

Space Fried Rice 2025-26: Monitoring Rice Growth in Lunar Regolith

Wesley Taylor, Gwen Dreeszen, Gabriel Perez-Soler, Ana Garza, Forrest Champlin, Shaelyn Selph,
Noah Smith, Mimi Telford, Melissa Heng, Rina Axtell-Aretz

Red Rocks Community College Plant the Moon 2025-2026

Mentors: Dr. Lynne Albert Lynne.Albert@rrcc.edu and Tyler Williams Tyler.Williams@rrcc.edu

Abstract

This Red Rocks Community College 2025-26 Plant the Moon project explored rice plant growth with different proportions of lunar regolith, potting soil, and the effects of water sources on plant health. Lunar regolith could serve as a potential growth medium for future lunar agriculture. The simulated lunar regolith used is mostly composed of anorthosite and silica, as well as other molecules composed of metal cations and oxygen anions. This mimics the mineral makeup and terrain of the lunar highlands to simulate experimental rice plant growth. The lunar regolith was divided into three different growing media compositions: 100% lunar regolith, 100% potting soil, and a 50% mix between the two media. Each combination of growth medium was watered with one of two different water-nutrient mixtures: run-off water from an existing aquaponic system or distilled water with a 2.34% concentration of all-purpose liquid fertilizer. This combination of variables yielded 6 experimental groups. Each experimental group had 3 growing pots of rice plants, leading to a total of 18 replications. The combination of 100% lunar regolith and aquaponic water grew the tallest rice plants, supporting the original hypothesis of this experiment that paddy farming rice with lunar regolith and aquaponic water would in fact yield the highest growth.

Introduction

For millenia, humanity has expanded its knowledge through exploration as a means to understand the world around them. As humanity modernized, science expanded its gaze to the cosmos. As humanity continues to explore space, and long term space missions become a fast approaching reality, the question of living systems on different planets becomes a crucial scientific inquiry. This sparks a large open-ended discussion of life in space, and the requirements for agriculture to support life. In order for human life to thrive in space, nutrition is a necessity. This project aims to look at the potential of supporting rice growth in future moon colonies. This experiment uses lunar regolith as an agricultural substrate with the hope that future researchers might find ways of making it a safe and efficient media for agriculture.

This experiment also investigates how the interaction of aquaponics and fertilized water with the different substrate compositions could affect conditions for the growth of the rice plants. Aquaponics is a subtype of aquaculture where plants and fish live symbiotically in an enclosed aquatic system. The fish waste is purified by the plants which use the waste as fertilizer. This cleans the water and gives a healthy environment for the fish to thrive, providing a potential added protein source for the farmers. The laboratory has an active aquaponics system, and run-off from the system was used to water the rice.

Data from a previous year indicated water concentration varied greatly between soil and regolith (Albert, L., et al., 2024). Rice is grown in standing water, and was selected because standing water alleviates the difference between water soil saturation between soil types.

Methods and Materials

Materials

This experiment used simulated lunar regolith from the Plant the Moon Challenge and Garden Kellogg Organics' all natural indoor potting mix for the different soil types. Plastic nursery pots were used to plant. A two-chambered system was devised with these pots, with the top pot holding the soil and plant and the bottom pot serving as a water reservoir. Ziplock bags were used to seal the holes of the bottom pot, cheese cloth was used to line the upper pot to prevent soil erosion,

and cotton wicks were used to connect the soil pot with the water reservoir, allowing for better water regulation. The water used for the rice plants was sourced either from the aquaponic fish tank in the Red Rocks CC IDEA Lab or by mixing distilled water with Garden-wise 10-10-10 Plus all-purpose liquid fertilizer, which is an ammonium based fertilizer. The rice seeds themselves were *Oryza sativa*, bought in bulk from an online store.

Methodology

A literature review was done on the plant to be selected for this experiment, determining a rice species would be used as it favors paddy-farming. The rice grows at a preferred temperature of 70° - 99°F, with an average growth time of 110-150 days to seed, and favors loamy, silty, clay-like soil with high water retention. Preferred pH for rice growth is from 5.5-6.5. Temperature of the room was not monitored, but pH was recorded weekly. To provide controlled lighting for the plants, 12 broad-spectrum grow lights were installed as the lab.

While handling the lunar regolith and garden soil, gloves and surgical masks were used for safety, and measuring and potting the substrate was performed under a fume hood. The initial watering was also performed under a fume hood.

The pots were labelled according to composition of soil and the type of water used, ie: regolith/aquaponic, soil/fertilizer, etc. Each pot contained 200 grams of total substrate. Within the 50/50 combination, the pot contained 100 grams of regolith and 100 grams of soil, which was mixed together with a sterile tongue depressor.

In total, 18 pots were set up, with 6 pots each for every soil type; as labelled above. The pots were then further bisected into groups of 3, with half of each soil group watered with a different water type - either the aquaponics water or the liquid fertilizer and distilled water. This allowed for replicable results for each soil and water combination, with six groups of three pots.

To begin the growth of the rice seeds, germination was initiated in a Ziplock bag, which contained paper towels saturated with distilled water. Once the seeds had sprouted, they were placed into the prepared pots. For the first month and a half of plant growth, the pots were kept supersaturated with their specific water types. After which the frequency of watering was lessened to mimic paddy farming.

Water Acquisition

The two types of water were gathered and mixed by the team as needed - about once per week. The aquaponics water was gathered through a siphon, extracting 5 gallons of water from the fishtank,

which was then placed into glass jars and stored for watering. The distilled water and fertilizer combination was made by following the instructions on the bottle for the recommended ratio to fertilize lawns: 23.4 mL/1 L of water. The components were mixed before being placed into glass jars for storage. The watering was performed with an automatic pipet and 25 mL pipet tips.

Data Collection Criteria

The plants were measured with consideration of three main factors. The first factor was the height of the plant above the soil in centimeters with a ruler, which was measured weekly. The second was pH, which was measured weekly except for two of the weeks during the growth period where conditions measuring pH were not possible given materials at hand. The third was mass, which was measured only at the end of the experiment. After the plants were removed from soil and thoroughly rinsed, the mass was measured with a precision scale in milligrams. Qualitative observations were recorded in an experimental journal over the trial. Cumulative soil samples from each of the six experimental groups were collected weekly over the last four weeks of the trial. It was intended that root length would also be measured, but this criterion became difficult as some pots inhibited growth and extracting full roots from some of the substrate mixtures without causing damage was unlikely.

Results

Height

Across all treatments, seed germination and height growth varied markedly with substrate composition and water source. The most robust seedling growth occurred in the 100% synthetic lunar regolith mixture supersaturated with aquaponic water. In particular, rice seedlings grown in a regolith supersaturated with aquaponic water reached greater heights than seedlings in any other condition, indicating that aquaponic nutrients may have interacted in unknown ways with the regolith (Figure 1).

Paddy farming was generally successful across treatments, with the exception of the 50:50 soil–regolith mixture watered with aquaponic solution, where no seeds sprouted (Figure 1). In all the pots, there developed bacterial and algal biofilms, with the thickest biofilm on the 50:50 soil–regolith mixture watered with aquaponic solution. Interestingly, the same 50:50 mixture did support rice growth and developed less film when supersaturated with fertilized water (Figure 2), suggesting that the interaction between aquaponic water and this particular substrate ratio may inhibit emergence.

Seedling height was further reduced across both fertilizer and aquaponic treatments in the 50:50 soil–regolith condition, highlighting this substrate combination as consistently unfavorable for early growth. The standard deviation for the average growth in each pot is presented in Table 1 to showcase the large differences.

Growth per Sprout for Each Soil-Water Combination

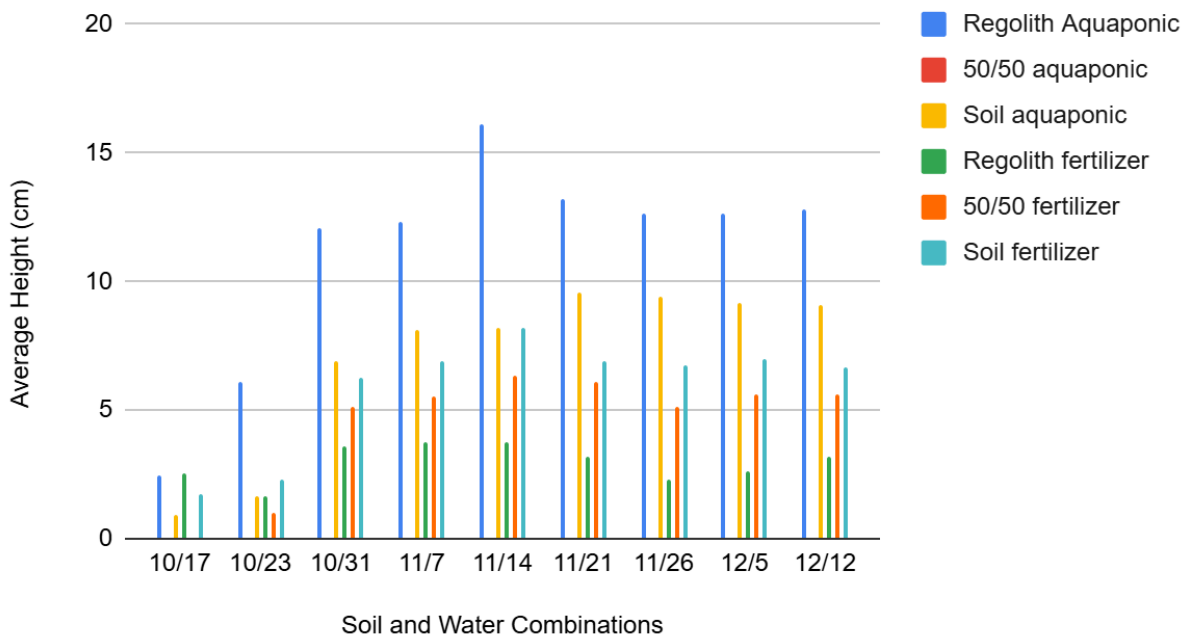


Figure 1. Shows the average height of the seedlings in each condition over time. For most of the growth period the seedlings watered with aquaponic water and grown in regolith were tallest.

Average Growth/Sprout/Soil Type (cm)

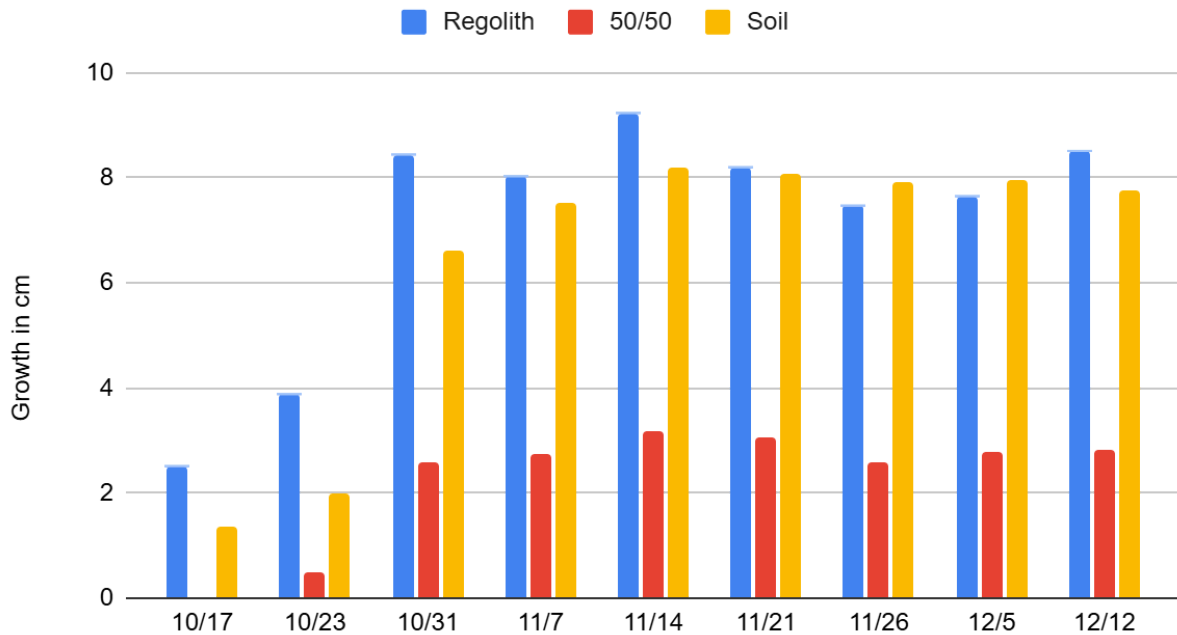


Figure 2. Shows the average height of the seedlings grown in each condition regardless of water-type. The figure shows that seedlings grown in 50/50 soil and regolith were inhibited.

Table 1. Average Height in cm of sprouts in each pot. The standard deviation for the average seedling height in each condition is included.

Average Growth per sprout				
10/17	Aquaponic	Standard dev.	Fertilizer	Standard dev.
Regolith only	2.475	2.0854465576	2.55	1.204159458
50/50	0	0	0	0
Soil only	0.9	0.8544003745	1.7	2.023198787
10/23	Aquaponic	St. Dev.	Fertilizer	St. Dev.
Regolith only	6.1	4.293017587	1.666666667	1.154700538
50/50	0	0	1	1
Soil only	1.666666667	1.527525232	2.333333333	3.214550254

10/31	Aquaponic	St. Dev.	Fertilizer	St. Dev.
Regolith only	12.0875	4.505991382	3.583333333	3.105774192
50/50	0	0	5.166666667	5.0083264
Soil only	6.875	4.888336459	6.25	5.48292805
11/7	Aquaponic	St. Dev.	Fertilizer	St. Dev.
Regolith only	12.34	6.712525605	3.72	2.415988411
50/50	0	0	5.5	4.924428901
Soil only	8.15	5.546470349	6.9	5.7218878
11/14	Aquaponic	St. Dev.	Fertilizer	St. Dev.
Regolith only	16.1	4.175324339	3.74	2.399583297
50/50	0	0	6.333333333	5.575242895
Soil only	8.225	6.311563462	8.2	7.907380519
11/21	Aquaponic	St. Dev.	Fertilizer	St. Dev.
Regolith only	13.18	7.048545949	3.22	2.112344669
50/50	0	0	6.133333333	5.387330817
Soil only	9.6	6.812243879	6.88	7.143318557
11/26	Aquaponic	St. Dev.	Fertilizer	St. Dev.
Regolith only	12.68	6.970796224	2.26	2.328733561
50/50	0	0	5.166666667	4.48144322
Soil only	9.425	6.660517998	6.74	6.827737546
12/5	Aquaponic	St. Dev.	Fertilizer	St. Dev.
Regolith only	12.68	6.965414561	2.62	2.705919437
50/50	0	0	5.6	4.850773134
Soil only	9.175	6.637456842	7	6.670832032
12/12	Aquaponic	St. Dev.	Fertilizer	St. Dev.
Regolith only	12.78	6.843390972	3.175	2.553918558
50/50	0	0	5.633333333	4.891148468
Soil only	9.125	6.637456842	6.7	6.088924371

pH

Despite these differences in germination and growth, pH remained stable around a pH of 7 to 8 across all treatments, showing no significant shifts attributable to substrate composition or nutrient source (Figure 3).

Average pH across all experimental groups over time

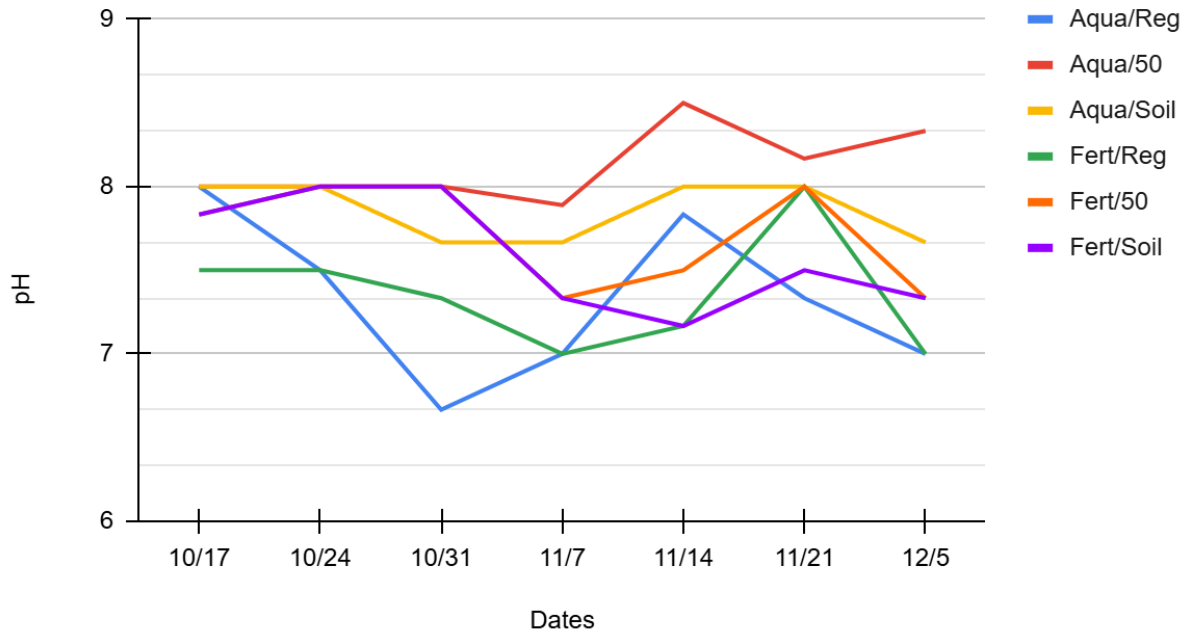


Figure 3. Shows the average pH of each experimental group across the growth period. pH across the entire experiment stayed between 6.5 and 8.5, lying outside the preferable pH range for optimal rice growth.

Mass

In terms of the overall weight of biomass that resulted from the rice seeds, there was initially no noticeable trend. When consideration shifted to the weight of only plants that developed roots and shoots, trends followed similar patterns to the height measurements (Figure 4). The combination that produced the highest shoots similarly had a larger total biomass amount, measured in milligrams. The 100% regolith supersaturated with aquaponic water had the most accumulated mass, however it is followed by the 100% soil supersaturated with fertilizer water, rather than the soil watered with aquaponic water. The remainder of the pot combinations had relatively similar values to one another, and the 50:50 combination supersaturated with aquaponic water, which showed no visible growth above soil, lacked any sprouted biomass of any kind.

Biomass of Growth of all Experimental Groups (mg)

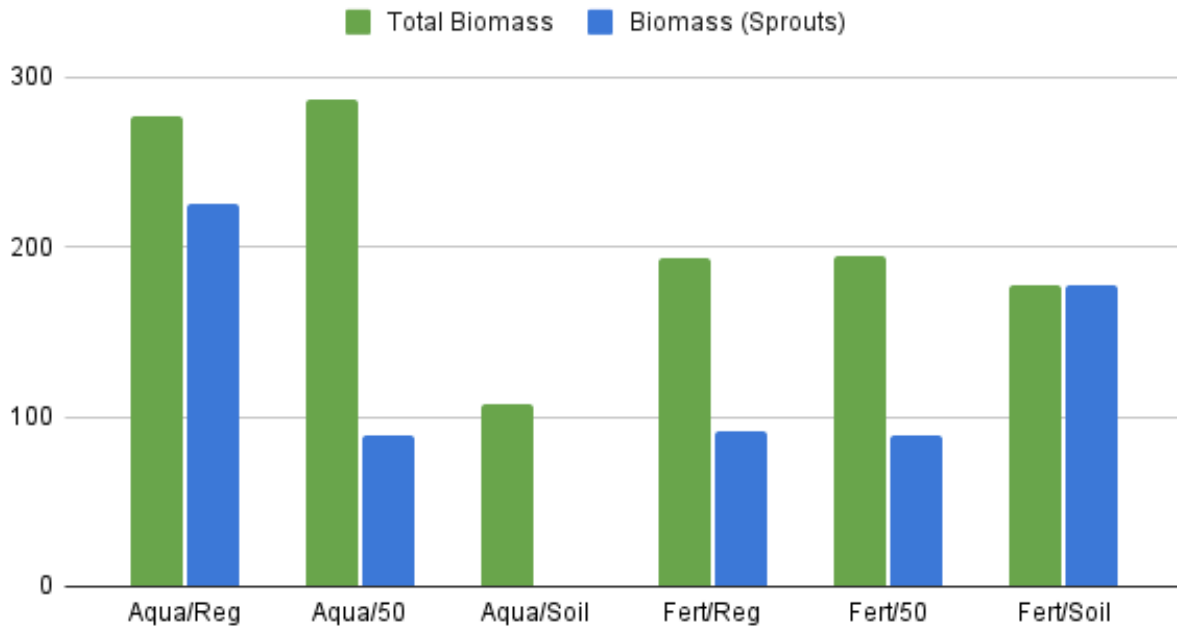


Figure 4. Presents both the biomass of shoots and seeds (Total Biomass) compared to the biomass of the sprouted plants (Sprouts) alone. The difference between each measured group represents the amount of total mass that is occupied by un-sprouted seeds alone.

Error

There were several possible sources of error during the trial. Almost all of the pots developed biofilms of some kind and the full profile of species in those films is unknown. There may have been interactions between these microbial communities and the experiment. Watering was also somewhat inconsistent over the trial, with the pots being watered between 2 to 5 times a week depending on apparent saturation levels and team availability. One other possible source of error is that the growing space may have been too cold and dry for this crop. Rice is accustomed to more tropical climates, and while the room was a comfortable temperature, it still may have not been ideal. The experiment did not yield sound data for plant biomass for two reasons: it didn't occur to the research group to collect the initial biomass of the seeds going into the pots, and retrieving all of the specimens intact out of the different substrates proved difficult. Toward the end of the growth period, some plants became somewhat brittle, resulting in further loss of biomass. As final mass was measured, some experimental groups that had only seeds with no growth ended up with more biomass than groups that had full plant growth. Finally, the group did not adequately determine a number for the amount of seeds per

pot, so the total number ended up with a range of seeds, which caused uncertainty regarding the amount of biomass to be measured and the amount of opportunity present for seeds to grow. More seeds in a given pot would provide an additional chance for a successful sprout and enable some combinations to appear to grow more than others.

Discussion

The research group set out to investigate rice growth in regolith, with the hope that a future moon base could produce food through lunar agriculture. These findings show that rice is able to grow in lunar regolith, given the right conditions, but ensuring that the crops are growing healthy and are safe to eat will require further intervention that was not implemented in this trial. Even though the aquaponic-regolith group produced the tallest plants, physiological deformities were noticed in some of the plants exposed to regolith, especially the 50/50 mixture. These plants were unable to develop fully, resulting in stringy tendrils for leaves and stunted, woody stalks. It is unclear if these plants would have been able to produce reproductive structures at all, let alone rice. The soil groups did not perform as well in terms of plant height. This was likely attributed to the conditions given for the plant to grow in: soil composition, heat, and pH.

Rice prefers to be saturated constantly in the early stages of growth. The soils given for them to grow in may not have retained water well enough given the frequency of watering and the dry climate of Colorado. Since it would not be feasible to bring enough silt and clay on lunar missions for better water retention in lunar soils, an aquaponic system might be a more sustainable option. The aquaponic groups produced the tallest plants, suggesting that aquaponics might be a more viable option for lunar operations that are able to support the infrastructure. Water exposure can cause the molecules in regolith to dissociate into metal ions and oxygen radicals which could harm the plants and anyone who consumes them, so further research must be conducted to find ways of neutralizing these threats if plants are to be grown and watered in lunar substrates. A fully aquaponic system could allow for lunar farming to bypass the issue of unwanted metals and oxygen radicals entirely, though the installation of such a system could require considerable cost up front and maintenance over time. Aquaponic systems could be a good investment for larger lunar bases due to the wide variety of life that could thrive in such a system, like food crops and fish that could nourish astronauts, medicinal plants, and algae, which could better oxygenate a space and produce useful materials like bioplastics.

It was also noticed that over the entire trial that the pH of all experimental groups stayed around or above pH of 7, which is not ideal for the rice crop grown in this trial. The highest pH was

consistently recorded in the 50/50 soil mixture with aquaponic water, which might explain the extreme lack of growth in that group. The lowest pH was recorded in the regolith pots across the trial. As rice prefers a more acidic soil pH, future projects might implement a pH buffer to keep the soil at a favorable level of acidity. One concern with this solution, however, is that a more acidic environment might have expedited the dissociation of the regolith minerals into their constituent ions, resulting in an increased uptake of the harmful components of regolith which inhibit successful growth and survival.

Several side projects are planned for the spring semester around this main objective, focusing on chlorophyll density, soil microbiome, and the chemical components of the regolith that might be passed on through these crops. Further investigation will also be conducted in improving the process of extracting DNA from microbes living in regolith. This research adds to the body of evidence that crops are indeed able to grow in lunar regolith, but this project came nowhere near producing edible food products. Humans are bound for other worlds, and extraterrestrial agriculture cannot be ignored as a keystone of future human settlements. Crops can be cultivated in extraterrestrial soils like lunar regolith, but growth is not enough. They must be able to produce food that is both free of the toxins found within their substrate and capable of sustaining a population or else any future settlement would struggle to maintain itself. Nevertheless, the findings in this paper and the future projects of students in the Plant the Moon Challenges give hope that lunar agriculture and lunar settlements are a very real possibility in humanity's future.

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