ARS Report to the NCR-101 Committee on Controlled Environment Technology and Use
Wooster, Ohio, 8-11 April 2006

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A. Growth Facilities Planned or Installed: A contract for $45,000 was pre-awarded on March 3, 2006 to Hemisphere Inc. to conduct a final inspection and evaluation of the Bio-Containment Greenhouse; it is expected to be fully operational by the end of 2006. Based on initial tests of the sterilization system, it appears that the waste drainage system needs to be redesigned. A $300,000 contract will be awarded to an outside firm to manage, maintain, and operate this facility, and to provide training to maintenance personnel. Construction of the new Plant Sciences Institute greenhouses in Range 1 is expected to be completed by mid-June, 2006. This complex will include the Bio-Containment Greenhouse, a support facility for the Bio-Containment Greenhouse, and a greenhouse for research on exotic citrus diseases. Several additional high tunnels have been erected to support research in the Fruit Laboratory. The Sustainable Agricultural Systems Lab has reconfigured their 21' x 96' long high tunnels into four 21' x 48' long high tunnels to permit replication of UV treatment. Three new growth chambers with fluorescent lamps (EGC M-18) were installed in the Controlled Environment Facility (CEF) for the Floral and Nursery Crops Lab. They have automatic watering systems and door locks and alarms to prevent entry for pathology and transgenic work. There is no longer a building engineer, so individuals must call in problems to the Facilities Management Services (FMS) trouble desk. The CEF users remain the same - mainly the Crop Systems and Global Change Lab, the Fruit Lab, the Floral and Nursery Crops Lab, the Environmental Quality Lab with a little use by the Phytonutrients Lab, the Soybean Lab, the Sustainable Perennial Crops Lab, and the Vegetable Lab. The planned automated alarm system to link all chambers to the work operations desk has never been completed. A water softener system was added to improve the quality of water in the cooling water tower.

B. Other Facilities Planned or Installed: A ground breaking ceremony was held on September 9, 2005 for a $52 million Poultry Production Facility at BARC. The Honorable Steny H. Hoyer, Representative, 5th District, was the featured speaker during the ceremony. Estimated completion date of this facility is June 2006. A $209,571 contract was awarded to Viking Contractors Inc. in September 2005 for design of an Insect Research Greenhouse in Range 1 (GH 17). A contract for $948,000 should be awarded in April 2006 for design and construction of the Insect Quarantine Facility in the basement of GH 17, A gate was installed at the front entrance to BARC-West. During the past two years, the National Agricultural Library (NAL) has made a number of renovations to the Abraham Lincoln Building in Beltsville. With funding from Homeland Security, all of the NAL security systems were replaced and upgraded. A sprinkler system was installed on the 2nd, 3rd and 4th floors and ceilings and lights were replaced. During FY 2005, NAL began extensive brick repairs to install weep holes and expansion joints and repoint the bricks of the entire façade of the Abraham Lincoln Building; weep holes and expansion joints were lacking in the original construction. Also, the failing chiller plant was replaced in FY 2005. In FY 2006, the brick repairs will be completed and NAL plans to renovate its Data Center by replacing two air conditioning units and installing a new fire suppression system. In addition, repairs are planned for the wing building air handling units and 24 of the windows on the 14th floor will be replaced. Plans are to move the NAL Special Collections to the renovated 5th floor once shelves are installed and it is certified as a National Archives facility.

C. Instruments and Sensors: Sensors were installed in the four SASL high tunnels to monitor soil moisture, air temperature, relative humidity, photosynthetically active radiation (PAR), total radiation, and ambient CO_2 using HOBO sensors obtained from Onset Computer Corp. (Bourne, MA). SASL has installed a system for automated control of the side curtains in the high tunnels; this system was obtained from Advancing Alternatives, Inc. Posi-Clasp Curtain Systems (Schuylkill Haven, PA). Modifications have been made to permit manual and separate control of the two side curtains.

D. Unique Plant Responses: A number of tomato plants in the high tunnels produced protuberances on the petioles and fruits. It is possible that this might have been induced by use of the red reflective mulches in the high tunnels. A few plants showed damage from the soil pathogen, *Sclerotinia sclerotiorum* (Lib.) de Bary in 2005. Tomato spotted wilt virus was observed in 2005 on some plants grown by high tunnel farmers on the SARE grant when nutrients were limiting.

E. Research Grants/Cooperative/Interdisciplinary Projects: Two cultivars of fresh market tomato ('Oregon Spring' and 'Red Sun') were each grown in two 21' x 96' long high tunnels at Beltsville, MD covered with a contrasting material of similar thickness (0.152 mm) and durability (4-year polyethylene) during the Spring/Summer of 2005. One covering material (Tyco Tufflite IV) transmitted ambient solar UV radiation from 290 to 400 nm (designated +UV) while the other material (Dura-Film Super 4) blocked UV wavelengths below 380 nm (designated -UV). Both films transmitted comparable amounts of photosynthetically active radiation (PAR) from 400 to 700 nm. Collaborative studies were conducted with Dave Luthria in the Food Composition Laboratory on the content of phenolic acids and total phenolic compounds in the two cultivars. Ripe tomato fruits comparable in size and development were collected at maturity from plants of the two cultivars grown in each high tunnel under the contrasting covering materials. The total concentration of three phenolic acids - caffeic acid, p-coumaric acid, and ferulic acid was approximately 20% higher under +UV than under -UV treatment; this was true for both cultivars. These results indicate that the phenolic content of tomato fruits can be impacted by the amount of ambient solar UV radiation available. Since phenolic compounds are known to play a key role as antioxidants in human nutrition, subtle differences in phenolic composition between the two high tunnels as a result of differences in the UV transmission properties of these different covering materials may be of considerable importance.

Collaborative studies were also conducted with Bob Saftner, Eunhee Park and Judy Abbott in the Produce Quality and Safety Laboratory and Dave Clark in SASL on the market quality of 'Oregon Spring' and 'Red Sun' tomatoes grown in the high tunnels. Seedlings were transplanted weekly to two high tunnels at Beltsville, MD from March 23 to April 13, 2005. Data were recorded on the date of anthesis, leaf expansion, and marketable yields of tomato fruits for each cultivar and transplant group under UV-transmitting (+UV) and UV-blocking (-UV) covering materials. Instrumental and sensory quality characteristics of fruit obtained from 'Oregon Spring' and 'Red Sun' in the two high tunnels were compared with field- and hydroponic greenhouse-grown fruit obtained from a wholesale warehouse. 'Oregon Spring' plants flowered in 16-17 d from transplanting versus 25 d for 'Red Sun'. 'Red Sun' produced 3X as much leaf area as did 'Oregon Spring'. The fresh weight of 'Red Sun' tomatoes in the +UV and -UV high tunnel was 60% and 22% greater, respectively, than that of 'Oregon Spring'. Intact fruit or extracts were used for measurements of firmness, titratable acidity (TA), soluble solids content (SSC), and aromatic volatile concentration. The SSC of high tunnel-grown tomatoes was higher than that of commercially grown fruit. Field-grown tomatoes had the highest firmness and hydroponically-grown tomatoes had the highest concentration of volatiles. 'Red Sun' fruit from plants grown under -UV had a higher SSC than corresponding fruit grown under +UV. High tunnel-grown tomatoes had higher sensory scores for sweetness, flavor, and for acceptability of texture, taste and overall eating quality than commercially grown fruit. These results are the first to show that high tunnel-grown tomatoes generally have better consumer acceptance than those grown commercially. Collaborative studies are continuing on the SARE grant on “Season Extension and Cultivar Evaluations for Increasing Farmer Profitability Using High Tunnels in the Baltimore-Washington Metropolitan Marketing Area.” We are cooperating with four high tunnel growers on this project. Mark Davis (Future Harvest/Chesapeake Alliance for Sustainable Agriculture) is currently the PI on this grant. SASL is continuing cooperative research with Rodale Institute and Penn State University on improving weed management for organic farming, John Teasdale is the PI on this grant.

F. Committees and Sub-Committees Served: During the past year, I continued to serve as Associate Editor, Photochemistry and Photobiology. I also served on the editorial board of Environmental and Experimental Botany.

G. Workshops/Colloquia/Symposia: The papers presented at the American Society for Photobiology (ASP) Symposium on UV Effects on Terrestrial Ecosystems in Seattle, WA on 13 July 2004 and several invited manuscripts were published in a Symposium-in-Print (SIP) in the September-October 2005 issue of Photochemistry and Photobiology. I assumed primary responsibility for editing this SIP (See J). In July, 2006, I will be giving an invited presentation on Effects of Global Climate Change on Terrestrial Ecosystems at a Symposium on “Global Climate Change and Photobiology” at the ASP Meeting in Puerto Rico. Partial funding for the ASP symposia in Seattle, WA was provided by the BA Director’s Office.

H. Personnel: There were several key personnel changes. Dr. Allison Yates was appointed Director of the Beltsville Human Nutrition Research Center (BHNRC) in 2006. Dr. David Granstrom was appointed Acting Director, Facilities Management and Operations Division (FMOD) replacing John Van de Vaarst who retired in 2005. Dr. Rob Griesbach is Acting Technology Transfer Coordinator. Charles Foy and Richard Thimijan continue to serve as SASL volunteers.

I. Internet Entries/Access: Information on ARS research programs in the 35 labs and 4 institutes at BARC may be accessed at: http://www.ba.ars.usda.gov/. Information on SASL may be accessed at: http://www.ba.ars.usda.gov/sasl/. Information on BHNRC and the Food Composition Lab (FCL) may be accessed at: http://www.barc.usda.gov/bhnrc/. Information on the Produce Quality and Safety Lab (PQSL) may be accessed at: http://www.barc.usda.gov/psi/pqsl/. Images of the construction of the CEF may be accessed at: http://www.ba.ars.usda.gov/sasl/krizek/cef_const.html .

J. Selected List of Recent Publications: 2005-2006

Allende, A. McEvoy, J. L., Luo, Y. Artes, F., and Wang, C. Y. Effectiveness of two-sided UV-C treatments in inhibiting natural microflora and extending the shelf-life of minimally processed 'Red Oak Leaf' lettuce. Food Microbiology. 23:241-249. 2006.

Ayala-Zavala, J. F., Wang, S. Y., Wang, C. Y., and Gonzalez-Aguilar, G. Methyl jasmonate in conjunction with ethanol treatment increases antioxidant capacity, aroma compounds and postharvest life of strawberry fruit. European Food Research and Technology. 221:731-738. 2005

Dadson, R.B., Hashem, F.M., Javaid, I., Joshi, J., Allen, A.L., Devine, T.E. Effect of water stress on the yield of cowpea (*Vigna unguiculata* L. Walp.) genotypes in the Delmarva region of the United States. Journal of Agronomy and Crop Science. 191:210-217. 2005.

Demmig-Adams, B., Adams, W.W., and Mattoo, A.K. Editors: Photoprotection, Photoinhibition, Gene Regulation and Environment. Springer-Verlag Publishers, 400 pp. 2006.

Duke, S.O., Scheffler, B.E., Boyette, C.D., Lydon, J. and Oliva, A. Herbicides, biotechnology. In Kirk-Othmer Encyclopedia of Chemical Technology, Vol. 13, Wiley-Interscience, New York, pp. 346-369. 2005.

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Erkan, M., Pekmezci, M. and Wang, C. Y. Hot water and curing treatments reduce chilling injury and maintain postharvest quality of 'Valencia' oranges. International Journal of Food Science and Technology. 40:91-96. 2005.

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Kumar, V., Abdul-Baki, A., Anderson, J.D., and Mattoo, A.K. Cover crop residues enhance growth, improve yield and delay leaf senescence in greenhouse-grown tomatoes. HortScience. 40: 1307-1311. 2005

Li, J-F., Qi, R., Qu, L-H., Mattoo, A.K., and Li, N. Cleavage of the carboxy-terminus of LEACS2, a tomato 1-aminocyclpropane-1-carboxylic acid synthase isomer, by a 64-kDa tomato metalloprotease produces a truncated by active enzyme. Journal of Integrative Plant Biology. 47: 1352-1363. 2005.

Liu, Y., Chen, Y. R., Wang, C. Y., Chan, D. E., and Kim, M. S. Development of hyperspectral imaging technique for the detection of chilling injury in cucumbers: Spectral analysis and image analysis. Applied Engineering in Agriculture. 22:101-111. 2006.

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McMurtrey, J.E., Daughtry, C.S.T., Devine, T.E., Corp, L.A. Spectral detection of crop residues for soil conservation from conventional and large biomass soybean. Agronomy for Sustainable Development 25:25-33. 2005.

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Razdan, M.K. and Mattoo, A.K., Editors: Genetic Improvement of Solanaceous Crops: Volume 1: Potato, Science Publishers, Inc., Enfield, USA. 451 pp. 2005.

Rice, C., Park, Y.B., Adam, F., Abdul-Baki, A.A., Teasdale, J.R. Hydroxamic acid content and toxicity of rye at selected growth stages. Journal of Chemical Ecology. 31(8):1887-1905. 2005.

Ritchie, J.C., Reeves, J.B. III, Krizek, D.T., Foy, C.D., Gitz, D.C. III. Fiber composition of eastern gamagrass forage grown in a degraded, acid soil. Field Crops Research 97(2-3): 176-181. 2006.

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Solomos, T., and Mattoo, A.K. Starch-sugar metabolism in potato (Solanum tuberosum L) tubers in response to temperature variations. In: Genetic Improvement of Solanaceous Crops: Volume 1: Potato, (M.K. Razdan and Mattoo, A.K., eds), pp. 209-234. 2005.

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Addendum to ARS Report to the NCR-101 Committee on Controlled Environment Technology and Use
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Use of Controlled Environments for Nutrition Studies at the Beltsville Human Nutrition Research Center (BHNRC)

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A. Growth Facilities Planned or Installed: Two EGC M-28 Step-in growth chambers with air-cooled condensing units and refrigerated light cap cooling modules were installed in Bldg. 308, BARC-East to support joint research by the Phytonutrients Lab and the Diet and Human Performance Lab. A third growth chamber has been ordered and will be installed in 2006. The first growth chamber is equipped with 24 180w low pressure sodium (LPS) and 24 40w fluorescent lamps and is designed to study regulation of phenolic accumulation in leafy vegetables by blue and UV radiation under conditions of relatively high photosynthetic rate. The second and third growth chambers will be equipped with 20 400w metal halide (MH) lamps plus 8 100w incandescent lamps and are intended as control chambers for the LPS chamber and also as "mother" chambers for air-tight acrylic chambers used to label plants with carbon-13, a stable isotope, introduced photosynthetically via ^{13}C-CO_2. In the past, it was possible to grow kale with about 98% of the carbon present as ^{13}C. This high level of specific activity resulted in vastly improved tracking of labeled nutrients and their metabolites in human test subjects and more accurate modeling of phytochemical metabolism. For example, it was possible to monitor plasma retinol derived from beta-carotene for at least 46 days following a single 400-g meal of kale. Comparing two carotenoids consumed simultaneously in a natural food matrix, lutein was shown to be much more bioavailable than beta-carotene.

The labeling chamber is constructed from UV-transmitting acrylic and is about 655 liters in volume. It uses a water trough to produce an air-tight seal while buffering small changes in pressure. Air temperature is controlled with an internal muffin fan circulating air across the top and sides of the chamber where it is cooled by contact with the acrylic surface and also with a large condensing coil at approximately 14^{o} C. Condensate drains to the trough where it is removed as needed. The acrylic chamber can be kept near 24^{o} C by keeping the "mother" chamber at about 19^{o} C while PAR at plant height is about 700 µmol m^{-2} s^{-1} using 16/20 MH lamps. Relative humidity (RH) has been running at about 80%. Temperature and RH inside the acrylic chamber are monitored continuously and logged at intervals (Model CR-23X, Campbell Scientific). The Campbell unit also monitors and stores barometric pressure data as well as thermocouple readings from the condensing coil and light cap. Plants in the inner compartment are sub-irrigated on an as needed basis using submerged inlet and outlet ports that maintain the air seal. CO_2 inside the acrylic chamber is controlled currently using a WMA-4 IRGA (PP Systems) with a 0-5 V analog output (0-2000 µmol mol^{-1} CO_2) wired to an Omega 77000 PID controller with solid state relay to activate a solenoid valve in the CO_2 dosing line. The WMA-4 logs the CO_2 concentration every minute, permitting regular monitoring of CO_2 uptake rate by the plants. A Li-7000 IRGA (LICOR Instruments Co.) will be used during labeling because it is expected to have improved sensitivity to ^{13}C-CO_2. Isotope effects on the infrared absorption of CO_2 require the IRGA to be calibrated with ^{13}C-CO_2 when using that gas. A gas mixing syringe has been purchased for that purpose.

B. Other Facilities Planned or Installed: Enhancements to the acrylic labeling chamber will soon include an integrating laminar mass flow meter (10 ms response time) to monitor CO_2 consumption, a supplementary air drying column to reduce humidity below 80%, and soil moisture sensors to determine irrigation requirements. An O_2 sensor (Apogee Instruments) has been ordered. Further modifications are expected to include a column to trap hydrocarbons released during plant growth and a liquid N_2 cold finger to trap ^{13}C-CO_2 (which is extremely expensive) during extended dark periods. Warming the trap will reintroduce CO_2 to the chamber during subsequent light periods. Strawberries are currently being grown in the labeling chamber to assess their adaptation to a closed environment using ^{12}C-CO_2. Plants (cv Troubdour) were previously induced to flower under short-day conditions and then stored in the cold to synchronize fruit development. After cold treatment they were transferred to continuous light in the growth chamber and gradually warmed to 24^{o} C at which time they were loaded into the acrylic chamber and sealed. Fruit development appears normal. Labeled strawberries will ultimately be fed to human volunteers to assess the uptake of anthocyanins and other phenolics. The availability of anthocyanins from foods is notoriously poor (on the order of 0.01 to 1% of fed material) and appears to depend on factors such as glycosylation and acylation. It is possible that intestinal breakdown products from anthocyanins are absorbed and are active in humans (e.g., as antioxidants) and this will also be tested by feeding purified labeled anthocyanins. Strawberries contain relatively simple anthocyanins that are composed primarily of pelargonidin,with some cyanidin, both mainly as 3-glycosides. Future experiments will entail using anthocyanins from red cabbage or kale with more complex glycosylation and acylation.

C. Instruments and Sensors: BARC continued to participate in the USDA UV-B Monitoring Program. This monitoring program is managed by the Natural Resource Ecology Laboratory of Colorado State University (CSU). A suite of instruments has been located on the South Farm since 1998 to measure UV radiation and atmospheric optical properties. CSU researchers will be making synthetic spectra available on their web site for any of the locations having shadow band radiometers. The data for the CSU instruments are available on-line within 1 day of measurement. Steve Britz and Roman Mirecki, Phytonutrients Lab. assist in the operation of the BARC facility which is on the South Farm.

E. Research Grants/Cooperative/Interdisciplinary Projects: The strawberry and kale work is being conducted by an ARS Administrator-funded post-doc, Dr. Craig Charron, who recently received his Ph.D. at the Univ. of Tennessee under Dr. Carl Sams. Additional collaborators/consultants in this work are Dr. Kim Lewers of the Fruit Lab at BARC and Drs. Jerry Deitzer and Harry Schwartz of the University of Maryland, College Park (UMCP). In other experiments being conducted in the Controlled Environment Facility (B-010C), EGC M-18 Step-In growth chambers are being used to explore interactions among temperature, drought, and atmospheric CO_2 with respect to levels of tocopherols, isoflavones and phytosterols in soybean seeds exposed to stress conditions during seed development. Previous work showed that elevated temperatures greatly increased vitamin E content but decreased content of isoflavones in soybean seeds. Elevated CO_2 ameliorated the effects of temperature on both compounds. Current studies are designed to identify if particular stages of seed development are more sensitive to temperature or drought. To increase the relevance of these studies for field conditions, plants are being raised in soil with N provided by N_2-fixation, lighting is controlled to simulate diurnal and seasonal changes in duration and provide irradiance between the summer solstice and the autumnal equinox, and temperature is gradually reduced during seed development. Temperature and drought stress treatments are based on an analysis of 20 years of weather data at Beltsville.

I. Internet Entries/Access: : A description of the USDA UV-B Monitoring Program may be obtained at: http://uvb.nrel.colostate.edu . Information on BHNRC may be accessed at: http://www.barc.usda.gov/bhnrc/.

J. List of Publications:

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