New Perspectives for Watering Substrate-Based Root Modules in Microgravity in the Advanced Plant Habitat (APH)

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Denver, Co

PH-01 Experiment in APH

- An Integrated Omics Guided Approach to Lignification and Gravitational Responses: The Final Frontier
- Plant Habitat-01 investigation comprehensively compares differences in genetics, metabolism, photosynthesis, and gravity sensing between Arabidopsis plants grown in space and on Earth.
- Results from this investigation will provide key insights on lignin formation occurring in plants exposed to microgravity.
- PH-01 Experiment utilized two consecutive 6-week long growouts on ISS. Two root modules were grown on ISS and 2 root modules were ground controls in APH facility at KSC.

Advanced Plant Habitat

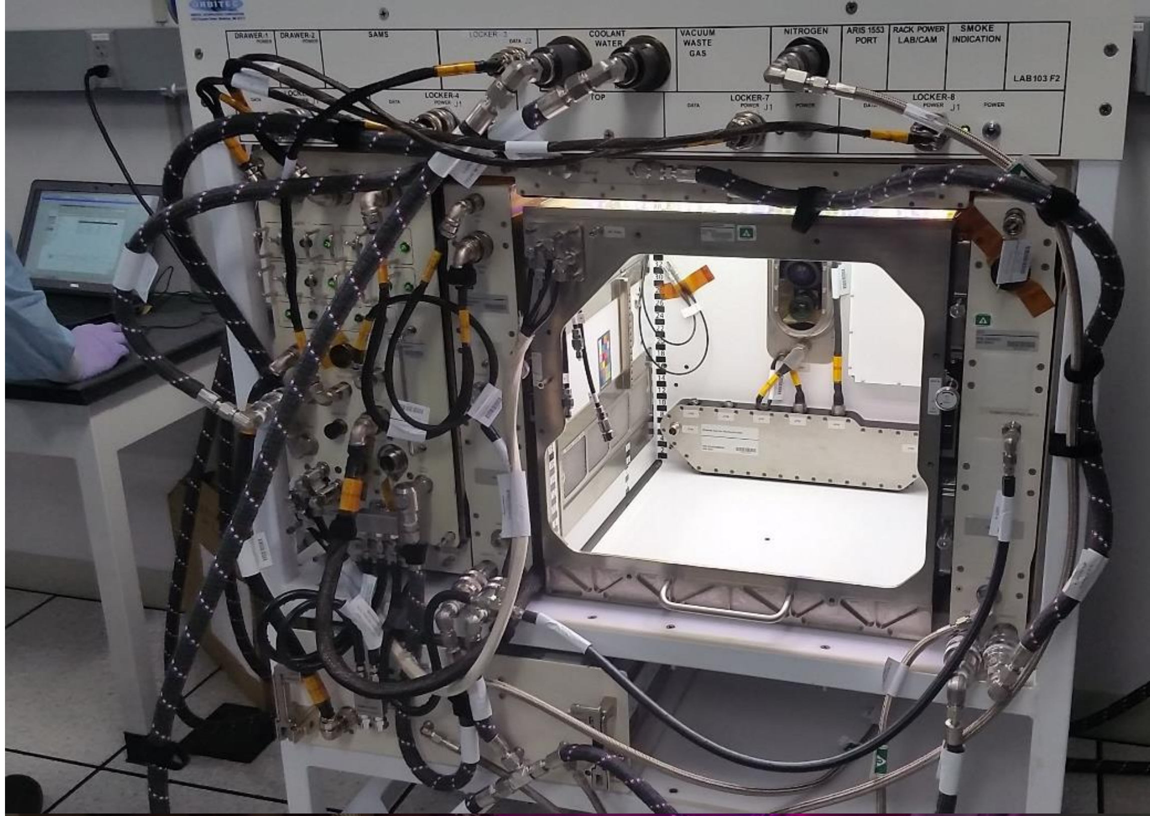
An automated plant growth facility for conducting plant research supporting space biology and food production projects on the International Space Station (ISS).

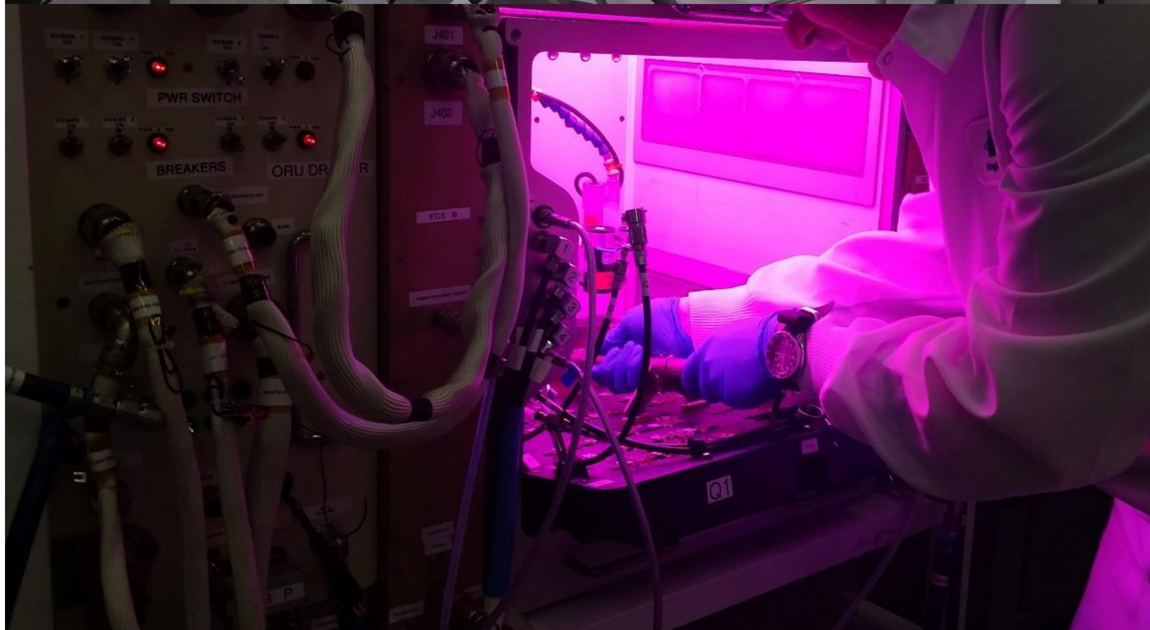
Plants are grown in the Science Carrier (SC) within the APH facility, (0.2 m^2 instrumented root module).

The SC is packed with fertilized media, seeded on Earth, and flown dry to the APH facility on ISS. The plant experiments are initiated when the SC is installed in the APH facility and it is fully wetted.

The SC watering protocols used for PH-01 were tested during the APH Hardware Validation test on ISS. The PH-01 watering protocols were implemented during the Science Verification Test (SVT) at KSC in the APH Engineering Development Unit (EDU).

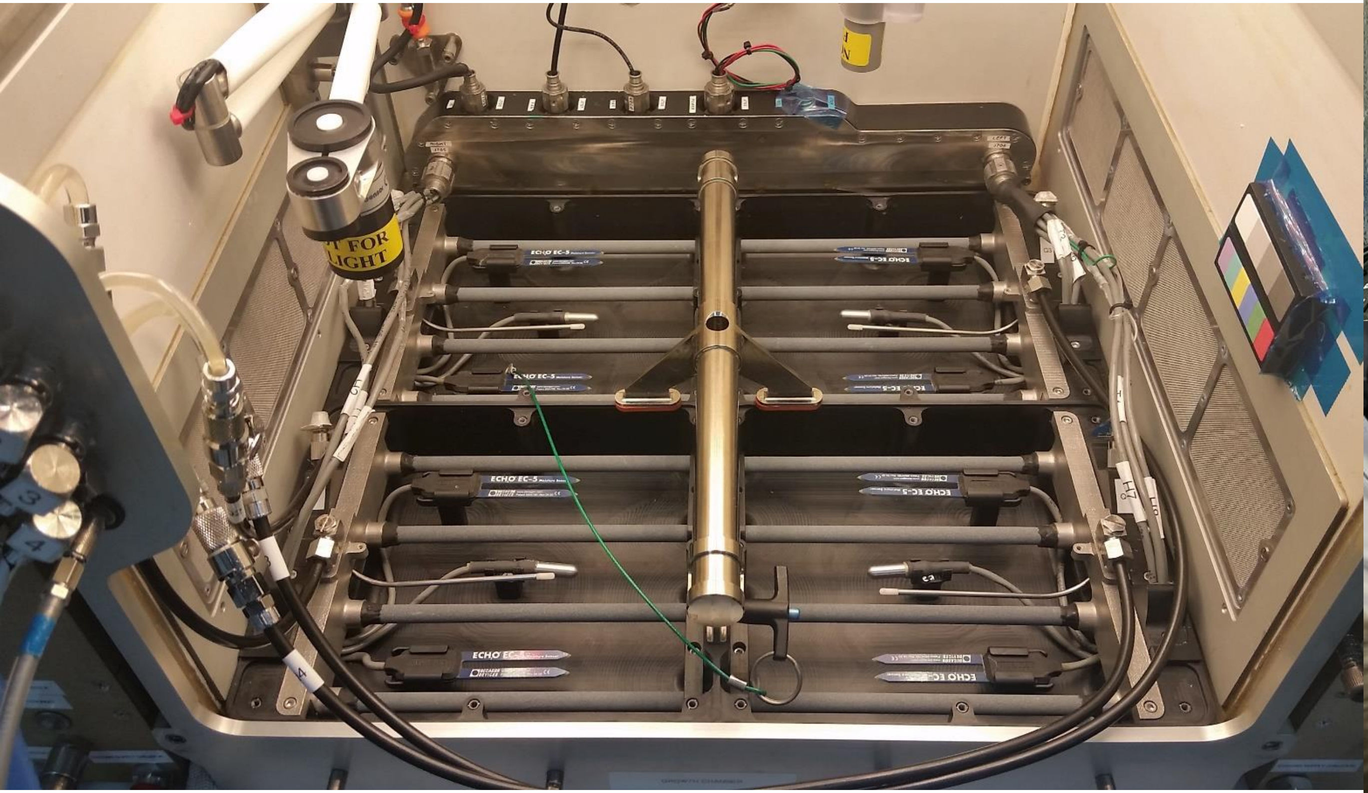
They were further tested during the Experiment Verification Test (EVT) and finally implemented during 2 consecutive experiments on ISS.

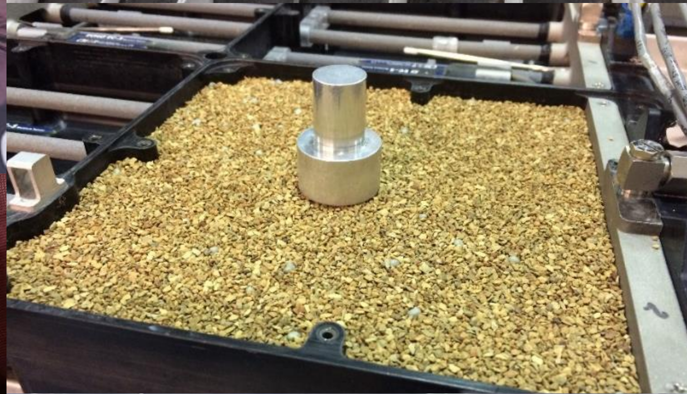
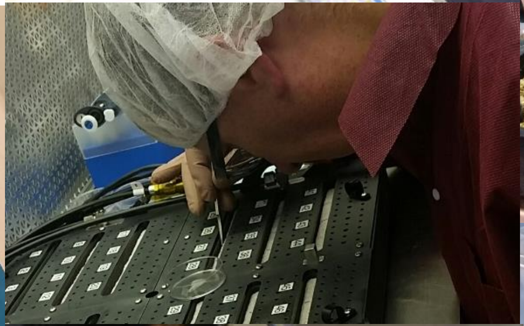
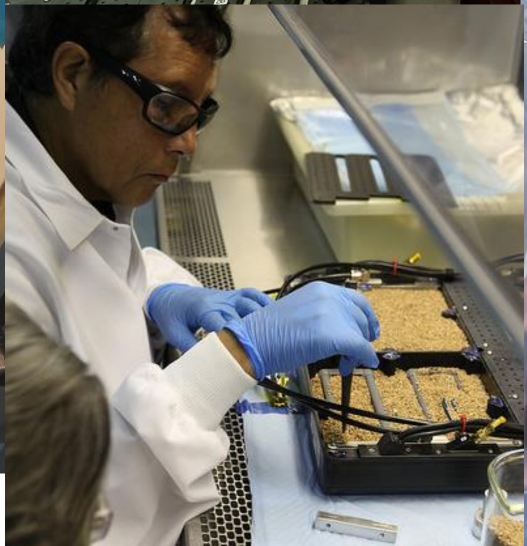




APH Science Carrier

- Four quadrants – independent moisture control
- Baseline – TRL-9 porous substrate / slow release fertilizer (1-2 mm Arcillite + T180 Osmocote)
- Pre-planted / Contains water and substrate

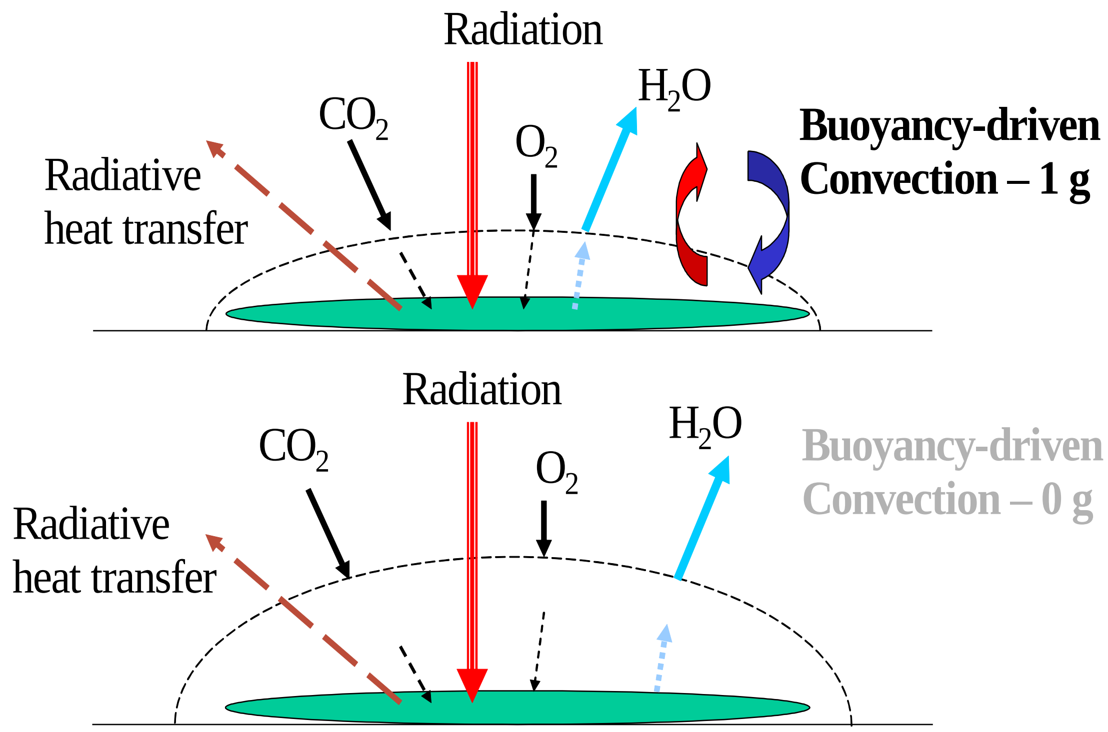


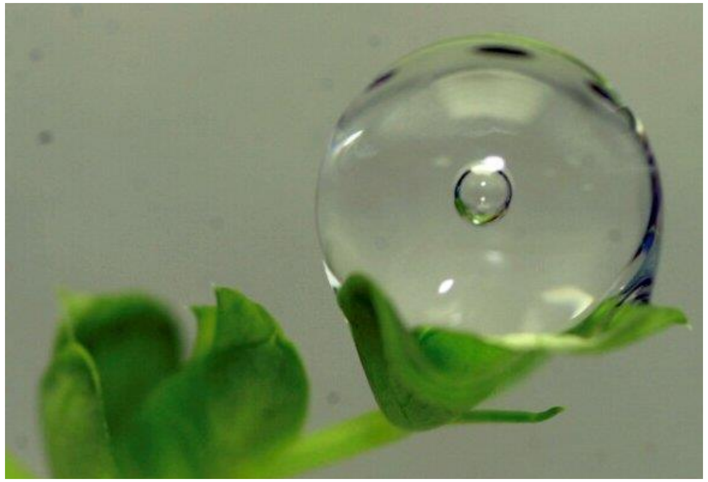

Space-Flight Environment

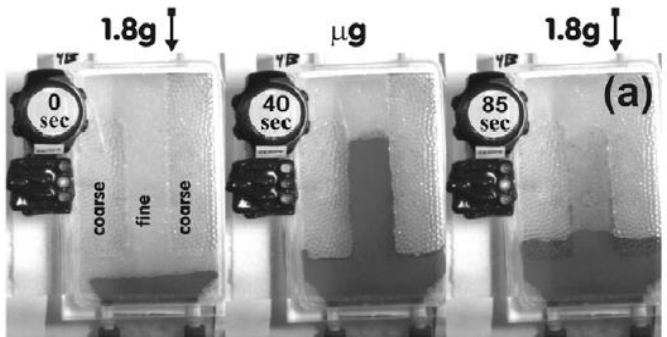
The absence of gravity induces physical effects that alter the microenvironment surrounding plants and their organs.

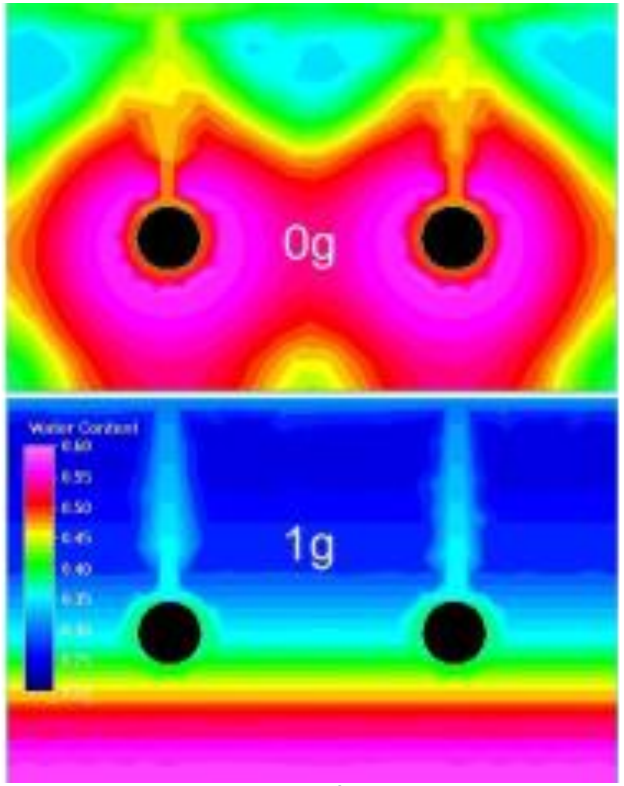
These effects include: increased boundary layers surrounding plant organs and the absence of convective mixing of atmospheric gases. In addition, altered behavior of liquids and gases is responsible for phase separation and for dominance of capillary forces in the absence of gravitational forces (moisture redistribution)



Monje et al. 2003







Jones and Or, 1998

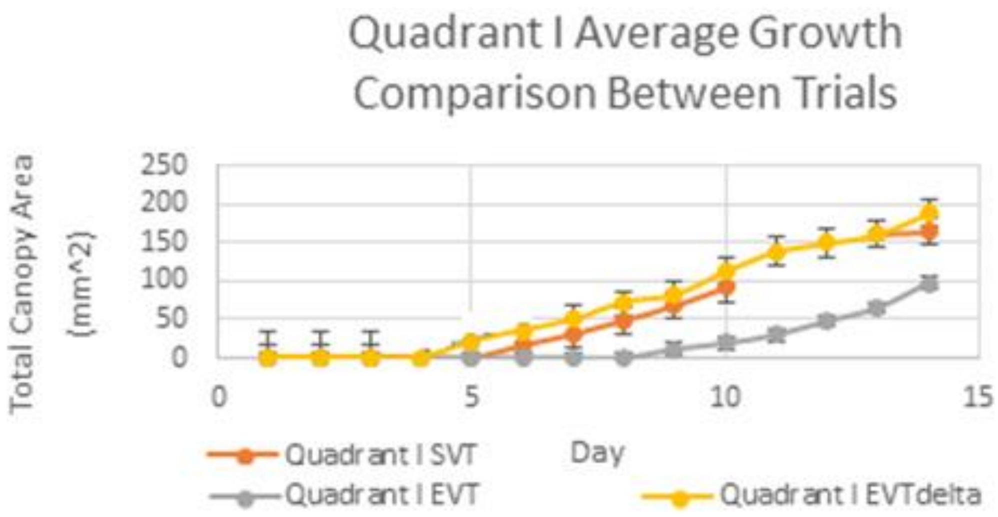
Initial Watering Protocol

Watering Protocol

- Each Quadrant holds ~1.1 L water, 1 kg dry Arcillite
- Goal: remove air bubbles from porous tubes/watering lines
- Flood fill SC to germinate seeds/uniformly wet arcillite
- Manufacturer Recommendation: Flood SC at high watering flow rates to remove air bubbles
- Maintain moisture setpoints – Pressure sensor settings

PH-01 Pre-Flight Ground Studies

- Initial SVT conducted in APH EDU.
- EVT reduced growth – plants grown in ground APH - underwatering.
- Action: calibrated pressure and volumetric moisture sensors for Flight and Ground units



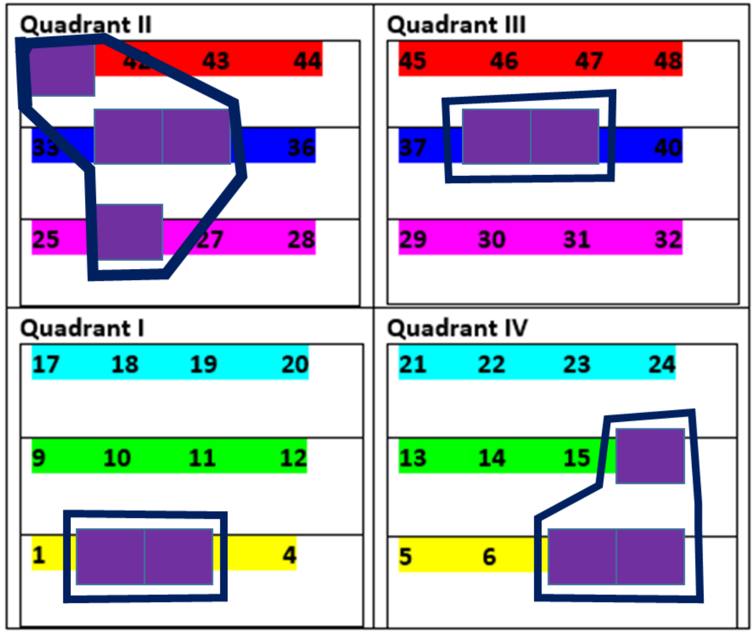
- EVTDelta – calibration corrected moisture problems
  - Developed pressure sensor offsets
  - Developed moisture sensor calibration equations

‘ time on the box’

PH-01 Flight Watering

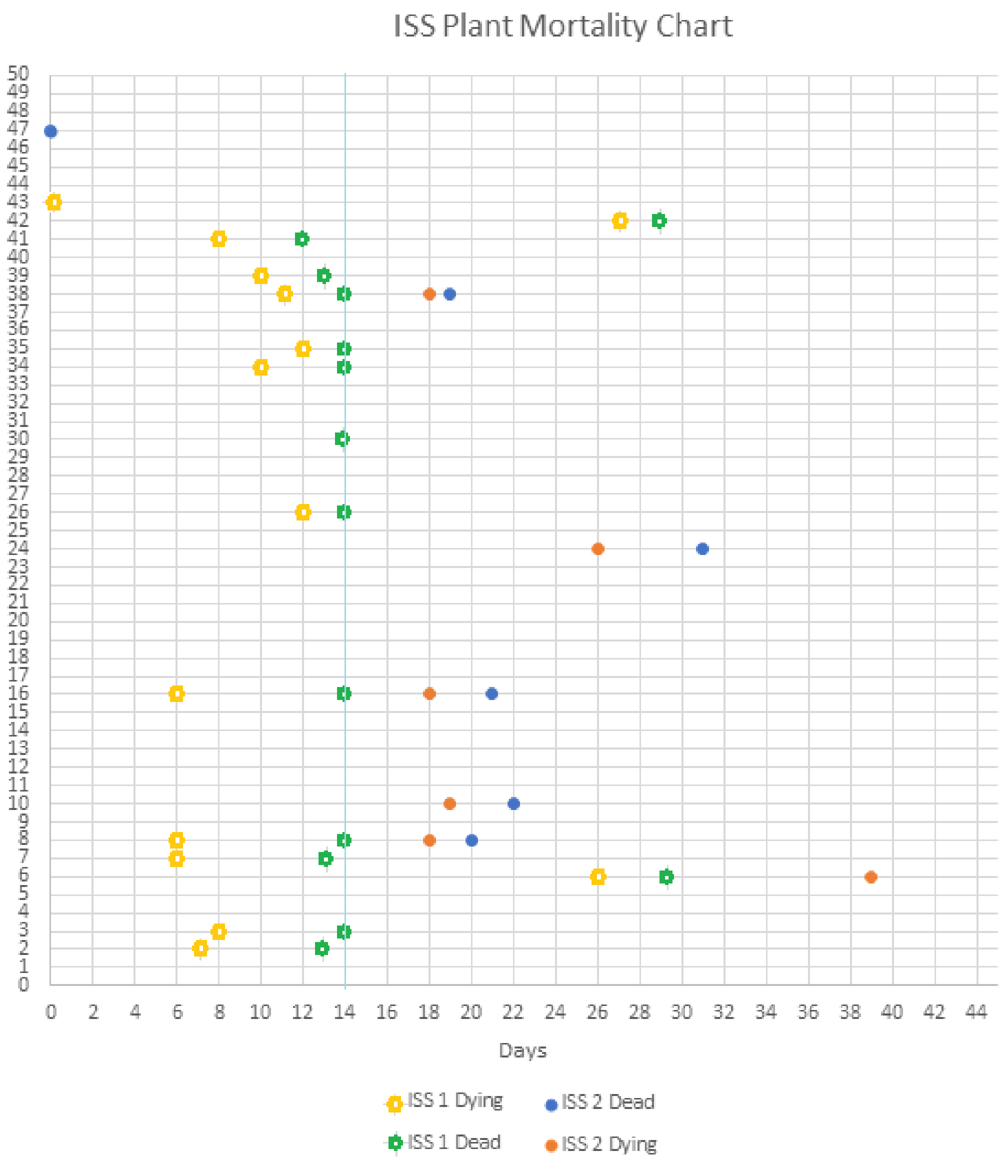
PH-01

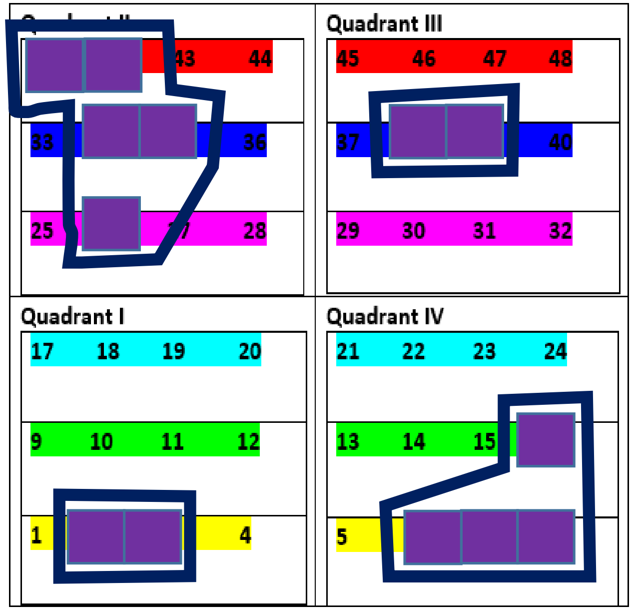
- ISS-1 – water escaped SC during watering
- Problem: fast fill can push water out low packing density pockets
- Plants germinated, but appeared to dry out.
- Pockets of trapped air within SC ?
- Solution: Revise watering protocol during ISS-2.
- Used slow flood fill and allow to equilibrate longer



ISS 1

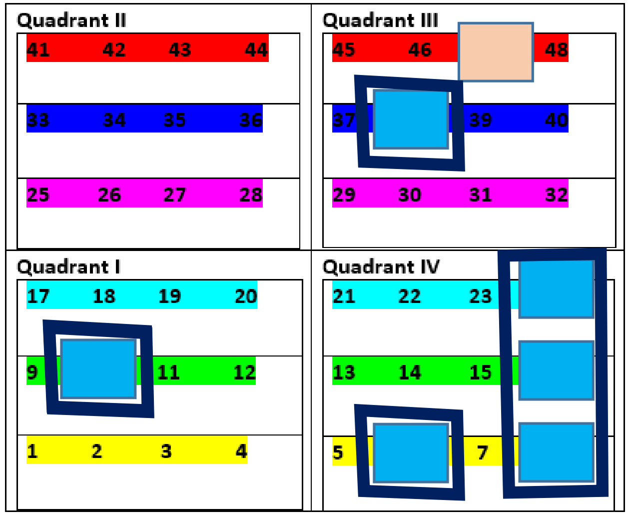
Plant Survival





ISS 1

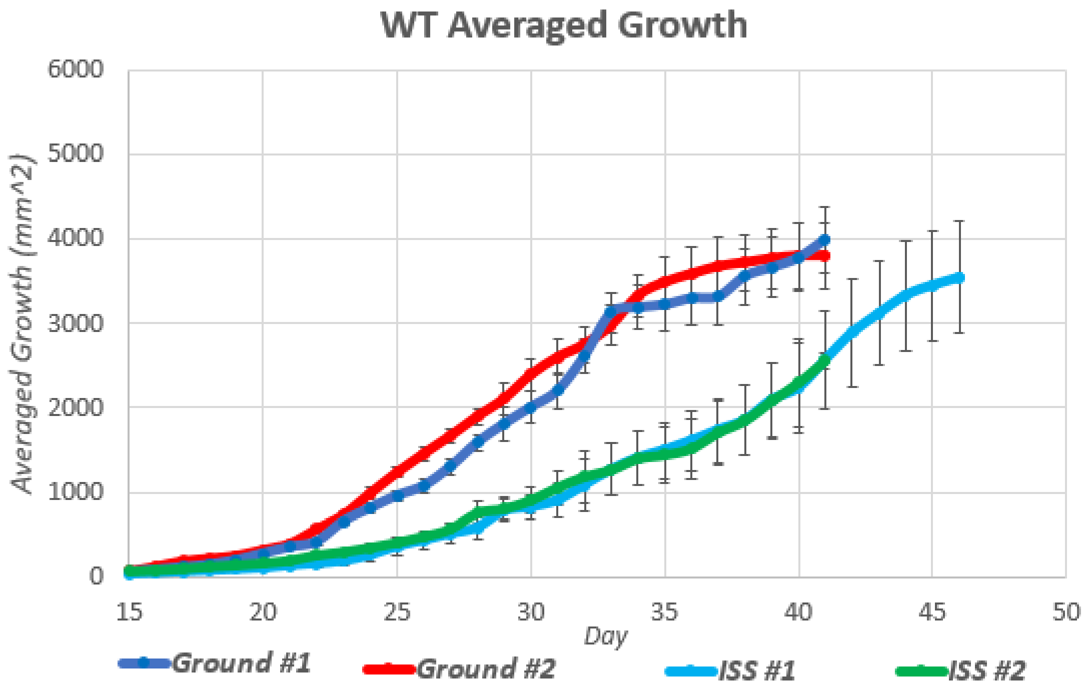
77.1 %

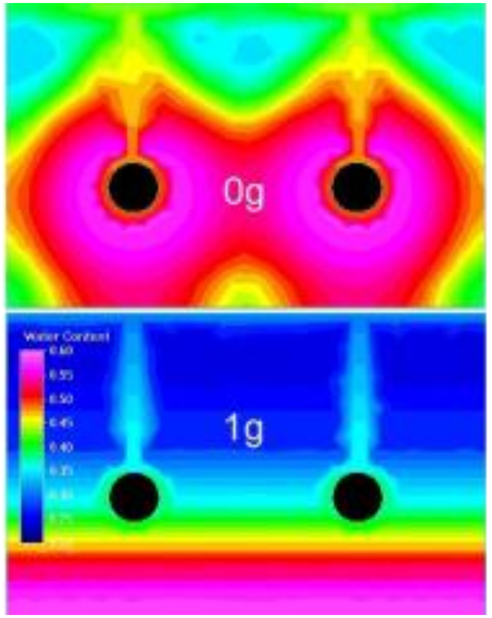


ISS 2

87.5 %

PH-01 Plant Growth Comparison





- ISS-1,2 – reduced growth compared to ground controls.
- Observations: Plants may be overwatered due to moisture redistribution phenomena

Conclusions

- PH-01 experiment completed.
- Determined that watering protocols determine plant survival due to hydraulic effects in microgravity (77% survival).
- Slower SC flood filling improved plant survival to 87%.
- Plants may be overwatered due to moisture redistribution phenomena.
- Future work: Conduct test to address moisture setpoints in microgravity compared to ground setpoints.

Questions?