

NCERA-101 STATION REPORT FROM KENNEDY SPACE CENTER, FL, USA (Mar. 2014)

Impact Nugget:

The Veggie Vegetable production system built by ORBITEC has been tested at KSC for flight and will soon be installed on the International Space Station (ISS). The hardware validation test for Veggie will be conducted with red romaine lettuce, which the crew will harvest, freeze, and return to Earth for food safety analysis.

Facility Description:

The Space Life Sciences Lab (SLSL) Controlled Environment Lab (CEL) has been operational for 9 ½ years (commissioned Sept. 2003) and provides 622+ ft² (58 m²) of controlled environment chamber space. The CEL provides support to both basic and applied research with emphasis on ground-based and space applications. NASA has returned operations of the SLSL to Space Florida, the agents representing the State of Florida.

Kennedy Space Center (KSC) management has moved the biological research group from the Space Life Sciences Lab (SLSL) to other facilities on the main part of KSC. Whether we can continue to use the growth chambers in the SLSL building, remains to be determined, however these represent the only large plant walk-in facilities available for continuous use at KSC. The large ISS Environment Simulator Chambers are reserved for conducting verification tests and ground controls of flight experiments. Several small reach-in chambers have been moved from the SLSL to other buildings at KSC. All of the associated life support biology and chemistry labs have been moved. Stay tuned for further developments.

New Equipment / Sensors / Control Systems:

- We received 30 PAR 38 dimmable LED lamps from Lighting Sciences Group (www.lsgc.com). These lamps operate in standard incandescent fixtures with household dimmers and we obtained lamps of either red or blue LEDs as well as three different red:blue ratios for use in plant dwarfing studies.

Unique Plant Responses:

- We noticed a peculiar curling of pepper leaves (i.e., they seemed to turn upside down) in some studies. We found some reports of this occurring when seedlings are moved from higher to lower humidity.

Accomplishments:

- We successfully grew 'Outredgeous' red romaine lettuce in the Veggie flight hardware as part of the payload verification test for the flight of this hardware. The hardware validation test of Veggie on the international space station is scheduled to commence in April.
- Levels of CO₂ in space shuttle cabin typically range between 4000-6000 µmol mol⁻¹ and can exceed 10,000 µmol mol⁻¹ with large crews. In order to use plants for life support (i.e., O₂ and food production, CO₂ removal, water purification) it is imperative that we understand how plants respond to super-elevated CO₂ (SE-CO₂) (>5000 µmol mol⁻¹). Controlled environment studies at KSC have shown that prolonged exposure to SE-CO₂ resulted in increased stomatal conductance and decreased water use efficiency by plants.

To understand this phenomenon, we continued to grow plants in controlled environment chambers and expose them to varying levels of CO₂. Using molecular genetics and Next Generation Sequencing (NGS) tools we are trying to dissect the mechanism behind plant responses to SE-CO₂. At the same time we are also using reverse genetics tools, such as T-DNA insertional mutants, to answer specific questions related to starch metabolism, which could be a key aspect of plant's response to SE-CO₂.



Arabidopsis thaliana
growing in a controlled
environment chamber in
SLSL

- Growth Chambers are currently being used to characterize a range of plant dwarfing tools and procedures that could be applied to Advanced Life Support. The ability to dwarf standard crops will help meet volume and mass limitations of spaceflight and planetary exploration. The following tools and procedures are currently under consideration:
 - Mechanical stimulation (e.g., thigmomorphogenesis, seismomorphogenesis)
 - Atypical temperature profiles (e.g., dip/diff)
 - Root restriction
 - Pruning and training
 - Genetic manipulations (e.g., FT constructs)
- Researchers from the USDA/ARS and NASA are collaborating to evaluate a rapid-cycle crop breeding system as a mechanism for using tree fruit crops for Advanced Life Support. In the past, tree fruits have not been a serious consideration due to long juvenile phases, dormancy requirements, large canopy architectures, and low harvest indices. Controlled environment chambers are being used to evaluate the performance the FT transformed plums (*Prunus domestica*) under spaceflight relevant conditions.



A. Bell peppers subjected to mechanical stimulation: Left is the control, right was mechanically stimulated twice per day for 10 seconds. **B.** FT transformed plums (*Prunus domestica*) demonstrating dwarf phenotypes compatible with the constraints of spaceflight.

Impact Statements:



Recent Publications/Presentations:

- Yang, Y., Massa, G.D., and Mitchell, C.A. 2014. Temperature DIP at the beginning of the photoperiod reduces plant height but not seed yield of maize grown in controlled environments. *Industrial Crops and Products* 53:120 – 127.
- Massa, G.D., Newsham, G., Hummerick, M.E., Caro, J.L., Stutte, G.W., Morrow, R.C., and Wheeler, R.M. 2013. Preliminary species and media selection for the Veggie space hardware. *Gravitational & Space Research* 1(1):95-106.
- Massa, G., M.S. Simpson, G. Newsham, G.W. Stutte, R. Wheeler. 2013. Plant atrium system for food production in NASA's Deep Space Habitat tests. *Amer. Inst. Aeronautics and Astronautics AIAA* 2013-3359.

- Nakamura, T., O. Monje, and B. Bugbee. 2013. Solar food production and life support in space exploration. Space 2013, Amer. Inst. Aeronautics Astronautics AIAA 2013-5399.
- Wheeler, R.M. 2014. Journal papers from Kennedy Space Center advanced life support and plant space biology. NASA Technical Memorandum 2014-217385.
- Stutte, G.W. and R.M. Roberts. 2013. Microgravity effects on the early events of biological nitrogen fixation in *Medicago truncatula*: Results from the SyNRGE experiment. Life is Space for Life on Earth, ESA SP-706. 5 pg.

Scientific Outreach:

Committees / Panels:

ASHS CE Working Group (Stutte, Wheeler, Massa)

Com. on Space Research (COSPAR) F4 (Wheeler)

ACMAP Board of Directors (Stutte)

ASGSR Governing Board (Massa)

Sabbatical Leave

Gary Stutte, Marie Curie Fellowship from EU
(working at Limerick Institute of Technology, IE)