Comparing Hydroponics and Regolith Growth and Evolution (CHRGE).

SPACE RESOURCES ROUNDTABLE

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In situ food production is mission critical to successful off-world settlements

- Improve food security to settlement
- Reduce menu fatigue
- Fresh plant material for nutrition
- Plants/Producers are a critical component of a sustainable ecosystem.
- Psychological benefits

REGOLITH vs HYDROPONICS

Regolith vs Hydroponics – Costs and Benefits

REGOLITH

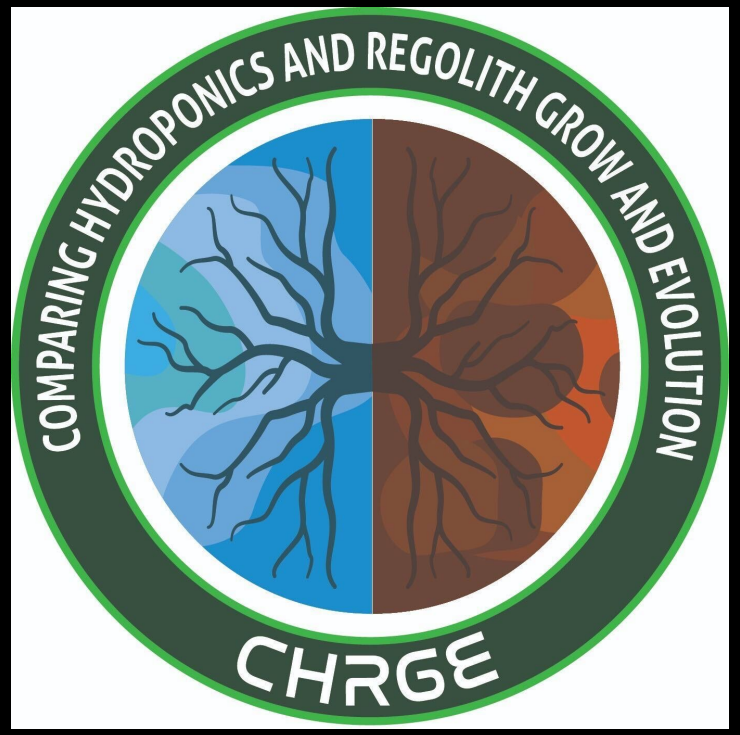
- Substrate already available on Mars & contains useful nutrients
- Add microorganisms to develop native carbon, phosphate, and nitrogen cycles, improving nutrient cycling.
- Can be run multiple times (improving soil)
- Contains useful nutrients for plants reducing transport costs (CAN THEY BE MADE AVAILABLE?)
- We don’t have any Martian regolith yet
- Potentially toxic elements

HYDROPONICS

- We could do it now! High TRL
- Controlled nutrient release
- ‘Better’ space utilization
- Can create some microbial associations
- Disease can spread more quickly
- May require more maintenance or setup
- More parts

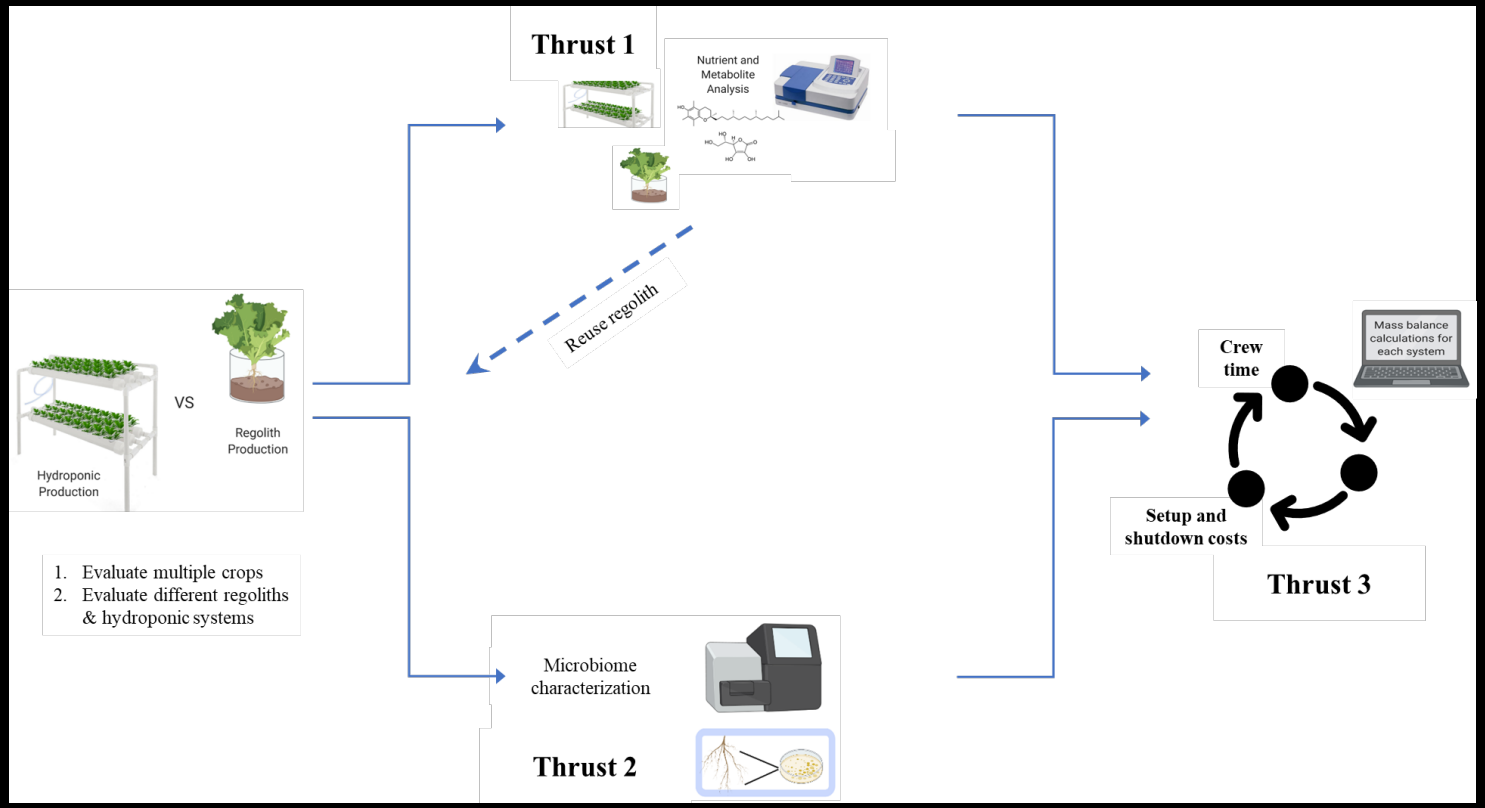
Regolith **AND** Hydroponics

Food security through diversity and resilience – CHRGE



- How do we decide which crops should be grown hydroponically? In regolith?
- How sustainable are these decisions?
- Do these choices change over time (multiple runs)
- How about elements beyond yield?
- A cradle-to-grave analysis
- Provide criteria for making decisions

CHRGE Pipeline, Deliverables, & Related Projects



- Systems approach to comparing technologies
- Integrating crop production more realistically into sustainable models (waste streams, etc.)
- Evaluating Space Crops to Advance Predictive Edibility (ESCAPE)
- Understand how the regolith microbiome evolves
- Transition from ‘regolith’ to ‘soil’

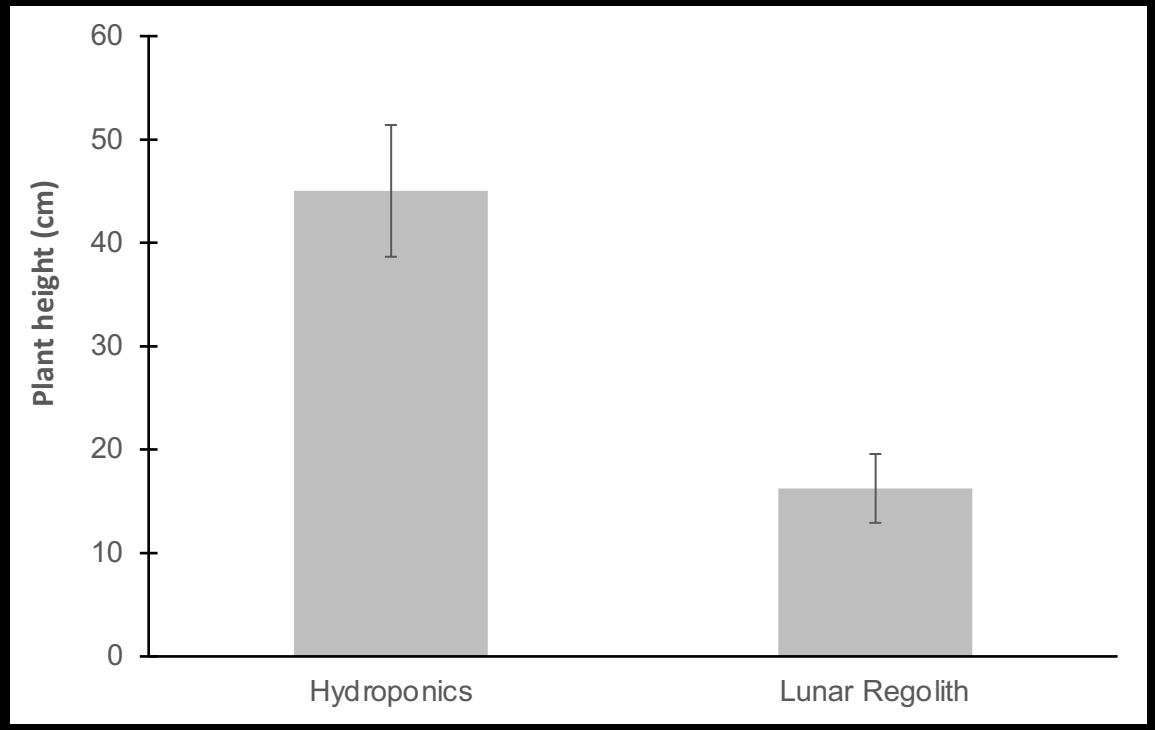
The side-by-side (Fodder King vs Hydroponics) N=15

Hydroponic lettuce is bigger, dense root system, etc.

‘Healthier plant’?

Hydroponics

Regolith



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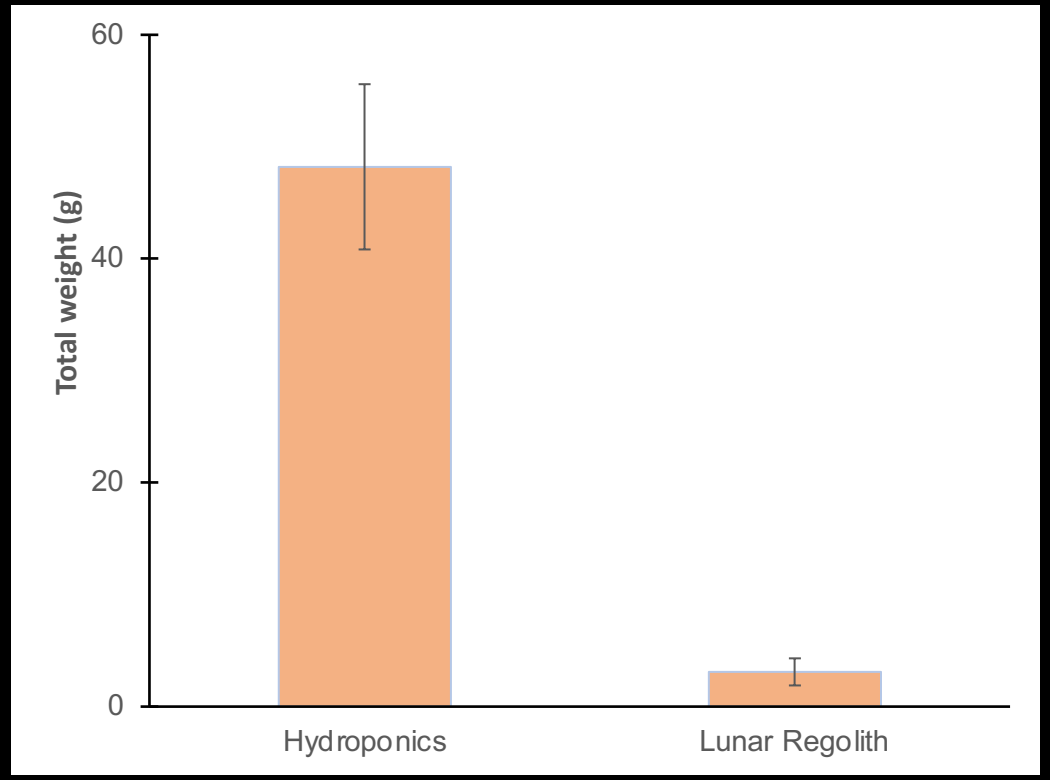
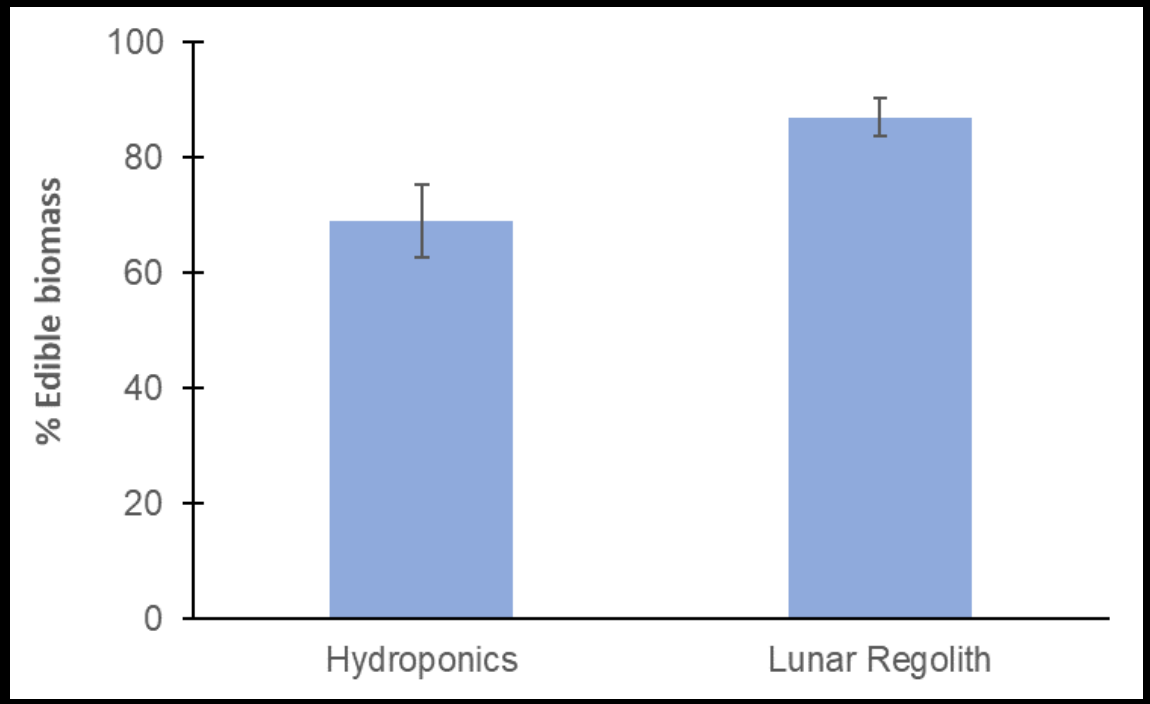


RBA has higher % edible biomass ($p<0.05$)

Hydroponics

Regolith



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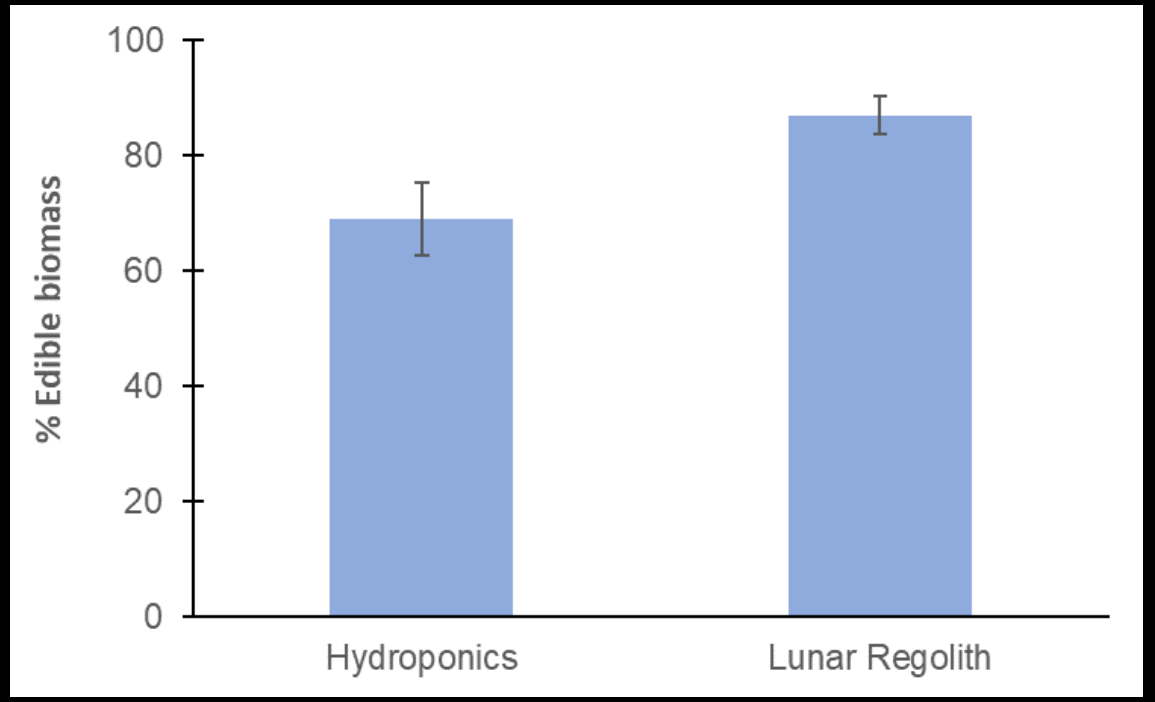
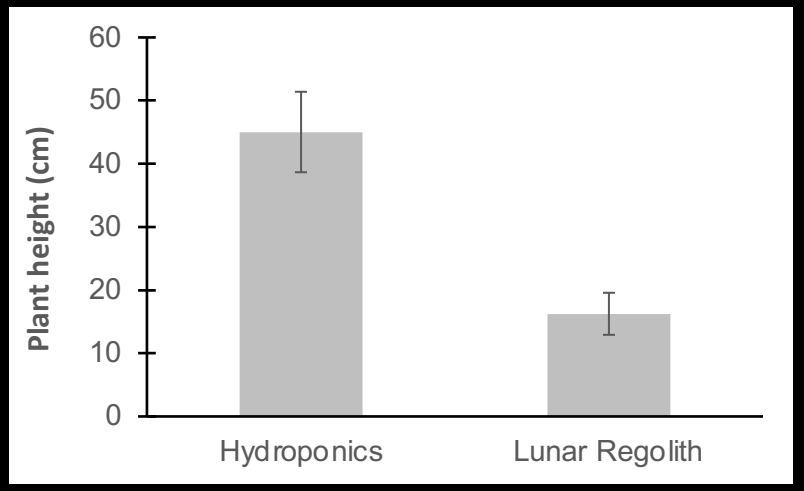


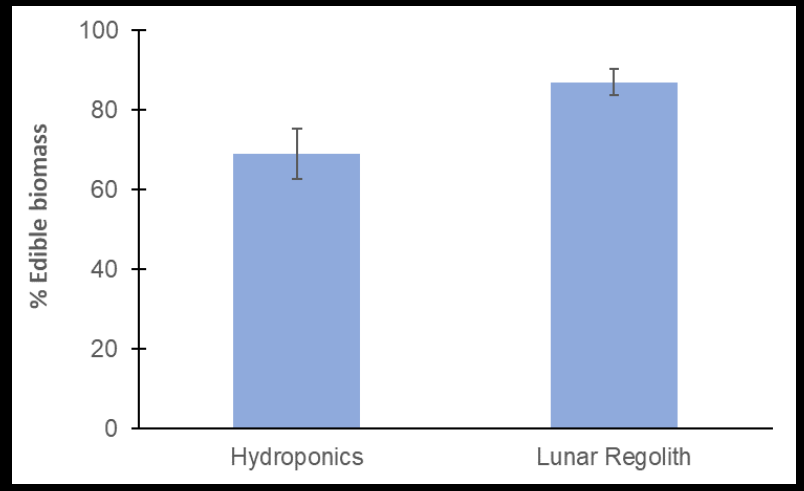
Hydroponics produced ≈50x more inedible biomass!

Hydroponics system takes more electricity and water

Hydroponics

Regolith





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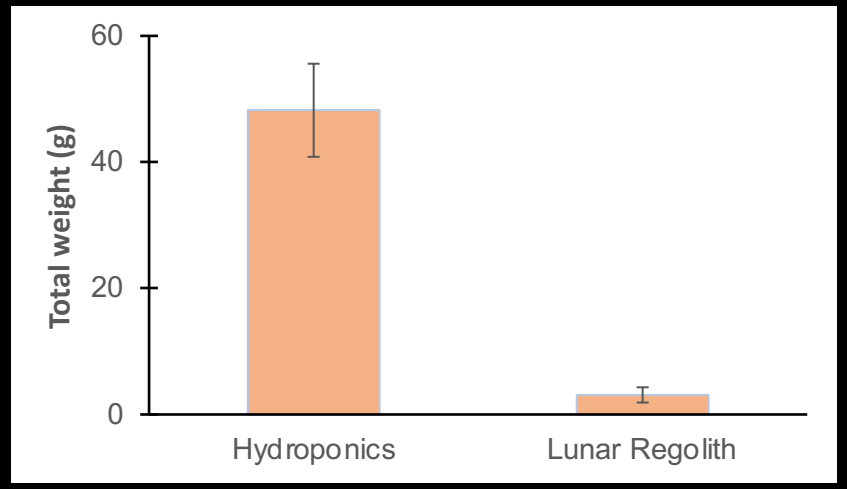
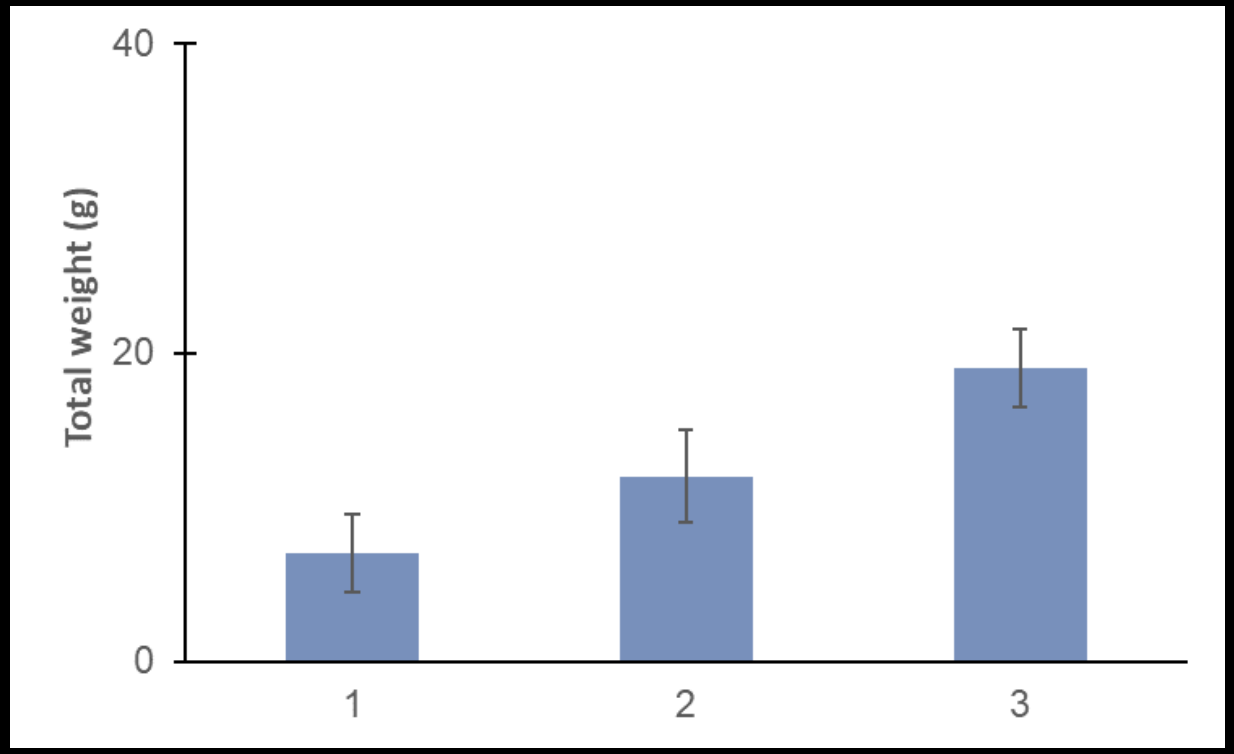
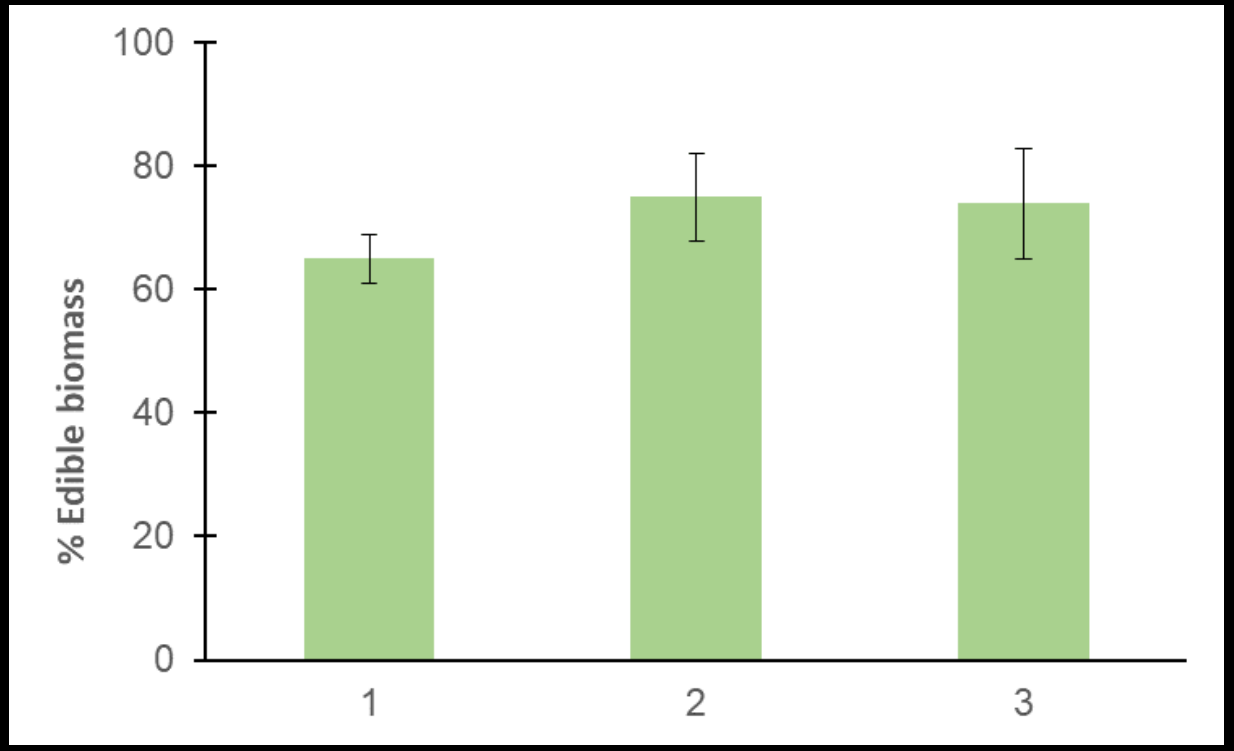


Recycling Martian Regolith Simulants…

It does get better….. Jujuing the regolith ←

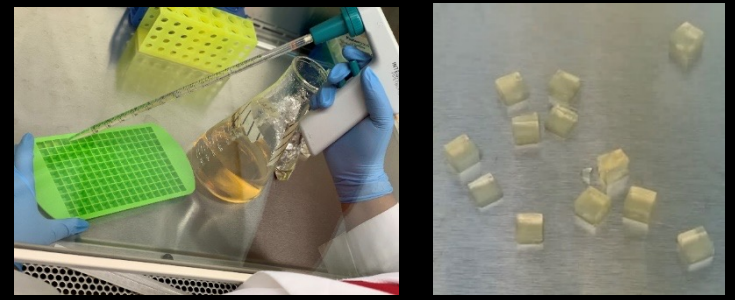




Controlled environment conditions (Photoperiod 16 light/ 8 dark; Temperature 23°C day/ 18 °C night; Relative humidity 70%; Irradiance (blue/red) ~400 µmol m^{-2} s^{-1} HPLED; CO2 ~ 1000 ppm) .Watering at 100 ml on the rooting area's surface (6 a.m. – 6 p.m.)

Variables Analyzed - Plant Height (cm); Number of Leaves; Number of Flowers; Stem Diameter (mm); Fruit Yield (g/plant); Fruit Size (g/fruit); Brix Level (°Bx); Seed Viability (germination rate, %)

RBA (regolith-based agriculture boxes) boxes – inoculants PEP1 recipe (*Azospirillum* spp., *Rhizobium* spp., *Azotobacter* spp., *Pseudomonas fluorescens*) using WSSU-ABL microbial cube ® technology.



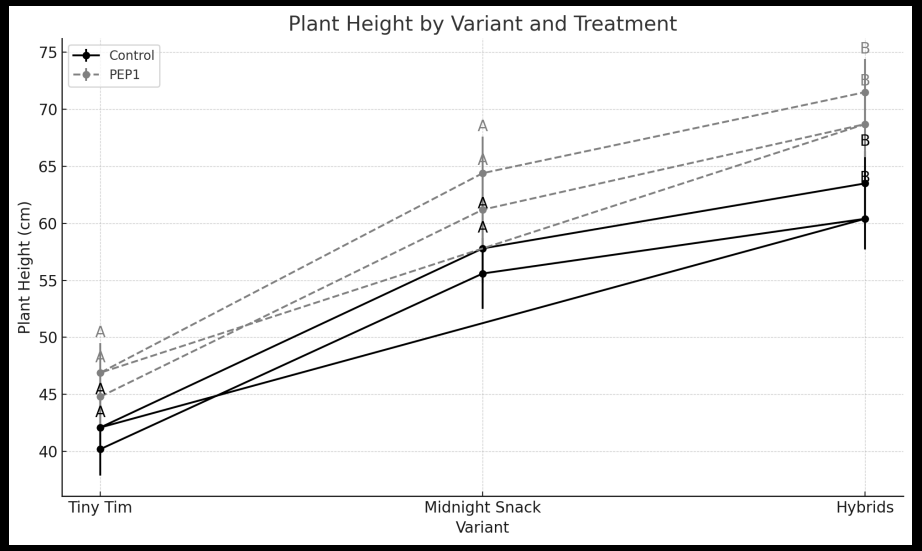
WSSU-ABL microbial cube ® for regolith inoculation for the PEP1 treatment

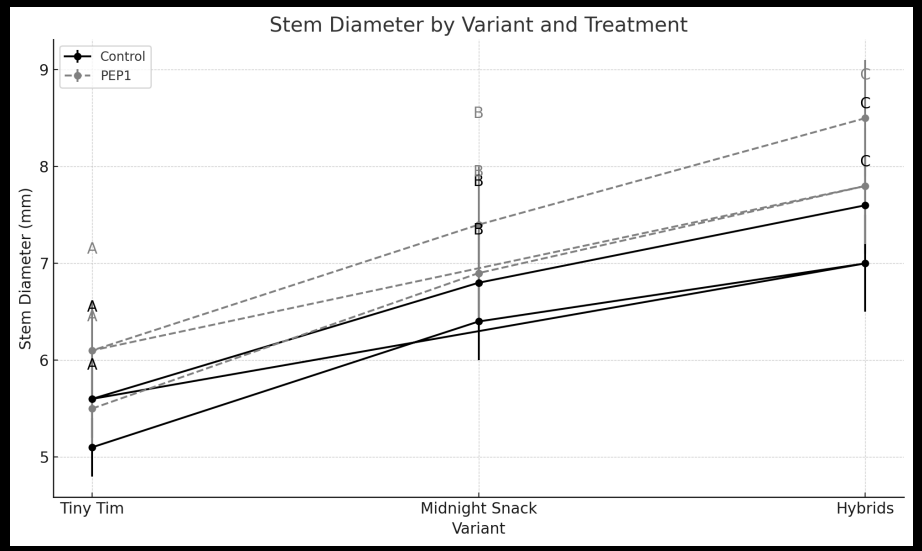
Tiny Tim - Midnight Snack – "Tiny Snack" hybrids tomato variants – 55 day grow-out (production cycle) – n=20 per variant, per treatment (n=120 plants per G)

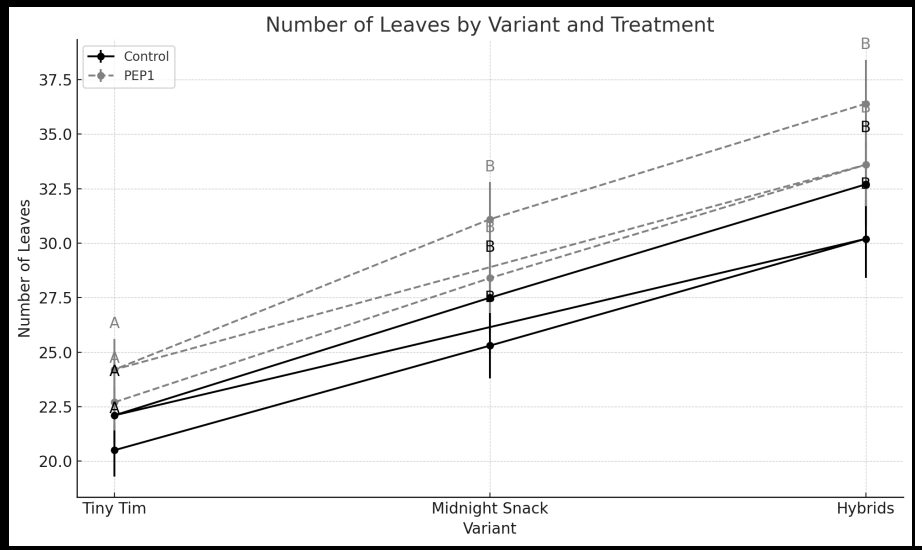
G1 – plants that grew in regolith that had never been used

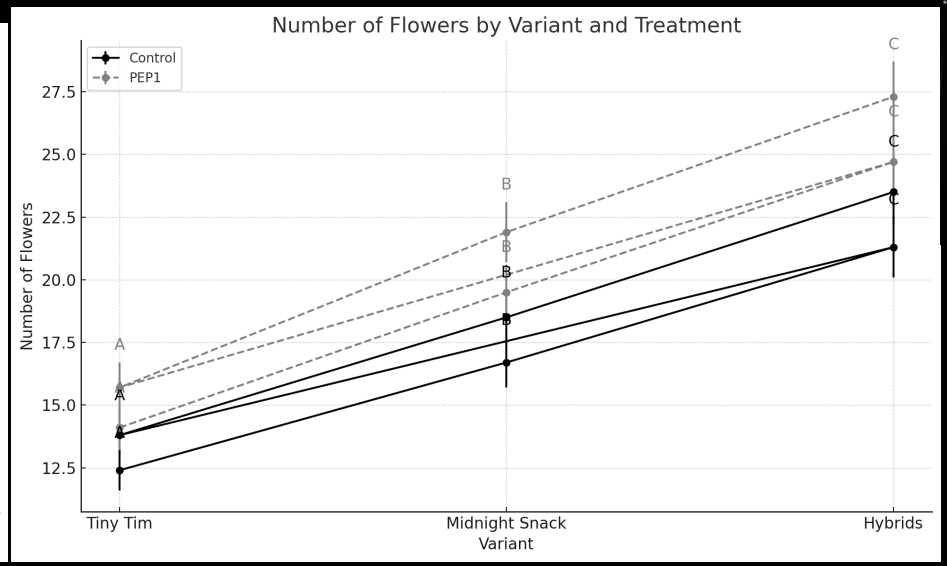
G2- plants that have been grown in regolith used in G1

Treatments – Control (regolith with no microbiome amendment); PEP1 (regolith with microbiome amendment)

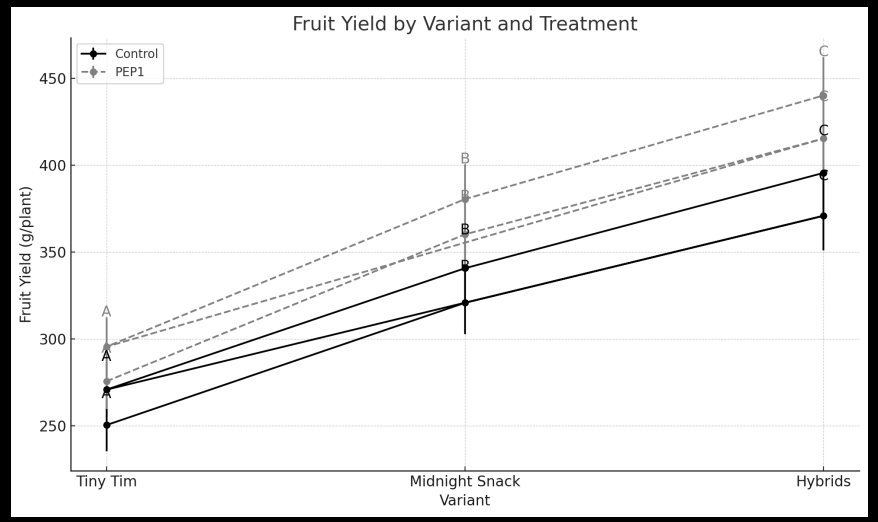


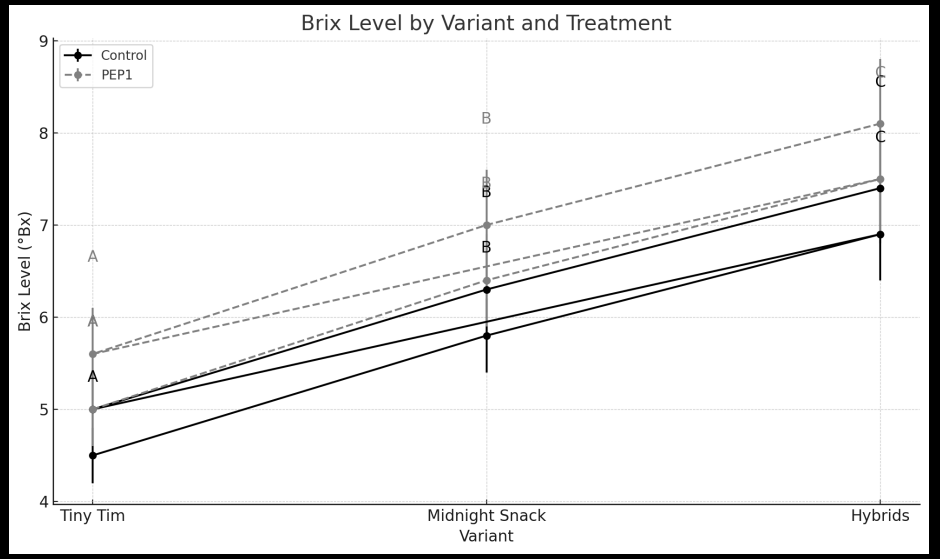


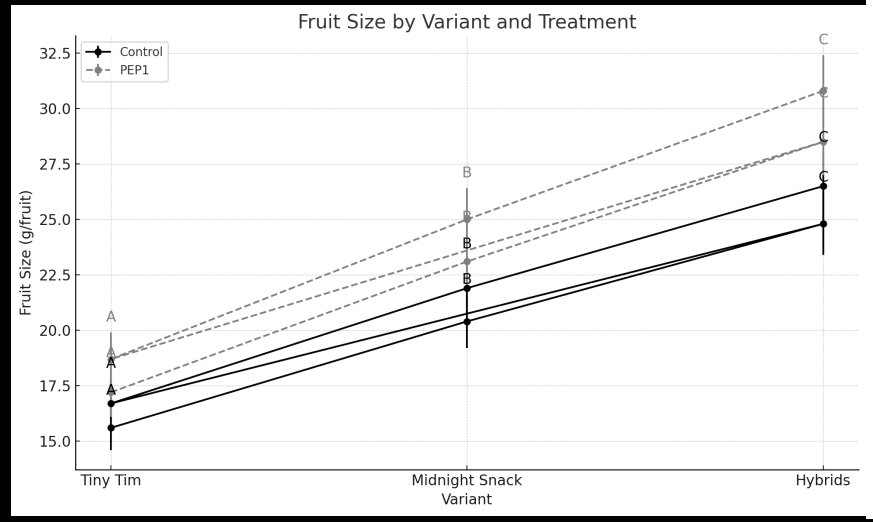


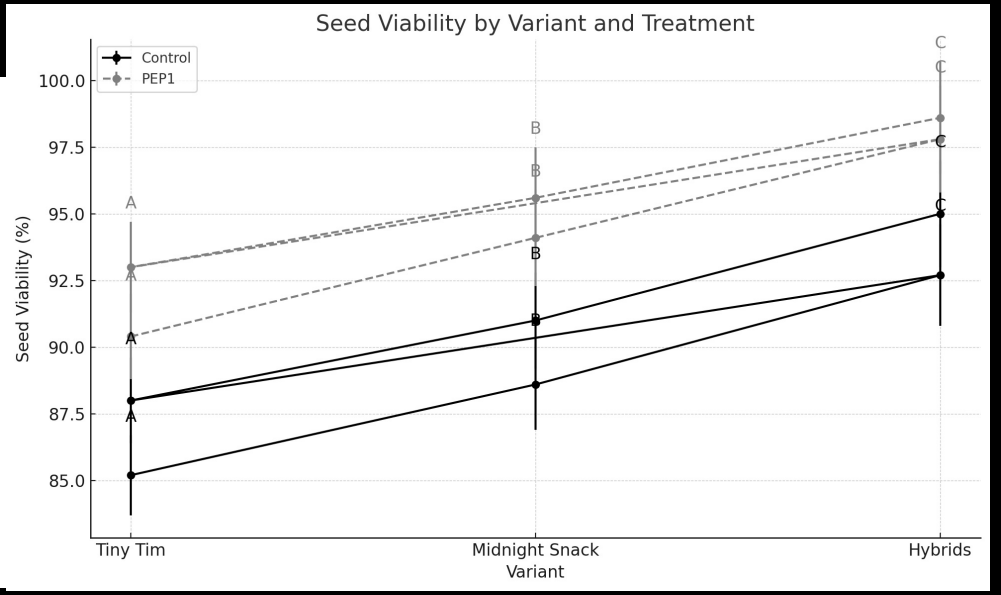


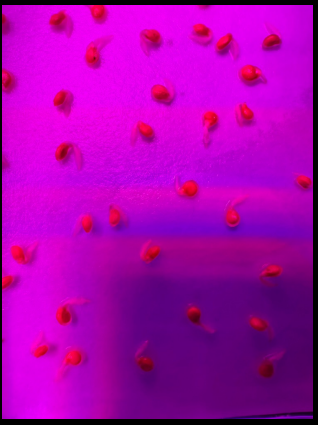
Tiny-Snack plant after 55 day grow-out (production cycle)











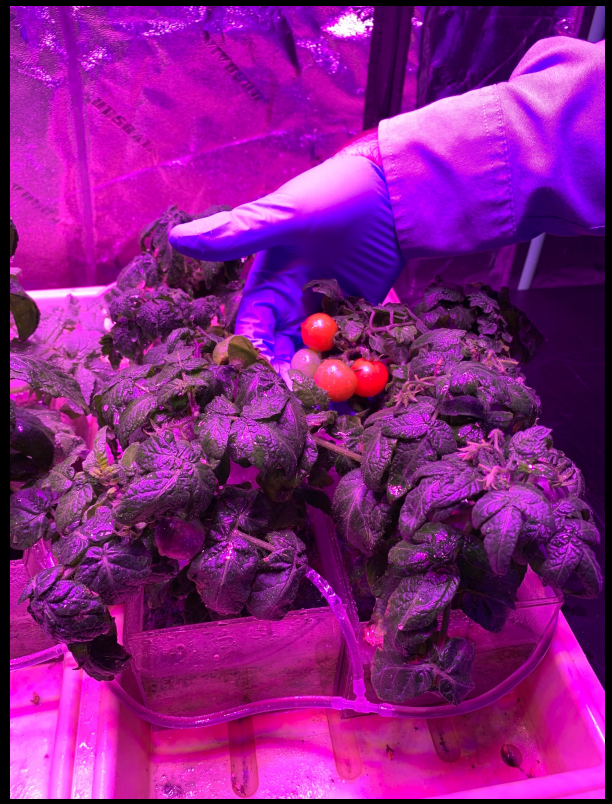
High seed viability across variants and treatments (PEP1 and Control)

Tiny-Snack fruits after 47 day grow-out mark.

Generation	Variant	Plant_Height (cm)	Stem Diameter (mm)	Number of Leaves	Number of Flowers	Fruit Yield (g/plant)	Fruit Size (g/fruit)	Brix Level	Seed Viability
G1	Tiny Tim	40.2 ± 2.1	5.1 ± 0.3	20.5 ± 1.2	12.4 ± 1.1	250.4 ± 15.4	12.6 ± 1.2	4.5 ± 0.3	85.2 ± 2.5
G1	Midnight Snack	55.6 ± 3.2	6.4 ± 0.4	25.3 ± 1.4	16.7 ± 1.2	320.8 ± 20.3	16.4 ± 1.8	5.8 ± 0.4	88.6 ± 2.8
G1	Hybrids	60.4 ± 2.5	7.0 ± 0.3	30.2 ± 1.3	21.3 ± 1.2	370.9 ± 18.5	18.8 ± 1.5	6.9 ± 0.4	92.7 ± 2.6
G2	Tiny Tim	42.1 ± 2.2	5.6 ± 0.3	22.1 ± 1.2	13.8 ± 1.1	270.8 ± 16.2	16.7 ± 1.3	5.0 ± 0.3	88.0 ± 2.6
G2	Midnight Snack	57.8 ± 3.1	6.8 ± 0.4	27.5 ± 1.5	18.5 ± 1.3	340.7 ± 19.8	18.9 ± 1.7	6.3 ± 0.4	91.0 ± 2.7
G2	Hybrids	63.5 ± 2.8	7.6 ± 0.4	32.7 ± 1.4	23.5 ± 1.2	395.6 ± 18.1	22.5 ± 1.6	7.4 ± 0.4	95.0 ± 2.7

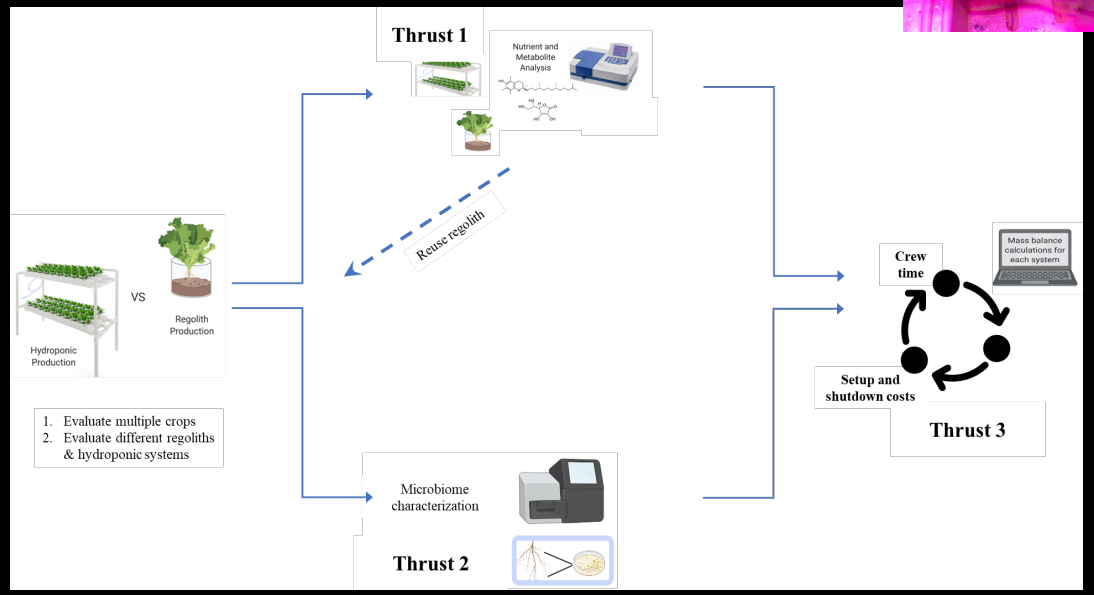
Write something here about the benefits of “used” regolith

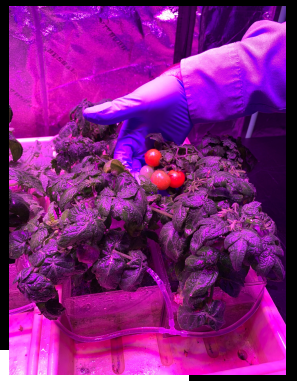
ANOVA results indicated significant effects of generation, variant, treatment, and their interactions on all measured variables. The second generation (G2) outperformed the first generation (G1) across all variables, regardless of the variant, with even better results when inoculated with PEP1. For plant height, ANOVA showed $F = 24.3$ (generation), 22.8 (variant), 18.4 (treatment), and 5.2 (interaction), all $P < 0.001$. Tukey tests confirmed that hybrids were significantly taller than other variants ($P < 0.001$), with PEP1-treated plants also showing increased height ($P < 0.001$).



Conclusions

How we define ‘success’….





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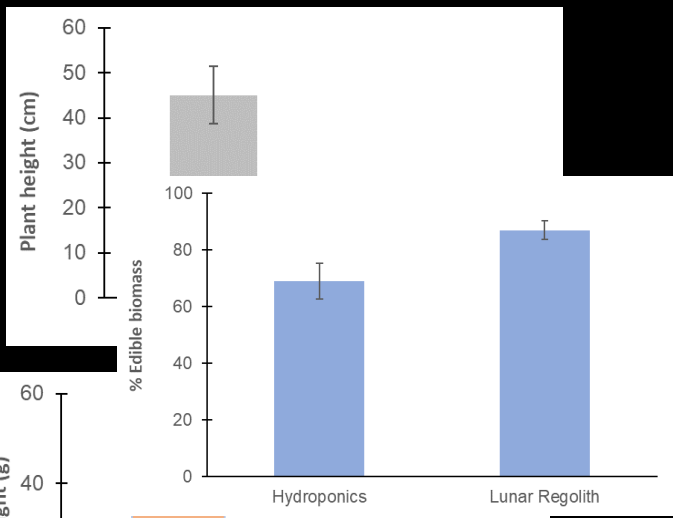

Questions

Indication of interest