# Southern High
# Plant the Moon Challenge

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## Design Overview

This experiment works in conjunction with Exolith, and the Plant the Moon Challenge to find a solution for growing plants on the moon. As humans begin considering colonizing the moon, there must be viable methods for growing crops in the lunar highland regolith as food cannot be transported to the moon in mass.

This experiment attempted to make lunar regolith more habitable for plants via implementation of peat moss. The goal was to determine what ratio can sustain plant life whilst using maximum lunar simulant. Green bean seeds (Phaseolus vulgaris) and Swiss Chard seeds (Beta vulgaris subsp. vulgaris) were planted in equal amounts. The initial experimental design called for the use of fertilizer on one half of the plants at the 4 week mark, as an additional variable for review. However replanting was done multiple times throughout the experiment pushing the 4 week fertilization point beyond the 8 week growing window for the experiment *Noted in Difficulties and Revisions*. As a result, this variable was removed from our experiment and data results will reflect this. Germination rates were recorded in addition to the height of the plants once they began growing.

## Original Hypothesis

If a tray of 48 seeds are planted with 4 ratios of Lunar Highland Simulant to Peat Moss *See Appendix A*, and half are fertilized with Miracle Grow, then the highest concentrations of Peat Moss with fertilizer will show the greatest Germination and growth rates. Due to the more hospitable conditions provided by Peat Moss, the plants started in Higher concentrations of Peat Moss will have more favorable chances of success. Although fertilization has no impact on germination the plants that are fertilized can be expected to grow more rapidly than those without fertilizer.

## Revised Hypothesis

If a tray is planted with 48 seeds, and 4 ratios of Lunar Highland Simulant to Peat Moss *See Appendix B* then the highest concentrations of Peat Moss will show the greatest Germination and growth rates, closest to the rates of the control seeds. Due to the more hospitable conditions provided by Peat Moss, the plants started in Higher concentrations of Peat Moss will have more favorable chances of success.

## Materials

- Lunar Soil (2,500 ml)
- Peat Moss (3,200 ml)
- 30 Green Bean Seeds
- 30 Swiss Chard seeds
- 2 x 6 Cell Seed Trays (10)
- Distilled Water
- 10 ml Syringes (2)
- 500 ml Beakers (2)
- Table Space
- LED Grow light (100-240 V)
- Heat  Mat (maintains 70-80 degrees)
- Scotch Tape
- Black Sharpie
- Scissors
- Glass stir rods (4)
- Water-Tight Buckets
- KN95 masks
- Lab Aprons
- Lab Goggles
- Disposable gloves

## Independent Variable:

>plant type (Swiss Chard and Green Beans)
>Growing Media makeup
-100% lunar highland simulant
-50% lunar highland simlant/ 50% peat moss
-25% lunar highland simulant/ 75% peat moss
-15% lunar highland simulant/ 85% peat moss

## Dependent Variable:

>Germination rate ( _/6) ,
>Growth rate (height mm)

## Control:

>Soil grown Swiss Chard and Green Beans

## Constants:

>Soil amount (20 ml)
>Light amount (100-240 V 24 hours a day)
>Environmental factors: temperature, humidity, airflow
>pH of water (7.2)
>Date of Germination (Final - 10/21/2022)
>Container shape and size

## Experimental Design/Procedures:

1.) Fill a non porous growing tray with 4 rows of 2 individual, porous planters (2x6 cells per planter)
2.) Fill a second non porous growing tray with 2 individual, porous planters (2x6 cells)
3.) Begin use of KN95 masks, aprons, and goggles
4.) Mix 2000ml Lunar simulant, 2000 ml peat moss in a plastic bucket, lid bin and shake to mix (Allow 5 minutes for dust in bin to settle before opening)
5.) Collect 500 ml 50/50 mix and 500 ml peat moss, combine in a new plastic bucket to make a 25% lunar simulant, 75% peat moss mix (Allow 5 minutes for dust in bin to settle before opening)
6.) Collect 300 ml 50/50 mix and 700 ml peat moss, combine in a new plastic bucket to make a 15% lunar simulant, 85% Peat moss mix (Allow 5 minutes for dust in bin to settle before opening)
7.) Fill row 1 planters with 100% Lunar simulant
8.) Fill row 2 planters with 50/50 mix
9.) Fill row 3 planters with new 25/75 mix
10.) Fill row 4 planters with 15/85 mix
11.) Water all planter cells with 10 ml of distilled water and stir simulant to hydrate
12.) Plant green bean seeds in first line of rows 1-4 approximately 1/2 inch deep in soil
13.) Plant Swiss chard seeds in second line of rows 1-4
14.) Set plants on growing mat and under LED Light 24/7
15.) Saran Wrap over the top of the growing tray for 4-10 days or until seeds begin germinating
16.) Water with 5 ml approximately once every 2 days (based upon school A/B schedule)
17.) When soil appears dry prior to watering, pour 400 ml of water in lower growing trays to be slowly absorbed by individual cells.
19.) Monitor/measure Growth in mm weekly

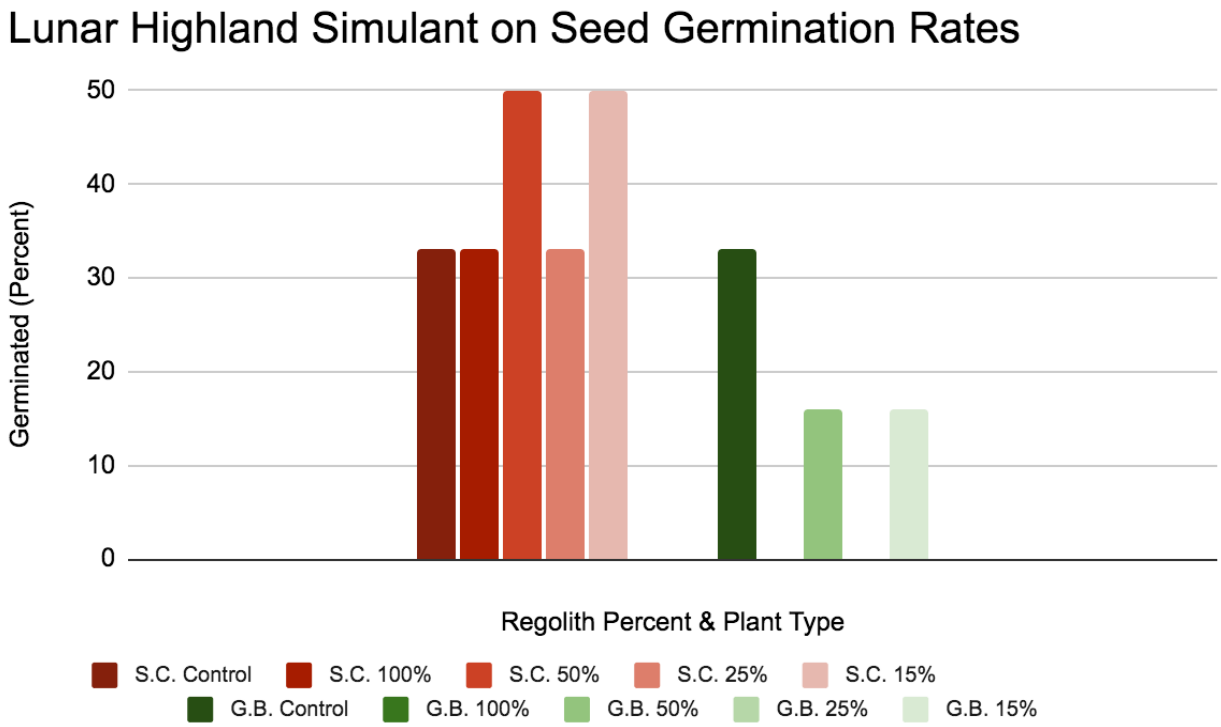
## Difficulties and Revisions

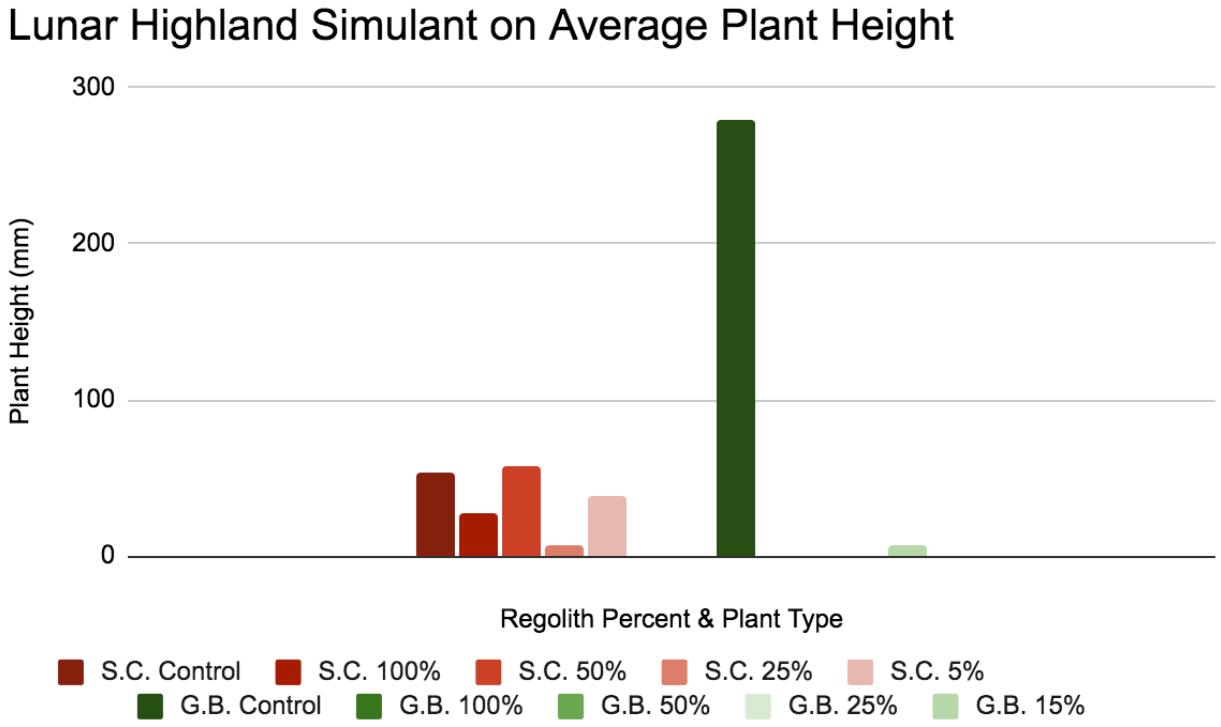
The initial Experimental Design had to be edited significantly before the current experimental layout was structured. The initial attempt at hydrating the lunar regolith failed, as too much water was used (25 ml). Due to the hydrophobic nature of the lunar simulant and its small particle size, the water took over a day to fully saturate the soil. Once saturated the simulant solidified due to the lack of pore space between soil particles. This was severe enough that seeds could not feasibly be planted. The experiment was restarted and the initial saturation amount was reduced to 10 ml.

The initial design also planned to track pH readings of soil/regolith throughout the experiment. However there was not enough spare growing media to effectively measure pH, making any readings taken an unreliable source of data and this variable was removed from the experiment.

Also removed as a variable was the use of fertilizer. The initial design called for the use of fertilizer at the 4 week growing mark, under the assumption that seeds were planted at the start of the 8 week growing period, and germinating within 4-7 days of the start date. However the first “set” of Swiss Chard and Green Bean seeds planted had a 0% germination rate after 10 days. The seeds were a year old and the assumption is that they were faulty. At this point, the experiment needed to be restarted with newly purchased seeds from 2022. The new planting date for the seeds was October 21, 2022. At this point there were less than 4 weeks remaining in the growing period and the observation of fertilizer use on plant growth could not be done.

## Results


Lunar Highland Simulant on Seed Germination Rates
Germinated (Percent)
50
40
30
20
10
0
Regolith Percent & Plant Type
S.C. Control
S.C. 100%
S.C. 50%
S.C. 25%
S.C. 15%
G.B. Control
G.B. 100%
G.B. 50%
G.B. 25%
G.B. 15%


Lunar Highland Simulant on Average Plant Height
Plant Height (mm)
300
200
100
0
Regolith Percent & Plant Type
S.C. Control
S.C. 100%
S.C. 50%
S.C. 25%
S.C. 5%
G.B. Control
G.B. 100%
G.B. 50%
G.B. 25%
G.B. 15%

## Results (Continued)

The Germination rate for the Swiss Chard Control was 2/6 and the die off rate was zero. The Swiss Chard in 100% Lunar Regolith had a germination rate of 2/6 with 50% die off. The 50% lunar regolith to peat moss samples germinated at 3/6 with 33% die off, The 25% lunar simulant germinated at 2/6 with a 50% die off, and 15% regolith germinated at 3/6 with a 66% die off rate.

The Green Bean control sample also germinated at 2/6 with zero die off. Green Bean seeds did not germinate in 100% or 25% lunar simulant. In the 50% regolith seeds germinated at a rate of 1/6 with 100% die off. In 15% simulant germination was also 1/6 with zero die-off.

The heights of all Swiss Chard and Green Bean plants were recorded throughout the experiment and taken in inches. The final heights recorded are as follows: The 2 Swiss Chard controls averaged 54.1mm, the 100% sample was 27.9mm, the 2 50% samples averaged 57.1mm, the 25% regolith sample was 6.4mm, and the 15 percent sample was 38.1mm. For Green Beans the 2 controls averaged 279.4mm with a notable differentiation between the measurements. One plant measured 12.7mm while the other measured 546.1mm. The only surviving lunar regolith Green Bean plant was a 15% regolith sample measuring 6.4mm.

This experiment most notably demonstrates the inhospitableness of Lunar regolith. Of the two seed types, Green Beans struggled particularly with germination, with only 2 of 24 seeds germinating in any lunar simulant samples, despite replanting of multiple seed samples. Of these only one seed survived in the most diluted 15% lunar to peat moss growing media. The Swiss Chard Seeds were more successful but still demonstrated a below average germination and survival rate with 10 of 24 seeds germinating and 5 plants surviving. Death, or complete lack of germination was recorded for both plant species in all 4 soil ratios. By comparison, the

soil/control samples for Swiss Chard and Green Beans both germinated at low rates of 2/6 but demonstrated consistent growth and zero die off throughout the experiment.

The most hospitable ratios of peat moss to lunar regolith simulant was relatively consistent between Green Beans and Swiss Chard. 50% Lunar regolith proved to be the best growing media for Swiss Chard plants, and 15% the best growing media for Green Beans and the second best for Swiss Chard.

Both plant species germinated at the highest rates in 50 and 15 percent lunar simulant. For Swiss chard, the 3/6 germination of both 15% and 50% was higher than the germination rate of the control. For Green Beans the most successful lunar simulants were half the germination rate of the control and were the default most successful as they were the only plants to germinate.

50% and 15% lunar simulant also persisted as the most hospitable conditions for long term survival and growth. For Swiss chard the largest plant height average between the control and lunar simulant samples were the 50% samples at 57.1mm this was also the most resilient of all the lunar/peat moss ratios. The 15% saw reasonable growth as the second largest lunar simulant plant reaching 38.1mm. The only surviving Green Bean sample was a 6.4 mm green bean plant from the 15% lunar regolith.

The least hospitable growing media for any plants was the 100% lunar simulant and the 25% simulant as Green Beans would not germinate in either and the smallest Swiss Chard plants of the experiment were grown in these soil samples. The 100% lunar regolith Swiss Chard that survived reached 27.9mm. This is logical as the lunar regolith by itself has little to no nutritional value, making survival and rapid growth less likely than in peat moss subsidized growing media. However, the persistent failure of plant growth in 25% lunar regolith is inconsistent with other

data results. The 25% seed sample results could be expected to fall somewhere between those of 50% and 15% but fall significantly closer to those of 100% lunar regolith.

## Conclusion

The purpose of this experiment was to determine whether a mixture of 50/50 lunar regolith and peat moss, a 25/75 mixture, a 15/85 mixture, or pure lunar regolith, would result in greater germination rates and greater plant heights for Swiss Chard and Green Beans.

The experiment results demonstrate that a mixture of up to 50% lunar regolith with peat moss can provide growth results comparable to that of the earth soil samples for Swiss Chard plants and a 15% lunar regolith mixture for Green Beans. The 50% and 15% lunar regolith mixture were the highest germinating growing media for both plant types. These two regolith mixtures also demonstrated the highest plant heights for Swiss Chard with average heights of 57.1mm for 50% and 38.1mm for 15%. The only surviving green bean plant after initial germination was a 6.4mm 15% regolith sample, making it the most, and only, hospitable growing medium for Green Bean survival long term. There was a result gap for the 25% simulant mix as germination rates and plant heights did not fall within that of the 50% and 15% as expected. The experimental data patterns indicate that the results for the 25% lunar regolith are inconsistent with the experiment.

It was hypothesized that the highest concentrations of Peat Moss would show the greatest Germination and growth rates, closest to the rates of the control seeds, due to the nutritional value added by peat moss. Our hypothesis is supported by the results of the Green Bean samples and partially disproved by the Swiss Chard Samples.

The highest Peat moss concentration sample made up of 85% peat moss and 15% lunar simulant was the only growing medium Green Beans could survive in. However Green Bean seeds were capable of germinating in 50% lunar simulant samples as well. Under the assumption

that the lack of data for 25% simulant is faulty, this supports the hypothesis as the Greatest success for Green Beans was found within the greatest Peat Moss Concentration samples.

The results of Swiss Chard are less supportive of the hypothesis as the most successful growing media was not the highest Peat Moss concentration sample. The most successful regolith mixture for germination and long term growth was the 50% mixture. However, the 15% regolith mixture fell close behind in germination and long term survival. In addition, the 100% lunar simulant for Swiss Chard was farther behind both in germination and final height. This demonstrates the positive impact of peat moss on Swiss Chard growth when combined with lunar regolith, but does not support the prediction that a correlation would be present between level of success and amount of peat moss present.

This experiment has provided valuable information on how to more effectively set up a study on lunar regolith simulants, but lacked the size to prove statistical significance. The results demonstrated inconsistencies that call for the experiment to be rerun over a full 8 week growth period with a larger experimental group for more accurate results.

## Appendix A - Initial Growing Tray Guide (W/Fertilizer)

### Key:

SC - Swiss Chard  GB - Green Beans
F - Fertilized  NF - Non Fertilized
Blue - 100% Lunar  Green - 50% Lunar  Yellow - 25% Lunar  Red - 15% Lunar
Purple - Control/Soil

| | | | | | |
|---|---|---|---|---|---|
| SC F | SC F | SC F | SC NF | SC NF | SC NF |
| GB F | GB F | GB F | GB NF | GB NF | GB NF |
| SC F | SC F | SC F | SC NF | SC NF | SC NF |
| GB F | GB F | GB F | GB NF | GB NF | GB NF |
| SC F | SC F | SC F | SC NF | SC NF | SC NF |
| GB F | GB F | GB F | GB NF | GB NF | GB NF |
| SC F | SC F | SC F | SC NF | SC NF | SC NF |
| GB F | GB F | GB F | GB NF | GB NF | GB NF |

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|---|---|---|---|---|---|
| SC F | SC F | SC F | GB F | GB F | GB F |
| SC NF | SC NF | SC NF | GB NF | GB NF | GB NF |

## Appendix B - Revised Growing Tray Guide (Non-Fertilized)

**Key:**

SC - Swiss Chard  GB - Green Beans
Blue - 100% Lunar  Green - 50% Lunar  Yellow - 25% Lunar  Red - 15% Lunar
Purple - Control/Soil

| | | | | | |
|---|---|---|---|---|---|
| SC | SC | SC | SC | SC | SC |
| GB | GB | GB | GB | GB | GB |
| SC | SC | SC | SC | SC | SC |
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