TEAM LUNAR LANDSCAPES
TEAM ID: 13003

How does the Ratio of Lunar Regolith Simulant to Terrestrial Soil Affect the Growth and Development of Radishes?

Final Written Report

Challenge Division: Elementary School
Facilitator: Brent Cunningham

April 21, 2023

Part I: Experimental Parameters

Driving Question:

How does the Ratio of Lunar Regolith Simulant to Terrestrial Soil Affect the Growth and Development of Radishes?

Hypothesis:

Primary Experiment (radishes)-

As the ratio of terrestrial soil (TS) to lunar regolith simulant is increased (such that $n \leq 50\%$ TS), then the plant will be healthier and produce a larger vegetable root because the plant will get more necessary nutrients.

Secondary Experiment (lima beans)-

As the ratio of terrestrial soil (TS) to lunar regolith simulant is increased (such that $n \leq 50\%$ TS), then the plant will be healthier and produce a more growth because the plant will get more necessary nutrients.

Reasoning:

Primary Experiment-

As humans continue to expand upon the missions to establish a base of operation on the lunar surface, sustainable food will be required. The need to transport terrestrial soil for initial plantings and growth will increase mass on the craft and require more fuel. Determining a proper ratio of mixture which will produce viable crops is important in limiting this fuel load.

Secondary Experiment-

Regarding seeds travelling to the lunar surface, they will be exposed to high levels of cosmic radiation during space flight. To mimic this portion of the experience (even in the most limited sense) we used lima bean seeds which had flown into near space aboard NASA sounding rocket from their facility at Wallop's. These seeds will also be grown in mixtures of lunar regolith simulant and terrestrial soil.

Independent Variable:

The independent variable was the ratio of lunar regolith simulant (LRS) to terrestrial seed starting mix (SSM) which would contain substantially more organic matter for the plants to use as essential nutrients. This was selected based on our hypothesis and driving question. Since plants require these nutrients for growth and development, the initial plants grown on the lunar surface will require a mixture of some sort (at least that was our hypothesis). Determining a mixture that would work the best would help to limit mass on any spacecraft and conserve fuel for the trip.

The experiment had three groups (A, B, and C) which contained mixtures of LRS and SSM:

Groups A and B (Radishes)

- 100% LRS
- 90% LRS / 10% SSM
- 80% LRS / 20% SSM
- 70% LRS / 30% SSM
- 60% LRS / 40% SSM
- 50% LRS / 50% SSM

Group C (Lima Beans)

- 100% LRS
- 75% LRS / 25% SSM
- 50% LRS / 25% SSM

All three groups also had a control pot containing 100% SSM.

Dependent Variable

The dependent variable(s) in the beginning of the experiment design was simply noticeable changes in the radish vegetable and root structure. As time progressed we changed that to include variations in plant height and leaf characteristics. This was done because we quickly realized on a discussion that not all of the plants may produce radishes, and this was be challenging to then use as a means of either supporting or refuting our hypothesis. Since radishes typically begin developing on the plant when the leaves reach a height of 4 inches, we decided to go with plant height and leaf characteristics since it was unlikely that most of the plants would not develop these measureable components.

For the lima bean study, the dependent variable was much the same, except that we would look at the plants' ability to form bean pods, rather than root vegetables.

Measurements:

Overview-

The plant height, number of leaves and cotyledons, width of the leaves and cotyledons, and pH of the soil. Measurements were collected every Thursday throughout the grow period. And final cumulative measurements were collected on April 6th, 2023.

Process-

Each weekly measurement gathering required first donning PPE, then students would carefully measure the plant's height from the point where the hypocotyl emerges from the soil to the top of the tallest leaf when it was stood upward. When measuring cotyledon/leaf width, the students would measure each cotyledon/leaf at its widest portion, then find the mean width of the leaves to record. And finally, measuring pH required use of the provided meter. The students would depress the meter into the soil in a corner of the pot containing no growth, wait approximately 60 seconds, and record the value.

Final Measurements Overview-

Students took measurements of total overall length from the bottom of the roots to the tip of the plant, diameter of the hypocotyl, length of the hypotcotyl (and epicotyl of the lima beans), color of the hypocotyl, a description of the root structure, and any other findings worthy of note when compared to a typical radish plant.

Final Measurements Process-

To begin, the students donned the appropriate PPE and all safety considerations were discussed and abided by.

First, the students carefully remove the plants from the pot and place the entire plant on the screen. Then, they gently spray water over the roots to rinse away all soil (Lunar and Terrestrial) until roots are clean. Following this they carefully picked up and placed the plant on a white table covering. A ruler was placed next to plant and it was photographed. Finally, students would gather data about the plant.

Additionally, we took samples of the lima bean plants (stem longitudinal and stem cross-sectional) to create microscope slides and observe the slides using a compound microscope with a camera lens. This was to see if any major differences existed in the cells of the plants from different mixtures.

Controls:

Lighting-

The lighting was set up at the same time. They would each get around 7.5 hours of light for 5 days a week.

Water-

The plants would be watered to meet the same level of soil moisture content on the provided sensor. Initially the plan was to apply the same amount of water, but this was quickly found to be flawed due to the different levels of drainage within the soils. So this amended plan was developed.

Temperature and Humidity-

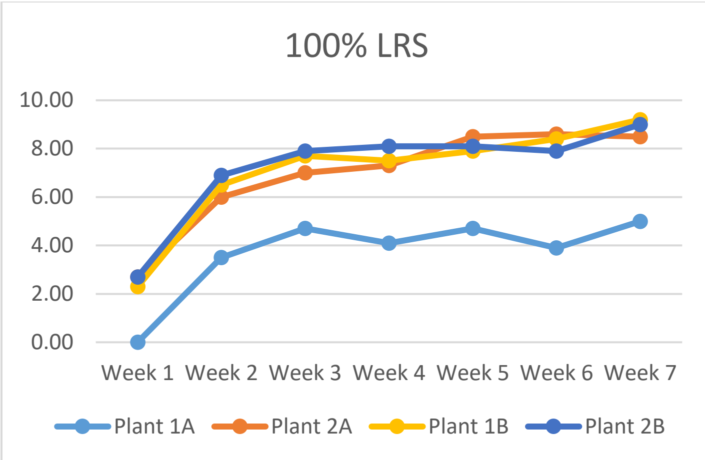
The temperature and humidity were kept the same and consistent throughout the 8-week period. The plants were not moved throughout the time they were growing. They were also kept in a greenhouse within the classroom to maintain the humidity and moisture levels.

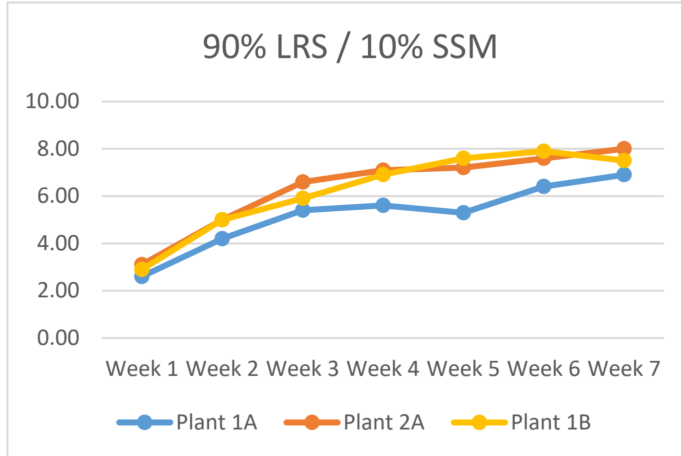
Grow Period-

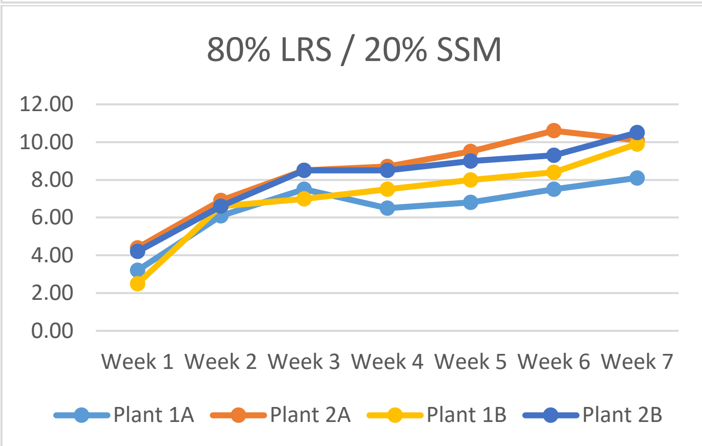
The plants got planted at the same time on the same day. The plants also got removed from the soil mixtures on April 6th at around the same time. After the plants were removed from soil mixtures, they were measured at the same time to avoid wilting, which would disrupt proper measurements.

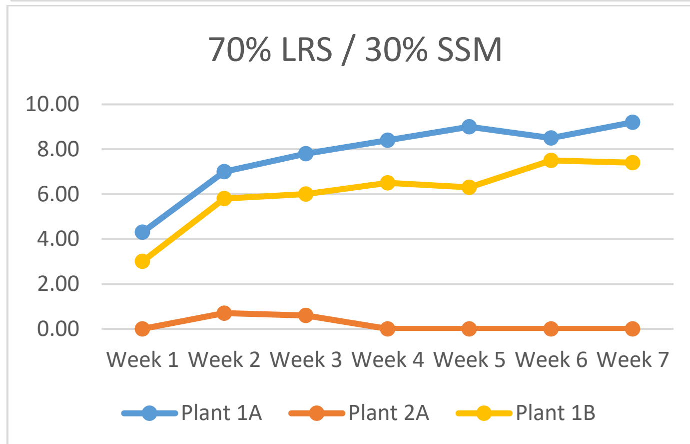
Reflections:
One factor that should be adjusted in future experiments is that while the experiment does include an LED light setup and natural light from a nearby window, on weekends, nights, and school breaks we cannot keep the overtop light on, so the plants must rely on natural light.
Our experiment contains 12 main pots with 2 radish plants in each pot (Plant 1 and Plant 2). Although keeping two plants in each pot is more efficient regarding soil usage, these two plants would be in competition with each other for resources due to their close proximity. In the future we should plant only one seed per pot. The biology professor from Kean University spoke with us and advised that this change would be beneficial for experiment design in the future.
Additionally, the small plastic pots used in this experiment are ideal for saving space, but the pots were far too shallow to support the plants' root and hypocotyl growth, so the plants fell over after a few weeks. This may also be due to the lack of air movement in the room the pots are stored in, which does not encourage the plants to grow their hypocotyl structures stronger, causing them to droop over.
Results:
Radishes-
No radishes were produced in any of the mixtures despite the plant have a labeled production time of 22 day.
In 100% Lunar Regolith Simulant: Plant IA1 grew 5.00 cm during the growth period. Plant IA2 grew 8.50 cm during the growth period. Plant IB1 grew 9.20 cm during the growth period. Plant IB2 grew 9.00 cm during the growth period.
The four plants we had in 90% lunar soil and our 10% terrestrial soil grew successfully. For Plant IIA1 it grew to 6.90 cm. And IIA2 grew to 8.50 cm. IIB1 grew to 7.50 cm and IIB2 never grew.
The plants in 80% lunar soil: Plant IIIA1 grew to 8.10 cm. Plant IIIA2 grew to 10.10 cm. Plant IIIB1 grew to 9.90 cm. And plant IIIB2 grew to 10.50 cm.
The plants in 70% lunar soil and 30% terrestrial grew but did not produce any radishes. Plant IVA1 grew 9.20 cm. Plant IVA2 grew 0.70 cm, then shrunk to 0.60 cm before dying on week 4. Plant IVB1 grew 7.40 cm and Plant IVB2 never grew.
The plants in 60% lunar soil and 40% Earth soil: Pot lVA1 grew to 9.20 cm and lVA2 grew to 0.60 cm and died in the process. For pot lVB1 it grows to 7.40 cm and IVB2 never grew.
The plants in the 50% lunar soil. Plant VIA1 grew to 8.50 cm. Plant VIA2 grew to 10.10 cm. Plant VIB1 had nothing grow at all. But VIB2 grew to 9.50 cm.
The averages of every week in each different mixtures:

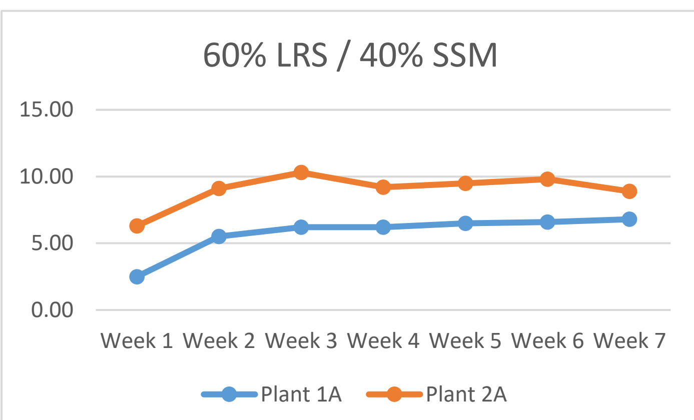
- In the 100% LRS the average height was 6.33 cm
- In the 90/10 mixture the average height was 5.94 cm
- In the 80/20 mixtures the average height was 7.2 cm
- In the 70/30 mixture the average height was 6.12 cm
- In the 60/40 mixture the average height was 7.39 cm
- And in the 50/50 mixture the average height was 7.86 cm

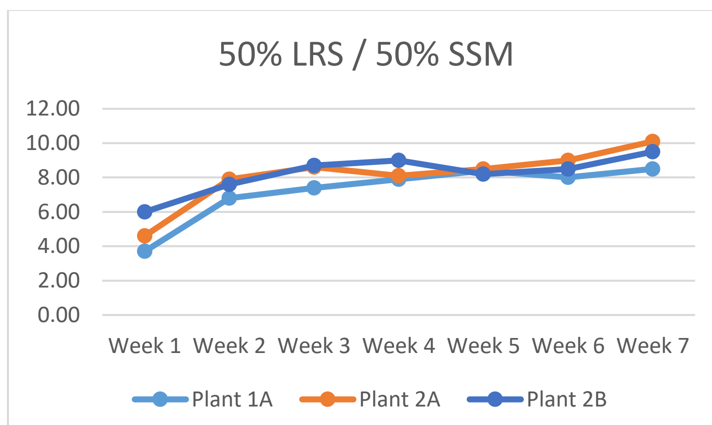

100% LRS
10.00
8.00
6.00
4.00
2.00
0.00
Week 1 Week 2 Week 3 Week 4 Week 5 Week 6 Week 7
Plant 1A
Plant 2A
Plant 1B
Plant 2B

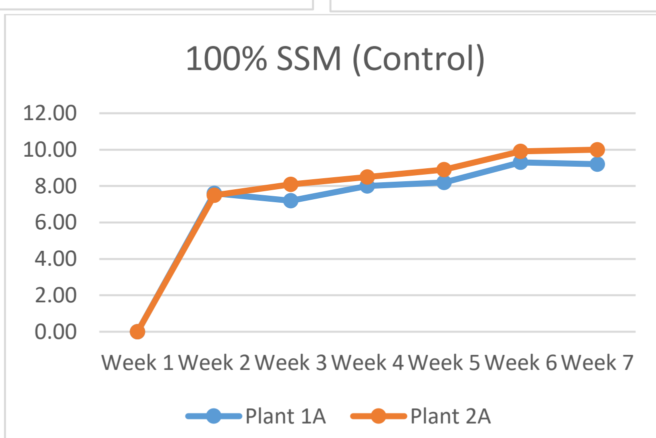

90% LRS / 10% SSM
10.00
8.00
6.00
4.00
2.00
0.00
Week 1 Week 2 Week 3 Week 4 Week 5 Week 6 Week 7
Plant 1A
Plant 2A
Plant 1B


80% LRS / 20% SSM
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Week 1 Week 2 Week 3 Week 4 Week 5 Week 6 Week 7
Plant 1A
Plant 2A
Plant 1B
Plant 2B

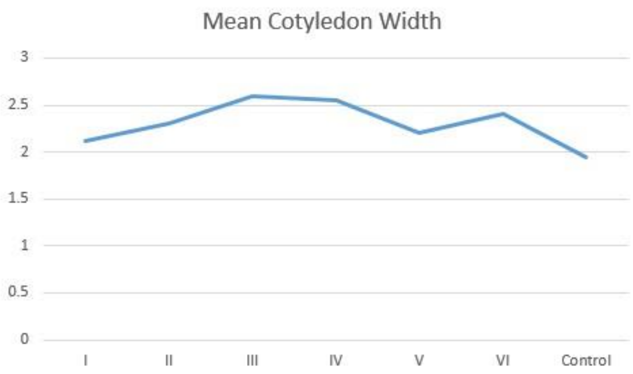

70% LRS / 30% SSM
10.00
8.00
6.00
4.00
2.00
0.00
Week 1 Week 2 Week 3 Week 4 Week 5 Week 6 Week 7
Plant 1A
Plant 2A
Plant 1B


60% LRS / 40% SSM
15.00
10.00
5.00
0.00
Week 1 Week 2 Week 3 Week 4 Week 5 Week 6 Week 7
Plant 1A
Plant 2A


50% LRS / 50% SSM
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Week 1 Week 2 Week 3 Week 4 Week 5 Week 6 Week 7
Plant 1A
Plant 2A
Plant 2B

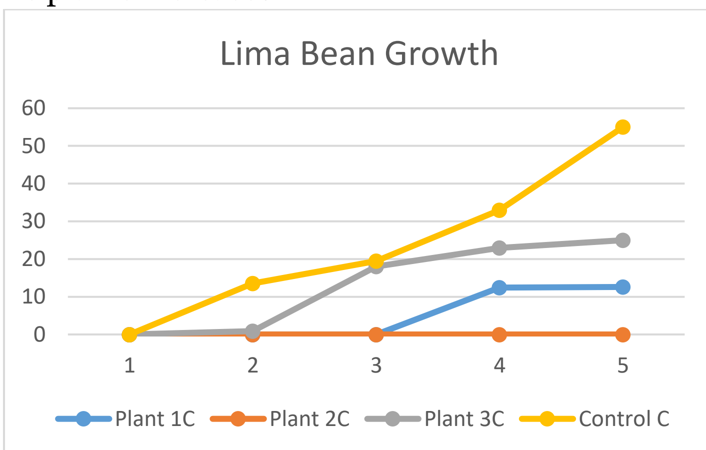

100% SSM (Control)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Week 1 Week 2 Week 3 Week 4 Week 5 Week 6 Week 7
Plant 1A
Plant 2A

Additionally, the leaves and cotyledons varied greatly and did not quite support the hypothesis.



Lima Beans-

The growth of the lima beans did support our hypothesis in that as the mixture approached 50/50, the growth and health of the plants increased.



Conclusion-

The plants that grew the best were in pots with 80% lunar regolith and 20% terrestrial soil.

The worst had 90% lunar regolith and 10% Terrestrial soil which doesn't make sense because the 90% lunar regolith pot has only 10% more lunar regolith than the pot that did the best.

The average leaf and cotyledon do not support the hypothesis, and even in some cases the leaves get smaller with higher concentrations of terrestrial soil.

We found that the evidence doesn't support our hypothesis when it comes to the radish plants. But with the lima bean growth it does support the hypothesis.

Plant	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
IA1	0.00	3.50	4.70	4.10	4.70	3.90	5.00
IA2	2.70	6.00	7.00	7.30	8.50	8.60	8.50
IIA1	2.60	4.20	5.40	5.60	5.30	6.40	6.90
IIA2	3.10	5.00	6.60	7.10	7.20	7.60	8.00
IIIA1	3.20	6.10	7.50	6.50	6.80	7.50	8.10
IIIA2	4.40	6.90	8.50	8.70	9.50	10.60	10.10
IVA1	4.30	7.00	7.80	8.40	9.00	8.50	9.20
IVA2	0.00	0.70	0.60	0.00	0.00	0.00	0.00
VA1	2.50	5.50	6.20	6.20	6.50	6.60	6.80
VA2	6.30	9.10	10.30	9.20	9.50	9.80	8.90
VIA1	3.70	6.80	7.40	7.90	8.40	8.00	8.50
VIA2	4.60	7.90	8.60	8.10	8.50	9.00	10.10
Con. A/B1	0.00	7.60	7.20	8.00	8.20	9.30	9.20
Con. A/B2	0.00	7.50	8.10	8.50	8.90	9.90	10.00
Week Mean							

Con. C	0.00	13.50	19.50	33.00	55.00	64.00	67.00

Plant	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	
IB1	2.30	6.50	7.70	7.50	7.90	8.40	9.20	
IB2	2.70	6.90	7.90	8.10	8.10	7.90	9.00	
IIB1	2.90	5.00	5.90	6.90	7.60	7.90	7.50	
IIB2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
IIIB1	2.50	6.60	7.00	7.50	8.00	8.40	9.90	
IIIB2	4.20	6.60	8.50	8.50	9.00	9.30	10.50	
IVB1	3.00	5.80	6.00	6.50	6.30	7.50	7.40	
IVB2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
VB1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
VB2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
VIB1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
VIB2	6.00	7.60	8.70	9.00	8.20	8.50	9.50	

Plant:	Week 1	Week 2	Week 3	Week 4	Week 5
Plant 1C	0	0	0	12.4	12.6
Plant 2C	0	0	0	0	0
Plant 3C	0	0.9	18	23	25
Control C	0	13.5	19.5	33	55