**Plant Growth Chamber with real-time monitoring and remote control**

# Primary contact for the team

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**Team**

Zhengao Di ([zd250@cam.ac.uk](mailto:zd250@cam.ac.uk)), Department of Plant Sciences. He will focus on the designs and applications of the chamber in real plant research as well as the remote monitor and visualisation of chamber conditions.

Weiming Che ([wc289@cam.ac.uk](mailto:wc289@cam.ac.uk)), Control Group, Department of Engineering. He will be in charge of electrical circuit integration as well as implementing control algorithms to modulate plant growth environment based on sensor readings.

**Summary**

Healthy plants grown in a favorable and controlled environment are at the centre of all plant science research. No reliable conclusion could be drawn if the plants used in the experiments are suffering from inadvertent stress or if plants to be compared grow in slightly different conditions. On the other hand, however, monitoring the growth of plants for each experiment is demanding and sometime impractical. Hereby, we aim to build an automated plant growth chamber that is featured with real-time remote monitoring of plant conditions through web servers, expandability to larger scales and compatibility to customable purposes. Our vision is that the chamber will provide a controlled environment for plant growth under a variety of conditions, automate regular workflow such as irrigation and imaging, and produce growth condition data for better understanding the metadata of each experiment and sharing reproducible protocols.

# Proposal:

# The problem

As mentioned in the summary part, having healthy plant materials and knowing the exact conditions that plant materials have been growing in are crucial for plant research. Traditionally growing plant materials for a set of experiments involves various levels of time commitment. Depending on the length and requirements of the experiments lots of time and effort could be wasted on performing simple routines such as watering and taking images of plants repetitively. The current COVID-19 pandemic has also flagged up the importance of remote working and motivated us to think about strategies that could transfer traditional wet lab work to ‘cloud’ experiments, in which experiments are performed within labs by automated equipment but remotely monitored and controlled by researchers at a different location.

We propose that by implementing real-time monitoring, automation on routine workflows and remote control on plant growth facilities, researchers could save a lot of time and produce high-quality and reproducible data for plant research.

**Biological systems**

We aim to apply our growth chamber to growing plant seedlings on multi-well plates under controlled environment for high-throughput chlorophyll fluorescence imaging assays.

Chlorophyll fluorescence imaging (CF imaging) measures the fluorescence of chlorophyll within a leaf upon incident light, which is emitted in a process in competition with the photochemistry reactions of photosystem II (PSII) and therefore served as an estimate of PSII activity. CF imaging assays are widely used in plant physiology research as it provides an accurate and non-invasive method to evaluate photosynthetic activity and responses to biotic and abiotic changes of plants.

It is also featured with the potential to screen a large number of samples simultaneously and brings up lots of opportunities to perform high-throughput screening for a variety of purposes.

High-throughput CF screening can be achieved by growing plants on multi-well plates for a number of days so that all plants can be imaged simultaneously. However, small plant seedlings such as these could easily suffer from subtle differences in the growth conditions, and in real experiments soil in multi-well plates could easily dry out if not watered promptly, therefore real-time monitoring is desirable but

a great amount of time needs to be spent to achieve this manually for each set of experiments and failure to do this could lead to non-synchronized plant material for analysis.

Herein we propose that by integrating the automated plant growth chamber with CF screening, we could assess photosynthesis activities of a range of plant species in a fast and automated manner. Especially we aim at assessing photosynthesis activities of various *Arabidopsis thaliana* transgenic lines that Zhengao is generating and across several C3 and C4 species.

**Hardware design goals**

The goal of hardware design is divided into two folds. The first is to integrate the sensors with the microcontrollers such as Arduino or Respray Pi. Light, temperature, humidity sensors will be applied to measure plant growing environments. In addition, we plan to use a camera to monitor the condition of the plants remotely. All data and videos will be logged and stored in a Cloud server through a WiFi module. The data can be reached and visualised on a web server upon request.

The other goal is to implement the control logic for the actuators, such as the lights, fan and water pump, based on sensor readings. We plan to apply PID controllers to keep the plant growing environment at a relative steady condition. An interrupt function will be embedded into the design to allow researchers reset the environment parameters and manipulate the actuators remotely based on their observation from the camera.

If time and funding permitted, we will also investigate the possibility of using robotic arm to achieve more accurate remote operations on plants throughout the growing period.

**Project implementation**

We plan to break the task into three stages. On the first stage, Zhengao will be in charge of designing 3D models and ordering necessary components to build the scaffold of the chamber. In the meantime, Weiming will integrate the sensors with the microcontrollers as well as set up the communication channel between the micro controller and the remote server. This will take about two months.

On the second state, we will together assemble the plant growing chamber and mount the microcontroller, sensor and actuator system to the chamber. We will also write functions on the server to visualise data from the sensors. This stage will take up another month.

Finally, on the third stage, we will together implement the automation algorithms to control the plant growing parameters and apply it to chlorophyll fluorescence imaging experiments. This will be an iterative design procedure and a test on the stability of the system will be carried on simultaneously.

# Outcomes and benefits

The direct benefit of this project would be that it allows plants for high-throughput CF screening to grow in controlled conditions and be monitored in real time. We aim to build it with cheap and commonly available electrical parts and provide simple and reusable codes for data logging, sharing and visualisation. So the long-term vision of this project is to provide a generic prototype to grow and monitor plants, automate common workflows and generate formulated data for analysing and sharing for a wide range of experiments.

**Sponsor for the work**   
Prof. Julian Hibberd

Head of Group;

Department of Plant Sciences, University of Cambridge

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**List the components and budget that you envisage you will need to complete the project:** (see <https://biomaker.squarespace.com/ordering-information/> for more details and supplier list) The more detailed your bill of materials, the higher your proposal will be ranked so please include everything you think you will need to complete the project. There will be an opportunity to make alterations at a later date.

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| --- | --- | --- | --- | --- | --- |
| **Item** | **Supplier** | **Catalogue #** | **Quantity** | **Price (each)** | **Total Price** |
| Camera | Raspberry Pi |  | 1 | £24 | £24 |
| Lamp |  |  |  |  |  |
| Fan | Raspberry Pi |  | 2 | £3 | £6 |
| Modules for temperature control |  |  |  |  |  |
| PLA 3D Printer Filament | RS |  | 1 | £12.89(inc. VAT) | £12.89 |
| Jump Wire | RS |  | 2 | £0.551 | £1.102 |
| Raspberry Pi 4 Model B | Raspberry Pi |  | 1 | £54 | £54 |
| Breadboard | RS |  | 1 | £14.44(inc. VAT) | £14.44 |
| Water Pump | Raspberry Pi |  | 1 | £23 | £23 |
|  |  |  |  |  |  |

**The full application should be no more than 3 pages, excluding any figures, photos and diagrams which should be inserted at the end of the document and referenced in the text. There are no word limits on any section apart from the 150-word summary.**

**Please submit your complete application to** [**synbio@hermes.cam.ac.uk**](mailto:synbio@hermes.cam.ac.uk) **by 6th December 2020.**