Asynchronous Education in Controlled Environment Agriculture

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Abstract: A web-based, multi-faceted educational instrument for the greenhouse Controlled Environment Agriculture (CEA) Program has been under development at The University of Arizona. The educational deliverables will include, not only libraries of information related to CEA, but also living laboratories with access to historical and real time climate data, and live images of the greenhouse crop production systems. Simulation modules are under development to enhance college and secondary school student education about the inter-related plant and greenhouse systems. These will include aspects of the design, monitoring and control of the greenhouse, as well as, the physiological plant responses within the greenhouse. The results of this program will not only benefit educational programs of CEA, but they will enhance the development and the ultimate capabilities of the worldwide greenhouse industry. Collaboration has recently expanded to include three other land-grant universities, including the University of Vermont, University of Florida and Ohio State University, which also have related educational programs in CEA.

Introduction

Modern agriculture is a complex enterprise. More people need to be supported with decreasing natural resources (land and water). Farmers need to satisfy the highly competitive worldwide market, which demands high quality and nutritious products at low-cost, within a healthy natural environment. Controlled Environment Agriculture (CEA) provides an increased efficiency in the use of resources such as water and lands, while it improves quality plant products, and the profitability of yields through consistent, predictable, year around production. Greenhouse industries, one primary facet of CEA, flourish within a considerably diverse array of climates and with a variety of food and floral crops throughout the United States and the world. In Arizona and the Southwestern states, CEA is developing very rapidly, with large-scale systems producing yields never before realized (Snyder, 2000; Jensen and Malter, 1995, Jensen, 2002). In Arizona, approximately 40 additional hectares (100 acres) of hydroponic greenhouses are planned or are under development, in addition to the 65 ha (160 acres) of greenhouse tomatoes currently in operation in Willcox, AZ.

Given the current growth of the CEA industry nationwide and worldwide, the demand of highly trained graduates will not be met. CEA and particularly greenhouse production is a complex system and to be successful agricultural specialists in both plant science and engineering are required. The related agricultural disciplines necessary for CEA include engineering design and environmental control of the greenhouse, plant physiology, crop production, integrated pest management, economics and environmental aspects (Giacomelli, 2002).

As an alternative to fulfill the lack of expertise and to educate interested people in Arizona, nationwide and also worldwide, a collaborative team of experts from four universities (The
University of Arizona, University of Vermont, University of Florida and Ohio State University) is collaborating to develop an instrument for worldwide greenhouse education. The combined expertise of the collaborators spans from agricultural engineering and environmental horticulture, to education. A 2003 – 2005 USDA Higher Education Challenge grant will support the interdisciplinary team to develop educational materials within the WebCT platform, which will be useful to undergraduates, graduates and extension clientele. WebCT is designed to aid students and faculty in all areas of course instruction including development, implementation, grading, discussions and evaluation. The final product will include an on-line and CD-based repository of materials for the different classes taught by the faculty at the participating universities, as well as a learner-centered core of simulation modules to simulate the plant-greenhouse system.

Rationale

The continuous growth of the greenhouse industry and consequently the continuous demand of qualified graduates in this multidisciplinary field require the improvement of the current teaching methodologies and efficient use of current teaching facilities. Access to laboratories (greenhouse production systems and teaching facilities) is limited, as well as, experts in the field that can be reached in an asynchronous way by people nation and worldwide. Libraries of information related to CEA will be available not only as information but also as living laboratories in different parts of the country where students from K-12, to college or the aficionados in the field can see the different processes within the greenhouse, plant responses to the environment, and how the various control systems try to maintain set points (optimum climate conditions for the plants) with a real crop production system.

Data retrieved from the living systems will be feeding mathematical models that later will be useful to simulate different climate scenarios and then virtually experiment on what will happen in production systems at different time scales given an actual or past decision. With this asynchronous educational tool, students will better learn how plants respond to the environment and then make more informed decision on how to apply climate control strategies or improve crop management techniques.

Researchers from the Controlled Environment Agricultural Center (CEAC) of the University of Arizona have been developing website repositories of information related to greenhouse engineering, physiology of plants, hydroponic crop production and also image and video libraries related to plant production in controlled environments. The three other universities will now join their efforts.

Requirements

In order to achieve compatibility among the participant universities, all the deliverables will be WebCT compatible. All educational programs centered on the common conceptual issues of controlled environment will have access to the resources and the main issues will focus on greenhouse energy conservation, environmental safety, greenhouse produce safety, labor efficiency, and manipulation of plant response by controlled environment. The simulations modules will be designed using WebCT technologies used widely among universities and becoming a tool helpful for teaching purposes and also accessible by CD’s for user with no Internet access.
**Architectural design**

The Virtual laboratories will be accessible through the Internet where a web-based environmental monitoring system will be implemented. This system is currently in operation at the new completely computerized greenhouse at the Controlled Environment Agricultural Center (CEAC) at the University of Arizona, Tucson, AZ. The greenhouse has a QCOM Environmental controller, (QCOM Corporation, Irvine California) which monitors and controls the plant environment by activating the ventilation (fans and wet pads, or roof openings) for cooling, thermal screens, natural gas operated heaters for energy conservation, shading and heating, and a CO2 generator for enrichment of the plant photosynthetic atmosphere. The system has a software (GC-Connect and Grower’s Choice) that records and controls inside greenhouse climate variables, and records outside climate data from a weather station. The QCOM software records all the variables at specified intervals (5 minutes). This interval is specified within the software and is synchronized with a C++ program developed to interact with the output of the QCOM software. The C++ program reads the QCOM software output, and sends the new records using the FTP protocol to a high-request capacity UNIX web server. A general schematic of the monitoring system is presented in Figure 1.

![Schematic of the monitoring system implemented in the greenhouse facility of the CEAC at the University of Arizona, Tucson, AZ.](image)

**Figure 1:** Schematic of the monitoring system implemented in the greenhouse facility of the CEAC at the University of Arizona, Tucson, AZ.

A Java applet was developed to read and display data graphics in a time frame of either 24 hours, seven days. Real-time data and seven days data records could be accessed through the web server directly. For an efficient and rapid access to historical data of the entire season an Oracle database has been implemented. In the Unix web server there is a program that continuously upgrades the Oracle database.

**Current status and future plans**
At the moment the four participating universities have developed websites with information in different areas of greenhouse production. The website of the Controlled Environment Agriculture Center (CEAC) at the University of Arizona, Tucson, AZ (http://ag.arizona.edu/ceac/) maintains a repository of CEA educational topics and research results in CEA, as well as, a library of pictures and movies of different crop management processes. A unique and exciting part of the CEAC website is the section called “Tomatoes Live” (Figure 2). At this site, the historical and real time environmental data of climate conditions both inside and outside of the greenhouse, as well as, live images of the crop and fruits are available through the Internet. Students can follow the crop at any time according to their schedules, making the learning process asynchronous. Collections of images have helped to build libraries of different aspects in the greenhouse production process, such as plant growth, fruit development and ripening, hydroponic system preparation, and light transmission in the greenhouse.

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Figure 2: Real time and historical climate data as well as live images of the crop are available through the Internet.

Currently a new set of web cameras with pan, till, and zoom (PTZ) capabilities are being tested, which will increase the possibilities of having a virtual tour of the facilities, or give the option to manipulate which systems or part of the plants the user wants to see.

Another website developed by the same research team with a repository of information specific to hydroponic production of greenhouse tomatoes can be accessed at: http://ag.arizona.edu/hydroponictomatoes/.

As part of the project, sets of simulation modules will be developed, to more clearly present to the new graduates of the greenhouse industry an understanding of the physics of the greenhouse, physiology of plant growth and development, crop culture techniques, and nutrient delivery.
systems of hydroponic crop production. These modules will be primarily used in classes taught in the programs of CEA at the collaborating universities.

The initial development will be focused in creating simulation modules of the plant-greenhouse systems to understand typical real-world scenarios. A module will simulate the climate conditions (temperature and solar radiation) of a greenhouse production system. Another module will then include ventilation and cooling systems to control the inner atmospheric conditions at specific set points. This will aid in the understanding of the physics of the greenhouse. Another more complicated module will include plants within the greenhouse and simulate how plants modify the environment and how the plant-greenhouse system responds. Ultimately the modules will simulate plant responses to various short-term conditions.

In the near future these living laboratories will be implemented in some rather unique remote locations, such as the Scott-Amundson South Pole Research Station in Antarctica. Here a food growth chamber is currently in development by CEAC in conjunction with the Raytheon Corporation, Office of Polar Programs and the NSF. The video and data link will be installed and web cast is expected to begin in 2005.

Summary

The development of these educational tools is critical not only for the success of greenhouse industries, but also, to benefit education programs with common interests of controlled environment agriculture. In addition, the general education of the public will be enhanced with clear, comprehensive information and databases, organized within a logical, interesting and readily available form.

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References


