

Team Name: **BioCosmos Crew,**  
Team #: **(20529)**  
Team Coach: Zedaker & Ciucci



**TEAM PHOTO:**

**Background & Reasoning:** Throughout history, one of man's greatest accomplishments is going to space. Nowadays, many people are filled with curiosity about the Artemis mission which is said to take astronauts back to the moon. What if this time we could find a way to grow food on the moon so that astronauts could actually live there? This led the BioCosmos Crew to ponder about the weight hurdle of carrying plant materials to space. If we want to carry materials to space while on a budget, we have to restrict the weight of the materials. Because the soil is such a foundational component when it comes to planting we knew that this was what our team would measure. This curiosity and passion is why we chose to manipulate the amendments that we add to lunar soil. That's why we decided to experiment and finalize which supplement would help grow kale plants the most to reduce the weight carried and increase the proficiency.

**Hypothesis:**

*Our hypothesis was "If we utilize various amendments and manipulate the amount of supplements we add to the lunar regolith, then we will be able to confirm which component will work best to cultivate kale plants in lunar soil which will allow us to note what nutrients kale plants need the most and what they can do without so that scientists will be able to save both money and space." For instance, kale plants need areas with sodium, potassium and nitrogen. However, carrying all these nutrients in bundles to outer space will be inefficient and difficult, therefore we must decide which elements are truly necessary and which we will not need. This is what our experiment revolves around. Our background research: According to NASA's article "Scientists Grow Plants in Lunar Soil" by Bill Keeter, "Sequencing the RNA revealed the patterns of genes that were expressed, which showed that the plants were indeed under stress and had reacted the way researchers have seen *Arabidopsis* respond to growth in other harsh environments, such as when soil has too*

much salt or heavy metals.” This led us to think about the sodium levels we would be using. We predicted that plants in the sodium rich fertilizer would not grow as well as the other plants. Another article “*How to make lunar soil suitable for cultivation?*” highlights the importance of sterilizing lunar soil to prevent unwanted bacteria. It also states that “Statistical analysis revealed that most of the simulated lunar soils had higher Na and K contents, implying that plants would be subjected to more severe salt stress. For improvement options, the addition of organic matter and microorganisms is the best choice.” This and the aforementioned NASA article had one key point in similarity; the higher sodium content in lunar soil that led to salt stress. After reading and perusing these articles, our team decided that the supplements would be what mattered the most. We wanted to experiment with different nutrient levels in the supplements and try to see which additive would ease the stress levels in kale plants while being cost efficient and minimal amount of weight as possible.

### **Mission Patch:**



**Procedures and Experimental Design:** Below, there is a list of what our variables were and how we used them to test the accuracy of our hypothesis. Then we have the setup and measurements of each pot that are our evidence as to which supplement grows the best kale crops.

**Independent Variable:** The independent variable that our team manipulated was the amount of additive we include to the base lunar soil. In our control pot we kept it 100% lunar regolith with no additives of any sort. In pots 1-9 we added different percentages of plant supplements like compost, earth soil, and fertilizer. We distributed 3 pots to each of the 3 supplements and modulated whether we put 25%, 35%, or 45% of an additive into the three pots. We had to make sure that our calculations about the volume of the pot were accurate and aligned with the restrictions of adding no more than 50% of any extra mixture other than lunar soil.

After figuring out the volume of each pot, we then combined our mixtures and put them into their respective pots. We decided that exploiting the regolith would be the most beneficial method to determine how we could successfully grow plants in lunar soil.

**Dependent Variable:** The dependent variable that our team collected data on was how robust each kale plant is after the growth period ends. We will determine which pot produced the best kale plant by comparing the height of the plant, the amount of sprouts in a pot, and the amount of kale leaves a plant has.

**Control:** In our experiment, our control was the first pot. In this pot we put the lunar regolith mixture without any other soil type.

**Constants:** There were many important factors that we had to monitor as constants. These constants were kept as consistent as possible so that we would receive precise results.

We controlled the amount of UV light that the plants would absorb each day to a 12 hour cycle. We felt that this would be most similar to the Moon's lighting conditions which would help us get the utmost similar data as if we planted the seeds on the Moon.

The water is another key component that we tried to keep persistent. Our watering schedule included the irrigators of the team to water each of the ten pots every other day. We sprayed each pot 8 times and tried to make sure that the water was well spread out. The water was distilled and purified of any particles before spraying. Additionally, we added one pipette filled with 10 cm of distilled water to each pot for the weekend when we were unable to manually water the plants.

Other constants include the greenhouse and shelves where we placed the pots in, ( 5 pots on each greenhouse rack) the temperature of the plants' surroundings, (60°-70°) and the pot we used (standard pots sent in the PTMC jr. kit). Also, the kale seeds were also constants. (5 seeds in each pot.)

**Grow Pot Setup:**

Pot #	Pot #1(control )	Pot #2	Pot #3	Pot #4	Pot #5	Pot #6	Pot #7	Pot #8	Pot #9	Pot #10
<b>Soil composition</b>	100% lunar soil	75% lunar soil, 25% fertilizer	65% lunar soil, 35% fertilizer	55% lunar soil, 45% fertilizer	75% lunar soil, 25% earth soil	55% lunar soil, 45% earth soil	75% lunar soil, 25% compost	65% lunar soil, 35% compost	55% lunar soil, 45% compost	65% lunar soil, 35% earth soil
<b>Amendments</b>	Lunar soil	Lunar soil, fertilizer	Lunar soil, fertilizer	Lunar soil, fertilizer	Lunar soil, earth soil	Lunar soil, earth soil	Lunar soil, compost	Lunar soil, compost	Lunar soil, compost	Lunar soil, earth soil
<b>Crop type</b>	<b>Kale</b>	<b>Kale</b>	<b>Kale</b>	<b>Kale</b>	<b>Kale</b>	<b>Kale</b>	<b>Kale</b>	<b>Kale</b>	<b>Kale</b>	<b>Kale</b>

Along with this we also added 2% of alfalfa meal to every pot except for the control group to boost the nitrogen levels in the mixture and improve soil structure of lunar regolith.

**Data collection routine (procedure):**

Data was collected by two team members every other day for the entirety of the growth period.

**Beginning:** plant 12 kale seeds in each pot.(4 cm deep and each seed placed at least 5 cm apart.) Then cover the seeds with a thin layer of alfalfa meal.

**Growth Period Data Gathering:**

**Step 1:** Wear the PPE- masks, gloves, and lab coats.

**Step 2 :** Prep the materials- Ph meter, water spray, height measuring device, etc.

**Step 3:** Remove plants from the greenhouse and place them on the lab table.

**Step 4:** Collect data (ph levels, soil moisture, # of sprouts, and number of leaves” and post on the data collection sheet.

**Step 5:** Water the plants.

**Step 6** Place plants back into the greenhouse and check lighting.

**Data Collection/Results:**

Below are tables that have the data average of each experimental group at the end of the growth period.

**Compost Pots’ Results**

Pot #	Pot #5	Pot #6	Pot #10
Height (cm)	8.5 cm	9 cm	11.43 cm
Health 1-dead 5-healthy	4	5	5
Number of sprouts	4	8	7
Average # of leaves	2	3	5

In pot 7 we put only 25% compost and 75% of lunar soil. We believe this was why in this pot, the plants would sprout and grow healthy, but after a certain height they would bend over because the stems were unable to support the leaves. Pot 8 and pot 9 both produced healthy sprouts that quickly grew multiple leaves.

### Earth Soil Pots' Results

Pot #	Pot #7	Pot #8	Pot#9
Height (cm)	3.2 cm	4.18 cm	6.32 cm
Health 1-dead 5-healthy	4	4	4
Number of sprouts	2	2	3
Average # of leaves	1	2	1

In this experimental group, the sprouts were quite healthy but their progress in growth wasn't high compared to the compost group. We believe that this is possibly because the earth soil wasn't able to maintain the required amount of nutrients for the plants when it was combined with the lunar regolith.

### Fertilizer Pots' Evaluation

Pot #	Pot #2	Pot #3	Pot #4
Height (cm)	0 cm	0 cm	0 cm
Health 1-dead 5-healthy	0	0	0
Number of sprouts	0	0	0
Average # of leaves	0	0	0

These results really shocked us. In all of the fertilizer pots not even one seed sprouted. We treated each experimental group the exact same way, but the only thing different about these pots was that we added fertilizer. Although we don't know for sure what the conflicting results were caused by, we infer that the lunar regolith didn't combine with the fertilizer well and caused the seeds to not receive the necessary amount of nutrients.

Lastly, our control pot. In pot 1 we did have two sprouts but they wilted within a day of germinating. Our team supposes that the reason for this unexpected sprouting was the 2% of alfalfa meal we added. Since the alfalfa meal was just on top of the seeds, some of the seeds were able to germinate through that. We assume that the sprouts died when the roots entered the lunar soil and didn't get any nutrients they needed.

### **Analysis:**

At the end of the growth period, our team took time to reflect on the experiment's journey together. When we thoroughly reviewed our data, we came to a deduction that kale plants with any amount of compost grew the best. The compost we implemented into the pots was one rich in nitrogen and potassium which were two very important elements that kale plants need. Since our dedicated team members collected data every other day and used expert-level data collecting tools, we believe that it would be safe to say that our data collection was consistent and reliable.

**Conclusions:** In our hypothesis, we stated that experimenting with different soil supplements would help our team determine which additive combined with lunar soil and provided the necessary nutrients the best without causing sodium stress for the plants. Our hypothesis was proved accurate by our experiment results. We can conclude that using 35% or more of compost to lunar soil allows plants to receive the essential nutrients they need because as shown in the above tables, the pots with composts produced the healthiest kale plants which also had bigger leaves.

Even though discovering the best supplement was our primary goal, this experiment taught us many other attributes about extraterrestrial conditions and how plants need to be nurtured in certain ways for them to truly flourish. For instance, lunar soil, which lacks nutrients, would turn into a concrete like substance when it made contact with water. This was a hurdle because if the water wasn't able to soak into the soil, then the seeds wouldn't be able to sprout. We had to devise methods like using pipettes to get the water all around the pot so that plants could germinate without trouble.

### **Future Considerations:**

In the future, if we were to do this experiment again, one of the major points would be to consistently water the plants. Due to the prolonged breaks, we were unable to water the initial seeds. This caused them to die and we had to replant. Although replanting was successful, we wasted valuable resources like time and money to replant. When using lunar soil, it would also be helpful to use slightly bigger seeds; we discovered that the kale seeds, which were bigger than arugula seeds, germinated quicker due to the toughness of the shell. The shell was able to withstand the grains of the lunar soil and sprout without trouble. The best seeds to plant in lunar soil would be bean seeds, cabbage seeds, or kale seeds. Knowing what seeds to plant beforehand would have helped our

experiment tremendously, because it would have increased the growth of the plant quicker.

**Experimental Rational:** Our experiment and outcome helps scientists determine what amendment is best for plant growth in lunar conditions so that they don't have to. This will allow botanists and scientists to better understand what types of plants resist the challenges placed by the grainy lunar soil and how we can support the plants growth in various conditions.

**Experiment Photos:**



**Message from Project Manager:** I would like to take this opportunity to express my gratitude to my team members who have so dedicatedly spent their time and efforts into this experiment. I would also like to thank my coaches Mrs. Zedaker, Ms. Ciucci, and Ms.

**Demille for presenting me with this project and allowing me to fulfill my aspirations of doing something practical for the space and science community. Most of all, thank you to NASA, ICS, and the Virginia Space Grant Consortium for acknowledging the passions of kids like me and supporting our dreams. I was and still am thrilled about this chance and look forward to many possibilities like this one.**