

NCR-101 Station Report from Kennedy Space Center, FL, USA (September 2001)

New Facilities:

Groundbreaking ceremonies for a new Life Science Facility at NASA's Kennedy Space Center (KSC) were conducted in February 2001. The facility will replace Hangar L and house the growth chambers used to support Advanced Life Support and Gravitational Biology research. The facility will also house the life science payload processing area for the International Space Station, and the KSC ecological monitoring research group. The large Biomass Production Chamber (BPC) will not be moved. The facility is at the 90% design review stage.

Equipment / Sensors / Control Systems:

Two pre-flight tests were performed in the Biomass Production System (BPS), a double mid-deck sized growth chamber for the International Space Station. These tests evaluated BPS capacity to control temperature, RH, and CO₂ over a range of environmental conditions and stages of plant development in support of the PESTO flight experiment. The first space flight test (Apogee wheat) is scheduled for Feb. 2002.

Comparisons of four types of humidity sensors (i.e., capacitance, wet / dry bulb, chilled mirror, and infrared) at different pressures showed that all four types worked well down to ~5 kPa (1/20 atm), but the infrared device was limited by the slow sample flow at low pressures. The tests are part of studies to assess issues for operating low-pressure greenhouses for space.

LEDs were confirmed to be a plausible alternative to conventional broad-spectrum lighting sources as shown by growth dynamics data from lettuce, spinach, radish, and chard under different wavelengths of red LEDs (660, 670, 680, 690 nm) along with supplemental 470 nm blue.

A growth chamber was modified to allow super-elevated CO₂ studies. This was accomplished by sealing the lamp barriers with tighter gaskets and clamps, and use of a LiCor Gas Hound IRGA to track CO₂ up to 20,000 ppm.

A series of porous tube nutrient/water delivery systems were constructed and tested to evaluate impacts of the different soil moisture conditions on plant growth in microgravity. This system will be used to support a shuttle experiment scheduled for no earlier than spring 2003.

Three existing chambers were modified to allow ethylene exposures in preparation for the RASTA (radish) space flight experiment. This required addition of ethylene dosing lines and monitoring capabilities. The space flight is scheduled for no earlier than spring 2003.

Unique Plant Responses:

A series of super-elevated CO₂ experiments were completed with three crops. CO₂ concentrations up to 16,000 ppm with bean and 15,000 for lettuce and radish resulted in increased water use relative to 1500 ppm.

Because of far-red promotion of leaf stretching / expansion, radish, lettuce and spinach grown under 680 and 690 nm LEDs intercepted more light earlier in growth and consequently grew faster than under 660 nm LEDs. Initial comparisons showed that plants grown under red LEDs required a minimal amount of blue light (~30 $\mu\text{mol m}^{-2} \text{s}^{-1}$) for acceptable growth.

Testing of nutrient solutions from potato studies continued under a Space Act Agreement with Dynamac Corporation. These efforts have focused on isolating the compound(s) responsible for early tuber initiation when successive generations of plants are grown in the same solution.

A series of tests identified four radish cultivars that were tolerant of temperatures up to 30°C. The cultivar 'Sora' was selected for further use on the RASTA space flight experiment because of its uniform germination, heat tolerance, growth rate, and flavor.

A series of ethylene exposure studies were conducted with radish. Chronic exposures to >40 ppb resulted in both morphological and development responses.

Committees / Panels:

ASHS Plant Biology Working Group (Stutte)

ASHS CE Working Group (Stutte, Yorio, Sager, Wheeler)

ASAE Env. of Plant Structures Com. (Sager): ASAE EP411.3

Plant Growth Regulator Society of America Steering President (Stutte)

Papers Published:

- Monje, O., G.E. Bingham, J.G. Carman, W.F. Campbell, F.B. Salisbury, B.K. Eames, V. Sytchev, M.A. Levinshikh, and I. Podolsky. 2000. Canopy photosynthesis and transpiration in microgravity: Gas exchange measurements about MIR. *Adv. Space Res.* 26(2):303-306.
- Levine, H.G., K.F. Anderson, and A.D. Krikorian. 2000. The 'gaseous' environment in sealed BRIC-100VC canisters flown on 'MIR' with embryogenic daylily cell cultures. *Advances in Space Research* 26(2):307-310.
- Levine, H.G., J.A. Sharek, K.M. Johnson, E.C. Stryjewski, V.I. Prima, O.I. Martynenko, and W.C. Piastuch. 2000. Growth protocols for etiolated soybeans germinated within BRIC-60 canisters under spaceflight conditions. *Adv. Space Res.* 26(2):311-314.
- Fowler, P.A. and R.A. Bucklin. 2000. Computer and microcontroller techniques for instrumentation and control systems in Advanced Life Support. SAE Tech. Paper 2000-01-2263.
- Stutte, G.W., O. Monje, G.D. Goins and D.K. Chapman. 2000. Measurement of gas exchange characteristics of developing wheat in the biomass production system. SAE Tech. Paper 2000-01-2292
- Goins, G.D. and N.C. Yorio. 2000. Spinach growth and development under innovative narrow- and broad-spectrum lighting sources. SAE Tech. Paper 2000-01-2290.
- Stryjewski, E., B. Peterson and G. Stutte. 2000. Long-term storage of wheat plants for light microscopy. SAE Tech. Paper 2000-01-2231.
- Garland, J.L., L.H. Levine, N.C. Yorio, J.L. Adams, and K.L. Cook. 2000. Graywater processing in recirculating hydroponic systems: Phytotoxicity, surfactant degradation, and bacterial dynamics. *Water Res.* 34:3075-3086.
- Li, J-H. P. Dijkstra, G.J. Hymus, R.M. Wheeler, W.C. Piastuch, C.R. Hinkle, and B.G. Drake. 2000. Leaf senescence of *Quercus myrtifolia* as affected by long-term CO₂ enrichment in its native environment. *Global Change Biol.* 6:727-733.
- Subbarao, G.V., R.M. Wheeler, G.W. Stutte, and L.H. Levine. 2000. Low potassium enhances sodium uptake in red-beet under moderate saline conditions. *J. Plant Nutr.* 23:1449-1470.
- Wheeler, R.M. and T.W. Tibbitts. 2000. Preface: Flight equipment design and flight experiment results in CELSS research. *Adv. Space Res.* 26(2):245.
- Subbarao, G.V., R.M. Wheeler, and G.W. Stutte. 2001. Feasibility of sodium for potassium in crop plants for advanced life support systems. *Life Support and Biosphere Sci.* 7: (Accepted).
- Yorio, N.C., G.D. Goins, H.R. Kagie, R.M. Wheeler, and J.C. Sager. 2001. Improving spinach, radish, and lettuce growth under red light-emitting diodes (LEDs) with blue light supplementation. *HortScience* 36:380-383.
- Paul, A.L., C. Daugherty, E. Bihn, R.J. Ferl, D. Chapman, and K. Norwood. 2001. Transgenic plant biomonitors: Stress gene biocompatibility evaluation of the plant growth facility of PGIM-01. SAE Tech. Paper 2001-01-2181.
- Tynes, G.K., T. W. Dreschel, H.G. Levine, and H. Kasahara. 2001. An evaluation of a fibrous ion exchange resin substrate for the provision of nutrients to wheat growing on a porous tube nutrient delivery system. SAE Tech. Paper 2001-01-2177.
- Yorio, N.C., J.E. Judkins, J.L. Garland, M.E. Hummerick, and T.H. Englert. 2001. Utilization of recovered inorganic nutrients from composted fresh or oven-dried inedible plant biomass for supporting growth of wheat in a BLSS. SAE Tech. Paper 2001-02-2273.
- Bucklin, R.A., J.D. Leary, V. Rygalov, Y. Mu, and P.A. Fowler. 2001. Design parameters for Mars deployable greenhouses. SAE Tech. Paper 2001-01-2428.
- Stutte, G.W., O.M. Monje, G.D. Goins and L.M. Ruffe. 2001. Evapotranspiration and photosynthesis characteristics of two wheat cultivars measured in the biomass production system. SAE Tech. Paper 2001-02-2180.
- Monje, O., J. Garland, and G.W. Stutte. 2001. Factors controlling oxygen delivery in ALS hydroponic systems. SAE Tech. Paper 2001-01-2425.
- Monje, O., G.W. Stutte, H.T. Wang, and C.J. Kelly. 2001. NDS water pressures affect growth rate by changing leaf area, not single leaf photosynthesis. SAE Tech. Paper 2001-01-2277.
- Stryjewski, E., G. Goins, and C. Kelly. 2001. Quantitative morphological analysis of spinach leaves grown under light-emitting diodes or sulfur-microwave lamps. SAE Tech. Paper 2001-01-2272.
- Goins, G.D., L.M. Ruffe, N.A. Cranston, N.C. Yorio, R.M. Wheeler, and J.C. Sager. 2001. Salad crop production under different wavelengths of red light-emitting diodes (LEDs). SAE Technical Paper 2001-01-2422.
- Rygalov, V.Ye., R.A. Bucklin, A.E. Drysdale, P.A. Fowler, and R.M. Wheeler. 2001. The potential for reducing the weight of a Martian greenhouse. SAE Technical Paper 2001-01-2360.
- Subbarao, G.V., R.M. Wheeler, L.H. Levine, and G.W. Stutte. 2001. Glycine betaine accumulation, ionic and water relations of re-beet at contrasting levels of sodium supply. *J. Plant Physiology* 158:767-776.
- Wheeler, R.M. 2000. Bioregenerative life support and nutritional implications for planetary exploration. In: H.W. Lane and D.A. Schoeller (eds.) *Nutrition in space flight and weightlessness*. CRC Press, Boca Raton, FL, USA. pp. 41-67.
- Tibbitts, T.W., R.M. Wheeler, C.A. Mitchell, and J. Heidmann (eds.). 2000. *Life Sciences; Space Life Support Systems and the Lunar Farside Crater Saha Proposal*. *Adv. Space Res.*, Vol. 26 No. 2. Elsevier Science Ltd., Oxford, UK.
- Subbarao, G.V., L.H. Levine, R.M. Wheeler, and G.W. Stutte. 2001. Glycine betaine accumulation-Its role in stress resistance. In: M. Pessaraki (ed.), *Handbook of Plant and Crop Physiology*, 2nd Edition. (In Press).
- Wheeler, R.M., G.W. Stutte, G.V. Subbarao, and N.C. Yorio. 2001. Plant growth and human life support for space travel. In: M. Pessaraki (ed.), *Handbook of Plant and Crop Physiology* 2nd Edition. (In Press).
- Subbarao, G.V., R.W. Wheeler, W. Berry, and G.W. Stutte. 2001. Sodium-A functional nutrient. In: M. Pessaraki (ed.), *Handbook of Plant and Crop Physiology*, 2nd Edition. (In Press).
- Levine, H.G., K.L. Norwood, G.K. Tynes, and L.H. Levine. 2001. Soybean and corn seed germination in space: The first plant study conducted on Space Station Alpha. Proc. 38th Space Congress, Cape Canaveral, FL. April 30-May 4, 2001. pp. 181-187.

Website:

KSC life science research activities: <http://bioscience.ksc.nasa.gov/oldals/index.html>