Bench-top Controlled Environment Growth Chamber for Speed-Breeding and Crop Transformation

Team:
Oscar E. Gonzalez-Navarro, John Innes Centre and Quadram Institute Bioscience, Food and Health, Post-Doctoral Scientist
oscar.gonzalez@quadram.ac.uk
Primary applicant.
Contribution: Crop physiology and hardware development.
Expertise: Plant development, Arduino and Raspberry PI microcontrollers, sensor modules.

Ricardo H. Ramirez-Gonzalez, John Innes Centre, Crop Genetics, ricardo.ramirez-gonzalez@jic.ac.uk
Post-Doctoral Scientist
Contribution: Software and controller development.
Expertise: Programming, data analysis and visualisation.

Sreya Ghosh, John Innes Centre, Crop Genetics, Sreya.ghosh@jic.ac.uk
Post-Graduate Student
Contribution: Implementation and technical advisor
Expertise: Biotechnology and speed-breeding.

Marcela Mendoza-Suarez, Oxford University, Plant Science, marcela.mendozasuarez@plants.ox.ac.uk
Post-Graduate Student
Contribution: Implementation and business feasibility advisor.
Expertise: Plant synthetic biology, crops macro- and micro-nutrients, and sustainable business practices.

Luis Hernan, Newcastle University, School of Architecture, me@luishernan.com
Contribution: Design and fabrication.
Expertise: Design, prototyping, fabrication.

Carolina Ramirez-Figueroa, Newcastle University, School of Architecture,
carolina@syntheticmorphologies.com
Contribution: Design and fabrication.
Expertise: *Design, prototyping, fabrication.*

Summary
Plant research institutes, like the John Innes Centre, depend greatly on controlled environment facilities for most of their projects. Shared facilities include glasshouses and controlled environment rooms which are high in demand. After consulting with project leaders at the John Innes Centre, we propose that development of an **open low-cost bench-top controlled environment chamber** can address this high demand and be of great benefit for plant synthetic biology and plant research worldwide. The incorporation of “speed-breeding” capability (growing plants under near continuous photoperiod) will prove useful for fast generation cycling. A device with these characteristics can be achieved with low-cost microcontrollers like Arduino and/or Raspberry Pi, and low-cost sensors and modules. To build this, an interdisciplinary team was assembled with a wide range of skills, from bioinformatics, plant science, to architecture. The output of this project will be **open source, the documentation and design will be available in a GitHub repository**.

Proposal

Limited glasshouse and controlled environment space is one of the principal constraints for running plant science experiments. The need for reducing crop generation cycling time is increasing as we adopt new and fast plant synthetic biology approaches (e.g. crop transformation). For high throughput methods, large walk-in controlled environment rooms are needed, but some research projects can benefit from smaller scale approaches at the fraction of the cost. This proves especially true for research groups that are venturing into new genome editing approaches.

A useful technique that is being adopted across breeding programs and genome editing approaches that rely on fast plant generation, is speed-breeding. This technique uses long photoperiods of high quality and high intensity light, in combinations with specific temperature and humidity, to accelerate plant development, without any obvious detrimental effect on the health of the plant.

We propose to develop a lab-scale controlled environment chamber that satisfies the required parameters for speed-breeding to allow the growth of small numbers of plants for crossing or harvesting immature embryos for crop transformation, as well as transformed explants, all of which are shown to work under such conditions (personal communication). The aims are:

- To engineer an ergonomically accessible chamber for the laboratory environment.
- Develop an array of LED capable of producing the quality and intensity of light needed for speed-breeding.
- Create a cooling/heating system using Thermoelectric Cooler (TEC) modules and heat sinks to precisely control the internal temperature.
- Incorporate an automatic watering system with soil moisture probes and a solenoid valve to provide precise irrigation throughout the crop's cycle and avoid water stress.
- Develop the software to integrate and control each individual subsystem (i.e. light, temperature, humidity, irrigation).
- Create a low-cost open-source product that can potentially benefit research institutes worldwide.

The main outcome will be openly available easy-to-follow instructions on how to build the chamber system. This will include a downloadable working software made available via OpenPlant's GitHub repository. We aim to produce a scientific publication comparing the developed tool against commercially available controlled environment chambers.

The interdisciplinary team has been carefully put together to provide a wide range of skills (i.e. engineering, computer science, plant science, industrial engineering, and architecture), that will enable the development of a highly functional device for research groups to extend their plant genome editing capabilities. The all-inclusive planning meetings and skill-based focus areas will ensure an efficient and practical approach. This means that computer scientists will focus on software development, biotechnologists will focus on hardware development, industrial engineers and architects will focus on structural design, and plant scientist will consolidate the project into a practical, efficient and useful tool for plant synthetic biology (see Table 1).

		Month					
Team member	Activity	Aug	Sep	Oct	Nov	Dec	Jan
Everyone	Coordination meeting	■			■		
OG, SG	LED array prototyping	■	■				

RR	Photoperiod software		■				
OG, RR, LH, CR	Temperature control hardware		■	■			
RR	Temperature control software			■			
OG, MM	Irrigation hardware			■			
RR	Irrigation software			■	■		
OG, LH, CR	Humidity hardware				■		
RR	Humidity software				■		
LH, CR	Structure design	■	■	■			
LH, CR, OG	Structure construction		■	■			
Everyone	Merging of systems				■	■	
Everyone	Develop working prototype and testing					■	■
Everyone	Uploading files to GitHub	■	■	■	■	■	■

Table 1. Schedule diagram.

Benefits and outcomes

Controlled environments are a fundamental tool in plant synthetic biology and crop research. These are used to grow explants for crop transformations, CRISPR, or marker-assisted selection breeding. Plant growth space in glasshouse or controlled environment rooms are constrained by the availability of shared resources across the institute. Therefore, the development of a controlled environment chamber that can be used in the laboratory can open the possibility for more research groups to carry out crop transformations, plant genome editing, and plant breeding.

Sponsor for the research and cost centre

Dr Brittany Hazard, Career-track Research Leader
John Innes Centre and Quadram Institute
Brittany.Hazard@quadram.ac.uk
Cost centre: C0741-H11-A

I confirm that I have the full support of the sponsor listed above and that they can be added to the OpenPlant Fund mailing list to receive project updates (to which they can unsubscribe at any time).

Estimated Budget

The budget will be used for buying all the components and accessories needed for building a working prototype of the controlled environment chamber, this includes the light, temperature, humidity and irrigation systems, along with the chamber structure. we also allocate a travel expense to cover transportation for two strategic team meetings that will allow us to fully organize and determine the needs and limitations of each component and system.

Sensors, LEDs and modules	£800
Microcontroller boards	£250
Electronic miscellaneous	£400
Structural components	£1550
Travel expenses	£500
3D printing and printed circuit board	£500
Total	£4000