BiosysFoodEng 2025

HUNGARIAN UNIVERSITY OF AGRICULTURE AND LIFE SCIENCES
Mechanical Engineering Doctoral School

Comparing the viability of Moon and Mars simulants for plant growth

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INTRODUCTION

- In the last decade, since the landing of the mission Mars Science Laboratory in 2011, carrying the Curiosity rover the understanding of Martian regolith chemical and physical properties has improved dramatically. For research purposes, engineers and scientists have relied on the Mars Regolith Simulants (MRS) designed in laboratories over the last 20 years (Cannon et al., 2018). The quality of the simulant is a determining characteristic of the success of experimental trials (Eichler et al., 2020).
- For plant cultivation, Martian dust's fine grain size and potential toxicity by perchlorates threaten to clog hydroponic systems, smother seedlings, or contaminate harvested crops (Hecht et al., 2009).
- Research conducted with regolith simulants, such as NASA's Martian JSC-1A and Lunar LMS-1, and LHS-1 has revealed critical differences in their mineralogy, nutrient availability, and physical structure.
- The compositional disparities demand tailored strategies for soil amendment, nutrient delivery, and crop selection to enable viable plant growth in extraterrestrial environments.

OBJECTIVE

- The main objective was to investigate the germination and survival of plants in soil simulants from the Moon and Mars. The work was carried out under laboratory conditions, using simulants supplied by the Exolith lab, and indicator plants, selected based on NASA's criteria for enclosed plant cultivation.

MATERIALS AND METHODS

- To evaluate the viability of plant cultivation in extraterrestrial regolith, four simulants were selected: JEZ-1 (Jezero Crater Mars Simulant) and MGS-1 (Mars Global Simulant) for Martian regolith, and LMS-1 (Lunar Mare Simulant) and LHS-1 (Lunar Highlands Simulant) for lunar regolith.
- A hybrid cultivation system, combining regolith with peat Earth soil was implemented to improve water retention and drainage, while Earth soil controls were included to isolate the effects of regolith properties on plant development in 50% of volume of the pot.
- Environmental conditions, including light of 16 hours photoperiod using tunable LEDs, temperature (20–24° C), and humidity (40–50%), were tightly controlled to mimic proposed space greenhouse settings.
- Plants were cultivated in 9 cm² pots filled with the designated treatments, consisting in earth soil + simulants in 50% volume. Three seeds of *Sinapis alba* (white mustard) were added to each pot. The germination of the seeds was previously measured achieving 90%. The experiment followed a randomized block design with three replicates. The experiment lasted 105 days where germination, biomass, and seed production were followed.

RESULTS AND DISCUSSION

- No plants could germinate or survive by simply planting them in the regolith. This corroborates with results found by authors Eichler et al. (2021).
- Moon simulant presented a higher germination rate then the Mars simulants.
- LMS-1 and LHS-1 presented full plant survival while Martian simulant cultivating plants did not survive longer than 14 days.
- In 2014, Wamelink et al. investigated the germination of several crops on Mars and Moon soil simulants, using poor nutrient Earth soil as control. They found that common vetch, a nitrogen-fixing legume, failed to germinate on Moon soil. The Martian soil simulant had the highest germination percentage, whereas the Moon soil simulant had the lowest.
- The results for Wamelink et al. studies do not corroborate with the results of this trial, where it was found better survival of plants, germination rates, and biomass production in Lunar simulants.
- Authors Rainwater and Mukherjee (2021) experimented with establishing the legume-rhizobia symbiosis using different Mars soil simulants, results indicated the successful development of root nodules on symbiotic bacteria in the roots when grown on Mars soil simulants. The study concluded that the Mars soil simulants investigated could indeed support the legume-rhizobia symbiosis.

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Figure 1: White mustard plants germinated in Moon simulant.

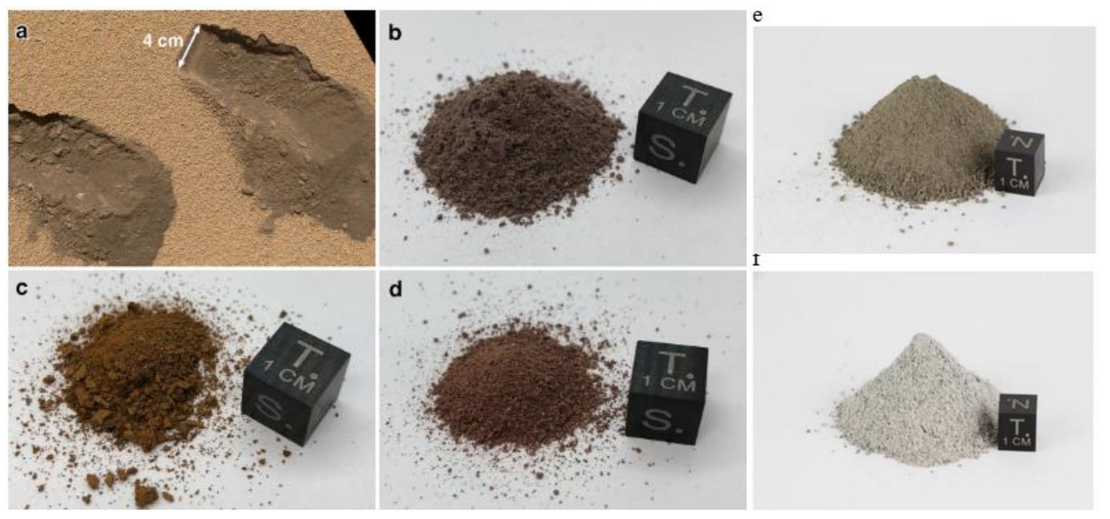

Figure 2: **a** MAHLI image of the scooped Rocknest soil, image credit NASA. **b** Simulant MGS-1 produced by authors Cannon et al 2019. **c** JSC Mars-1 simulant. **d** MMS-1 simulant. **e** LMS **f** LHS.

- The results from this study suggests that the chemical composition of the simulants is more influential than their grain size in determining biomass production. Therefore, nutrient deficient extraplanetary soils will require fertilization to become agricultural viable.
- The lack of soil structure due to fine particles and dust poses as an obstacle for root development, hence soil amendments like perlite or coarse particles are necessary for water retention and root support.
- Nutrient deficiency was identified in all plants; nutrition should be added to the treatments to make cultivation possible in both Moon and Mars.
- Moon presented higher germination and plant survival than Mars simulants.

CONCLUSION

- Mustard was able to survive and produce the full plant cycle in Moon simulants LMS-1 and LHS-1. Yet, plant had stress signals such as yellow leaves and irregular growth.
- Further research must assess the simulants' water-holding capacity, structure and nutrition to improve the plant production in extraplanetary conditions.

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