Demonstration of a Long Duration Crop in the Advanced Plant Habitat Engineering Demonstration Unit: Key Factors to Consider Prior to Testing and Lessons Learned

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Plant Habitat-04

- **Microgravity Growth of New Mexico Hatch Green Chile as a Technical Display of Advanced Plant Habitat's Capabilities**
- **Principal Investigator**: Mathew Romeyn – NASA KSC
- **Technology Demonstration:** Advanced Plant Habitat Facility
  - **Successfully cultivate the first pepper plant in space.** Peppers have long germination times (10-14 days), long growth cycles (90-120 days) and fruiting periods (pick and eat crop).
  - **Perform detailed microbial analysis to screen peppers** for potential plant and human pathogens - advance the understanding of plant-microbe interactions in space.
  - **Assess the nutritional quality of peppers grown in space**, versus those on the ground. Peppers are an exceptional source of Vitamin C and K – greater Vitamin C content than fresh citrus fruit.
  - **Determine crew acceptability of peppers grown in space.** The flavor and texture of peppers respond to changes in growth environment. Spiciness -the 'Espanola Improved' pepper has a medium scoville rating of 2000-4000 (<1/2 a jalapeno).
- **PH-04 Mission:** Launch on NG-15 – Feb 2021
- **Acknowledgements:** This work is funded by NASA's Biological and Physical Sciences (formerly SLPSRA) Division and by NASA's ISS Program Office.

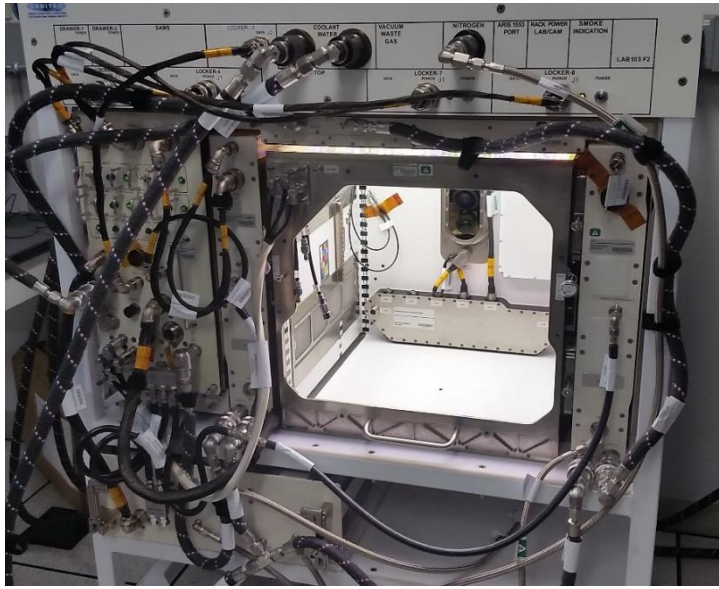
APH Facility

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

Plants are grown in the Science Carrier (SC) of the APH, (0.2 m^2 instrumented) root module. The SC is packed with media, seeded on Earth, and transferred dry to the APH facility on ISS. The plant experiments are initiated when the SC is installed in the APH growth chamber and it is fully wetted.

APH 1st Plant Test – Tech Demo:

- Initiated First Plant Test on 22 Jan 2018 - verify that science is supported on APH.
- Install pre-planted SC: WT Arabidopsis and Apogee semi-dwarf wheat
- Two week growth of WT Arabidopsis and 33 days of wheat conducted to demonstrate adequate plant growth on APH facility.
- Demonstrate and evaluate performance of on-orbit watering protocols.



APH Literature:

Morrow et al. "A new plant habitat facility for the ISS," ICES-2016-320, 2016.

Monje et al. "Hardware Validation of APH on ISS: Canopy Photosynthesis in reduced gravity", Frontiers in Plant Science 2020.

‘Hatch to ISS’ Stakeholders

- PI/Crop Production Team
  - Matt Romeyn, LaShelle Spencer and Jacob Torres
- APH Hardware Project Science
  - Oscar Monje and Jeffrey Richards
- NASA Hardware Project Manager
  - Nicole Dufour
- TechShot Mission Integration and Operations
  - Dave Reed, Thomas Tyson, and Clayton Gross

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What inputs are required from PI team for a successful APH mission?

- Lighting/Spectrum/Photoperiod
  - Lighting affects physiology
- Environmental set points
- Seed germination
- Media and fertilizer
- Crop moisture requirements
- Pollination Method
- Seed cultivars an Sanitization

Ground testing was conducted by the crop production team for Hatch to ISS.

- Light Recipe - optimal spectral quality
  - Control plant height with high blue ratios
  - Green light reduces intumescence (leaf lesions)
- Elevated CO_2 increases intumescence
- Wicking configurations affect germination, emergence and seedling viability
- Optimize time release fertilizer amount
- Consult NM growers ; Determine upper and lower moisture limits by wilting test
- Two options - cycling of fan speed and manual tapping of flowers
- Cultivar selection ; Verified germination and seed sanitization protocols

Mission Timeline

- Thinning - Detritus Removal
- Environment
  - RH, wind speed, light intensity, moisture levels
- Estimate crew time
  - Thinning, videos, harvest
- Crew operations

Life Cycle

Stage	DAI
Initiation	0
Germination	1 to 14
Seedling	15
Budding	30
Flowering	45
Fruiting	50
Fruit Ripening	90

	Days After Initiation (DAI)															
	0	5	10	15	20	30	40	45	50	60	70	80	90	100	110	120
Initiation	x															
Germination																
Seedling																
Vegetative																
Budding																
Flowering																
Fruiting																
Fruit Ripening																
Final Harvest																x
%RH	70	70	70	50	50	50	50	50	50	50	50	50	50	50	50	50
Air Speed (m/s)	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9\1.5 cy	0.9\1.5 cy	0.9\1.5 cy	0.9\1.5 cy	0.9	0.9	0.9	0.9	0.9
SC Moisture	hi	hi	hi	mid	mid	mid	lo	lo	lo	lo	lo	lo	lo	lo	lo	lo
PPFD*	hi	hi	hi	hi	hi	hi	mid	mid	mid	mid	mid	mid	mid	lo	lo	lo
CO_2	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550	550
Tair	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
Thinning					x 28DAP											
Detritus removal							x		x		x		x		x	
Insert Stands**									x							
Gas Exchange Expts											x	x	x	x		
1st harvest														x		
2nd (final) harvest																x

Samples frozen (-20°C) for analysis

Nutritional:

12 peppers

Microbial:

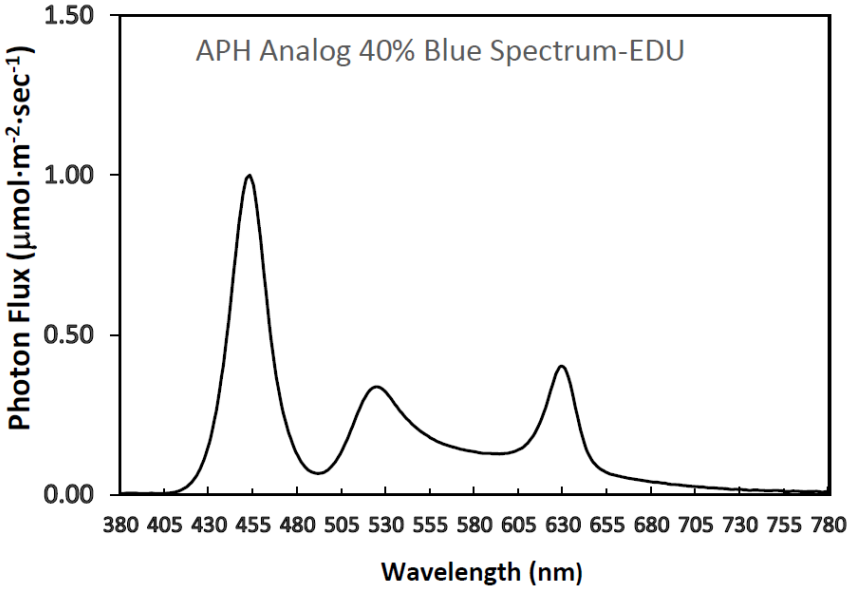
8 peppers

Crew Taste:

4 peppers

Hatch to ISS – 122 d APH EDU Test

- Four ‘Espanola Improved’ pepper plants
- 550 ppm CO_2, 50%RH, 23°C
- 16/8 Photoperiod
- PPFD: 300 µmol m^{-2} s^{-1} at plant height
  - 27:33:40 RGB
- Media volumetric moisture – wilting

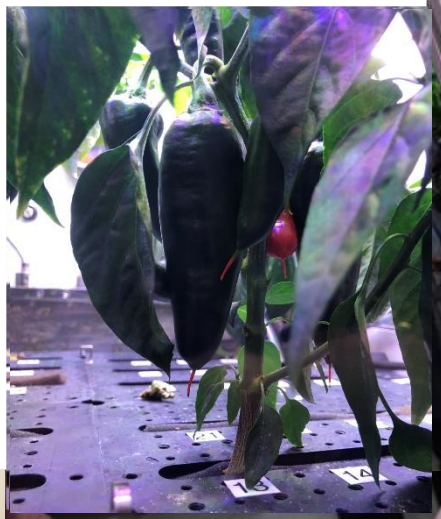






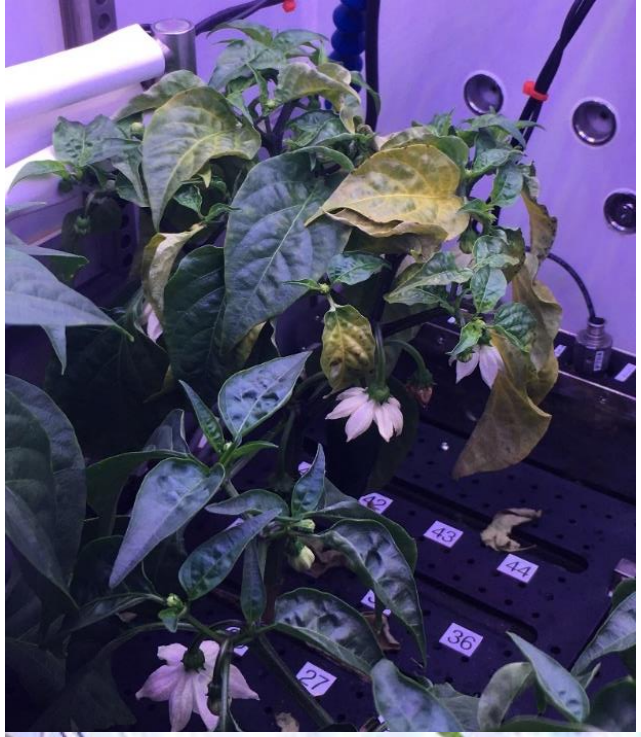
Hatch to ISS – 122 d APH EDU Test

- Four 29 cm tall plants
- 3 harvests
  - 50 fruits, 10-17 fruits/plant
  - 674 g edible biomass
  - 65% red, 24% green, 12% mixed
- Wilted plants – spicy
- Met success criteria



Cultural Observations

28 DAP
Thinning



58 DAP; Excessive moisture causing chlorosis

116 DAP; Harvest #2 red and green fruit

68 DAP; Stem girdling due salt build up on wick

74 DAP; Healthier plants after reducing irrigation level

Lessons Learned

- Discuss APH hardware early in design – ethylene, watering, and environmental control
- Conduct extensive ground testing – Light recipe, CO_2, fertilizer amounts
- Use APH analog science carriers – Scheduling, plant growth, germination
- Monitor environmental conditions daily – Root zone moisture
- Science Verification Test
  - Define crew operations, crew kits and mission timeline
  - Identify factors reducing crop growth – wick configuration and salt stress
  - Reduce risk and increase mission success

- For questions and comments:
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