Summary Report to NCR-101: Controlled Environment Technology and Use

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New Facilities: None

New or Different Control Systems: One year of operation has been completed using a new computer control software system developed being by a control company already active in the animal housing industry. The company seeks to begin competing in the greenhouse market. The software has worked well for temperature control as well as supplemental light and movable shade control (Cornell patented) to reach a consistent daily light integral in the Cornell CEA greenhouse (see URL below).

Sensors and Instruments: None

Hardware and Control Software:

1. Off-center placement of HPS lamps within double-walled water jackets is being evaluated. A water layer thickness of at least 20 mm is required to remove 90% of the IR from the lamp. Off-center placement of the lamp within the jacket reduces direct reflections of light back into the arc tube.

2. An algorithm to optimize the addition of carbon dioxide to greenhouse air when supplemental lighting is used was tested by simulation, using Ithaca, NY, weather data and the Cornell CEA greenhouse as a model. Simulations showed electric energy for lighting to a constant daily PPFD integral of 17 mol m^{-2} in Ithaca could be reduced significantly with proper CO_2 control. Deducting the cost of CO_2 still leads to significant cost savings. The algorithm is based on hourly time steps for control, with air temperature projected for the next hour and light projected for the day. Light predictions were based on the light integral control algorithm developed at Cornell and patented in 1998. Temperature predictions for the next hour were within 1 C 75% of the time during the year. Unique to the algorithm is a method to translate combinations of elevated CO_2 concentration and the light integral for an hour to reach, by the end of the day, the prescribed plant growth increment.

Unique Plant Responses:

1. A lettuce growth model as a possible basis for fault detection was tested. The NItrate COntrol in LETtuce (NICOLET) model was selected for evaluation. Simulating growth using 20-minute light and air temperature input data gave better results than using daily values of input data. Using a 30-plant sample size, it was possible to predict daily crop growth at a 5% significance level until 22 days after seeding, at which time data variability exceeded daily crop growth. The simulation did capture diurnal variations in growth. The model must, however, be calibrated to the specific growth system being modeled if it is to be useful as a prediction tool.

2. Shoot nitrate concentration data supported the diurnal predictions of the NICOLET model (rises during the day and decreases during the night). However, in contrast to predictions of the NICOLET model that nitrate concentration increases rapidly to a maximum value at the beginning of the lighted period, results of the study showed the nitrate concentration rises gradually during the first half of the "day" of the diurnal oscillation. The NICOLET model assumes nitrate uptake is completely passive, which is unlikely to be true at the cellular level. Additionally, a linear relationship between plant age and tissue nitrate concentration was observed.

3. Light period transpiration of lettuce was modeled and predicted successfully on a one-hour time step.

4. Aphid alate (winged) formation was found not to be promoted by long photoperiods or light spectrum differences (HPS, fluorescent or MH) in greenhouse winter supplemental lighting situations. Alate aphids are particularly difficult to control. Alate production is suppressed when greenhouse air temperature is maintained above 15C, the photoperiod is at least 16 hours, and plant vigor is high.

Technology Transfer: Intellectual property owned by Cornell University is managed through a corporation wholly owned by Cornell, the Cornell Research Foundation (CRF). The CRF has formed a unique relationship with a local firm, CEA Systems of Ithaca, NY, to transfer CEA technologies from the university to the private sector. CEA Systems has been actively engaged during the past year in developing relationships to license IP developed at Cornell, related to CEA, to private sector businesses.

Cooperative/Interdisciplinary Projects: None

Workshops, etc.: For the second year in a row, a special workshop was created for three Raytheon Corporation employees who operate the small greenhouse at the South Pole Research Station. Dr. Corey Johnson Rutzke led the three-day workshop. The objective was to transfer information and skills to increase fresh vegetable production at the South Pole Station greenhouse significantly. The greenhouse is now being operated with more than double the productivity of fresh vegetables, making the long winters more acceptable to the personnel who spend the winter at the station - which is eight months without resupply.

Publications:

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Ferentinos, K.P., L.D. Albright and B. Selman. 2003. Neural network-based detection of mechanical, sensor and biological faults in deep-trough hydroponics. Computers and Electronics in Agriculture. 40(2003)65-85.

Ho, J.W. 2003. Optimization and computer control implementation of photosynthetically-active radiation (PAR) and carbon dioxide in controlled environment agriculture. Master of Engineering Project Design Report submitted to the Faculty of the Graduate School of Cornell Univ. 58 pp.

Katzman, L. 2003. Influence of plant age, inoculum dosage, and nutrient solution temperature on the development of Pythium aphanidermatum in hydroponic spinach (*Spinacia oleracea L.*) production systems. Doctoral thesis, Cornell Univ. Libraries, Ithaca, NY. 163 pp.

Mathieu, J.J. 2004. Lettuce crop evapotranspiration, nitrate uptake, and growth mechanistic simulation modeling: for use in fault detection in hydroponic production systems. Doctoral thesis, Cornell Univ. Libraries, Ithaca, NY. 246 pp.

Software/video presentations developed: Nothing to report

Internet sites: www.cornellcea.com