Kale Growth in MMS-2 Enhanced Mars Regolith Simulant During Indoor Earth Conditions

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Abstract

Plant growth in Martian regolith simulant was studied to determine a resource-efficient method of food production on Mars. The goal of this work is to use the existing soil of Mars with minimal interference and minimal required materials from Earth to grow nutrient dense food.

Results for Kale growth of 15 plants are compared between adjusted percentages of Earth soil and other amendments added to Mars regolith simulant. Amendment strategies targeted:

- water retention
- air channel creation
- pH adjustments to acidify the soil.

Scientific Background

Survival on Mars requires building a system rooted in self-sustainability, to include generating, processing, and renewing the minimal resources available. **How can Mars regolith be efficiently adjusted to sustain plant growth?**

1. Adjustments should be fuel-efficient.
2. The existing soil of Mars should be utilized.
3. Minimal materials from Earth should be used.

For this project, plants were grown in simulant Martian regolith simulant "MMS-2" obtained from The Martian Garden [5].

- This simulant is sourced from the same Mojave Desert basalt deposit that NASA and JPL's Martian simulant is sourced.
- Iron-rich basalt deposits left behind by ancient lava flows mimic the composition of Martian regolith [3].

MMS-2

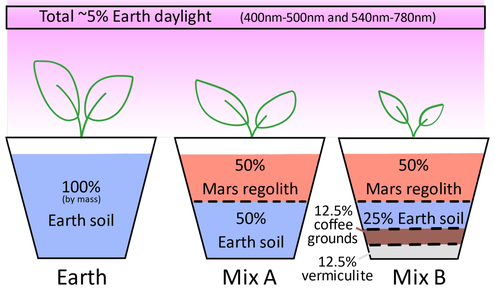
Earth Mix A Mix B

This experiment contributes to the developing study of Martian agriculture. Previous work by Guinan and Engle et al, of Villanova University [1], and Wamelink et al. of Wageningen University [6] have shown evidence of plant growth in similar simulant regolith. Challenges faced in such nutrient poor soil included [1]

- root rot
- wilting
- inhibited root growth caused by clay-like consistency
- high pH of the regolith.

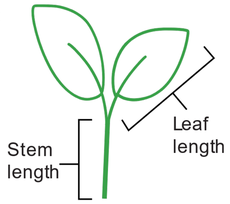
Kale Growth Experimental Design

Three mediums of soil with five seedlings per mix were prepared: One tablespoon of water-absorbent crystals were added to all soil mediums to increase water retention due to the porous nature of the Martian regolith simulant.



Plants were kept in a closed cabinet to limit sunlight exposure. Plants were manually watered two to three times per week.

Stem and leaf lengths, soil pH, and temperature were recorded twice a week.



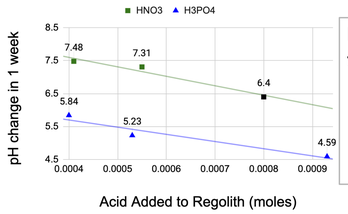
Plant Length = Stem + Leaf Length

pH Adjustment of Soil Mix A

The pH of the Martian regolith was adjusted in three trials prior to planting in order to lower the Mixture A pH from 8 to 6. Two cost effective acids were tested based on their potential to introduce key elements needed for plant growth: nitrogen and phosphorous.

Nitric Acid, HNO_3 Phosphoric Acid, H_3PO_4

5g samples of Martian regolith were mixed with 5mL of water and titrated with different amounts of each acid. Nitric acid and phosphoric acid have both effectively lowered the pH to 6, similar to the optimal pH range for plant growth.



Moles of Acid required to adjust 1 g of Martian regolith to a pH of 6

1.6×10^{-4} moles HNO_3
6.4×10^{-6} moles H_3PO_4

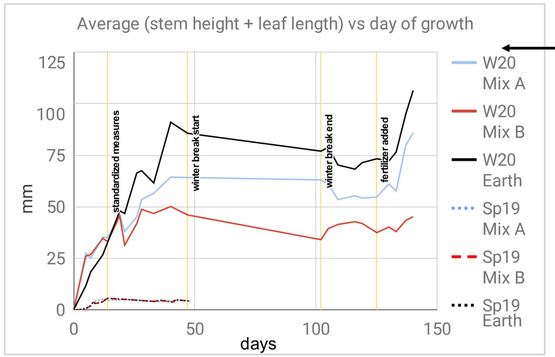
Initial pH Adjustment of Mix A for Kale Growth:

- Nitric Acid : 5.71
- Phosphoric Acid: 5.98
- Nitric Acid with buffer: 5.25
  Buffer: NaH_2PO_4 & Na_2HPO_4

Initial Regolith pH = 8

Earth Mix A Mix B Mix A HNO_3 Mix A H_3PO_4 Mix A Buffer

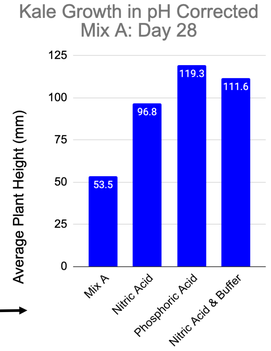
Results:



W20 is plants grown from October 2019-March 2020 Sp19 is plants grown from April-June 2019

15 plants observed over 130 days. Plant growth decreased with a decrease in the percentage of earth compost additive as measured by plant length (stem + leaf length) and robustness. Of the regolith mixes, **Mix A** was the most successful.

Preliminary results from 15 other plants show the acidification of regolith Mix A improves kale growth, with plants almost doubled in size.



Future Research: Overview

Repeat experiment with different plant species:

- Plants that develop strong, course roots
- Plants that can live in tundra-like environments

SPECIES	Siberian Iris [7]	Rosa Rugosa [8]	Siberian Garlic
PROS	Cold-hardy plant (tolerates USDA zones down to Zone 2); bulbous plant (i.e. keeps reserve of nutrients in bulb).	Very hardy rose species; can tolerate low temps (down to USDA Zone 1); is tolerant of clay soils and even salty soils.	Cold-hardy plant; tolerates clay-like soils, bulbous plant.
CONS	Little research conducted on soil requirements; not a low-light plant.	Not a low-light plant; grows thorns (students would have to be mindful when handling the plant).	Not a common cultivar; long growth periods with little above-ground growth.

Expand pH additives by using sulfuric acid to control for the fertilizing effects of the nitrogen and phosphorus.

Test new soil mixtures:

- Modify soil to hold water similarly to a loam
- Modify soil to maintain its structure and compact less
- Modify soil to allow fine roots to push through more easily

Employ fertilizers:

- 5:1:1 fish fertilizer to add essential nutrients in Mars regolith: nitrogen, phosphorous, and potassium.

Introduce endophytic fungi to improve plant resilience.

Increase the number of subjects to build data significance.

Null Results of Interest

Several other species were attempted with minimal success.

- Leeks & spinach sprouted initially but soon withered.
- Dandelions failed to sprout in both of the Mars mixes.
- Moss (a pioneer species) failed due to water issues.
- Prickly pear cactus has rooted, but long-term growth pattern currently prohibits meaningful measurement.

Dandelion Results

Earth Mix A Mix B

References & Acknowledgements

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