

# **The Effect of Lunar Regolith on Oriental and Herbaceous Species Plant Growth**

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## **Background:**

Plants can enhance social, physical, psychological, cognitive, environmental, and spiritual well-being. For astronauts to perform at their best away from Earth, their working environment should provide benefits to those 6 areas of well-being. Many past Plant the Moon experiments have grown consumable or nutritional plants, which most directly contribute to an astronaut's physical well-being. However, the mere presence of plants also induces positive psychological effects such as reducing anxiety, stress, and depression while increasing memory retention, creativity, productivity, and attention span. Additionally, according to an experiment by Vedder and their colleagues in 2015, non-beautiful environments induce more mental processing and stress on the mind than beautiful environments. While beauty is subjective, humans also have an innate tendency to seek connections with other forms of life, a trait defined as biophilia. Likewise, the more lush and healthy a plant is, the more likely it is to induce positive psychological effects. As such, this experiment was conducted to test how well oriental and herbaceous plants could grow in the presence of lunar regolith. For the oriental plants, Kong Rose coleus and English lavender were chosen, and for the herbaceous plants, peppermint and Italian basil were chosen.

Some benefits of lavender include improving sleep, anxiety, headaches, acne, and dry skin. Lavender is commonly used in aromatherapy for headaches and muscle pain, relieving menopausal symptoms such as hot flashes, reducing blood pressure, and helping with asthmatic symptoms. Peppermint can help with digestion, headaches, memory, and decongesting your nose during allergic reactions. Peppermint is also used to help soothe coughs. Italian basil mediates anxiety and depression, helps people think clearly, and helps prevent age-related memory loss. Lastly, while Kong Rose coleus cannot be eaten, its presence can still induce positive mental effects. Adult Kong Rose coleus plants have wide leaves with vibrant colors, which are traits that can constitute as 'beautiful' that would stimulate a positive mental response.

Coleus prefers an NPK of 10-10-10 and a pH of 6-7. Peppermint prefers an NPK of 20-20-20 and a pH of 6-8. Lavender prefers an NPK of 20-10-10 and a pH of 7-9. Basil prefers an NPK of 10-10-10 or 12-12-12 and a pH of 5.5- 6.5.

## **Experimental Design:**

The growing area was set up in the greenhouse at the Chesterfield Career and Technical Center Courthouse campus. Temperature and relative humidity were measured weekly using a Govee Smart Thermo-Hygrometer. The experiment was set up on top of a table in the campus' greenhouse. To germinate the plants, seedling trays with 2.54 cm diameter pots were cut into sections of 6 pots for each plant species and their corresponding control. Each plant had 6 experimental pots and 6 control pots. Once the plants sprouted, they were moved into 6.35 cm diameter pots and labeled accordingly by plant species and test group. Each well had a label numbered 1 through 6 to denote its pot number. All of the pots were washed and sanitized with Hilliard Sanitizer spray before the respective growing medium was added. Three seeds each were planted in each pot except Coleus, which only had one seed per pot due to supply availability. Coleus and Peppermint seeds were pressed onto the soil surface, English Lavender seeds were planted at 0.318 cm depth, and Italian Basil seeds were planted at 0.635 cm depth in the soil. Experimental pots contained 50% lunar regolith and 50% Miracle-Gro Garden Soil as an additive by volume, and control pots contained 100% Miracle-Gro Garden Soil by volume. Other than the Miracle-Gro soil, which already included mulch, no other amendments were added. In total, control pots contained 3.31 L of Miracle-Gro soil, and experimental pots contained 1.66 L of lunar regolith and Miracle-Gro soil each. An in-depth analysis of soil composition was conducted by Waypoint Analytical for both the Miracle-Gro Garden Soil and 50/50 lunar regolith and soil blend. Results of the analysis can be seen in Appendices A and B. Pots were put on top of a seedling heat mat to stimulate germination and set under grow lights with timers to offset shorter winter daylight. All grow lights were set to 12 hours from 6am to 6pm. A plastic tarp measuring 610 cm by 366 cm was draped over the grow light setup to help control temperature and humidity.

While still in their germinating pots, plants were watered via spray bottle every day when possible, keeping within 20 sprays or until the topsoil appeared moist but not watery. Once transferred to the larger pots, a wick watering system was set up by cutting a cotton wick cord into sections of 15.24 cm, threading the rope through the bottom of the pots while leaving some cord outside the bottom of the pot, and then setting the whole planting tray in another tray with standing water in it. Water was added to the system every odd numbered school day or when the tray appeared close to drying up. The wick watering system was to ensure that the plants stayed watered over the weekend and in case of school closures. Photos were taken and plant height and leaf width were measured every available odd numbered school day. Soil pH and soil moisture was measured when the plants were moved to the larger pots since the pH probe purchased for the test was too big to fit in the smaller germinating pots.

Plant height and leaf width were measured with a ruler for each plant in centimeters, and soil pH and moisture were measured using a Sonkir 3-1 Soil Moisture/Light/pH Tester following the instrument's instructions. For the sake of time, only 1 pot per test group was probed for pH, and its value was assumed to be the same for the rest of the pots in that group. At the end of the growth period, plants were gently taken from their pots, washed of soil from their roots, dried in an oven at 70°C overnight, and then weighed on a scale for final dry plant weight. Plant height, leaf width, soil pH, soil moisture, and final dry weight data was recorded on Google Sheets, and averages were calculated for plant height, leaf width, and final dry weight. With the data, line graphs were made for average plant height and leaf width over time, and a bar graph was made for final average dry weight. In case of school closures, the team coach went to the greenhouse location to water the plants and record the appropriate measurements as described above.

#### **Pictures of the Growing Set Up:**



The initial growing set up



Installing the wick watering rope

#### **Hypothesis:**

If Kong Rose coleus, English lavender, peppermint, and Italian basil are grown in a mix of 50% regular soil and 50% lunar regolith, then peppermint will show the most growth.

#### **Independent Variables:**

Our independent variables were the different plant species, which were peppermint (*Mentha piperita*), Italian basil (*Ocimum basilicum*), kong rose coleus (*Solenostemon scutellarioides*), and English lavender (*Lavandula angustifolia*), and the soil mixture, which included 100% normal soil for the control and a 50/50 blend of normal soil and lunar regolith for the experimental group.

#### **Dependent variable:**

Our dependent variable was plant growth in terms of plant height, leaf width, and final dry mass.

#### **Measurements:**

To measure plant growth, we measured plant height in centimeters, leaf width in centimeters, and final dry mass in grams. The plants chosen for the experiment generally express healthy growth in differing ways,

such as lavender showing growth in height and coleus showing growth in leaf width. As such, while these measurements were taken for each species, each species was judged separately according to its species average.

**Controls:**

The controls for the experiment were the 6 pots of 100% normal potting soil per plant species.

**Results:**

Plant heights for lavender were 0 cm on average across all 50/50 pots, and only one lavender plant grew in the control pots which resulted in an average height for the control pots of around 0.291 cm. Leaf widths for lavender were 0 cm on average across all 50/50 pots and around 0.05 cm on average for the control pots. The final average dry plant mass was 0 g across the 50/50 pots and 0.002 g on average for the control pots.

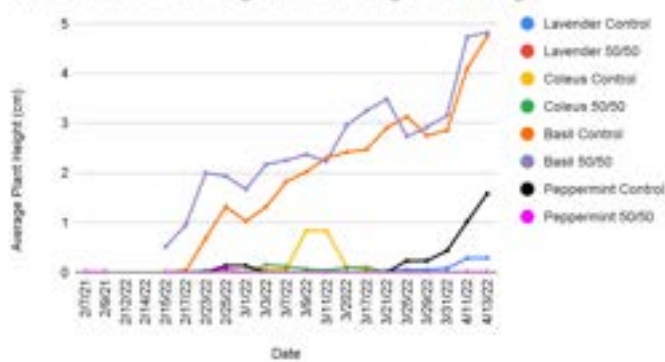
Plant heights for coleus were 0 cm on average across all control pots and 50/50 pots. Leaf widths for coleus were also all 0 cm on average across all control pots and 50/50 pots. The final average dry plant mass was 0 g across the 50/50 pots and 0 g on average for the control pots. While some of the coleus plants did end up growing in both types of soil, they died out around mid-March.

Plant heights for basil were 4.82 cm on average across all 50/50 pots and 4.74 cm on average across all control pots. Leaf widths for basil were 1.2 cm on average across all 50/50 pots and 1.58 cm on average across all control pots. The final average dry plant mass was 0.122 g across the 50/50 pots and 0.102 g on average for the control pots. Only 1 basil plant in the 50/50 blend died by the end of the growth period.

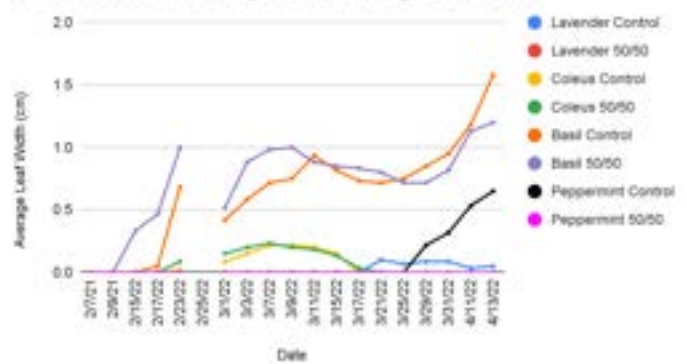
Plant heights for peppermint were 0 cm on average across all 50/50 pots and 1.58 cm on average across all control pots. Leaf widths for peppermint were 0 cm on average across all 50/50 pots and 0.65 cm on average across all control pots. The final average dry plant mass was 0 g across the 50/50 pots and 0.015 g on average for the control pots. Only around half of the peppermint plants grew in the control pots, and none ended up surviving in the 50/50 pots by the end.

The data written here describe the averages calculated at the end of the growth period. For a more detailed graph of the averages over time (aside from final dry mass), see the graphs below.

The Effect of Lunar Regolith on Average Plant Height

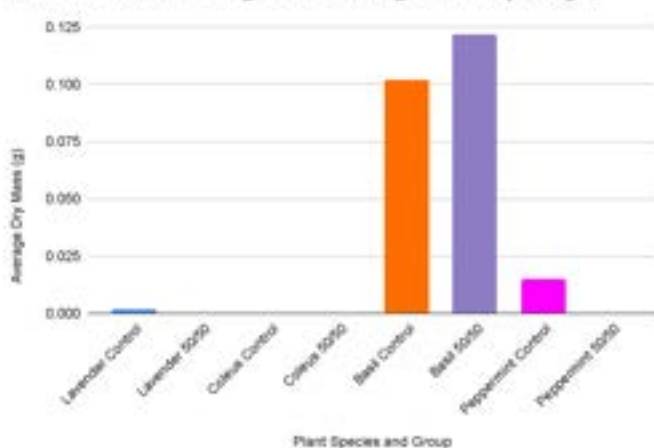


The Effect of Lunar Regolith on Average Leaf Width



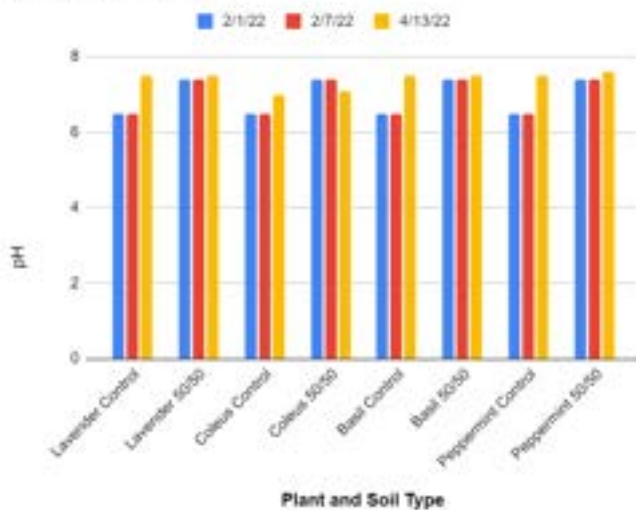
Note: No data was collected for all plants on 2/12/22 and 2/14/22, and 2/25

The Effect of Lunar Regolith on Average Final Dry Weight

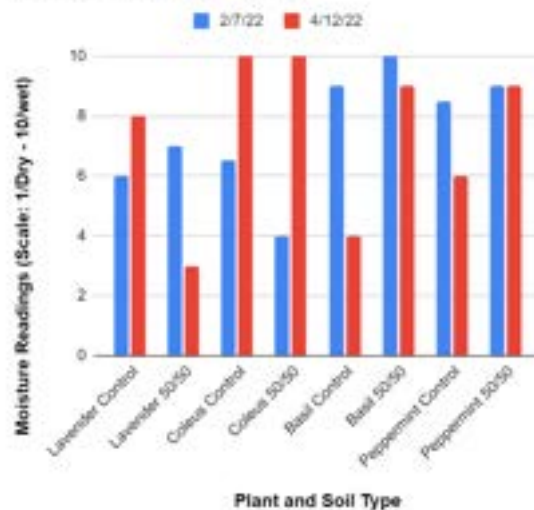


Other observations made during the experiment were that most of the seeds in the 50/50 blend germinated first out of all of the plants. Additionally, plant growth seemed to be stunted before the plants could be moved to larger pots.

pH Measurements



Moisture Measurements



Preliminary soil testing before the seeds were planted yielded pH results of 6.5 and 7.4 for regular soil and 50/50 regular soil and lunar regolith mix respectively. The results of this preliminary soil testing can be viewed in Appendices A and B.

A soil percolation test was also attempted after final measurements were taken. To perform the soil percolation test, 1.18 L of each soil type were put into pots with holes at the bottom, and then 500 mL of water was run through each pot for 5 minutes. Visual observations were noted. The control soil drained slower than the 50/50 soil at first, but all of the water drained out of the control soil by the end of the 5 minutes while water in the 50/50 soil pooled. Less soil washed out of the control pot than the 50/50 pot, and the final texture for the control soil was moist while the texture for the 50/50 soil was very watery and soupy. It was observed that mulch from the regular soil from the 50/50 mix clogged the holes of the pot, which most likely caused the water to pool in the 50/50 pot.

### **Discussion and Conclusion:**

The hypothesis predicted that peppermint would grow the most, but it turned out to be basil. This is surprising because research suggested a 5.5-6.5 optimal soil pH range for basil while the soil was consistently around 7.5 for the 50/50 blend. While the nutrient composition of the soils was analyzed, it was not factored into the hypothesis due to the complexity of the data. Perhaps the nutrient composition was more suited for basil than the other plants, but basil seems more able to grow with lunar regolith present than the other chosen plants. Most of the plants in other pots did not survive or grow to more advanced adult stages, so analyzing plant growth based on the other chosen metrics of leaf width and final dry weight was practically unnecessary.

In lower gravity, the wick watering system used in this experiment would have to have a closed water reservoir so that water would not float away. Plants grown on the ISS have been observed to have similar root growth to plants grown on Earth, so the root systems of the plants we used would likely not be as affected by lower gravity. Without gravity as a guide, a gradient of light may act as a secondary indicator to tell the plants how their roots should grow, so the lighting system would have to be taken into more consideration on the moon. It has also been observed that plant hormone signaling changes in lower gravity to develop other ways of sensing the environment, such as loosening their cell walls or letting their roots detect light. As such, lower gravity may not be as much of a detriment to plant growth as it seems. However, if plant cell walls are loosened in lower gravity, more structural support may have to be provided to the plants to prevent them from drooping.

Some improvements that could be made to the experiment include making the beginning pot size bigger because the smaller pots likely stunted the plants' growth. The location of where the plants were grown could also change because the plants were not accessible at all times, and the greenhouse was inconsistent in temperature and humidity with temperatures ranging from 4°C to 38°C. The additive soil could also be changed for one that's more lightweight instead of a mulchy compost potting soil blend so that seeds are not obstructed. For one variation of the experiment, different species of basil could be grown since basil grew so well.



**Appendix A: Waypoint Analytical Soil Analysis - Miracle-Gro Garden Soil and Lunar Regolith Mix (50/50 blend)**




**Appendix B: Waypoint Analytical Soil Analysis - Miracle-Gro Garden Soil**



Appendix C: Weekly Plant Photos

Week	Soil	Basil	Lavender	Coleus	Peppermint
1	Control				
	50/50				
2-3	Control	 <i>*Germinated 2/18</i>			
	50/50	 <i>*Germinated 2/16</i>			
4-5	Control				
	50/50				

7-8	Control				
	50/50				
9-10	Control	  <p><i>*100% germination</i></p>	 <p><i>*16% germinated</i></p>	 <p><i>*2 germinated plants died during week 9, no plants survived</i></p>	 <p><i>*50% germinated but little growth</i></p>
	50/50	  <p><i>*100% germinated but 1 plant died during week 9</i></p>	 <p><i>*0% germinated</i></p>	 <p><i>*2 germinated plants died during week 9, no plants survived</i></p>	 <p><i>*0% germinated</i></p>

	Date:	2/7/21	2/9/21	2/15/22	2/17/22	2/23/22	2/25/22	3/1/22	3/3/22	3/7/22	3/9/22	3/11/22	3/20/22	3/17/22	3/21/22	3/25/22	3/29/22	3/31/22	4/11/22	4/13/22	
Plant Type	Plant #	Height (cm)	Height (cm)	Height (cm)	Height (cm)	Height (cm)	Height (cm)	Height (cm)	Height (cm)	Height (cm)	Height (cm)	Height (cm)	Height (cm)	Height (cm)	Height (cm)	Height (cm)	Height (cm)	Height (cm)	Height (cm)	Height (cm)	
Lavender	Control 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Control 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Control 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Control 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Control 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Control 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0.3	0.3	0.5	1.7	1.75
	Control Avg.	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0333	0.05	0.05	0.083	0.283	0.291	
	50/50 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	50/50 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	50/50 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	50/50 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	50/50 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	50/50 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	50/50 Avg.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Notes			0					3/3 - Lighting changed to 12hrs/d						Fungus on Lav 50/50 4	Fungus on Lav 50/50 4 is gone					
Coleus	Control 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Control 2	0	0	0	0	cotyledon	>1cm	cotyledon	0.1	0.2	0.2	0.2	0.3	wilted	0	0	0	0	0	0	
	Control 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Control 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Control 5	0	0	0	cotyledon emergence	0.1 cm	0.1 cm	0.1 cm	0.2	0.2	0.3	0.3	0.4	0.05	wilted	0	0	0	0	0	
	Control 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Control Avg.	0	0	0	0	0.01666	0.01666	0.01666	0.05	0.0666	0.83333	0.83333	0.116666	0.05	0	0	0	0	0	0	
	50/50 1	0	0	0	0	cotyledon		0.3	0.4	0.3	Wilted	0	0	0	0	0	0	0	0		
	50/50 2	0	0	0	0		cotyledon	cotyledon	cotyledon	cotyledon	cotyledon	0.1	wilted	0	0	0	0	0	0		
	50/50 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	50/50 4	0	0	0	0	0	0	0	0	0	0	0	cotyledon	cotyledon	0.1	0	0	0	0		
	50/50 5	0	0	0	cotyledon emergence	0.2 cm		0.4	0.5	0.4	0.4	0.2	0.5	wilted	0	0	0	0	0		
	50/50 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	50/50 Avg.	0	0	0	0	0.03333		0	0.15	0.116666	0.0666666	0.03333	0.1	0.1	0	0	0	0	0		
	Notes								Lighting changed to 12hrs/day on 3/2/22	Coleus 50/50 1 plant seems to have shrunk a little	50/50 1 has wilted			noted plants wilting	Extreme wilting on coleus plants						
Basil	Control 1	0	0	0	0	0.3 cm	1.5	0.9	1.2	1.4	1.6	1.6	1.8	1.9	2.5	2.6	2.6	2.7	4.5	5	
	Control 2	0	0	0	cotyledon emergence	0.8 cm	1.7	1.7	2.3	2.6	2.9	3.2	3.1	3.1	3.7	3.8	3.9	3.1	4.2	4.75	
	Control 3	0	0	0	0	0.9	1.5	1.4	1.9	2.1	2.2	2.5	3.2	3.2	4.2	4.3	4	3.7	5.2	5.5	
	Control 4	0	0	0	0	0.9	1.1	1.2	1.6	1.9	2	2.3	2.2	2.3	2.3	2.9	1.9	2.6	3.8	4.5	
	Control 5	0	0	0	cotyledon emergence	0.2	1.3	1.4	1.3	1	1.8	1.9	2.3	2.3	2.3	2.9	2.5	3.2	3.7	4.5	
	Control 6	0	0	0	0	0.8	1.8	0.9	1.2	1.2	1.5	1.9	1.9	2	2.4	2.3	1.6	1.8	3.2	4.2	
	Control Avg.	0	0	0	0.03333	0.68333	1.32	1.03	1.32	1.82	2.02	2.3	2.41666	2.47	2.9	3.13	2.75	2.85	4.1	4.74	
	50/50 1	0	0	0.6	1.1	2.2	1.8	1.3	1.7	1.8	1.8	1.7	3.2	3.2	3.3	2.4	2.5	3.5	5.2	6	
	50/50 2	0	0	0.6	1.2	1.8	1.7	1.5	2.3	2.3	2.2	2.6	2.4	3	3.1	3.3	3.9	4.2	6.5	6	
	50/50 3	0	0	0.7	1	1.6	2	1.4	2	2	2.1	2.3	1.9	2.7	3.4	3.3	3.1	2.8	4.3	4.2	





