Purdue University
NCR-101 Station Report for 2005

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New Growth Chamber

A high-performance, high-bay plant-growth chamber was recently installed in the Department of Horticulture and Landscape Architecture in Purdue University. The chamber was purchased as an advanced tool to study optimal environmental conditions and operational protocols that will eventually be adopted in the production of genetically modified (GM) crops in an underground controlled environment growth facility. The outside size of the chamber is 13'(L) × 9'll" (W) × 13'2" (H). Inside the chamber a growth area of 96.7 square feet with a height clearance of 11 feet is available. A mixture of Metal Halide (MH) and High Pressure Sodium (HPS) lamps in the chamber can supply up to 1400 $\mu mol\ s^{-1}\ m^{-2}$ of photosynthetically active radiation (PAR) at the top of crop canopy. As crop grow closer to the high intensity discharge (HID) lamps, the lamps can be electronically dimmed to maintain the light intensity at crop canopy. Temperature in the chamber can be controlled between 5 ^{0}C/10 ^{0}C to 30 ^{0}C /43 ^{0}C when the HID lights are OFF/ON. Air humidity inside the chamber is designed to be between 40% to 75% when lights are off and 40% to 85% when lights are on. Efforts are made to prevent any corrodible parts in the humidifier kettles to avoid attacks of RO water. Air flow is delivered downward to the plants. A touch screen computer provide the human-machine interface for chamber operations such as controlling, alarm setting, automatic datalogging etc. An unregulated transgenic Bt corn will first be grown in the chamber to identify appropriate high intensity discharge (HID) lighting protocols, air temperature and relative humidity, etc. that permit adequate seed yield and expression of gene of interest (GOI) in corn seed while minimizing electrical lighting costs.

Intra-canopy Light Study

In a jointly sponsored collaborative research project between the crops group of the NASA Specialized Center of Research and Training in Advanced Life Support (ALS-NSCORT) and Orbital Technologies Corporation (ORBITEC), a reconfigurable LED lighting system has been designed. The purpose of this work is to reduce the energy required for controlled environment crop growth by targeting low-power, cool LED light in specific optimal wavebands to inner-canopy leaves, keeping pace with plant growth. For planophile crops, such as cowpea and soybean, the LED array will be a group of vertical strips that hang within the crop stand. One-inch-square light engines containing multiple printed-circuit LEDs are switched on as plants increase in height and eventually close their canopy. For erectophile crops such as wheat, and rosette crops such as lettuce, the array can be reconfigured to an overhead planar form, and this sheet of LEDs can be brought in close proximity to the expanding plants. Ultimately, automated detection of plant tissue and switching on or off of LED engines will allow the light engine illumination pattern to track plant growth. We are currently testing the first array in an intracanopy configuration using cowpea as the test crop. Initial tests show vigorous crop growth, and electrical conversion efficiency of 0.98 gDW/kW-h power has been obtained with this first generation hardware. We anticipate obtaining a second array to use as an overhead control later this year, and work is currently underway to develop the second-generation software capabilities under a NASA Phase-1 SBIR awarded to ORBITEC for High Efficiency Lighting with Integrated Adaptive Control (HELIAC).

Underground Pharma-Crop Production Environment Development

This project has been conducted in collaboration with Controlled Pharming Ventures, LLC, of Indianapolis. The ultimate goal of the project is to create of an underground, scalable, cost-effective, contained and controlled environment for pharma plants production. So far emphasis have been placed on identifying appropriate root media and lighting protocol for growing Bt corn in a controlled environment as well as studying the feasibility of growing Bt corn within a limestone mine.

Two experiments were conducted in a standard controlled-environment growth room in Purdue University to compare root media on vegetative growth. One further experiment was conducted in greenhouse under supplemental light in order to grow plants to maturity and collect yield data. All the experiments used automated irrigation with drip irrigation rings activated by a simple garden timer, delivering a general-purpose fertilizer with micronutrients at a strength of 200 mg/l N. Commercial soilless mixes, Turface calcined-clay soil conditioner (Profile Products, LLC, Buffalo Grove, IL, USA), a finer grade calcined clay product called Profile were studied alone or as different level of incorporation with each other. Profile or Turface as the sole component of the root media resulted in best vegetative growth, as judged by plant height, leaf color and caliper size. Corn plants in the third experiment was taken to maturity, with a mean 550 seeds/ear on the plants growing in Profile with the fitted reservoir, irrigated every 8 hours. This is an improvement in the 300 seeds/ear yield commonly reported among research greenhouse curators, and came with a reduction in labor required to mix special soil mixes, irrigate, fertilize, supplement iron, or apply soil fungicide treatments to plants.

Lighting protocols were studied in two experiments that were conducted in the standard growth room in Purdue University. MH and HPS lights were applied in different combination to study the effect of light quality on the growth of Bt corn. To study the effect of quantity of light, light fixtures were hang at different distance from the top of the canopy to provide various light intensity level at the canopy top. As plants grew the light fixtures were raised to keep pace with increase in plants height. Results of the experiments indicated that HID lights could be used as the sole light source for Bt corn growth in a controlled environment. To obtain healthy corn plants, a light source that is a mixture of both MH and HPS lamps is necessary. Adequate corn seed production was proved possible under light intensity between 600 –800 μmol $s^{-1}m^{-2}$. To insure high percentage of pollination, staggering planting of pollen donor plants was found to be essential.

An experimental production facilities was constructed within a former limestone mine at Marengo city in southern Indianan. MH and HPS lamps were adopted as the sole source for both PAR as well as heat inside the facility. The naturally cool temperature of the mine was utilized as cooling mechanism that prevents overheating of the air in the facility. Fresh air was continuously introduced into the facility through ventilation fans. After coming into the facility at the top, the cool fresh air was first warmed up by the heat from the HID light fixtures and then was forced down to plant growth area by a couple of ceiling fans. The ventilation rate of the facility was determined as a compromise between heat balance and mass balance inside the room to insure adequate air temperature as well as CO_2 concentration. An automatic environmental monitoring system was installed in the facility. The system could automatically monitor and save the data on environment aspects such as temperature, humidity, CO_2 concentration, wind velocity, etc. This system was also connected to the internet, making it possible to remotely monitor and control the environment of the underground facility. Data collected from the sensors provided information on improvements that are needed in the design for future facilities. A timer controlled automated irrigation system with drip irrigation rings was set up in the facility to deliver general-purpose fertilizer with micronutrients at a strength of 200 mg/l N. Bt corn plants were grown to maturity in the underground facility, with an average 558 seeds/ear on the plants. This result indicated that it is feasible to grow corn in controlled environment within a limestone mine.

Publications

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