (Wamelink et al. pg 5), though the Earth derived simulants may not fully replicate toxicity or other issues we may encounter when working with in-situ regolith. Recently, a plant (*Arabidopsis thaliana*) has been successfully grown in true Lunar regolith using an MS nutrient solution (Paul et al. pg 1, 7). An MS nutrient solution is a plant growth medium used in laboratories and is similar to liquid fertilizer. *Arabidopsis thaliana*'s growth was described as challenging, but plants were nonetheless able to grow (Paul et al. pg 1).

¹ The moon has an atmosphere, though an extremely thin one (NASA; [Is There an Atmosphere on the Moon?](#))

² Earth has organisms that are not linked to a food chain that is dependent on photosynthesis (University of Hawai'i at Mānoa; [Weird Science: Hydrothermal Vents and Cold Seeps](#)), and are not dependent on the nitrogen cycle to the same degree as their sun dependent friends.

Lava rock and volcanic ash

Volcanoes built the lush Hawaiian landscape and the fertile lands of Pompeii. Volcanoes have made the most productive lands on Earth. Mars and the Moon both have a volcanic history. Lava rock and volcanic ash are present on both and may serve as a valuable in-situ resource for future explorers. Vesicular basalt, referred to as lava rock in this study, serves as a soil amendment that increases water absorbency, reduces soil compaction, and increases soil aeration. Team Rainbird saw root surfacing, likely due to soil density of the simulated Lunar regolith, which may have been worse without added compost (Team Rainbird 5:32). In this study, lava rock is used to decrease soil density while increasing aeration and water absorption.

Lava rocks may also break down into nutrients that can be used by plants, though that process takes anywhere from a few to hundreds of years (University of California). It is likely that volcanic ash deposits are also accessible on the Moon and Mars. On Earth volcanic ash has transformed into a form that can be utilized by plants in a shorter timespan than lava rock (Fisher et al. pg 240). The transformation into a plant usable form is by no means instantaneous, and trying to grow plants in volcanic ash has been compared to growing plants in styrofoam (Fisher et al. pg 241). The timeline for both volcanic ash and rock's transformation into a plant usable form is heavily influenced by atmospheric and geological factors (Fisher et al. pg 241). Ways to speed volcanic ash and rock's transformation into a form that can be easily utilized by plants will be tested in future studies.

Worms, recycled organic material, fungi & bacteria

Worms, fungi, and bacteria should be a part of any off Earth settlements, as they play an essential role in the nitrogen cycle. The nitrogen cycle produces plant-available nitrogen, which is not thought to be present in off-Earth regolith. In-situ regolith may have other differences to the Earth derived simulant that could impact organisms' survivability. Possible issues include the 'sharper' regolith on the Moon (ESA) and high levels of radiation impacting the surface layers of regolith on both the Moon and Mars. The use of compost bins may avoid these issues. Barring any unforeseen effects of the Lunar and Martian environments (ie; lower gravity), worms, bacteria, and fungi should be able to become self-sustaining in some form of a compost bin using plant, food and/or human waste. The compost could then be mixed with regolith, though the plants would ultimately face the same issues when growing in the regolith.

As attempted in this and another experiment (Wamelink et al. pg 238), worms can be introduced into the regolith itself along with organic matter. Once introduced, the worms may be able to become self-sustaining in the regolith. Fungi and bacteria are also being introduced into the regolith in this experiment. These additions may help to kick start the nitrogen cycle, and provide an avenue outside of fertilization for plant usable nitrogen to be maintained while starting the regolith on a path to transforming into something closer to fertile soil.

What we are testing

We are investigating if:

- plants can grow in simulated regolith and lava rock without any soil amendments.
- soil amendments (dried plant matter, mycorrhizal fungi, liquid microbial inoculant, liquid fertilizer and worms) impact plant growth.
- soil amendments (dried plant matter, mycorrhizal fungi, liquid microbial inoculant, liquid fertilizer and worms) impact simulated regolith development.
- varying simulated regolith to lava rock ratios impacts plant growth.
- worms can survive in simulated regolith and lava rock.



Above: Vineyard at the ruin city of Pompeii. Pompeii was part of a region that has very fertile soil due to volcanic ash from Mount Vesuvius' erupting (Omeka-Wellesley College). Pompeii was destroyed by the eruption of Vesuvius in the year 79 AD.



Left: Noni (*Morinda citrifolia*) is a versatile plant that can grow in lava flows and tolerate a variety of conditions, including brackish, or somewhat salty, water. Polynesian voyagers are thought to have taken the plant with them when exploring and settling the Pacific (University of Hawaii). The plant has a variety of uses. The fruit and leaves are edible, though the fruit's smell has been described as less than desirable.

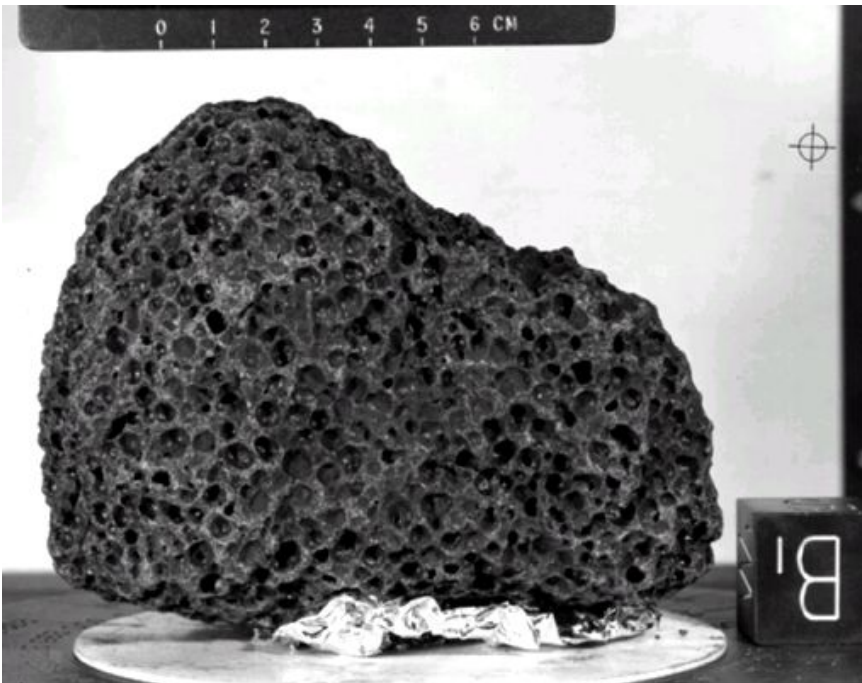
Image source: Scot Nelson / [Flickr](#)



Above: The Eldraun Lava Field in Iceland was created in an immensely devastating eruption in 1783 and 1784. Moss now blankets the lava field. Moss gets nutrients and water through its leaves and stem (Nordstrom pg 9) and nitrogen from cyanobacteria (Liu and Rousk pg 149).

Right: Mt St Helens. Wildflowers, some of which are nitrogen-fixing, grow in volcanic ash and rock distributed by a cataclysmic eruption in 1980 (Karras).



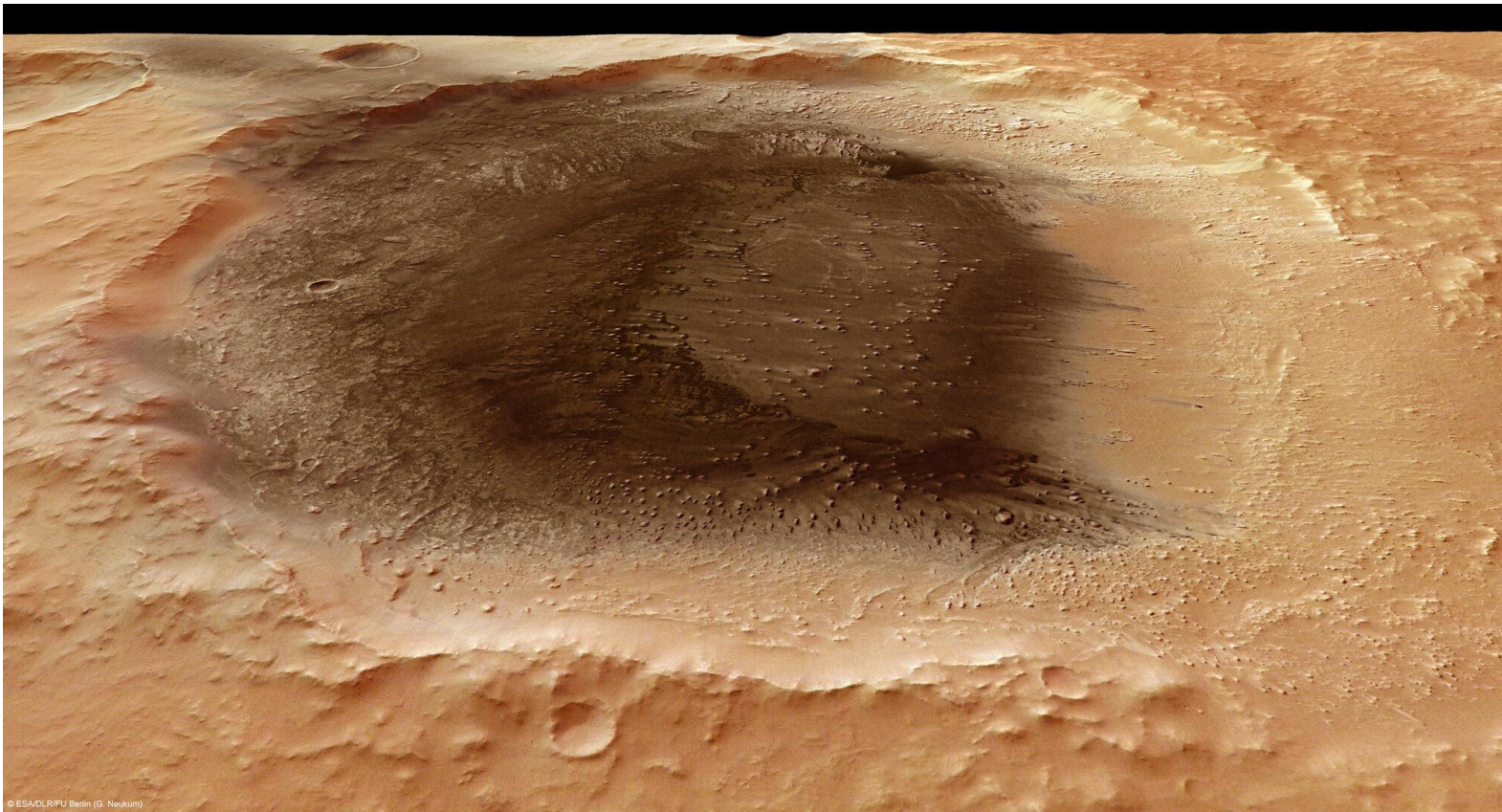


Above: 18 images taken by the Galileo spacecraft were combined to make this view looking down on the north pole of the moon. Lava plains of the Marginis and Smythii basins and the Humboldtianum Basin, which is partly filled with dark volcanic deposits, are visible.

Image source: NASA / [The Moon from Above](#)

Left: Vesicular basalt from the moon.

Image source: NASA / [Mare Basalt Volcanism](#)



© ESA/DLR/FU Berlin (G. Neukum)

Above: This image was taken by the Mars Express High Resolution Stereo Camera of Meridiani Planum on Mars. The black areas are likely composed of volcanic ash-rich sediments.

Image source: ESA / [Volcanic ash in Meridiani Planum](#)

Right: The basalt rocks shown have many small holes or vesicles. This image was taken by the Spirit rover in the basin south of "Husband Hill."

Image source: [Gusev Lava Rocks](#)



Study Methodology

Pots and grow station setup

Grow pots consisting of 4 pieces were 3D printed using polylactic acid filament (see pot visual page 12). Each grow pot has its own individual height adjustable full spectrum grow light. The maximum measured lux on the grow lights was approximately 18,000 lx. The pots were set up in a temperature controlled house. The pot location received no direct natural sunlight.

Pot and regolith preparation

The Purdue Interplanetary and Space Agriculture Team encountered stunted growth and browning on the plants, after wash out of the simulated Mars regolith the plants growth appeared healthy and normal (Bailey et al. pg 13-14). Therefore simulated Mars regolith was rinsed with water several times prior to potting. Note this type of treatment may eliminate water soluble percolates thought to be in true Martian regolith. The simulated Lunar regolith was not rinsed prior to potting. The organic material used was taken from a watermelon plant. The vine and leaves were cut into fine pieces and dried in a very warm California sun.

Both Mars and Moon plants had two controls. One control pot used only potting soil and lava rock. The other control pot used only simulated regolith and lava rock. Non-control pots consisted of simulated regolith and lava rock in varying ratios. Dried plant matter, mycorrhizal fungi (Trifecta Myco Supreme), liquid microbial inoculant (FoxFarm Microbrew), liquid fertilizer (FoxFarm Grow Big) and red wiggler worms were all introduced to the non-control pots.

For more details on pot preparation and composition, see Moon pot set up (page 10) and Mars pot set up (page 11).

Planting and plant care

Both pok choi and avalanche beet seeds were soaked in water 24 hours before planting. The seeds were covered with a thin layer of simulated regolith/soil when planting in the pot. Plants were gradually thinned out until only one pok choi and one beet remained in each pot. The grow pot's top portion was removed once the plants reached a height beyond the middle section. The plants are in a temperature controlled house, watered daily, and received 12 hours of light each day at the full spectrum plant light's maximum brightness. Aside from adding liquid fertilizer into the non-control pots prior to planting, fertilization for the non-control plants was done according to FoxFarm's feeding schedule.

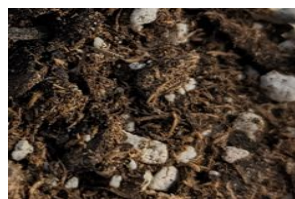
Measurement methods

- Visual comparison of simulated regolith at experiment start and end
- Visual count of living worms at experiment start and end
- Plant weight and appearance at the end of experiment
- Plant appearance and height throughout experiment

Moon pot set up

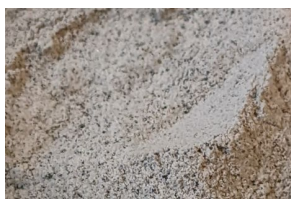
Controls

C1A & C2A



Foxfarm Ocean Forest Potting Soil

or



Simulated Lunar Regolith

+



Black Lava Rock

Test Plants

M1, M2 & M3



Trifecta Myco Supreme
Mycorrhizal Fungi

+



Simulated Lunar Regolith

+



Dried Watermelon Vine and
Leaves

+



Black Lava Rock

+



5 Red Wiggler Worms

+



Foxfarm Microbrew & Grow
Big Liquid Fertilizers

		Plant#				
Pot breakdown		C1A	C2A	M1	M2	M3
Initial watering		20 ml water	20 ml water	10 ml microbrew 10 ml growbig	10 ml microbrew 10 ml growbig	10 ml microbrew 10 ml growbig
Top	Layer 5	n/a	n/a	200g moon soil/ 200g lava rock	200g moon soil/ 200g lava rock	100g moon soil/ 100g lava rock
	Layer 4	200g moon soil/ 200g lava rock	50g potting soil/ 50g lava rock	400g moon soil	200g moon soil/ 200g lava rock	300g moon soil/ 100g lava rock
	Layer 3	400g moon soil	100g potting soil	9g dried leaf matter / 4g myco / 5 worms	9g dried leaf matter / 4g myco / 5 worms	9g dried leaf matter / 4g myco / 5 worms
	Layer 2	200g moon soil/ 200g lava rock	50g potting soil/ 200g lava rock	200g moon soil/ 200g lava rock	200g moon soil/ 200g lava rock	200g moon soil/ 200g lava rock
Bottom	Layer 1	200g lava rock	200g lava rock	200g lava rock	200g lava rock	200g lava rock
Total regolith						
Soil (Lunar or potting)		800g	200g	800g	600g	600g
Lava		600g	450g	600g	800g	600g
Ratio		1.3	0.4	1.3	0.8	1.0

Mars pot set up

Controls

C1B & C2B



Foxfarm Ocean Forest Potting Soil

or



Simulated Mars Regolith

+



Red Lava Rock

Test Plants

Ma1, Ma2 & Ma3



Trifecta Myco Supreme
Mycorrhizal Fungi

+



Simulated Mars Regolith

+



Dried Watermelon Vine and
Leaves

+



Red Lava Rock

+



5 Red Wiggler Worms

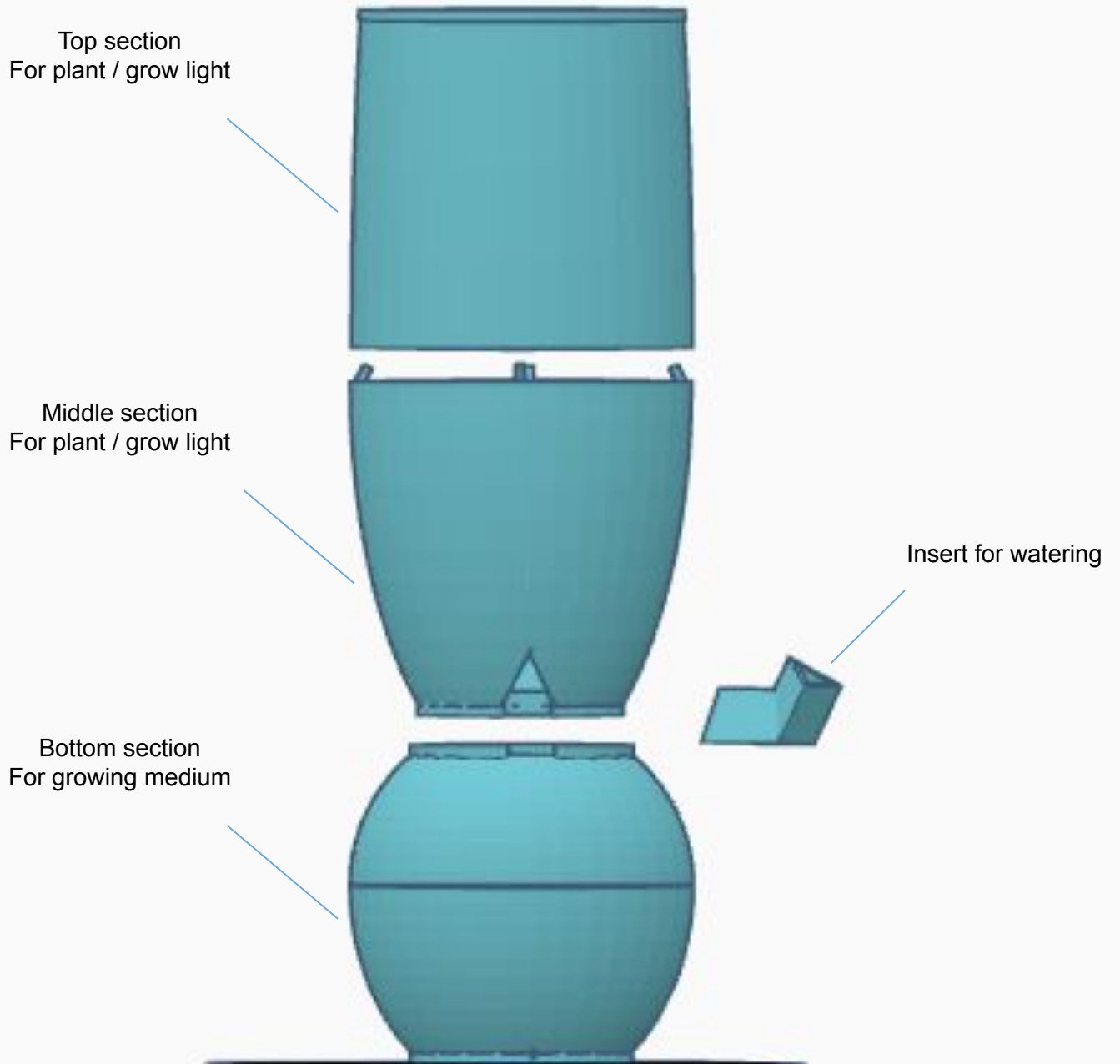
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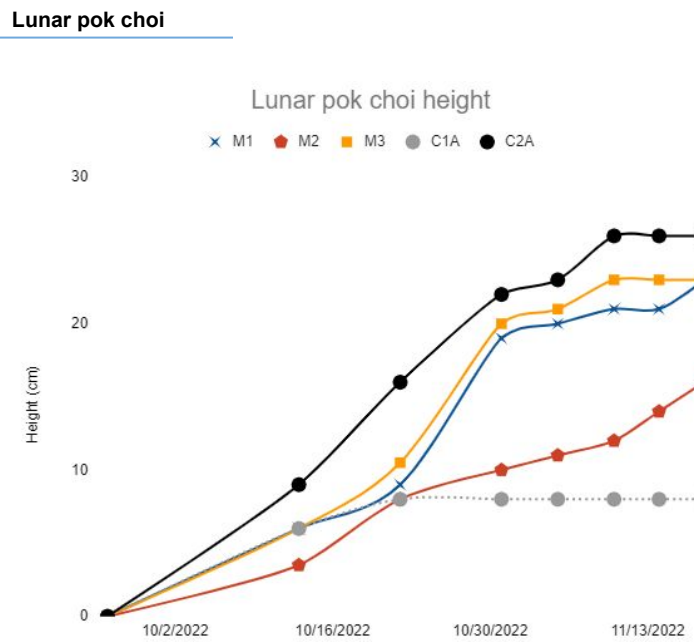
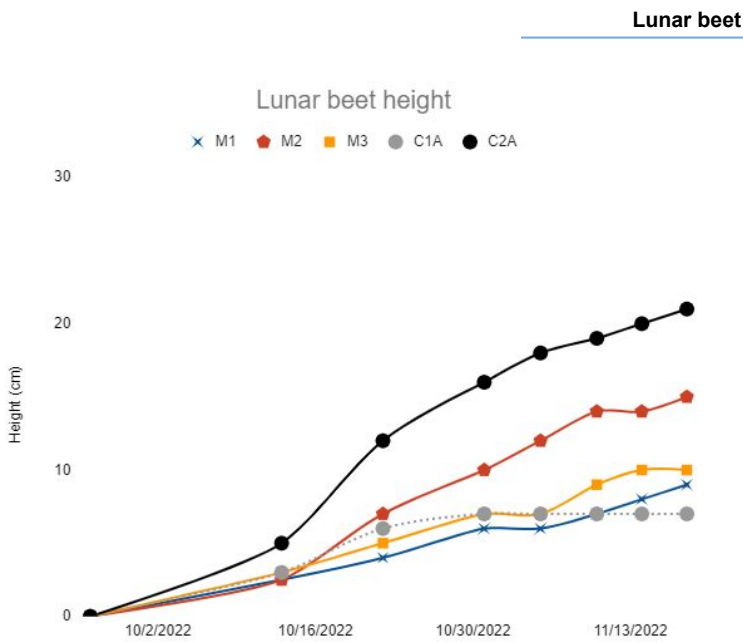
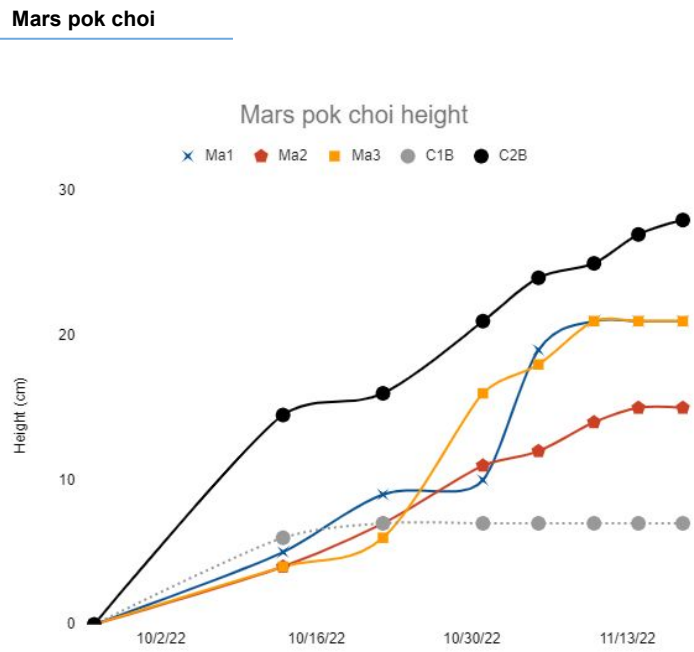
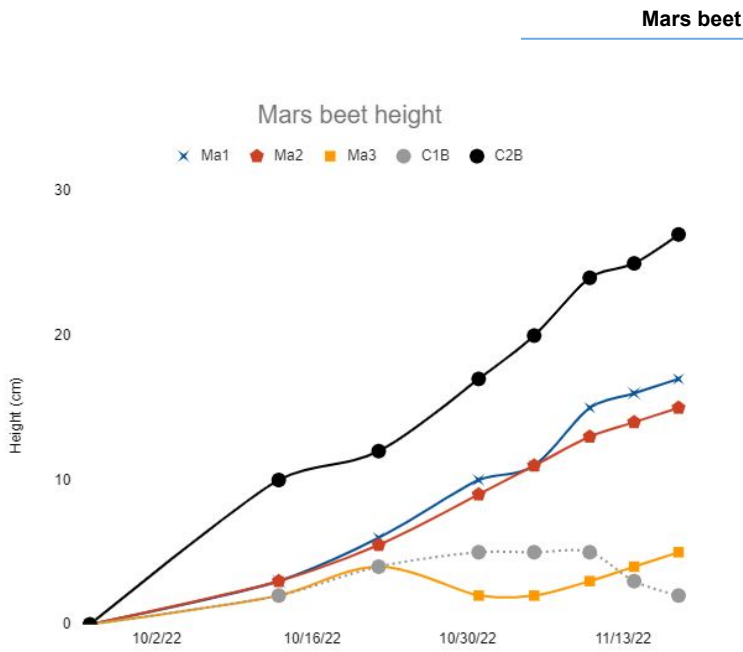
Foxfarm Microbrew & Grow
Big Liquid Fertilizers

		Plant#				
Pot breakdown		C1B	C2B	Ma1	Ma2	Ma3
Initial watering		20 ml water	20 ml water	10 ml microbrew 10 ml growbig	10 ml microbrew 10 ml growbig	10 ml microbrew 10 ml growbig
Top	Layer 5	n/a	n/a	20g lava rock	n/a	n/a
	Layer 4	50g mars soil/ 50g lava rock	n/a	400g mars soil	200g mars soil/ 200g lava rock	300g mars soil/ 100g lava rock
	Layer 3	400g mars soil	100g potting soil	9g dried leaf matter / 4g myco / 5 worms	9g dried leaf matter / 4g myco / 5 worms	9g dried leaf matter / 4g myco / 5 worms
	Layer 2	200g mars soil/ 200g lava rock	50g potting soil/ 200g lava rock	200g mars soil/ 200g lava rock	200g mars soil/ 200g lava rock	200g mars soil/ 200g lava rock
Bottom	Layer 1	200g lava rock	200g lava rock	200g lava rock	200g lava rock	200g lava rock
Total regolith						
Soil (Mars or potting)		650g	150g	600g	400g	500g
Lava		450g	400g	420g	600g	500g
Ratio		1.4	0.4	1.4	0.7	1.0

Stackable grow pot



Growth charts



Final Moon plants

C1A

Control-regolith
1.3 Regolith/rock ratio



Plant mass: <1g

M1

1.3 Regolith/rock ratio



Plant mass: 11g

M3

1.0 Regolith/rock ratio



Plant mass: 14g

M2

.8 Regolith/rock ratio



Plant mass: 15g

C2A

Control-potting soil
.4 Soil/rock ratio



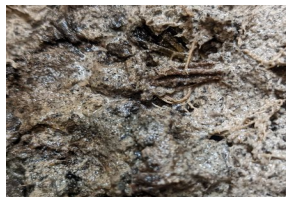
Plant mass: 58g



Soil



Soil



Soil



Soil



Soil



Lava Rock



Lava Rock



Lava Rock



Lava Rock



Lava Rock



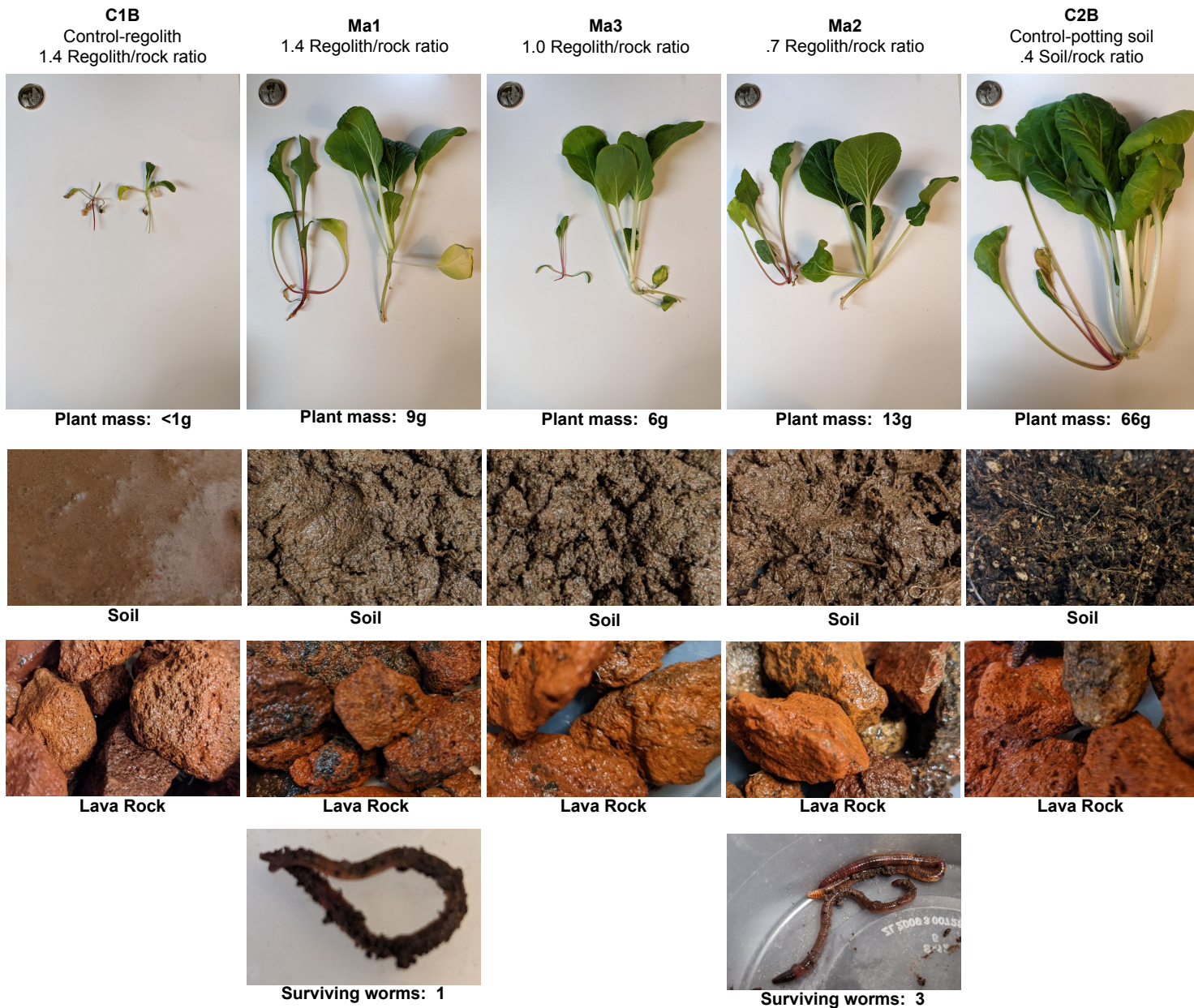
Surviving worms: 1

Plant weight and yield per Earth derived gram of materials

Plant	Earth sourced		Eventual In-Situ sourced				In-Situ sourced		Weight cost		Final plants weight			Plant yield for each Earth derived gram
	Liquid fertilizer	Potting soil	Seeds	Mycorrhizal fungi	Dried organic matter	Worms	Regolith	Lava rock	In-situ	Earth sourced	Pok choi	Beet	Total	Plant weight yield per gram of Earth sourced
C2A	0g	200g	0.1g	0g	0g	0g	0g	450g	450.1g	200.0g	55g	3g	58g	0.29g
C1A	0g	0g	0.1g	0g	0g	0g	800g	600g	1400.1g	0.0g	<1g	<1g	0g	N/A
M1	0.7g	0g	0.1g	4g	9g	0.5g	800g	600g	1413.6g	0.7g	11g	<1g	11g	15.67g
M3	0.7g	0g	0.1g	4g	9g	0.5g	600g	600g	1213.6g	0.7g	14g	<1g	14g	19.95g
M2	0.7g	0g	0.1g	4g	9g	0.5g	600g	800g	1413.6g	0.7g	12g	3g	15g	21.37g



Final Mars plants



Plant weight and yield per Earth derived gram of materials

Plant	Earth sourced		Eventual In-Situ sourced				In-Situ sourced		Weight cost		Final plants weight			Plant yield for each Earth derived gram
	Liquid fertilizer	Potting soil	Seeds	Mycorrhizal fungi	Dried organic matter	Worms	Regolith	Lava rock	In-situ	Earth sourced	Pok choi	Beet	Total	Plant weight yield per gram of Earth sourced
C2B	0g	150g	0.1g	0g	0g	0g	0g	400g	400.1g	150.0g	62g	4g	66g	0.44g
C1B	0g	0g	0.1g	0g	0g	0g	650g	450g	1100.1g	0.0g	<1g	<1g	0g	N/A
Ma1	0.7g	0g	0.1g	4g	9g	0.5g	600g	420g	1033.6g	0.7g	7g	2g	9g	12.82g
Ma3	0.7g	0g	0.1g	4g	9g	0.5g	500g	500g	1013.6g	0.7g	6g	<1g	6g	8.55g
Ma2	0.7g	0g	0.1g	4g	9g	0.5g	400g	600g	1013.6g	0.7g	10g	3g	13g	18.52g



Discussion

Findings

This study demonstrated that plants had stunted growth in simulated regolith and lava rock without any soil amendments. The study also demonstrated that both the simulated regolith to lava rock ratio and use of soil amendments has an impact on plant growth, a limited amount of worms were able to survive in both the Martian and Lunar simulated regolith, and the regolith appears to be on a path to developing into something more similar to fertile soil under the right conditions. More detailed findings covering the 'what we are testing' section are outlined below. Also refer to final Moon plants (page 14), final Mars plants (page 15), and Moon and Mars growth charts (page 13) for visual details of the findings.

Plants grew in simulated regolith and lava rock without any soil amendments, however the plant growth was stunted. The Mars beet was almost entirely wilted when the study ended. The beets grew to a maximum height of 7 cm while the pok choi reached a maximum height of 8 cm. The control pot's plants had a combined weight of less than 1 gram when the study concluded.

Adding the soil amendments positively impacted Lunar and Mars plant growth when compared to the regolith controls. The test pots' pok choi and beet had a combined weight ranging from 6 g to 15 g at experiment end, which is greater than the regolith control pots' weights of less than 1 g.

The soil amendments also impacted regolith development. The regolith control pots' soil at experiment end appeared almost unchanged, as both the Martian and Lunar soils were extremely dense with little organic matter. The test pots' soil had more organic matter, and was less dense, when compared to the regolith control pots. This may have been due to more plant roots in the soil, however the organic materials mixed in at experiment start were found fully decomposed in 4 of the 6 test pots at experiment end.

The simulated regolith to lava rock ratios appears to impact plant growth. The Lunar plant with the highest amount of lava rock had the greatest mass of the Lunar test pots, while the Lunar plant with the highest amount of regolith had the lowest mass of the test pots. The Mars plant with the highest amount of lava rock also had the greatest mass of the Mars test pots. Mars test pot Ma3 had the lowest mass of the Mars test pot group but did not have the highest amount of regolith. The watermelon leaves and vine that was used as organic matter for pot Ma3 was not dried and had to be freshly harvested at the time of pot set up. This may have impacted the soil, as the soil had a foul smell for the first several weeks of the study and plant growth was hindered up until the final weeks of the study.

The survival rate of worms in the test pots was low. The lunar test pots had one surviving worm, while the Martian test pots had a total of four surviving worms. The Lunar pots were set up earlier than the Mars pots. The lunar worm was in the pot for 69 days, while the 3 Mars' worms were in the pots for 57 days. Each group started with 15 worms, or 5 worms per test pot. Even considering the low survival rate, this shows that worms still have a chance of survival in simulated regolith and lava rock. More research is needed considering limitations of this study. The soil was hand sifted to find surviving worms and better methods should be utilized in future studies to ensure all worms are counted. There could also be other factors at play besides the simulated regolith that are contributing to the low survival rate. Perhaps there was not enough organic matter introduced into the pots to sustain all the worms. For the lunar pots, the two pots with higher amounts of regolith had watermelon vine and leaves that were not fully decomposed and these pots also did not have any worms at experiment end. It is possible

that the higher amount of regolith, and resulting higher soil density, had a negative impact on the worms' survivability and also limited decomposition of the watermelon vine and leaves.

The control pots with potting soil and lava rock had the greatest plant mass in this study. The plant mass of both control pots was approximately four times as much as the highest weighted test pots. However, logistical metrics beyond total plant mass should be considered. At the onset, resources like potting soil and liquid fertilizer will probably need to be continuously brought from Earth. Looking from another perspective, all test pots outperformed the controls in terms of plant mass generated per gram of Earth derived materials. The contrast is stark as the test pot plant yield per gram of Earth material ranges from 9 g to 21 g, while the potting soil control pots yielded 0.29 g and 0.44 g per gram of Earth material (see 'plant weight and yield per Earth derived gram of materials' section on pages 14 and 15). The potting soil would have to be reused multiple times in order to compare to the test pot's yield per Earth derived gram of materials.

Conclusion

Based on this study, plants will be able to grow in both Lunar and Martian regolith with lava rock and soil amendments, including liquid fertilizer. The regolith can also be started on a path of transforming into a form that resembles fertile Earth soil. Furthermore, worms can likely survive in the regolith provided the right conditions. This is important as worms play an essential role in the nitrogen cycle and soil health. From a logistical perspective, higher yield per Earth derived gram of material can be achieved using liquid fertilizer mixed with in-situ regolith and lava rock rather than potting soil mixed with lava rock. Optimizing the ratio of regolith to lava rock and increasing sample size numbers in future studies could solidify findings from the current study.

Limitations

- Plants on Mars and the Moon will be exposed to factors we cannot easily replicate on Earth (ie; less gravity, more and different types of radiation, etc).
- Lunar and Martian regolith simulants may not fully replicate the regolith we will encounter on the Moon and Mars.
- Vesicular basalt on the Moon and Mars may not be present in a form similar to that used in this study.
- There may be differences between the water used in this study and water that is available on Mars and the Moon.
- Sample size is low in this exploratory study, and a larger study with greater sample size is needed.

Future questions and ideas

- Evaluate methods to speed volcanic ash and rock's transformation into a form that can be easily utilized by plants and consider how those methods may be impacted by lower gravity.
- Further assess the optimum regolith to lava rock ratio for plant growth. Lower and/or different ratios should be tested.

- In terms of regolith development, a highly subjective visual approach was used to measure changes in soil. More robust measurement methods are needed to understand soil development over a single and multiple growth periods.
- Evaluate how to improve worm survivability and improve study methodology.
- Lava tubes could provide a place to grow off-Earth, possibly even using regolith placed directly on the tube's floor, with artificial lighting. Assess methods to seal off Earth lava tubes. Also evaluate gas and water permeability along with maintenance of desired temperature and pressure.
- Research ideal canoe plants (bamboo, noni, nitrogen fixing starter plants, etc). Plants may be utilized for more than solely food, and other possible uses should be considered (ie; for building materials, medicinal, regolith development, soil health, etc).

Work Cited

Bailey, Josh, et al. *Effects of Aeration on Soybean Plant Growth in Lunar and Martian Regolith*.

2022. *Plant the moon*,

<https://plantthemoon.com/wp-content/uploads/2022/05/Purdue-Interplanetary-and-Space-Agriculture.pdf>.

ESA. "ESA - The toxic side of the Moon." *European Space Agency*,

https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/The_toxic_side_of_the_Moon. Accessed 14 October 2022.

Fisher, Richard V., et al. *Volcanoes: Crucibles of Change*. Princeton University Press, 1998.

Karras, Christy. "Take a wildflower hike through the volcanic St. Helens landscape." *The Seattle Times*, 26 July 2017,

Times, 26 July 2017,

<https://www.seattletimes.com/life/travel/take-a-wildflower-hike-among-the-volcanic-st-helens-landscape/>. Accessed 14 October 2022.

Liu, Xin, and Kathrin Rousk. "The moss traits that rule cyanobacterial colonization." *Annals of Botany*, vol. 129, no. 2, 2022, pp. 147–160. *Journal of Ecology*,

Journal of Ecology, vol. 129, no. 2, 2022, pp. 147–160.

<https://doi.org/10.1093/aob/mcab127>.

NASA. "Is There an Atmosphere on the Moon?" *NASA*, 12 April 2013, https://www.nasa.gov/mission_pages/LADEE/news/lunar-atmosphere.html. Accessed 24 October 2022.

NASA. "Scientists Grow Plants in Lunar Soil." *NASA*, 12 May 2022, <https://www.nasa.gov/feature/biological-physical/scientists-grow-plants-in-soil-from-the-moon>. Accessed 14 October 2022.

Nordstrom, Ulrica. *Moss: From Forest to Garden: A Guide to the Hidden World of Moss*. WW Norton, 2019.

Omeka-Wellesley College. *The Founding and History of Pompeii until 79 AD*, <http://omeka.wellesley.edu/piranesi-rome/exhibits/show/discovery-of-pompeii-and-hercufounding-pompeii>. Accessed 14 October 2022.

Paul, Anna-Lisa, et al. "Plants grown in Apollo lunar regolith present stress-associated transcriptomes that inform prospects for lunar exploration." *Communications Biology*, vol. 5, no. 382 (2022), 2022. *Communications Biology*, <https://www.nature.com/articles/s42003-022-03334-8>.

Team Rainbird. "Plant the Moon with Team Rainbird! EP 4." *YouTube*, 13 March 2021, <https://www.youtube.com/watch?v=Rk7FFNINix0>. Accessed 15 October 2022.

University of California. "UCSB Science Line." *UCSB Science Line*, 21 March 2017, <http://scienceline.ucsb.edu/getkey.php?key=5796>. Accessed 1 November 2022.

University of Hawaii. "The Noni Website - Natural Habitats." *CTAHR*, 7 December 2006, https://www.ctahr.hawaii.edu/noni/natural_habitats.asp. Accessed 14 October 2022.

University of Hawai'i at Mānoa. "Weird Science: Hydrothermal Vents and Cold Seeps." *University of Hawaii at Manoa*, <https://manoa.hawaii.edu/exploringourfluidearth/biological/aquatic-plants-and-algae/energy-acquisition/weird-science-hydrothermal-vents-and-cold-seeps>. Accessed 24 October 2022.

Wamelink, Gerrit Willem Wieger, et al. "Growth of Rucola on Mars soil simulant under the influence of pig slurry and earthworms." *Open Agriculture*, vol. 7, no. 1, 2022, pp. 238-248. <https://journals.plos.org/>, <https://doi.org/10.1515/opag-2022-0079>.

Wamelink, GWW, et al. "Can Plants Grow on Mars and the Moon: A Growth Experiment on Mars and Moon Soil Simulants." *PLoS ONE*, vol. 9, no. (8), 2014, pp. 1-9. <https://journals.plos.org/>, <https://doi.org/10.1371/journal.pone.0103138>.

Moon timeline

C1A
1.3

M1
1.3

M3
1.0

M2
.8

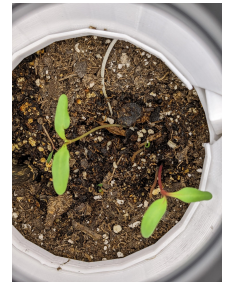
C2A
.4

9/26



9/26

10/4



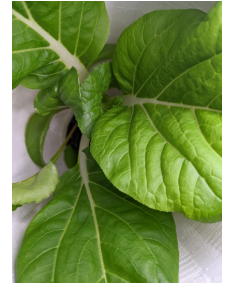
10/4

10/15



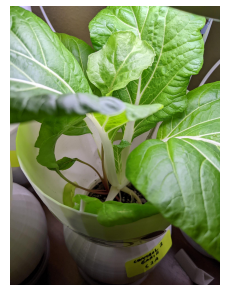
10/15

10/31



10/31

11/10



11/10

Mars timeline

	C1B 1.4	Ma1 1.4	Ma3 1.0	Ma2 .7	C2B .4	
9/26						9/26
10/4						10/4
10/15						10/15
10/31						10/31
11/10						11/10

Moon observations / water and fert schedule					
Plant	Date	Measure	Feed	Type	Grow light
C1A	9/10/2022	20 mL	Water		Pot set up
C2A	9/10/2022	20 mL	Water		Pot set up
M1	9/10/2022	20 mL	Microbrew Water Dilution/GrowBig Water Dilution		Pot set up
M2	9/10/2022	20 mL	Microbrew Water Dilution/GrowBig Water Dilution		Pot set up
M3	9/10/2022	20 mL	Microbrew Water Dilution/GrowBig Water Dilution		Pot set up
C1A	9/11/2022	20 mL	Water	Start max bright / 8 hr day	
C2A	9/11/2022	20 mL	Water	Start max bright / 8 hr day	
M1	9/11/2022	20 mL	Water	Start max bright / 8 hr day	
M2	9/11/2022	20 mL	Water	Start max bright / 8 hr day	
M3	9/11/2022	20 mL	Water	Start max bright / 8 hr day	
C1A	9/12/2022	20 mL	Water		
C2A	9/12/2022	20 mL	Water		
M1	9/12/2022	20 mL	Water		
M2	9/12/2022	20 mL	Water		
M3	9/12/2022	20 mL	Water		
C1A	9/13/2022	20 mL	Water		
C2A	9/13/2022	20 mL	Water		
M1	9/13/2022	20 mL	Water		
M2	9/13/2022	20 mL	Water		
M3	9/13/2022	20 mL	Water		
C1A	9/14/2022	20 mL	Water		No smell
C2A	9/14/2022	20 mL	Water		Earthy smell
M1	9/14/2022	20 mL	Water		Earthy smell
M2	9/14/2022	20 mL	Water		Earthy smell
M3	9/14/2022	20 mL	Water		Earthy smell
C1A	9/15/2022	20 mL	Water		
C2A	9/15/2022	20 mL	Water		
M1	9/15/2022	20 mL	Water		
M2	9/15/2022	20 mL	Water		
M3	9/15/2022	20 mL	Water		
C1A	9/16/2022	20 mL	Water		
C2A	9/16/2022	20 mL	Water		
M1	9/16/2022	20 mL	Water		
M2	9/16/2022	20 mL	Water		
M3	9/16/2022	20 mL	Water		
C1A	9/17/2022	20 mL	Water		
C2A	9/17/2022	20 mL	Water		
M1	9/17/2022	20 mL	Water		
M2	9/17/2022	20 mL	Water		
M3	9/17/2022	20 mL	Water		
C1A	9/18/2022	20 mL	Water		
C2A	9/18/2022	20 mL	Water		
M1	9/18/2022	20 mL	Water		
M2	9/18/2022	20 mL	Water		
M3	9/18/2022	20 mL	Water		
C1A	9/19/2022	20 mL	Water		
C2A	9/19/2022	20 mL	Water		
M1	9/19/2022	20 mL	Water		
M2	9/19/2022	20 mL	Water		
M3	9/19/2022	20 mL	Water		
C1A	9/20/2022	20 mL	Water		
C2A	9/20/2022	20 mL	Water		
M1	9/20/2022	20 mL	Water		
M2	9/20/2022	20 mL	Water		
M3	9/20/2022	20 mL	Water		
C1A	9/21/2022	20 mL	Water		
C2A	9/21/2022	20 mL	Water		
M1	9/21/2022	20 mL	Water		
M2	9/21/2022	20 mL	Water		
M3	9/21/2022	20 mL	Water		
C1A	9/22/2022	20 mL	Water		
C2A	9/22/2022	20 mL	Water		
M1	9/22/2022	20 mL	Water		
M2	9/22/2022	20 mL	Water		
M3	9/22/2022	20 mL	Water		
C1A	9/23/2022	20 mL	Water	Start max bright / 12 hr day	

Moon observations / water and fert schedule						
Plant	Date	Measure	Feed	Feed Type	Grow light	Comment
C2A	9/23/2022	20 mL		Water	Start max bright / 12 hr day	
M1	9/23/2022	20 mL		Water	Start max bright / 12 hr day	
M2	9/23/2022	20 mL		Water	Start max bright / 12 hr day	
M3	9/23/2022	20 mL		Water	Start max bright / 12 hr day	
C1A	9/24/2022	20 mL		Water		
C2A	9/24/2022					break on water, is starting to pool below pot
M1	9/24/2022	20 mL		Water		
M2	9/24/2022	20 mL		Water		
M3	9/24/2022	20 mL		Water		
C1A	9/25/2022	20 mL		Water		soak seeds
C2A	9/25/2022	20 mL		Water		soak seeds
M1	9/25/2022	20 mL		Water		soak seeds
M2	9/25/2022	20 mL		Water		soak seeds
M3	9/25/2022	20 mL		Water		soak seeds
C1A	9/26/2022	20 mL		Water		Plant seeds; Found 5 dried worms under moon/mars pots
C2A	9/26/2022	20 mL		Water		Plant seeds; Found 5 dried worms under moon/mars pots
M1	9/26/2022	20 mL		Water		Plant seeds; Found 5 dried worms under moon/mars pots
M2	9/26/2022	20 mL		Water		Plant seeds; Found 5 dried worms under moon/mars pots
M3	9/26/2022	20 mL		Water		Plant seeds; Found 5 dried worms under moon/mars pots
C1A	9/27/2022	20 mL		Water		
C2A	9/27/2022	20 mL		Water		
M1	9/27/2022	20 mL		Water		
M2	9/27/2022	20 mL		Water		
M3	9/27/2022	20 mL		Water		
C1A	9/28/2022	20 mL		Water		
C2A	9/28/2022	20 mL		Water		
M1	9/28/2022	20 mL		Water		
M2	9/28/2022	20 mL		Water		
M3	9/28/2022	20 mL		Water		
C1A	9/29/2022	20 mL		Water		
C2A	9/29/2022	20 mL		Water		
M1	9/29/2022	20 mL		Water		
M2	9/29/2022	20 mL		Water		
M3	9/29/2022	20 mL		Water		
C1A	9/30/2022	20 mL		Water		
C2A	9/30/2022	20 mL		Water		
M1	9/30/2022	20 mL		Water		
M2	9/30/2022	20 mL		Water		
M3	9/30/2022	20 mL		Water		
C1A	10/1/2022	20 mL		Water		Only 1 seed germ'd (bok choy) so far; added more presoaked seeds (3 bok choy, 3 beet)
C2A	10/1/2022	20 mL		Water		1 bok choy germ'd so far; 5 beet germ'd so far; thinned out 3 beet (looks like a few extra beet seed made it in on planting)
M1	10/1/2022	20 mL		Water		2 bok choy germ'd so far; 3 beet germ'd so far; thinned out 1 beet
M2	10/1/2022	20 mL		Water		2 bok choy germ'd so far; 2 beet germ'd so far
M3	10/1/2022	20 mL		Water		Only 1 seed germ'd (bok choy) so far; added more presoaked seeds (3 bok choy, 3 beet)
C1A	10/2/2022	20 mL		Water		
C2A	10/2/2022	20 mL		Water		
M1	10/2/2022	20 mL		Water		
M2	10/2/2022	20 mL		Water		
M3	10/2/2022	20 mL		Water		
C1A	10/3/2022	20 mL		Water		
C2A	10/3/2022	20 mL		Water		
M1	10/3/2022	20 mL		Water		
M2	10/3/2022	20 mL		Water		
M3	10/3/2022	20 mL		Water		
C1A	10/4/2022	20 mL		Water		
C2A	10/4/2022	20 mL		Water		
M1	10/4/2022	20 mL		Water		
M2	10/4/2022	20 mL		Water		
M3	10/4/2022	20 mL		Water		
C1A	10/5/2022	20 mL		Water		Thinned out 3 bok choy
C2A	10/5/2022	20 mL		Water		
M1	10/5/2022	20 mL		Water		
M2	10/5/2022	20 mL		Water		Thinned out 2 beet
M3	10/5/2022	20 mL		Water		
C1A	10/6/2022	20 mL		Water		
C2A	10/6/2022	20 mL		Water		

Moon observations / water and fert schedule					
Plant	Date	Measure	Feed	Type	Grow light
M1	10/6/2022	20 mL	Water		
M2	10/6/2022	20 mL	Water		
M3	10/6/2022	20 mL	Water		
C1A	10/7/2022	0 mL			
C2A	10/7/2022	0 mL			
M1	10/7/2022	0 mL			
M2	10/7/2022	0 mL			
M3	10/7/2022	0 mL			
C1A	10/8/2022	20 mL	Water		
C2A	10/8/2022	20 mL	Water		
M1	10/8/2022	20 mL	GrowBig Water Dilution		
M2	10/8/2022	20 mL	GrowBig Water Dilution		
M3	10/8/2022	20 mL	GrowBig Water Dilution		
C1A	10/9/2022	20 mL	Water		
C2A	10/9/2022	20 mL	Water		
M1	10/9/2022	20 mL	Water		
M2	10/9/2022	20 mL	Water		
M3	10/9/2022	20 mL	Water		
C1A	10/10/2022	20 mL	Water		
C2A	10/10/2022	20 mL	Water		
M1	10/10/2022	20 mL	Microbrew Water Dilution		
M2	10/10/2022	20 mL	Microbrew Water Dilution		
M3	10/10/2022	20 mL	Microbrew Water Dilution		
C1A	10/11/2022	20 mL	Water		
C2A	10/11/2022	20 mL	Water		
M1	10/11/2022	20 mL	Water		
M2	10/11/2022	20 mL	Water		
M3	10/11/2022	20 mL	Water		
C1A	10/12/2022	10 mL	Water		
C2A	10/12/2022	10 mL	Water		
M1	10/12/2022	10 mL	Water		
M2	10/12/2022	10 mL	Water		
M3	10/12/2022	10 mL	Water		
C1A	10/13/2022	20 mL	Water		
C2A	10/13/2022	20 mL	Water		
M1	10/13/2022	20 mL	GrowBig Water Dilution		
M2	10/13/2022	20 mL	GrowBig Water Dilution		
M3	10/13/2022	20 mL	GrowBig Water Dilution		
C1A	10/14/2022	20 mL	Water		
C2A	10/14/2022	20 mL	Water		
M1	10/14/2022	20 mL	Microbrew Water Dilution		
M2	10/14/2022	20 mL	Microbrew Water Dilution		
M3	10/14/2022	20 mL	Microbrew Water Dilution		
C1A	10/15/2022	10 mL	Water		
C2A	10/15/2022	10 mL	Water		
M1	10/15/2022	10 mL	Water		
M2	10/15/2022	10 mL	Water		
M3	10/15/2022	10 mL	Water		
C1A	10/16/2022	20 mL	Water		
C2A	10/16/2022	20 mL	Water		
M1	10/16/2022	20 mL	GrowBig Water Dilution		
M2	10/16/2022	20 mL	GrowBig Water Dilution		
M3	10/16/2022	20 mL	GrowBig Water Dilution		
C1A	10/17/2022	20 mL	Water		
C2A	10/17/2022	20 mL	Water		
M1	10/17/2022	20 mL	Water		
M2	10/17/2022	20 mL	Water		
M3	10/17/2022	20 mL	Water		
C1A	10/18/2022	20 mL	Water		
C2A	10/18/2022	20 mL	Water		
M1	10/18/2022	20 mL	Microbrew Water Dilution		
M2	10/18/2022	20 mL	Microbrew Water Dilution		
M3	10/18/2022	20 mL	Microbrew Water Dilution		
C1A	10/19/2022	10 mL	Water		
C2A	10/19/2022	10 mL	Water		
M1	10/19/2022	10 mL	Water		
M2	10/19/2022	10 mL	Water		
M3	10/19/2022	10 mL	Water		

Moon observations / water and fert schedule					
Plant	Date	Measure	Feed	Type	Grow light
C1A	10/20/2022	20 mL	Water		
C2A	10/20/2022	20 mL	Water		
M1	10/20/2022	20 mL	GrowBig	Water Dilution	
M2	10/20/2022	20 mL	GrowBig	Water Dilution	
M3	10/20/2022	20 mL	GrowBig	Water Dilution	
C1A	10/21/2022	20 mL	Water		
C2A	10/21/2022	20 mL	Water		
M1	10/21/2022	20 mL	Microbrew	Water Dilution	
M2	10/21/2022	20 mL	Microbrew	Water Dilution	
M3	10/21/2022	20 mL	Microbrew	Water Dilution	
C1A	10/22/2022	20 mL	Water		
C2A	10/22/2022	20 mL	Water		
M1	10/22/2022	20 mL	Water		
M2	10/22/2022	20 mL	Water		
M3	10/22/2022	20 mL	Water		
C1A	10/23/2022	20 mL	Water		
C2A	10/23/2022	30 mL	Water		
M1	10/23/2022	20 mL	Water		
M2	10/23/2022	20 mL	Water		
M3	10/23/2022	20 mL	Water		
C1A	10/24/2022	20 mL	Water		
C2A	10/24/2022	30 mL	Water		
M1	10/24/2022	20 mL	Water		
M2	10/24/2022	20 mL	Water		
M3	10/24/2022	20 mL	Water		
C1A	10/25/2022	20 mL	Water		
C2A	10/25/2022	30 mL	Water		
M1	10/25/2022	20 mL	GrowBig	Water Dilution	
M2	10/25/2022	20 mL	GrowBig	Water Dilution	
M3	10/25/2022	20 mL	GrowBig	Water Dilution	
C1A	10/26/2022	20 mL	Water		
C2A	10/26/2022	30 mL	Water		
M1	10/26/2022	20 mL	Water		
M2	10/26/2022	20 mL	Water		
M3	10/26/2022	20 mL	Water		
C1A	10/27/2022	20 mL	Water		
C2A	10/27/2022	30 mL	Water		Took 'hat' (top section of grow pot) off
M1	10/27/2022	20 mL	GrowBig	Water Dilution	
M2	10/27/2022	20 mL	GrowBig	Water Dilution	
M3	10/27/2022	20 mL	GrowBig	Water Dilution	
C1A	10/28/2022	20 mL	Water		
C2A	10/28/2022	30 mL	Water		
M1	10/28/2022	20 mL	Water		
M2	10/28/2022	20 mL	Water		
M3	10/28/2022	20 mL	Water		
C1A	10/29/2022	20 mL	Water		
C2A	10/29/2022	30 mL	Water		
M1	10/29/2022	20 mL	GrowBig	Water Dilution	
M2	10/29/2022	20 mL	GrowBig	Water Dilution	
M3	10/29/2022	20 mL	GrowBig	Water Dilution	
C1A	10/30/2022	20 mL	Water		
C2A	10/30/2022	20 mL	Water		
M1	10/30/2022	20 mL	Microbrew	Water Dilution	
M2	10/30/2022	20 mL	Microbrew	Water Dilution	
M3	10/30/2022	20 mL	Microbrew	Water Dilution	
C1A	10/31/2022	20 mL	Water		
C2A	10/31/2022	30 mL	Water		
M1	10/31/2022	20 mL	Water		
M2	10/31/2022	20 mL	Water		
M3	10/31/2022	20 mL	Water		
C1A	11/1/2022	20 mL	Water		
C2A	11/1/2022	30 mL	Water		
M1	11/1/2022	20 mL	Water		
M2	11/1/2022	20 mL	Water		
M3	11/1/2022	20 mL	Water		
C1A	11/2/2022	20 mL	Water		
C2A	11/2/2022	30 mL	Water		
M1	11/2/2022	20 mL	GrowBig	Water Dilution	

Moon observations / water and fert schedule					
Plant	Date	Measure Feed	Feed Type	Grow light	Comment
M2	11/2/2022	20 mL	GrowBig Water Dilution		
M3	11/2/2022	20 mL	GrowBig Water Dilution		
C1A	11/3/2022	20 mL	Water		
C2A	11/3/2022	40 mL	Water		
M1	11/3/2022	20 mL	Microbrew Water Dilution		Took 'hat' (top section of grow pot) off
M2	11/3/2022	20 mL	Microbrew Water Dilution		
M3	11/3/2022	20 mL	Microbrew Water Dilution		Took 'hat' (top section of grow pot) off
C1A	11/4/2022	20 mL	Water		
C2A	11/4/2022	40 mL	Water		
M1	11/4/2022	30 mL	Water		
M2	11/4/2022	20 mL	Water		
M3	11/4/2022	30 mL	Water		
C1A	11/5/2022	20 mL	Water		
C2A	11/5/2022	45 mL	Water		
M1	11/5/2022	30 mL	Water		
M2	11/5/2022	20 mL	Water		
M3	11/5/2022	30 mL	Water		
C1A	11/6/2022	20 mL	Water		
C2A	11/6/2022	45 mL	Water		
M1	11/6/2022	20 mL	GrowBig Water Dilution		
M2	11/6/2022	20 mL	GrowBig Water Dilution		
M3	11/6/2022	20 mL	GrowBig Water Dilution		
C1A	11/7/2022	20 mL	Water		
C2A	11/7/2022	45 mL	Water		
M1	11/7/2022	30 mL	Water		
M2	11/7/2022	20 mL	Water		
M3	11/7/2022	30 mL	Water		
C1A	11/8/2022	20 mL	Water		
C2A	11/8/2022	45 mL	Water		
M1	11/8/2022	30 mL	Water		
M2	11/8/2022	20 mL	Water		
M3	11/8/2022	30 mL	Water		
C1A	11/9/2022	20 mL	Water		
C2A	11/9/2022	45 mL	Water		
M1	11/9/2022	20 mL	GrowBig Water Dilution		
M2	11/9/2022	20 mL	GrowBig Water Dilution		Took 'hat' (top section of grow pot) off
M3	11/9/2022	20 mL	GrowBig Water Dilution		
C1A	11/10/2022	20 mL	Water		
C2A	11/10/2022	45 mL	Water		
M1	11/10/2022	30 mL	Water		
M2	11/10/2022	20 mL	Water		
M3	11/10/2022	30 mL	Water		
C1A	11/11/2022	20 mL	Water		
C2A	11/11/2022	45 mL	Water		
M1	11/11/2022	30 mL	Water		
M2	11/11/2022	20 mL	Water		
M3	11/11/2022	30 mL	Water		
C1A	11/12/2022	20 mL	Water		
C2A	11/12/2022	45 mL	Water		
M1	11/12/2022	20 mL	GrowBig Water Dilution		
M2	11/12/2022	20 mL	GrowBig Water Dilution		
M3	11/12/2022	20 mL	GrowBig Water Dilution		
C1A	11/13/2022	20 mL	Water		
C2A	11/13/2022	45 mL	Water		
M1	11/13/2022	20 mL	Microbrew Water Dilution		
M2	11/13/2022	20 mL	Microbrew Water Dilution		
M3	11/13/2022	20 mL	Microbrew Water Dilution		
C1A	11/14/2022	20 mL	Water		
C2A	11/14/2022	45 mL	Water		
M1	11/14/2022	30 mL	Water		
M2	11/14/2022	30 mL	Water		
M3	11/14/2022	30 mL	Water		
C1A	11/15/2022	20 mL	Water		
C2A	11/15/2022	45 mL	Water		
M1	11/15/2022	35 mL	Water		
M2	11/15/2022	35 mL	Water		
M3	11/15/2022	35 mL	Water		
C1A	11/16/2022	20 mL	Water		

Moon observations / water and fert schedule					
Plant	Date	Measure Feed	Feed Type	Grow light	Comment
C2A	11/16/2022	45 mL	Water		
M1	11/16/2022	35 mL	Water		
M2	11/16/2022	35 mL	Water		
M3	11/16/2022	35 mL	Water		
C1A	11/17/2022	20 mL	Water		
C2A	11/17/2022	45 mL	Water		
M1	11/17/2022	35 mL	Water		
M2	11/17/2022	35 mL	Water		
M3	11/17/2022	35 mL	Water		
C1A	11/18/2022	0 mL		Lights off / pot take down	Very dense soil
C2A	11/18/2022	0 mL		Lights off / pot take down	
M1	11/18/2022	0 mL		Lights off / pot take down	Watermelon vine still appears to be in soil, from when pot was set up
M2	11/18/2022	0 mL		Lights off / pot take down	Watermelon vine not visible in soil; found 1 worm in soil
M3	11/18/2022	0 mL		Lights off / pot take down	Watermelon vine still appears to be in soil, from when pot was set up

Mars observations / water and fert schedule					
Plant	Date	Measure	Feed	Type	Grow light
C1B	9/22/2022	20 mL	Water		
C2B	9/22/2022	20 mL	Water		
Ma1	9/22/2022	20 mL	Microbrew Water Dilution/GrowBig Water Dilution		
Ma2	9/22/2022	20 mL	Microbrew Water Dilution/GrowBig Water Dilution		
Ma3	9/22/2022	20 mL	Microbrew Water Dilution/GrowBig Water Dilution		
C1B	9/23/2022	20 mL	Water	Start max bright / 12 hr day	
C2B	9/23/2022	20 mL	Water	Start max bright / 12 hr day	
Ma1	9/23/2022	20 mL	Water	Start max bright / 12 hr day	
Ma2	9/23/2022	20 mL	Water	Start max bright / 12 hr day	
Ma3	9/23/2022	20 mL	Water	Start max bright / 12 hr day	
C1B	9/24/2022	20 mL	Water		
C2B	9/24/2022	20 mL	Water		
Ma1	9/24/2022	20 mL	Water		
Ma2	9/24/2022	20 mL	Water		
Ma3	9/24/2022	20 mL	Water		
C1B	9/25/2022	20 mL	Water		soak seeds
C2B	9/25/2022	20 mL	Water		soak seeds
Ma1	9/25/2022	20 mL	Water		soak seeds
Ma2	9/25/2022	20 mL	Water		soak seeds
Ma3	9/25/2022	20 mL	Water		soak seeds
C1B	9/26/2022	20 mL	Water		Plant seeds; Found 5 dried worms under moon/mars pots; not much earthy smell for mars pots
C2B	9/26/2022	20 mL	Water		Plant seeds; Found 5 dried worms under moon/mars pots; not much earthy smell for mars pots
Ma1	9/26/2022	20 mL	Water		Plant seeds; bit of white fungus/mold showing on top of soil; Found 5 dried worms under moon/mars pots; not much earthy smell for mars pots
Ma2	9/26/2022	20 mL	Water		Plant seeds; Found 5 dried worms under moon/mars pots; not much earthy smell for mars pots
Ma3	9/26/2022	20 mL	Water		Plant seeds; Found 5 dried worms under moon/mars pots; not much earthy smell for mars pots
C1B	9/27/2022	20 mL	Water		
C2B	9/27/2022	20 mL	Water		
Ma1	9/27/2022	20 mL	Water		
Ma2	9/27/2022	20 mL	Water		
Ma3	9/27/2022	20 mL	Water		
C1B	9/28/2022	20 mL	Water		
C2B	9/28/2022	20 mL	Water		
Ma1	9/28/2022	20 mL	Water		
Ma2	9/28/2022	20 mL	Water		
Ma3	9/28/2022	20 mL	Water		
C1B	9/29/2022	20 mL	Water		
C2B	9/29/2022	20 mL	Water		
Ma1	9/29/2022	20 mL	Water		
Ma2	9/29/2022	20 mL	Water		
Ma3	9/29/2022	20 mL	Water		
C1B	9/30/2022	20 mL	Water		
C2B	9/30/2022	20 mL	Water		
Ma1	9/30/2022	20 mL	Water		
Ma2	9/30/2022	20 mL	Water		
Ma3	9/30/2022	20 mL	Water		
C1B	10/1/2022	20 mL	Water		2 bok choi germ'd so far; 4 beet germ'd so far; thinned out 2 beet (looks like a few extra beet seed made it in on planting)
C2B	10/1/2022	20 mL	Water		2 bok choi germ'd so far; 2 beet germ'd so far
Ma1	10/1/2022	20 mL	Water		2 bok choi germ'd so far; 3 beet germ'd so far; thinned out 1 beet. Beet leaves have 'healthy' looking red
Ma2	10/1/2022	20 mL	Water		2 bok choi germ'd so far; 1 beet germ'd so far. Added 3 more presoaked beet seeds.
Ma3	10/1/2022	20 mL	Water		Only 1 seed germ'd (bok choi) so far; added more presoaked seeds (3 bok choi, 3 beet)
C1B	10/2/2022	20 mL	Water		
C2B	10/2/2022	20 mL	Water		
Ma1	10/2/2022	20 mL	Water		
Ma2	10/2/2022	20 mL	Water		
Ma3	10/2/2022	20 mL	Water		
C1B	10/3/2022	20 mL	Water		
C2B	10/3/2022	20 mL	Water		
Ma1	10/3/2022	20 mL	Water		

Mars observations / water and fert schedule					
Plant	Date	Measure Feed	Feed Type	Grow light	Comment
Ma2	10/3/2022	20 mL	Water		
Ma3	10/3/2022	20 mL	Water		
C1B	10/4/2022	20 mL	Water		
C2B	10/4/2022	20 mL	Water		
Ma1	10/4/2022	20 mL	Water		
Ma2	10/4/2022	20 mL	Water		
Ma3	10/4/2022	20 mL	Water		
C1B	10/5/2022	20 mL	Water		Thinned out 1 beet
C2B	10/5/2022	20 mL	Water		Thinned out 1 beet
Ma1	10/5/2022	20 mL	Water		
Ma2	10/5/2022	20 mL	Water		Thinned out 1 beet
Ma3	10/5/2022	20 mL	Water		
C1B	10/6/2022	20 mL	Water		
C2B	10/6/2022	20 mL	Water		
Ma1	10/6/2022	20 mL	Water		
Ma2	10/6/2022	20 mL	Water		
Ma3	10/6/2022	20 mL	Water		
C1B	10/7/2022	0 mL			Trimmed 1 bok choy; 1 bok choy left (in addition to beets); plants are doing well so far in mars regolith without amendments
C2B	10/7/2022	0 mL			Trimmed 1 bok choy; 1 bok choy left (in addition to beets)
Ma1	10/7/2022	0 mL			
Ma2	10/7/2022	0 mL			
Ma3	10/7/2022	0 mL			
C1B	10/8/2022	20 mL	Water		
C2B	10/8/2022	20 mL	Water		Trimmed 1 beet, so that 1 beet / 1 bok choy remain
Ma1	10/8/2022	20 mL	GrowBig Water Dilution		
Ma2	10/8/2022	20 mL	GrowBig Water Dilution		Trimmed multiple beet; 2 beet left (in addition to 2 bok choy)
Ma3	10/8/2022	20 mL	GrowBig Water Dilution		
C1B	10/9/2022	20 mL	Water		
C2B	10/9/2022	20 mL	Water		
Ma1	10/9/2022	20 mL	Water		
Ma2	10/9/2022	20 mL	Water		
Ma3	10/9/2022	20 mL	Water		
C1B	10/10/2022	20 mL	Water		
C2B	10/10/2022	20 mL	Water		
Ma1	10/10/2022	20 mL	Microbrew Water Dilution		
Ma2	10/10/2022	20 mL	Microbrew Water Dilution		Thinned out 1 bok choy; 2 beet 1 bok choy left
Ma3	10/10/2022	20 mL	Microbrew Water Dilution		
C1B	10/11/2022	20 mL	Water		
C2B	10/11/2022	20 mL	Water		
Ma1	10/11/2022	20 mL	Water		
Ma2	10/11/2022	20 mL	Water		
Ma3	10/11/2022	20 mL	Water		
C1B	10/12/2022	10 mL	Water		
C2B	10/12/2022	10 mL	Water		
Ma1	10/12/2022	10 mL	Water		
Ma2	10/12/2022	10 mL	Water		
Ma3	10/12/2022	10 mL	Water		
C1B	10/13/2022	20 mL	Water		Trimmed one beet; one beet one bok choy left
C2B	10/13/2022	20 mL	Water		
Ma1	10/13/2022	20 mL	GrowBig Water Dilution		Trimmed one beet; one beet one bok choy left
Ma2	10/13/2022	20 mL	GrowBig Water Dilution		Trimmed one beet; one beet one bok choy left
Ma3	10/13/2022	20 mL	GrowBig Water Dilution		
C1B	10/14/2022	20 mL	Water		
C2B	10/14/2022	20 mL	Water		
Ma1	10/14/2022	20 mL	Microbrew Water Dilution		
Ma2	10/14/2022	20 mL	Microbrew Water Dilution		
Ma3	10/14/2022	20 mL	Microbrew Water Dilution		
C1B	10/15/2022	10 mL	Water		
C2B	10/15/2022	10 mL	Water		

Mars observations / water and fert schedule						
Plant	Date	Measure	Feed	Feed Type	Grow light	Comment
Ma1	10/15/2022	10 mL		Water		
Ma2	10/15/2022	10 mL		Water		
Ma3	10/15/2022	10 mL		Water		
C1B	10/16/2022	20 mL		Water		
C2B	10/16/2022	20 mL		Water		
Ma1	10/16/2022	20 mL		GrowBig Water Dilution		GrowBig Water Dilution increased from 1 tsp / gallon to 2 tsp / gallon
Ma2	10/16/2022	20 mL		GrowBig Water Dilution		GrowBig Water Dilution increased from 1 tsp / gallon to 2 tsp / gallon
Ma3	10/16/2022	20 mL		GrowBig Water Dilution		GrowBig Water Dilution increased from 1 tsp / gallon to 2 tsp / gallon
C1B	10/17/2022	20 mL		Water		
C2B	10/17/2022	20 mL		Water		
Ma1	10/17/2022	20 mL		Water		
Ma2	10/17/2022	20 mL		Water		
Ma3	10/17/2022	20 mL		Water		
C1B	10/18/2022	20 mL		Water		Found 1 dried worm under moon/mars pots
C2B	10/18/2022	20 mL		Water		Found 1 dried worm under moon/mars pots
Ma1	10/18/2022	20 mL		Microbrew Water Dilution		Found 1 dried worm under moon/mars pots
Ma2	10/18/2022	20 mL		Microbrew Water Dilution		Found 1 dried worm under moon/mars pots
Ma3	10/18/2022	20 mL		Microbrew Water Dilution		Found 1 dried worm under moon/mars pots
C1B	10/19/2022	10 mL		Water		
C2B	10/19/2022	10 mL		Water		
Ma1	10/19/2022	10 mL		Water		
Ma2	10/19/2022	10 mL		Water		
Ma3	10/19/2022	10 mL		Water		
C1B	10/20/2022	20 mL		Water		
C2B	10/20/2022	20 mL		Water		
Ma1	10/20/2022	20 mL		GrowBig Water Dilution		
Ma2	10/20/2022	20 mL		GrowBig Water Dilution		
Ma3	10/20/2022	20 mL		GrowBig Water Dilution		
C1B	10/21/2022	20 mL		Water		
C2B	10/21/2022	20 mL		Water		
Ma1	10/21/2022	20 mL		Microbrew Water Dilution		
Ma2	10/21/2022	20 mL		Microbrew Water Dilution		
Ma3	10/21/2022	20 mL		Microbrew Water Dilution		
C1B	10/22/2022	20 mL		Water		
C2B	10/22/2022	20 mL		Water		
Ma1	10/22/2022	20 mL		Water		
Ma2	10/22/2022	20 mL		Water		
Ma3	10/22/2022	20 mL		Water		
C1B	10/23/2022	20 mL		Water		
C2B	10/23/2022	30 mL		Water		
Ma1	10/23/2022	20 mL		Water		
Ma2	10/23/2022	20 mL		Water		
Ma3	10/23/2022	20 mL		Water		
C1B	10/24/2022	20 mL		Water		
C2B	10/24/2022	30 mL		Water		
Ma1	10/24/2022	20 mL		Water		
Ma2	10/24/2022	20 mL		Water		
Ma3	10/24/2022	20 mL		Water		
C1B	10/25/2022	20 mL		Water		
C2B	10/25/2022	30 mL		Water		Took 'hat' (top section of grow pot) off
Ma1	10/25/2022	20 mL		GrowBig Water Dilution		
Ma2	10/25/2022	20 mL		GrowBig Water Dilution		
Ma3	10/25/2022	20 mL		GrowBig Water Dilution		
C1B	10/26/2022	20 mL		Water		
C2B	10/26/2022	30 mL		Water		
Ma1	10/26/2022	20 mL		Water		
Ma2	10/26/2022	20 mL		Water		

Mars observations / water and fert schedule					
Plant	Date	Measure Feed	Feed Type	Grow light	Comment
Ma3	10/26/2022	20 mL	Water		
C1B	10/27/2022	20 mL	Water		
C2B	10/27/2022	30 mL	Water		
Ma1	10/27/2022	20 mL	GrowBig Water Dilution		
Ma2	10/27/2022	20 mL	GrowBig Water Dilution		
Ma3	10/27/2022	20 mL	GrowBig Water Dilution		
C1B	10/28/2022	20 mL	Water		
C2B	10/28/2022	30 mL	Water		
Ma1	10/28/2022	20 mL	Water		
Ma2	10/28/2022	20 mL	Water		
Ma3	10/28/2022	20 mL	Water		
C1B	10/29/2022	20 mL	Water		
C2B	10/29/2022	30 mL	Water		
Ma1	10/29/2022	20 mL	GrowBig Water Dilution		
Ma2	10/29/2022	20 mL	GrowBig Water Dilution		
Ma3	10/29/2022	20 mL	GrowBig Water Dilution		
C1B	10/30/2022	20 mL	Water		
C2B	10/30/2022	20 mL	Water		
Ma1	10/30/2022	20 mL	Microbrew Water Dilution		
Ma2	10/30/2022	20 mL	Microbrew Water Dilution		
Ma3	10/30/2022	20 mL	Microbrew Water Dilution		
C1B	10/31/2022	20 mL	Water		
C2B	10/31/2022	30 mL	Water		
Ma1	10/31/2022	20 mL	Water		
Ma2	10/31/2022	20 mL	Water		
Ma3	10/31/2022	20 mL	Water		
C1B	11/1/2022	20 mL	Water		
C2B	11/1/2022	30 mL	Water		
Ma1	11/1/2022	20 mL	Water		
Ma2	11/1/2022	20 mL	Water		
Ma3	11/1/2022	20 mL	Water		
C1B	11/2/2022	20 mL	Water		
C2B	11/2/2022	30 mL	Water		
Ma1	11/2/2022	20 mL	GrowBig Water Dilution		
Ma2	11/2/2022	20 mL	GrowBig Water Dilution		
Ma3	11/2/2022	20 mL	GrowBig Water Dilution		
C1B	11/3/2022	20 mL	Water		
C2B	11/3/2022	40 mL	Water		
Ma1	11/3/2022	20 mL	Microbrew Water Dilution		Took 'hat' (top section of grow pot) off
Ma2	11/3/2022	20 mL	Microbrew Water Dilution		
Ma3	11/3/2022	20 mL	Microbrew Water Dilution		
C1B	11/4/2022	20 mL	Water		
C2B	11/4/2022	40 mL	Water		
Ma1	11/4/2022	30 mL	Water		
Ma2	11/4/2022	20 mL	Water		
Ma3	11/4/2022	20 mL	Water		
C1B	11/5/2022	20 mL	Water		
C2B	11/5/2022	45 mL	Water		
Ma1	11/5/2022	30 mL	Water		
Ma2	11/5/2022	20 mL	Water		
Ma3	11/5/2022	20 mL	Water		
C1B	11/6/2022	20 mL	Water		
C2B	11/6/2022	45 mL	Water		
Ma1	11/6/2022	20 mL	GrowBig Water Dilution		
Ma2	11/6/2022	20 mL	GrowBig Water Dilution		

Mars observations / water and fert schedule						
Plant	Date	Measure	Feed	Type	Grow light	Comment
Ma3	11/6/2022	20 mL	GrowBig Water	Dilution		
C1B	11/7/2022	20 mL	Water			
C2B	11/7/2022	45 mL	Water			
Ma1	11/7/2022	30 mL	Water			
Ma2	11/7/2022	20 mL	Water			
Ma3	11/7/2022	20 mL	Water			
C1B	11/8/2022	20 mL	Water			
C2B	11/8/2022	45 mL	Water			
Ma1	11/8/2022	30 mL	Water			
Ma2	11/8/2022	20 mL	Water			
Ma3	11/8/2022	20 mL	Water			
C1B	11/9/2022	20 mL	Water			
C2B	11/9/2022	45 mL	Water			
Ma1	11/9/2022	20 mL	GrowBig Water	Dilution		
Ma2	11/9/2022	20 mL	GrowBig Water	Dilution		
Ma3	11/9/2022	20 mL	GrowBig Water	Dilution		
C1B	11/10/2022	20 mL	Water			
C2B	11/10/2022	45 mL	Water			
Ma1	11/10/2022	30 mL	Water			
Ma2	11/10/2022	20 mL	Water			
Ma3	11/10/2022	20 mL	Water			Thinned out 3 beets; 1 beet and 1 pok choi remain
C1B	11/11/2022	20 mL	Water			
C2B	11/11/2022	45 mL	Water			
Ma1	11/11/2022	30 mL	Water			
Ma2	11/11/2022	20 mL	Water			
Ma3	11/11/2022	20 mL	Water			Took 'hat' (top section of grow pot) off
C1B	11/12/2022	20 mL	Water			
C2B	11/12/2022	45 mL	Water			
Ma1	11/12/2022	20 mL	GrowBig Water	Dilution		
Ma2	11/12/2022	20 mL	GrowBig Water	Dilution		Took 'hat' (top section of grow pot) off
Ma3	11/12/2022	20 mL	GrowBig Water	Dilution		
C1B	11/13/2022	20 mL	Water			
C2B	11/13/2022	45 mL	Water			
Ma1	11/13/2022	20 mL	Microbrew Water	Dilution		
Ma2	11/13/2022	20 mL	Microbrew Water	Dilution		
Ma3	11/13/2022	20 mL	Microbrew Water	Dilution		
C1B	11/14/2022	20 mL	Water			
C2B	11/14/2022	45 mL	Water			
Ma1	11/14/2022	30 mL	Water			
Ma2	11/14/2022	30 mL	Water			
Ma3	11/14/2022	30 mL	Water			
C1B	11/15/2022	20 mL	Water			
C2B	11/15/2022	45 mL	Water			
Ma1	11/15/2022	35 mL	Water			
Ma2	11/15/2022	35 mL	Water			
Ma3	11/15/2022	35 mL	Water			
C1B	11/16/2022	20 mL	Water			
C2B	11/16/2022	45 mL	Water			
Ma1	11/16/2022	35 mL	Water			
Ma2	11/16/2022	35 mL	Water			
Ma3	11/16/2022	35 mL	Water			
C1B	11/17/2022	20 mL	Water			
C2B	11/17/2022	45 mL	Water			
Ma1	11/17/2022	35 mL	Water			
Ma2	11/17/2022	35 mL	Water			
Ma3	11/17/2022	35 mL	Water			
C1B	11/18/2022	0 mL			Lights off / pot take down	Very dense mud like soil
C2B	11/18/2022	0 mL			Lights off / pot take down	
Ma1	11/18/2022	0 mL			Lights off / pot take down	Watermelon vine not visible in soil; found 1 worm in soil
Ma2	11/18/2022	0 mL			Lights off / pot take down	Watermelon vine not visible in soil; found 2 worms in soil on 11/18 and an additional worm in the pot on 11/22

Mars observations / water and fert schedule					
Plant	Date	Measure Feed	Feed Type	Grow light	Comment
Ma3	11/18/2022	0 mL		Lights off / pot take down	Watermelon vine not visible in soil