

## NCERA-101 STATION REPORT FROM KENNEDY SPACE CENTER, FL, USA (July 2015)

### **Impact Nugget:**

The Veggie Vegetable production system built by ORBITEC was launched to the International Space Station and an initial crop of red romaine lettuce plants were grown as part of a validation test (Fig. 1). Plant materials were returned to Kennedy Space Center and analyzed for microbial counts and tissue composition.



Figure 1. The Veggie Plant Growth in the Columbus Module of the International Space Station. Lighting is provided primarily with red and blue LEDs.

### **Facility Description:**

We have now completely moved out of the Space Life Sciences Lab (SLSL) but continue to rent chambers there to support our plant research. Two reach-in chambers were moved to the Space Station Processing Facility (SSPF) and several smaller incubators were moved to the O&C Building on the main campus of Kennedy Space Center. Three walk-in chambers used for ISS Environmental Simulation are also maintained at the SSPF building, but are reserved for conducting verification tests and ground controls for spaceflight experiments.

### **New Equipment / Sensors / Control Systems:**

- We have ordered a Decagon SC-1 porometer for stomatal conductance measurements. Our Li-Cor 1600 Steady State porometer is about 25 years old and Li-Cor no longer makes or services these devices. We'd welcome any comments from owners / users of the Decagon device.

### **Unique Plant Responses:**

- Tom Graham has developed a reliable approach for rooting cuttings of genetically engineered plum (*Prunus domestica*) trees overexpressing the FT1 flowering gene (developed by ARS group at Kearneysville, WV). Once rooted, Tom can get these cuttings to flower and set fruit in a period of just months (Fig. 2).



Figure 2: Dwarf FT overexpressed plum cuttings with flowers.

### **Accomplishments:**

- Gioia Massa oversaw the “validation” testing with Veggie plant growth systems on the International Space Station last spring. Veggie has come a long way from Bob Morrow’s back of the envelope concepts in the mid-1990s to seeing actually growing plants (red romaine lettuce) on the ISS in 2014! Gioia also received a 3-yr NASA grant to conduct the first official plant testing with Veggie (with leafy greens and dwarf tomato). Ray Wheeler at KSC, Bob Morrow at ORBITEC, and Cary Mitchell at Purdue are co-Is on the grant.
- We completed a comparison of leafy “greens” as possible space salad crops and sent them to NASA’s Johnson Space Center for sensory evaluation with panels of tasters (Chinese cabbage, mizuna, Swiss chard, and lettuce all scored well). We are following this with a series of tests to compare dwarf tomato and pepper varieties, and LaShelle Spencer and Mary Hummerick deserve much of the credit for this work. We plan to send peppers and tomatoes to Johnson Space Center for taste testing in August 2015.

- Tom Graham continued his testing with dwarf GM plum trees. He has selected several lines (genotypes) that flower reliably and stay short. These GM plums were developed by the USDA / ARS group at the Appalachian Fruit Research Station (AFRS) in Kearneysville, WV (Ralph Scorza and colleagues) and flower continuously with no dormancy requirements. Tom is looking at photoperiod, CO<sub>2</sub>, and other responses, as well as plowing new ground for our group in working out horticultural techniques with woody species in our growth chambers.
- Tom Graham is working with Ani Dixit to establish the protein production levels associated with the FT1 transformation in *P. domestica*. The protein expression will be correlated with the phenotypes observed and used as a further metric in the down selection of lines for use in space applications.
- Ani Dixit in our group continues to study responses of *Arabidopsis* to elevated and super-elevated CO<sub>2</sub> (4000 and 8000 ppm) (Fig. 3). We have been conducting these studies for a number of years but still do not understand the mechanisms that cause stomata to “re-open” at super-elevated levels. Ani is working with several mutant lines and is doing full RNA sequencing runs for the different treatments in an attempt to better understand the responses.

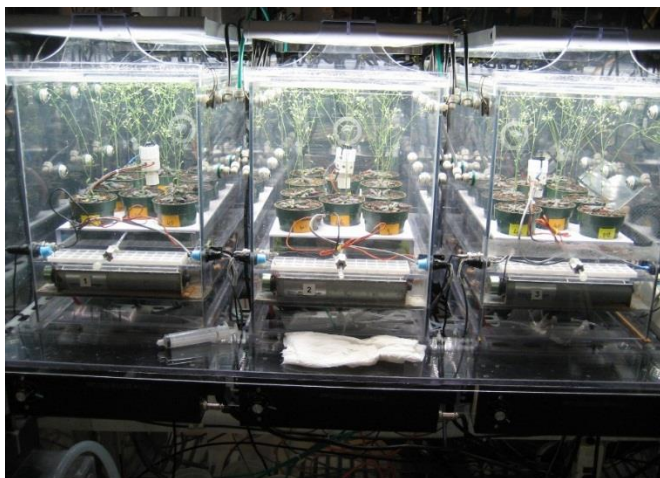


Figure 3. *Arabidopsis thaliana* growing in a controlled environment chamber at super-elevated CO<sub>2</sub> levels, viz. 4000 and 8000 ppm.

- Tom Graham is also continuing his work to use thigmo/seismo stimuli, pot-binding, and spectral quality to reduce the height of plants for use in space. Tom's latest test is comparing different red and blue light ratios with LEDs (like many others in NCERA-101!) and the tests include tomato, pepper, soybean, cucumber, snow pea, and radish. Due to chamber and time constraints these studies are limited to seedling tests.

- Our nomadic colleague, Gary Stutte has finally returned to KSC from his EU Marie Curie fellowship to Limerick Institute of Technology (LIT), IE. During his visit, Gary was able to get LIT involved with a Space Florida / Nanoracks sponsored spaceflight experiment, SyNRGE<sup>3</sup>, investigating plant/microbe interactions and biological nitrogen fixation on the ISS, acquire 2 Heliospectra LED arrays, join a German Space Agency-led effort on an EU grant (EDEN-ISS) to develop plant growth systems for the

Neumayer Station in the Antarctic, and design a prototype “salad machine” for the International Space Station. Gary also officially visited the “Blarney Stone” while on sabbatical!

#### **Impact Statements:**

- Thanks to many hard working colleagues at KSC, ORBITEC, and numerous universities, the plant controlled environment and CEA community have successfully extended their reach to the International Space Station with the Veggie plant growth unit. NASA and ORBITEC are planning to build an even larger (0.2 m<sup>2</sup>), more highly controlled plant research chamber called the Advanced Plant Habitat, or APH. Hopefully we can keep the momentum.

#### **Recent Publications/Presentations:**

- Bamsey, M.T., A.L. Paul, T. Graham, and R.J. Ferl. 2014. Flexible imaging payload for real-time fluorescent biological imaging in parabolic, suborbital and space analog environments. *Life Sci. Space Res.* 3:32-44.
- Graham, T., R. Scorza, R. Wheeler, C. Dardick, B. Smith, A. Dixit, D. Raines, A. Callahan, C. Srinivasan, L. Spencer, J. Richards, G. Stutte. 2015. Over expression of FT1 in plum (*Prunus domestica*) results in phenotypes compatible with spaceflight: A new candidate crop for bioregenerative life-support systems? *Gravitational and Space Res* (accepted)
- Hayes, M.W., G.W. Stutte, M. McKeon-Bennett, P.G. Murray. 2014. Mutualism within a simulated microgravity environment- *Piriformospora indica* promotes the growth of *Medicago truncatula*. *Grav. Space Res.* 2: 21-33.
- Massa, G.D., T. Graham, T. Haire, C. Flemming, G. Newsham, and R. Wheeler. 2015. Light-emitting diode light transmission through leaf tissue of seven different crops. *HortScience* 50(3):501–506.

- Massa, G.D., E. Chase, J.B. Satini, and C.A. Mitchell. 2015. Temperature affects long-term productivity and quality attributes of day-neutral strawberry for a space life-support system. *Life Sciences in Space Research* 5:39-46.
- Poulet, L., G.D. Massa, R.C. Morrow, C.M. Bourget, R.M. Wheeler, and C.A. Mitchell. 2014. Significant reduction in energy for plant-growth lighting in space using targeted LED lighting and spectral manipulation. *Life Sci. Space Res.* 2:43-53.
- Stutte, G.W. 2015. Commercial transition to LEDs: A pathway to high value products. *HortScience* (accepted)
- Yamashita, M. and R.M. Wheeler. 2014. Habitation in space. In M. Macdonald and V. Badescu (eds.): *The International Handbook of Space Technology*, Springer Praxis Books, DOI: 10.1007/978-3-642-41101-4\_17, Springer-Verlag, Berlin Heidelberg 2014. Pages 493-513.
- 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

### ***Scientific Outreach:***

#### ***Committees / Panels:***

- ASHS CE Working Group (Stutte, Wheeler, Massa)
- Com. on Space Research (COSPAR) F4 (Wheeler)
- ACMAP Board of Directors (Stutte)
- NCERA-101 Secretary (Massa)