NCERA-101 STATION REPORT FROM KENNEDY SPACE CENTER, FL, USA (March 2010)

Impact Nugget:

Concentration of the bioprotective anthocyanin pigments were increased fourfold in lettuce cv. Outredgeous grown under red LEDs through selective application of blue or ultraviolet light.

Facility Description:

The Space Life Sciences Lab (SLSL) Controlled Environment Lab (CEL) has been operational for 6 ½ years (commissioned Sept. 2003) and provides 622+ ft^2 (58 m^2) of controlled environment chamber space. The CEL provides support to both basic and applied research with emphasis on ground-based and space applications. Redundant to local chamber environmental control, the laboratory has developed and maintained a centralized command, monitoring, and data system (CMDS) with an associated database and alarming capabilities. The CEL is used to support the requirements of a variety of scientific research areas including NASA, private industry, and academia.

New Equipment / Sensors / Control Systems:

- The primary control and monitoring system for the CEL, CMDS [Command, Monitoring and Data System], continues to improve with added capabilities including remote access via internet, alarming, and data collection and analysis. The flexibility of CMDS allows for development to meet user or project specific requirements.
- An EGC M-48 chamber was modified to have zero-humidity air input (via facility installed desiccant dryer) as a method of dropping chamber relative humidity to < 10%. These low humidity conditions were required to support Space Shuttle materials testing.
- Maintenance of two m^2 solar light concentrator to the roof of the SLS Lab continues. This system was developed as a NASA phase II small business innovative research (SBIR) grant to Physical Sciences, Inc. and is intended for a plant growth lighting application. Primary collection mirrors focus solar radiation on secondary cold mirrors (transparent to long wave radiation), which then focus the visible (PAR) radiation onto an inlet fiber optic bundle. The radiation is transported via fiber optics into a modified EGC GC-36 chamber to irradiate ~ 1 m^2 with PAR equivalent to full sunlight.
- Continued testing and use of a high output LED array from ORBITEC with >300 μmol m^{-2} s^{-1} PPF @ each of six wavelengths (400, 440, 520, 640, 660, and 730 nm).
- A Low Pressure Testbed (LPT) is an available capability for maintaining atmospheric pressure, temperature, and relative humidity for a variety of testing applications.
- A vacuum chamber for lunar and Mars dust/regolith testing continues to operate and can provide 10^{-7} Torr capability (hard vacuum).
- LADA plant growth units similar to those being used in the Russian module of the International Space Station continue to be tested in an EGC M-12 chamber to assess microbial communities on radish roots for food safety.
- ORBITEC developed two "VEGGIE" units (Phase II SBIR grant from NASA) as a deployable plant growth system for producing salad type crops. The VEGGIE design provides growing areas that can be "daisy chained" together to provide approximately a one m^2 growing area (6 VEGGIE units) and can be stowed within a single crew transfer bag on the Space Shuttle. The VEGGIE units provide LED lighting and a water/nutrient delivery matting, but utilize the cabin environment for temperature and CO2 control to minimize complexity and power requirements.
- Continued to maintain a "Lighting Testbed" with the addition of a 1-m integrating sphere and an Optronics spectroradiometer with spectral range in the visible and near IR (380 to 1180 nm) to obtain spectral power distributions and total lumen outputs as well as a goniometer to obtain lamp distribution characteristics.

Unique Plant Responses:

- Anthocyanin production in red leaf lettuce (cv. Outredgeous) grown under red (640 nm) LEDs was shown to be dependent upon blue light exposure. Anthocyanin production in lettuce grown under red (640 nm) LEDS was greatly enhanced with application of UVB radiation. Cultivar differences in response to UVA were observed.

Accomplishments:

- Continued series of experiments change light quality in order to increase the bioprotective value of red leaf lettuce grown under conditions that were relevant to long duration space missions. Bioprotective properties can be

significantly enhanced without increases in volume, power or mass inputs through the selective dosing of blue and/or UV light.

- Completed a series of experiments to demonstrate sustained production of lettuce and radish in prototype "Salad Machine" modules in order to identify issues associated with plant production on a lunar base. The food production system with VEGGIE LED light cap is being prepared for operational field testing for NASA in the Habitat Demonstration Unit (HDU).
- Developing protocols for passive water and nutrient delivery system in microgravity to support salad crop production in microgravity using Orbitec's VEGGIE LED light source and passive environmental control system.
- The Solid State Lighting Module (SSLM) recently developed at KSC was fully characterized on the following parameters: photopic luminous flux, scotopic luminous flux, color rendering index, correlated color temperature, total radiant power, radiant efficiency, luminous efficacy, color coordinates in four different color spaces, color gamut area, power spectral distribution, light distribution profile, photosynthetic active radiation (PAR), photosynthetic photon flux (PPF), and phytochrome photostationary state. The SSLM is an LED replacement for the fluorescent lighting assembly on the International Space Station (ISS) and is currently onboard the ISS undergoing mission relevant testing.

Impact Statements:

- NASA KSC has demonstrated that the bioprotective value of salad crops, which have potential as a biological countermeasure to radiation on long-duration space missions, can be significantly increased by the selective application of blue or UV light to regulate plant morphology and anthocyanin synthesis.
- NASA KSC has conducted experiments to evaluate the continuous production of salad crops using realistic environmental constraints on a Lunar outpost. Several issues associated with maintaining soil water content, environmental control, and mission operations are being addressed to allow for operational field testing of the production system as part of the 2010 NASA Desert RATS activities.

Recent Publications/Presentations:

Levine, L.H., J.T. Richards, and R.M. Wheeler. 2009. Super-elevated CO_2 interferes with stomatal response to ABA and night closure in soybean (*Glycine max*). J. Plant Physiol. 166:903-913.

Levine, L.H., J.R. Richards, W.A. Rigdon, P.E. Hintze, R.M. Wheeler, and J.C. Sager. 2009. Development of a photocatalytic oxidation-based TOC analyzer Part II: Effect of reactor design and operation parameters on oxidation efficiency of VOCs. SAE Technical Paper 2009-01-2545.

Stutte, G.W. 2009. Light emitting diodes for manipulating the phytochrome apparatus. HortScience 44: 231-234.

Stutte, G.W., O. Monje, N.C. Yorio, S.L. Edney, G. Newsham. L. Connole, and R.M. Wheeler. 2009. Sustained salad crop production requirements for lunar surface. SAE Tech. Paper 2009-01-2381.

Stutte, G.W. 2009. Effect of light quality on morphology and antioxidant content of red leaf lettuce. Proc. 35th Plant Growth Reg. Soc. Amer. Pg. 52-57.

Monje, O., P.R. Kenny, N.A. Sexson, B. Brosnan, and R.M. Wheeler. 2009. Sub-scale testbed for characterizing dynamic performance of regenerable adsorbents for filtering trace contaminants from cabin atmosphere. SAE Technical Paper 2009-01-2526.

Levine, L.H., J.T. Richards, W.A. Rigdon, P.E. Hintze, R.M. Wheeler, and J.C. Sager. 2009. Development of a photocatalytic oxidation-based TOC analyzer Part II: Effect of reactor design and operation parameters on oxidation efficiency of VOCs. SAE Technical Paper 2009-01-2545.

Wheeler, R.M. 2009. Potatoes for human life support in space. *In:* J. Singh and L. Kaur (*eds.*) Advances in Potato Chemistry and Technology. Academic Press, NY. 528 pages.

Wheeler, R.M. 2009. Roadmaps and strategies for crop research for bioregenerative life support systems. NASA Technical Memorandum 2009-214768.

Scientific Outreach:

Committees / Panels:

ASHS CE Working Group (Stutte, Yorio, Wheeler)
Intl. Advanced Life Support Working Group (Wheeler)
Com. on Space Research (COSPAR) F4 (Wheeler)
ACMAP Board of Directors (Stutte)

Visiting Researchers:

Peter Downey, Limerick University, Ireland
Tony Skerritt, Limerick University, Ireland
Aisling Flanagan, Limerick University, Ireland
Gerard Newsham, Limerick University, Ireland