

Development of the Enviratron Facility

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Introduction

A proposal to the National Science Foundation's Major Research Instrumentation Program was funded in 2014 to develop a plant phenotyping facility called the "Enviratron." The Enviratron, located at the Ag Engineering/Agronomy Research Farm, Boone, Iowa, is a unique concept in which plant performance would be monitored under different environmental conditions, rather than a single environmental condition as is characteristic of other plant phenotyping facilities.

The Enviratron consists of eight environmentally controlled plant growth chambers, controlling conditions such as light intensity, photoperiod, humidity, temperature, soil moisture, nutrient conditions, and CO₂ concentrations (Figure 1A). In this way, plant performance can be assessed under different highly controlled environmental conditions.

In other plant phenotyping facilities, plants in pots are routinely transported on a conveyer belt to an analyzer that scans plants for different growth characteristics. In the Enviratron, the plants in pots are never moved,

but instead a robotic rover visits each chamber to record plant growth.

Materials and Methods

Both the plant growth chambers and robotic rover were specially designed and fabricated for the Enviratron. The plant growth chambers were designed by Percival Scientific, Inc. to accommodate visits by the robotic rover. The chambers have two compartments—an "airlock" to accommodate the rover, and a plant growth compartment. When the rover approaches the chamber, the sliding door to the airlock opens allowing the rover to enter the chamber. Once inside, the door closes, allowing conditions to equilibrate between the airlock and the growth compartment. When conditions are equilibrated, a curtain separating the two compartments rolls up giving the rover access to the plant growth compartment (Figure 1C).

The robotic rover was designed and fabricated by the Ag and Biosystems Engineering team. The rover follows a magnetic tape on the floor. The rover has a robotic arm able to reach into the chamber from the airlock. On the head of the arm is mounted an array of cameras and sensors to image the plants and make various physiological measurements (Figure 1B). The array includes RGB, hyperspectral and holographic cameras, an infrared imager, PAM fluorometer, and Raman scattering spectrometer. The collected images and data are streamed wirelessly to a server located in the Enviratron building.

When the rover enters a chamber and the curtain is raised, the laser scanner on the rover creates a map of the plants in the chamber. The maps are used to guide the robotic arm and position the sensors to make the measurements.

Results and Discussion

The Enviratron will go through preliminary testing in April 2018. The rover and the chambers have been tested separately, but their operation together will require further investigation. Reliability is essential for the operation of the Enviratron, because users will conduct experiments lasting for weeks.

The chambers are equipped with various sensors and alarms to detect and notify users and operators of any problems. In addition, security cameras are located in each chamber and in the alleyway between the two rows of chambers.

Software has been developed for users to input instructions for the chambers and the rover. Users will be able to sit at their desks on campus and input instructions and monitor the status of the chambers and the rover. Developing the software has been a major undertaking, particularly the software to guide the rover. The pattern of foliage in the chamber is complex, and it changes each time the rover enters the chamber because of plant growth.

Users will have access to the Enviratron on fee-for-service basis. In general, users will need to seek research funds to be able to use the facility. Priority will be given to users who will use all eight chambers for their experiments. The chambers can accommodate experiments in which plants grow 7 ft high, sufficient to grow some varieties of corn to maturity.

Growth chambers are severely limited in space, so intelligent design of experiments is paramount. Also, there are many combinations of conditions to which the chambers can be set. While some users may want to vary a single environmental parameter and keep others constant, others may choose combinations of conditions to simulate different climates.

The Enviratron building has an observation room with a touch screen TV allowing visitors to watch the rover in action through the cameras mounted in each chamber. In addition, the observation room has posters to inform visitors about the Enviratron and the importance of research to understand how plant performance is impacted by changing environmental conditions.

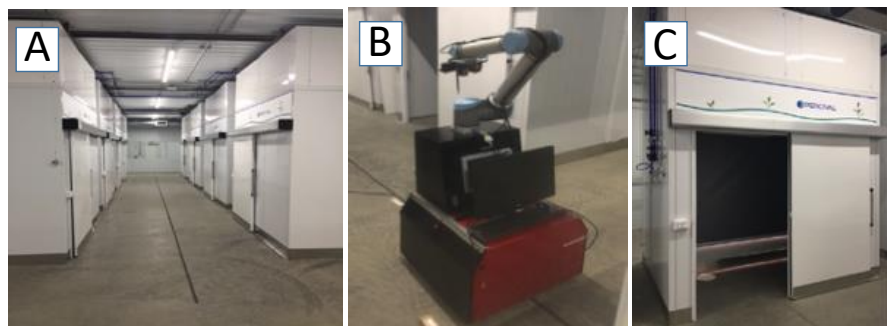


Figure 1. The Iowa State University Enviratron. (A) The Enviratron consists of eight growth chambers that can be set to different growth conditions. (B) A rover with a robotic arm is programmed to visit the chambers and record plant performance. The rover is equipped with an array of cameras and sensors to image plant growth and measure physiological parameters. (C) The chamber doors slide open to allow the rover to enter the airlocks in each chamber. The door slides close and an interior curtain rises to allow the rover to scan plants and take measurements.