

Effects of Soil Amendments on Growth of *Phaseolus vulgaris* in Martian Regolith–Soil Mixtures

Introduction

Long-duration space missions require sustainable food production systems. Martian regolith lacks organic matter, exhibits poor water retention, and contains limited bioavailable nutrients, making it unsuitable for plant growth without modification. Soil amendments such as perlite, Biochar, and peat moss may improve regolith structure and nutrient availability. This study investigates whether these amendments enhance plant growth in a regolith-based substrate.

Research Question

Research Question:

How do different soil amendments affect the growth of *Phaseolus vulgaris* in a Martian regolith soil mixture?

Hypothesis: Soil amendments, particularly in combination, will significantly increase plant growth compared to regolith only conditions due to improved nutrient availability, aeration, and water retention.

Methods

Experimental Setup

Bean plants (*Phaseolus vulgaris*) were grown in individual cells containing a 50/50 mixture by volume of Martian regolith simulant (MGS-1) and soil amendments. Treatments included perlite, biochar (hydrochar), peat moss, and gypsum, both individually and in combination.

Variables

- **Independent Variable:** Type of soil amendment
- **Dependent Variables:** Plant height (mm), soil pH, leaf color (LCC), plant survival, growth patterns, and root development
- **Controlled Variables:** Water volume, light exposure, pot/cell size, total soil volume, and proportion of regolith (50% by volume)

Procedure

1. Each soil component (regolith, perlite, biochar, peat moss, and gypsum) was measured by fully filling a single cell to determine its mass-to-volume relationship.
2. These measurements were used to calculate the correct ratios to maintain a consistent 50% regolith composition by volume across all treatments.
3. Regolith and soil amendments were combined according to the calculated ratios and added to planting cells.
4. Bean seeds were planted in each cell under identical conditions.
5. Plants will be watered daily with a fixed volume of water.
6. Plant height will be measured every two days, and soil pH and leaf color (using an LCC) recorded periodically.
7. Qualitative observations, including growth patterns and survival, will be recorded throughout the experiment, and root development measured at the conclusion of the study.

Matthew Weeks, Abby Wong, and Ignacio Maravilla
Advisor: Gabriel Chavez
CSU Monterey Bay

A	B	C	D	E	F	G	H	I	J	K	L



Figure 2: Seed Starter System

Figure 3: MGS-1 Simulant

Figure 1: Seed Starter System Setup

- A: Control Group and volume measurements (See methods)
- B: Peatmoss
- C: Perlite
- D: Biochar
- E: Gypsum
- F: Peatmoss & Peralite
- G: Peatmoss & Biochar
- H: Peatmoss & Gypsum
- I: Peralite & Biochar
- J: Peralite & Gypsum
- K: Biochar & Gypsum
- L: Peatmoss, Peralite, Biochar, & Gypsum

Note: All pots in rows B-L have 50% regolith per volume.

P.T.M.C Challenge



Component	Wt.%	Oxide	Wt.%
Anorthosite	27.1	SiO ₂	43.90
Glass-rich basalt	22.9	TiO ₂	0.46
Bronzite	20.3	Al ₂ O ₃	12.84
Olivine	13.7	FeO	10.60
Mg- sulfate	4.0	MnO	0.11
Ferrihydrite	3.5	MgO	14.81
Hydrated silica	3.0	CaO	7.91
Magnetite	1.9	Na ₂ O	1.49
Anhydrite	1.7	K ₂ O	0.29
Fe-carbonate	1.4	P ₂ O ₅	0.17
Hematite	0.5	LOI	4.90
		Total	97.48

Figure 4: MGS-1 Specs Sheet

Methods (Cont.)

- Soil amendments were selected based on their ability to improve the physical and chemical properties of Martian regolith and support plant growth.
- **Perlite** - Improves soil aeration and drainage, helping roots access oxygen and reducing compaction.
- **Biochar** - increases water retention, which is important in dry environments.
- **Peat moss** - improves soil structure and helps maintain moisture.
- **Gypsum** - provides calcium and helps reduce soil compaction while stabilizing pH conditions.
- Combining these amendments is expected to produce synergistic effects that enhance plant growth in regolith-based systems.

Analysis

- **Quantitative data:** Plant height (mm) measured over time, along with soil pH levels.
- **Qualitative data:** Leaf color (measured using a Leaf Color Chart, LCC), growth patterns, and plant survival.
- At the end of the experiment, root development will also be measured to assess below-ground growth.
- Results will be compared and cross-referenced with other groups conducting similar experiments using the same soil amendments and/or plant species.

Future Work

This study serves as a pilot investigation to evaluate the feasibility and effectiveness of using soil amendments to support plant growth in Martian regolith simulant. The results will inform a larger, more comprehensive study planned for Fall 2026, where we aim to refine treatment ratios, expand sample sizes, and incorporate additional plant species. Future work will also include more detailed analysis of root systems, nutrient cycling, and long-term soil sustainability across multiple growth cycles. By building on this pilot study, we seek to develop more optimized and scalable strategies for plant growth in extraterrestrial environments.

Acknowledgements

We would like to thank the Institute of Competition Sciences, the California NASA Space Grant Consortium, UROC, the CSUMB Watershed Institute, and Professor Gabriel Chavez.

Contact info
gchavez@csumb.edu

