

NCR-101 STATION REPORT FROM KENNEDY SPACE CENTER, FLORIDA

(Mar. 2000, West Lafayette, IN, USA)

New Facilities:

Plans are continuing for a new life sciences support / research facility at Kennedy Space Center (KSC). The facility would replace Hangar L, which is currently used to support bioregenerative research and life science payload processing. NASA has been discussing funding the new facility with the state of Florida.

Sensors and Instruments:

We conducted several tests comparing the performance of four different humidity sensors: Vaisala capacitance type; wet-dry bulb, chilled mirror/dew point (EdgeTech), and infrared (LiCor 6252) at different atmospheric pressures. All the sensors tracked closely down to about 0.05 atm (~5 kPa), but the infrared system was slightly offset and a bit sluggish. We suspect that air (mass) flow through the infrared sensor was too low at the lower pressures.

We recently obtained a prototype water-cooled HPS lamp (250-W) from Sadler Machine Co., (Tempe, AZ). Radiation measurements taken with and without a water cooling jacket indicate the glass envelope was reducing PAR by about 15-20%, but the water cooling cut the long wave (3000-50,000 nm) from the lamp by a factor of ten.

Ground testing and preparations continued for three plant-related spaceflight experiments. One will study wheat in the Biomass Production System (plant chamber) being built by Orbitec Corp. (Madison, WI) for the Intl. Space Station (G. Stutte, PI); a second will test radish development in weightlessness using a modified version of Shuttle mid-deck plant growth facility (PGF) (G. Stutte, PI), and a third will compare different water/nutrient delivery concepts using the double mid-deck plant growth chamber (PGBA) built by BioServe Technologies (Univ. of Colorado) (H. Levine, PI).

Unique Plant Responses:

Recent plant testing includes studies of spinach and radish growth under “red” LEDs with different peak wavelengths—660, 670, 680, 690, 700, and 725; in all cases, these are supplemented with 470 nm blue LEDs. The LED electrical conversion efficiencies increase with wavelength, and we are trying to find the optimal combination for total PAR and acceptable growth.

We are exploring the idea of adding “graywater” (soapy water) directly to plant hydroponic systems as means of wastewater processing. Wheat plants can tolerate daily graywater additions of up to 900 ppm Igepon soap (~300 ppm is a typical concentration for graywater) with no effects on growth, but lettuce shows some growth reduction at 900 ppm. The rhizosphere bacteria appear to degrade the soap very quickly. Deliberate inoculations with several human-associated bacteria and attenuated poliovirus showed that these organisms disappeared quickly, i.e. were not competitive in the rhizosphere. One exception was *Pseudomonas aeruginosa*, which can persist but at diminished levels.

We are continuing studies on the effects of super-elevated CO₂ (i.e., >2000 ppm) on plants. The most recent tests with bean (*Phaseolus*) show the expected decrease in stomatal conductance and increased biomass at 1200 ppm compared to 400. The next treatment will be 4000 ppm.

Workshops / Colloquia / Symposia:

KSC hosted a workshop in Dec. 1999 on the challenges of designing and deploying “greenhouses” on Mars. Discussions covered a range of topics including, descriptions of the Martian environment, effects of low atmospheric pressure and high CO₂ on plants, concepts for plant enclosures, use of inflatable materials capable of withstanding the pressure and thermal gradients, approaches for plant lighting, and the economics of using plant systems for life support on Mars. (Contact Ray Wheeler)

Small Business Innovative Research Grants through NASA/KSC (SBIRs): (Contact John Sager)

Physical Optics Corp. (Torrance, CA); Sol-Gel Glass Holographic Light Shaping Diffusers
Orbital Technologies Inc. (Madison, WI); Moisture / O₂ Content Sensor for Nutrient Delivery Systems
Fusion Lighting Inc. (Rockville, MD); Ultra High Efficiency Solid State Sources for Electrodeless Lighting
Orbital Technologies Inc. (Madison, WI); Small Payload Fluid Servicing System (SPAFSS)
Orbital Technologies Inc. (Madison, WI); Use of Reformed Plant Fiber for Seed Starting Plugs

1999 Publications:

- Colon, G. and J.C. Sager. 1999. On-line removal of volatile fatty acids from an anaerobic bioreactor via nanofiltration. *Dimension* 13(2):25-33.
- Garland, J.L., A.L. Mills, A. Morales, and K. Cook. 1999. Survival of human-associated bacteria in prototype Advanced Life Support Systems. *SAE Technical Paper Series* 1999-01-2061.
- Garland, J.L., R.Fortson, N. Packham, and J. Sager. 1999. Testing bioregenerative waste processing approaches in BIO-Plex. *SAE Technical Paper Series* 1999-01-2189.
- Garland, J.L., M. P. Alazraki, N.C. Yorio, and J.L. Adams. 1999. Composting inedible crop residue for advanced life support systems: Nutrient extraction and recycling for hydroponic plant growth. *Proc. of the Intl. Composting Symp.* (ICS), Halifax, NS Sept.
- Goins, G.D., G.W. Stutte, and D.K. Chapman. 1999. Designing experiments for direct measurement of wheat photosynthesis in microgravity. *SAE Technical Paper Series* No. 1999-01-2179.
- Goins, G.D., N.C. Yorio, R.M. Wheeler, D.G. Mortley, and P.A. Loretan. 1999. Hydroponic nutrient solution management strategies for optimizing yield of sweetpotato storage roots. *SAE Technical Paper Series* No. 1999-01-2022.
- Johnson, C.F., R.W. Langhans, L.D. Albright, G.F. Combs, R.W. Welch, L. Heller, R.P. Glahn, R.M. Wheeler, and G.D. Goins. 1999. Spinach: Nitrate analysis of an Advanced Life Support (ALS) crop cultured under ALS candidate artificial light source. *SAE Technical Paper Series* No. 1999-01-2107.
- Lea-Cox, J.D., W.L. Berry, B.W. Stutte, and R.M. Wheeler. 1999. Nutrient dynamics and pH / charge balance relationship in hydroponic solutions. *Acta Horticulturae* 481:241-249.
- Levine, H.G., W.C. Piastuch, and T.W. Dreschel. 1999. Development of a Microgravity-Rated Hydroponic Plant Culture Apparatus. *Proc. 36th Space Congress*, pp. 295-302.
- Levine, H.G. 1999. The growth of wheat in three nutrient-providing substrates under consideration for spaceflight applications. *Acta Horticulturae* 481:251-258.
- Levine, H.G. and W.C. Piastuch. 1999. A method for the imbibition and germination of wheat seeds in space. *Life Support and Biosphere Science* 6:221-230.
- Loader, C.A., J.L. Garland, L.H. Levine, K.L. Cok, C.L. Mackowiak, and H.R. Vivenzio. 1999. Direct recycling of human hygiene water into hydroponic plant growth systems. *Life Support and Biosphere Science* 6:141-152.
- Mackowiak, C.L., G.W. Stutte, R.M. Wheeler, L.M. Ruffe, and N.C. Yorio. 1999. Tomato and soybean production on a shared recirculating hydroponic system. *Acta Horticulturae* 481:259-266.
- Nitithamyon, A., J.H. Vonelbe, R.M. Wheeler, and T.W. Tibbitts. 1999. Glycoalkaloids in potato tubers grown under controlled environments. *American Journal of Potato Research* 76:337-343.
- Pitts, M. and G. W. Stutte. 1999. Computer modeling of hydroponics nutrient pH control using ammonium. *Life Support and Biosphere Science* 6: 73-85.
- Strayer, R.F., M.P. Alazraki, J. Judkins, J. Adams, J.L. Garland, and V. Hsu. 1999. Development and testing of inocula for biodegradation of Igepon under denitrifying conditions. *SAE Technical Paper Series* No. 1999-01-1949.
- Stutte, G.W. 1999. Advanced Life Support Systems: A glimpse at plant research on-board the International Space Station. *Proceedings Florida Logistics Soc.* 99. pg 113-120.
- Stutte, G.W. 1999. Phytochemicals: Implications for long-duration space missions. pg. 275-286. *In* H. Cutler and S. Cutler (eds). *Biologically Active Natural Products: Agrochemicals*. CRC Press. Boca Raton, FL
- Subbarao, G.V., R.M. Wheeler, and G.W. Stutte. 1999. Water relations and leaf gas exchange of table-beet in response to replacement of nutrient K with Na. *SAE Technical Paper Series* No. 1999-01-2020.
- Subbarao, G.V., C.L. Mackowiak, and R.M. Wheeler. 1999. Recycling of Na in Advanced Life Support: Strategies based on crop production systems. *Life Support and Biosphere Science* 6:153-106.
- Subbarao, G.V., R.M. Wheeler, G.W. Stutte, and L.H. Levine. 1999. How far can sodium substitute for potassium in red beet. *Journal of Plant Nutrition* 22:1745-1761.
- Tibbitts, T.W., J.C. Croxdale, C.S. Brown, R.M. Wheeler, and G.D. Goins. 1999. Ground-based studies and space experiment with potato leaf explants. *Life Support and Biosphere Science* 6:97-106.
- Tibbitts, T.W. and B. Peterson. 1999. Toxicity of ethylene glycol vapors to cucumbers. *HortScience* 34:221-222.
- Voeste, D. M. Andriske, F. Paris, H.G. Levine, and V. Blum. 1999. An aquatic ecosystem in space. *Journal of Gravitational Physiology*. 6:p83-p84.
- Wheeler, R.M., C.L. Mackowiak, W.L. Berry, G.W. Stutte, N.C. Yorio, L.M. Ruffe, and J.C. Sager. 1999. Nutrient, acid, and water budgets of hydroponically grown crops. *Acta Horticulturae* 481:655-661.
- Wheeler, R.M., C.L. Mackowiak, N.C. Yorio, and J.C. Sager. 1999. Effects of CO₂ on stomatal conductance: Do stomata open at very high CO₂ concentrations? *Annals of Botany* 83:243-251
- Wheeler, R.M. 1999. Bioregenerative life support system testing at NASAs Kennedy Space Center. *Proc. of Intl. Com. for Material Circulation in Geo-Hydrosphere and Its Application*. pp. 59-65. Rokkasho, Aomori, Japan.
- 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 models*. CRC Press, Boca Raton, pp. 41-67.
- Yorio, N.C., M.P. Alazraki, J.L. Garland, T.H. Englert, and L.M. Ruffe. 1999. The utilization of recovered nutrients from composted inedible wheat biomass to support plant growth for BLSS. *SAE Technical Paper Series* No. 1999-01-2062.