Legumes in Space

Growing More than Lettuce for Food Crop Production

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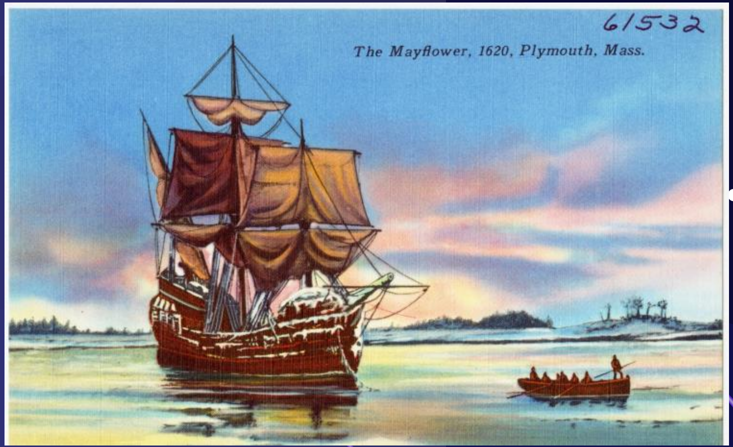
Why study food crop production in space?



- Humans require energy from food.
- Combat malnutrition with nutrient-dense food.
- Breakdown of nutrients in aged, pre-packaged food.
- Difficulty in transporting animals for food.
- Resupply missions like to ISS not feasible.
- Need to understand how organisms (plants, humans, bacteria) affected by spaceflight

Lessons from Early Explorers

Malnutrition was the leading cause of death!

NASA Strategic Objectives: Food is mission critical.

Meals in Space

- **LIMITED CHOICES**
- **FOOD APPEAL**
- **EATING ENOUGH**
- **FOOD DEGRADATION**
- **DIGESTIVE ISSUES**

NASA Food Scientist Vickie Kloeris reports, “Very few foods in our current food system that would maintain sufficient quality after that long. Even though we can stop microbial changes in these products by preserving them, **we can’t stop the chemical changes**. The color, texture, and flavor are going to change, and the **nutritional content is going to degrade**” (Koren, 2017)

Eating During a Three-Year Mission to Mars

- 24,000 pounds of food will be required, which would fill two SpaceX Dragon Cargo capsules.
- Food must be shipped ahead of crew arrival since resupply missions are not possible.
- Food degradation is a significant concern as food ages, which causes taste, texture, and nutritional decline.

In-situ food crop production will be needed to supplement astronaut diets and ultimately feed future settlements on the moon and Mars.

Space Flight Human Health Impacts

Nutritional Countermeasures

CARDIOVASCULAR DECONDITIONING

Omega-3 fatty acids, Vitamin D, phytochemicals and antioxidants

RADIATION EXPOSURE

Vitamin C, Vitamin E, Antioxidants, Selenium

IMMUNE SYSTEM IMPAIRMENT

Protein, Vitamin D, Vitamin B12, Vitamin C, Vitamin A, Vitamin E, Copper, Zinc, Iron

MUSCLE LOSS

Vegetable proteins contain less sulfur, which is beneficial.

BONE LOSS

Omega-3 fatty acids, Vitamins D, K, Phosphorus, Magnesium, Zinc

OPHTHALMIC (EYE) HEALTH

Folate, Vitamin B6 and B12, Biotin, Vitamin A

The Hardware to Grow Plants in Space

VEGGIE

The Veggie unit is growing chamber on the ISS that uses LED lights and specially designed clay-substrate seed pillows with time-release nutrients.

Crops: microgreens, lettuce, algae, and zinnias.

Advanced Plant Habitat: “APH”

The APH uses cameras and 180 sensors in a closed chamber to monitor plants growing in a clay-substrate with time-released nutrients. Radishes are a recent crop, and peppers will be grown in the spring.

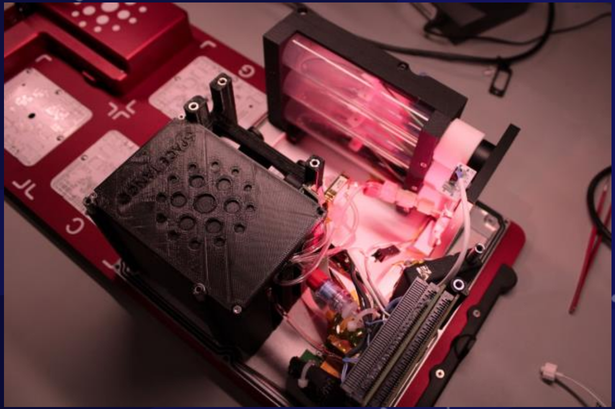
Legumes in Space: ExoLab-8

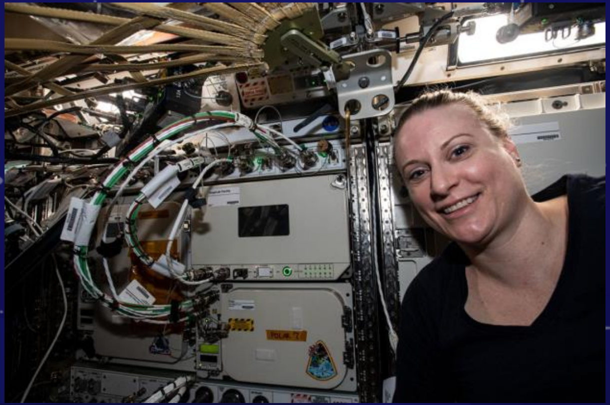
SCIENCE MISSION GOAL

Achieve root nodulation by symbiotic rhizobia bacteria on red clover plants while under the stress of spaceflight

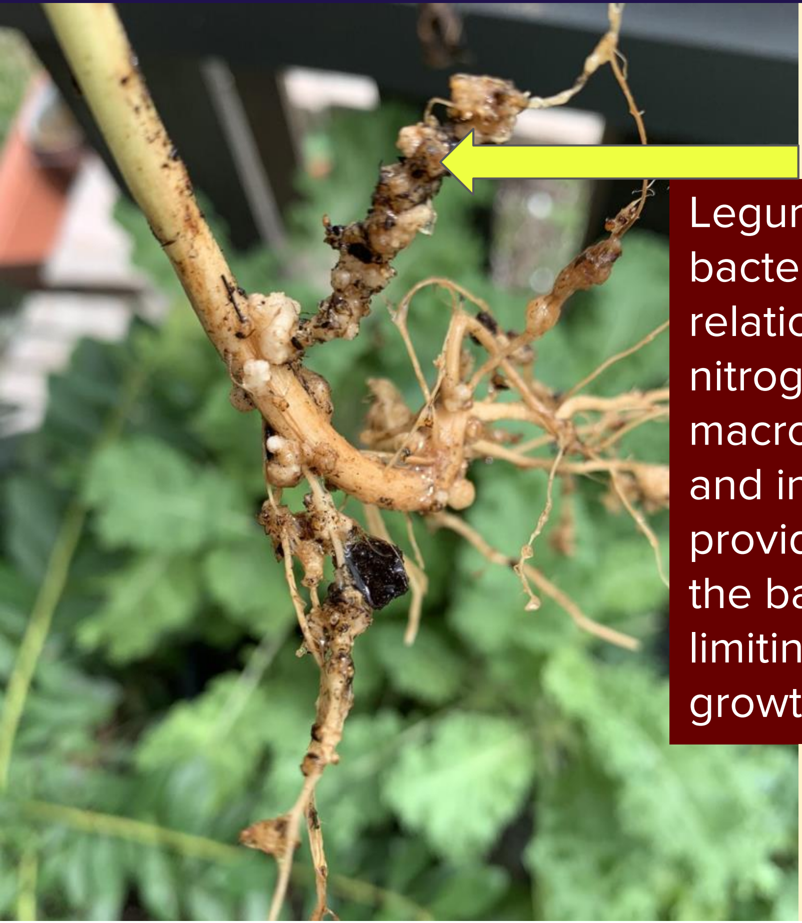
SCIENTIFIC INQUIRY

Students conduct ground trials growing clover and compare to the images and data while on the ISS





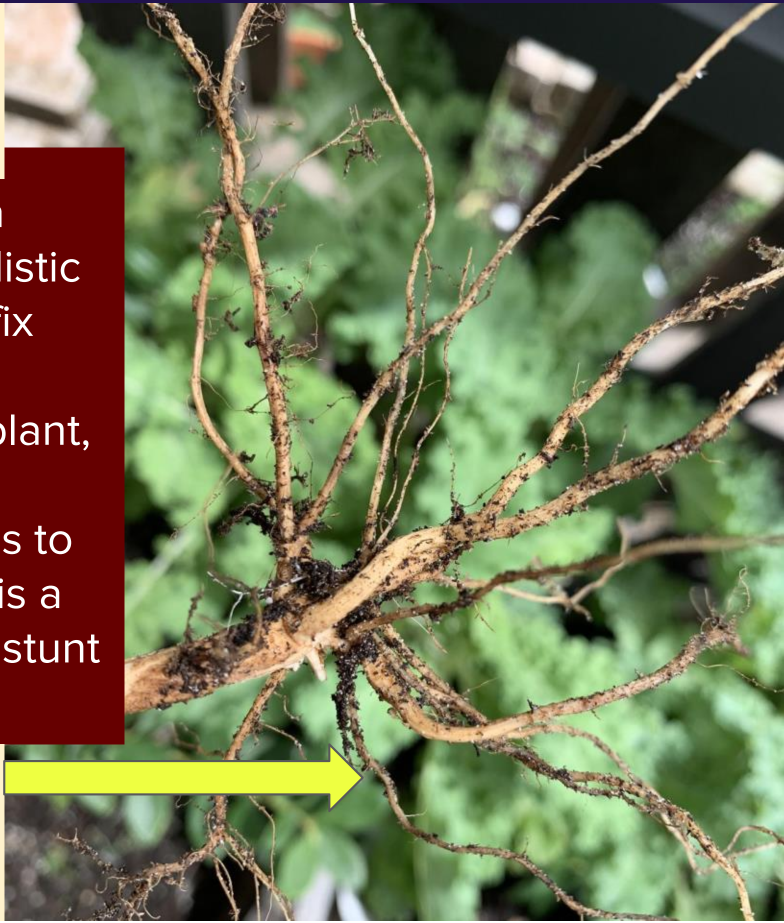
Investigating a Symbiotic Relationship



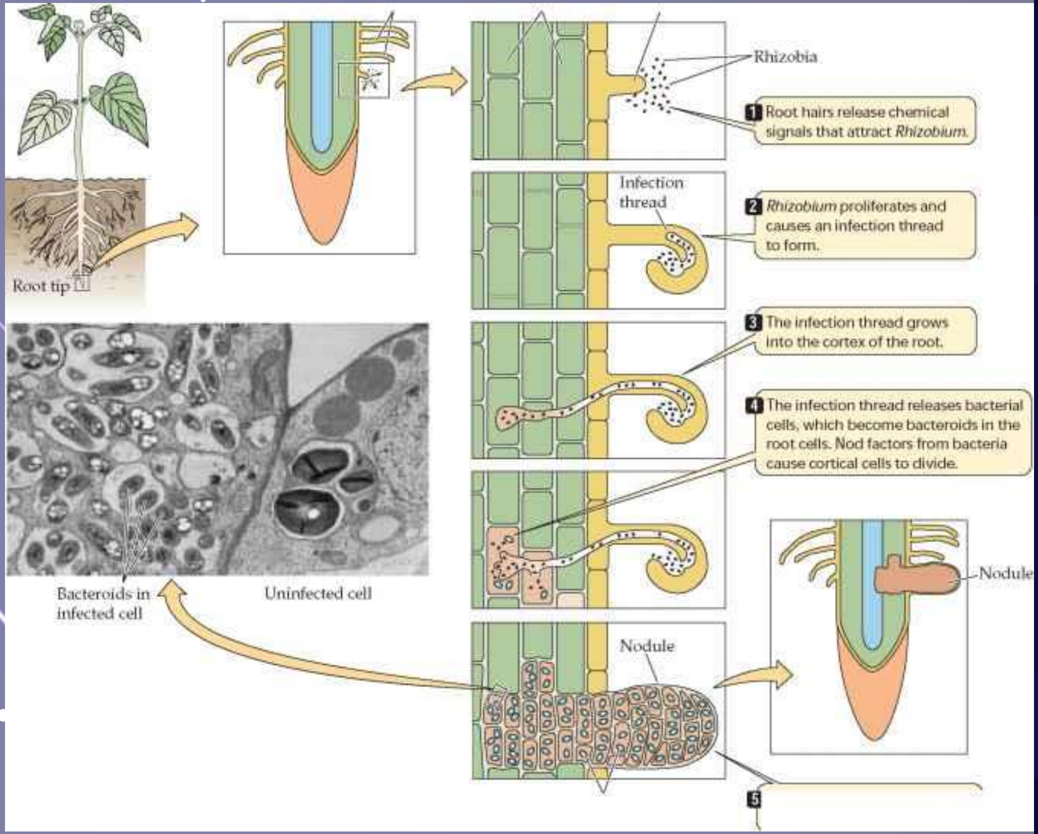
Nodulation on garden bean roots

Legumes and Rhizobia bacteria have a mutualistic relationship. Rhizobia fix nitrogen, a critical macronutrient for the plant, and in return the plant provides carbohydrates to the bacteria. Nitrogen is a limiting factor that can stunt growth.

No nodules formed



Will the Stress of Spaceflight Inhibit Nodulation?



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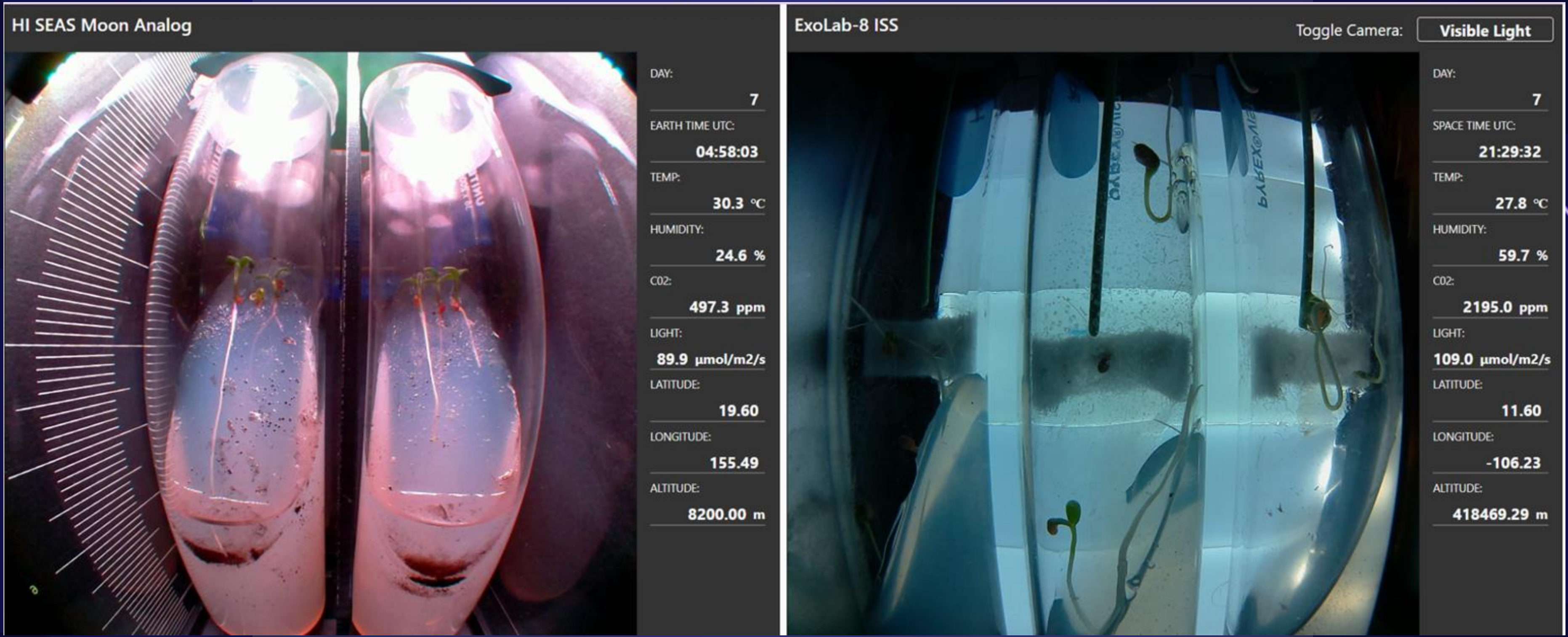
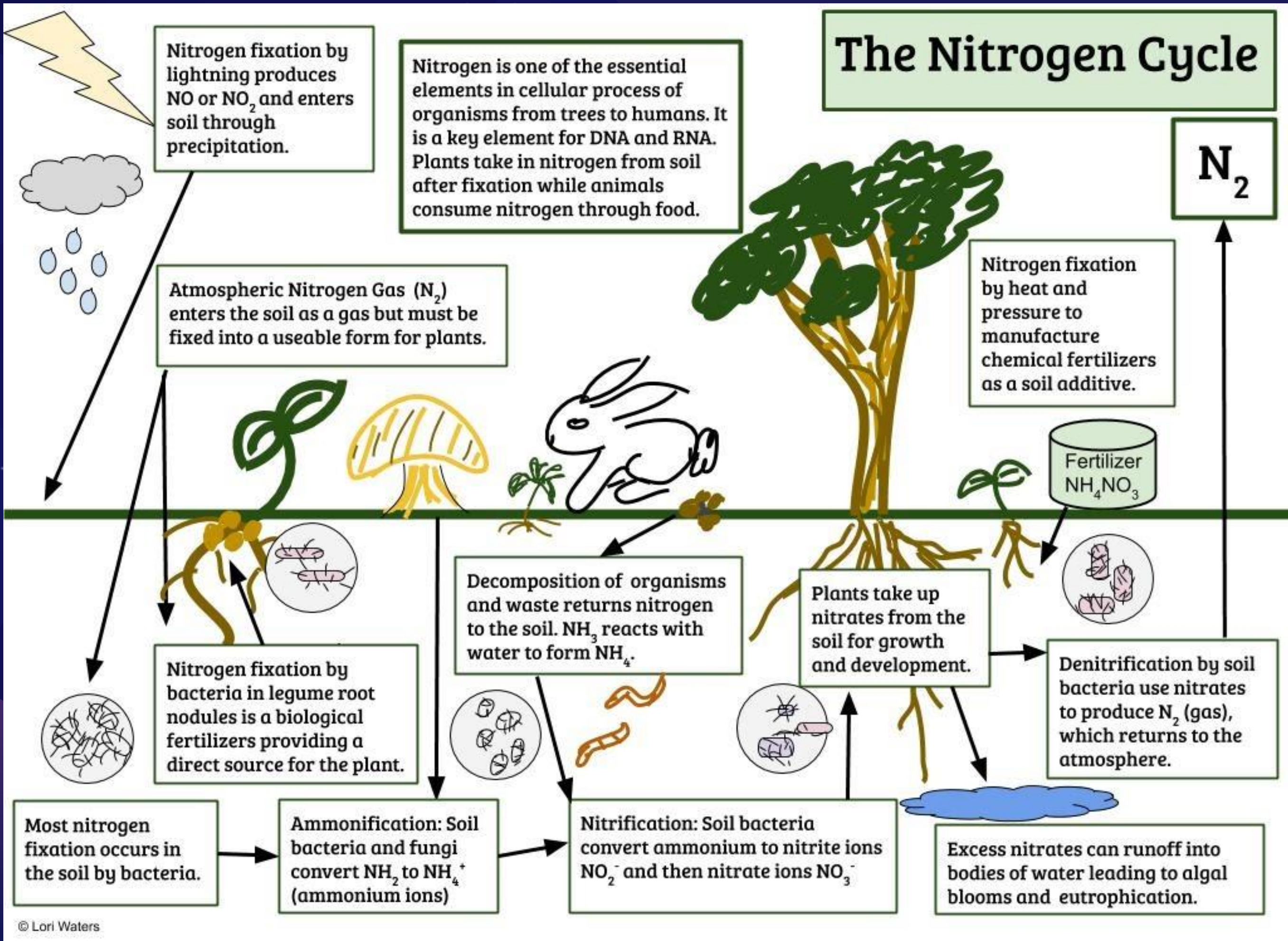
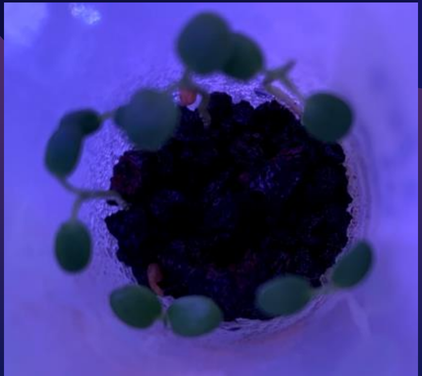


Food and environmental sustainability in space and on Earth

Biological fertilizer is more sustainable. It's a win for bacteria, plants, humans, and the entire ecosystem.



Martian and Lunar Regolith



Challenges

1. No micro-organisms
2. Toxic Perchlorates
3. Clay-sized particles suffocate roots
4. Rapid water loss
5. Nutrient deficiency

Plants don’t grow in “dead” dirt on the Earth, Moon, or Mars. Growing and composting cover crops like red clover could enrich the regolith to make it a productive media.

Legumes in Space

Questions?