NCR-101 STATION REPORT FROM KENNEDY SPACE CENTER, FL, USA (April 2006)

New Facilities:

The Space Life Sciences (SLS) Lab Controlled Environment Lab (CEL), formerly the "phytotron", has been operational for 2 ½ years. The 606+ ft^2 of controlled environment chamber space consists of eight EGC M-48 walk-in chambers, four GC-36 reach-in chambers with ante-rooms, two GC-15 reach-in chambers, four M-12 reach-in chambers, and a number of smaller Percival and Conviron incubators. The lab recently inherited an EGC model GC-8 from Johnson Space Center and is currently being installed and modified to meet lab requirements.

Equipment / Sensors / Control Systems:

- The control and monitoring system for the CEL, CMDS [Command, Monitoring and Data System], was completed. Capabilities that have been added to the system include remote access via internet, alarming, and database collection and analysis capabilities.
- Following successful testing last year, ultrasonic humidifiers were installed in all of the CEL's M-48 and M-12 chambers.
- Testing was completed with red (R), red-blue (RB), and red-blue-green (RGB) LED arrays as sources for plant lighting. Plant growth testing was completed with radish using the newly acquired R, RB, and RBG Snap Lite units from Quantum Devices, Inc. Irradiance of the Snap Lite units declined after ~10,000 hours of operation nearly 60% in overall output of PAR. Irradiance output performance continues to be evaluated for both the Snap Lite and Norlux units. A new high output LED array from ORBITEC with $\geq$300 µmol m^{-2} s^{-1} PPF @ each of six spectral components (400, 440, 520, 640, 660, and 720 nm) was received and testing is underway.
- LADA plant growth units that are currently being used in the Russian module of the International Space Station were tested in an M-12 chamber to assess microbial numbers and types on radish roots for food safety.
- Variety trials were completed with strawberry to assess growth, pollination, and fruit set traits under controlled environment conditions. Cultivars included: Tristar, Tribute, Whitney, and Everest.
- Volatile organic compound analysis (VOCA) hardware was upgraded with internal temperature control so each chamber has internal temperature, RH, CO_2, and water/nutrient delivery control.
- Bench scale VOC exposure system was completed that allows independent control of up to 16 individual chambers. This system is suitable for seedling and germination assays.
- The Biomass Production System for Education (BPSe), an educational unit produced by ORBITEC (Phase III SBIR) for ground research in plant production and systems engineering were tested this past summer. Similar chambers were tested at Purdue and the USDA, Toledo. The BPSe consists of a base unit, a 0.25 m^2 root tray, fluorescent light cap capable of a PPF of 400+, and bellows for height expansion. A companion curriculum for high school was developed by Purdue and the targeted price is about $1500/unit.
- Kennedy Space Center was not affected by the two significant hurricanes that made landfall in Florida this past year (Katrina in late August and Wilma in late October).

Unique Plant Responses:

- VOC exposure studies are being conducted at 100, 50, 25 and 10% of NASA's Spacecraft Maximum Allowable Concentration (SMAC) levels for target VOCs. Ethanol inhibits growth of radish at 10% of the human SMAC level and is lethal at 50% of SMAC. Growth of *Fusarium* sp was observed at low concentrations of acetone, ethanol, butanol and toluene.
- Environmental baseline studies for typical open cabin atmosphere in space (such as the Intl. Space Station) were completed with radish, lettuce, and onion. Treatments included ambient, elevated, and super-elevated CO_2 (400, 1200, and 4000 ppm), air temperatures of 22, 25, and 28°C, and PPFs of 150, 300, and 450 µmol m^{-2} s^{-1} with a 16-h photoperiod with fluorescent lamps. Biomass yields show optimal temperatures for growth and generally increasing yield with increasing PPF. Significant tipburn was observed on lettuce plants at higher PPFs.
- Evaluation of six strawberry cultivars under at 22°C, 16-h photoperiod at 300 µmol m^{-2} s^{-1} was completed. Changes in nutrient requirements during vegetative, flowering, and fruit development phases made system management challenging.
- Environmental baseline studies similar to those above continued with dwarf tomato (Red Robin) and dwarf pepper (Hanging Fruit Basket). Mild oedema (intumescence) continues to occur on pepper leaves, likely due to low UV radiation in these controlled environment tests.
- Radishes grown under red LEDs only showed spindly leaf development and relatively damped stomatal rhythms compared to plants grown under red/blue or red/green/blue.
- Wheat grown at 450 umol m^{-2} s^{-1} under 640 and 440 nm wavelengths required 15 µmol 440 nm to achieve heading. No additional effect of increasing intensity of 440 nm has been observed. Heading was greatly delayed when 400 nm was used instead of 440, and up to 35 umol m^{-2} s^{-1} was required.
- Testing has begun on studying the effects of low level light "pollution" on the tuberization of potatoes.
- Plant responses show differences between the "bare tube" only NDS and granular media filled NDS modules, indicating possible water and nutrient uptake limitations with the bare tube NDS.

Committees / Panels:

ASHS Publications Committee (Stutte)
ASHS CE Working Group (Stutte, Yorio, Wheeler)
Plant Growth Reg. Society of America Steering Com. (Stutte)
Intl. Advanced Life Support Working Group (Wheeler)
ASABE Board of Trustees (Sager)
Com. on Space Research (COSPAR) F4 (Wheeler)

Visiting Scientists:

Hyeon-Hye Kim, NASA-National Research Council Fellowship
Sarah Matthews, Limerick University, Limerick, Ireland
Deirdre Hayes, Limerick University, Limerick, Ireland
Roger Johnson, sabbatical, University of Central Florida
Joey Norikane, summer faculty, University of Kentucky
Peter Ling, summer faculty, The Ohio State University
Jane Shevtsov, Entrypoint student intern, UCLA

Recent Publications:

Berkovich, Yu.A., N.M. Krivobok, S.O. Smolianina, A.N. Erokhin and H. G. Levine. 2005. Development and operation of a space-oriented salad machine "Phytoconveyer." *SAE Tech. Paper* 2005-01-2842.

Clawson, J.M., A. Hoehn, and R.M. Wheeler. 2005. Inflatable transparent structures for Mars greenhouse applications. *SAE Tech. Paper* 2005-01-2846.

Edney, S.L., J.T. Richards, M.D. Sisko, N.C. Yorio, G.W. Stutte and R.M Wheeler. 2006. Compatibility of salad crops grown in mixed crop hydroponic systems. *Proc. Plant Growth Reg. Soc.* 32: (in press).

Eraso, I., G.W. Stutte, O. Monje, S. Anderson, and R.D. Hickey. 2006. Sensitivity screening of radish seedlings to spacecraft VOC's. *Proc. Plant Growth Reg. Soc.* 32: (in press).

Folta, K.M.. L.L. Koss, R. McMorrow, H.H. Kim, J.D. Kenitz, R. Wheeler, and J.C. Sager. 2005. Design and fabrication of adjustable red-green-blue LED light arrays for plant research. *BMC Plant Biology* 5:17-27.

Kim, H-H, R.M. Wheeler, J.C. Sager, N.C. Yorio, and G.D. Goins. 2005. Lighting emitting diodes as an illumination source for plants: A review of research a Kennedy Space Center. *Habitation* 10(2):71-78.

Kim, H-H., R.M. Wheeler, J.C. Sager, and J.H. Norikane. 2005. Photosynthesis of lettuce exposed to different short term light qualities. *Environment Control in Biology* 43(2):113-119.

Larrat, E.P., G.W. Stutte, and R.M. Wheeler. 2005. Potential Effects of Biogenic Compound Production on Human Health in Closed Life Support Systems. *SAE Tech Paper* No. 2005-1-2772.

Levine, H.G. and W.C. Piastuch. 2005. Growth patterns for etiolated soybeans germinated under spaceflight conditions. *Adv. Space Res.* 36:1237-1243.

Levine, H.G., J.J. Prenger, D.T. Rouzan, A.C. Spinale, T. Murdoch and K.A. Burtness. 2005. Feed-back moisture sensor control for the delivery of water to plants cultivated in space. *SAE Tech. Paper* 2005-01-2952.

Levine, L.H., J. Bauer, S. Edney, J. Richards, N. Yorio, K. Li, P.W. Pare, and R. Wheeler. 2005. Scallion (*Allium fistulosum* L.) pungency regulated by genetic makeup and environmental conditions (light and CO_2). *SAE Tech. Paper* 2005-01-2770.

Monje, O., G.W. Stutte and D.C. Chapman. 2005. Microgravity does not alter plant stand gas exchange of wheat at moderate light levels and saturating CO_2 concentration. *Planta* 222:336-345.

Monje, O., J.T. Richards, I. Eraso, T. P. Griffin, K.C. Anderson, and J.C. Sager. 2005. Designing a reusable ethylene filter cartridge for plant flight hardware: Characterization of thermally desorbing compounds. *SAE Tech. Paper* 2005-01-2953.

Musgrave, M.E., A. Kuang, L.K. Tuominen, L.H. Levine, and R.C. Morrow. 2005. Seed storage reserves and glucosinolates in *Brassica rapa* L. grown on the International Space Station. *J. Amer. Soc. Hort. Sci.* 130:848-856.

Norikane, J.H., J.C. Sager, R.M.Wheeler, G.W. Stutte, and H.H. Kim. 2005. Characterization of nutrient solution changes during flow through media. *SAE Tech Paper* No. 2005-01-2774.

Norikane, J.H., J.J. Prenger, D.T. Rouzan, and H.G. Levine. 2005. A comparison of soil moisture sensors for space flight. *Applied Engineering in Agriculture* 21(2):211-216.

Prenger, J.J., H.-H. Kim, J.T. Richards, O. Monje, H.G. Levine, N. Yorio, G. Stutte, R. Wheeler, and J. Sager. 2005. Crop production in an extraterrestrial (controlled-environment, microgravity) environment. *J. Agricul. Meteorology* 60(5):385-390.

Richards, J.T., S.L. Edney, N.C. Yorio, G.W. Stutte, M.D. Sisko, N.Cranston, and R.M. Wheeler. 2005. Effect of light intensity and temperature on yield of salad crops for space exploration. *SAE Tech. Paper* No. 2005-01-2820.

Sager, J.C., J.H. Norikane, A.J. Both, and T.W. Tibbitts. 2005. Quality assurance for environment of plant growth facilities. *ASAE Paper* 054137.

Stutte, G.W. 2006. Process and Product: Recirculating hydroponics and bioactive compounds in a controlled environment. *HortScience* 41: (in press).

Stutte, G.W. O. Monje, G.D. Goins, and B.C. Tripathy. 2005. Microgravity effects on thylakoid, single leaf, and whole canopy photosynthesis of dwarf wheat. *Planta* 223: 46-46.

Stutte, G.W., I. Eraso, S. Anderson and R.D. Hickey. 2006. Bioactivity of volatile alcohols on the germination and growth of radish seedlings. *HortScience* 41(1): 108-112.

Stutte, G.W., P.A. Fowler, I. Eraso and L.L. Koss. 2005. Volatile organic compound analysis (VOCA): A system for evaluating atmospheric contaminants on plant growth. *SAE Tech. Paper* No 2005-01-2771.

Wheeler, R.M. 2006. Potatoes for human exploration of space: Observations from NASA-sponsored controlled environment studies. *Potato Research* (in press).