3rd Funding Call: Diego Corona Lopez

November 26, 2021 (updated January 21, 2022)

University of Manchester; e-Agri Sensors Centre, Elec. & Electronic Engineering

Project Title

Seeing the unseeable –

Scaling Electrical Impedance Tomography (EIT) to enable a whole plant, high-throughput, phenotyping demonstrator asset for the Phenom-UK community.

Total fund Requested

£20,000

Project Summary

The project will enable a 'value-engineered' variant of Electrical Impedance Tomography (EIT) to be fabricated and deployed within the recently opened (October 2020) research glasshouse facility, in the University of Manchester's (UoM) Fallowfield campus, South Manchester (Figure 1), which are designed to accommodate both conventionally bred and high-containment GM crops, within individual controlled environment chambers.

Fig 1: *(a) Fallowfield Research Glasshouse. (b) Detail within one cubicle (6 x 3m).*

The EIT technology has previously been demonstrated to be capable of sensing and imaging the interaction (functioning) of crop roots with soils and other growth media (Corona-Lopez *et al*, 2019). This can be achieved in a non-invasive and real-time manner through the capacity of the approach to sensitively track the flows in 3-dimensions (3D) of aqueous electrolytes, e.g. labile nutrients and chemistries, in and around the rhizosphere and root-bundle. Recent research between the sensor engineering team at the UoM and plant science group at the University of Sheffield has enabled a new generation of the technology to be realised in a cost-effective manner which overcomes previous limitations in the dynamic range and reliability of soil-based EIT measurements. The latter relate to a complex combination of changes in the flux linkage between the electrodes and soil structure as the

crop-root's environment transitions from being dielectric dominated to conductive, and vice-versa.

In combination with high-definition above crop sensing of 3D phenotypes, such as through active multispectral (MSI) or fluorescence imaging and / or thermography, this EIT approach paves the way to synchronous, high-throughput, screening of crop phenotypes both above and below the soil ('roots-to-shoots'). The potential to then accessibly stream 10-dimensional data, i.e. 3 spatial + spectral + temporal dimensions both from above the crop canopy and from within the root-zone, from all the cultivars within a phenotyping screen enables emerging machine and deep learning technologies to be exploited by plant scientists to identify and investigate subtle variations in genotypic effects that may otherwise be hidden.

To-date internal investment by the UoM, in excess of £70K, has delivered the first Phase of an open-access demonstrator facility in Fallowfield, for use by the Phenom-UK community. This Phase-1 has delivered a robotic gantry assembly suitable for scanning over an area of approximately 4 square metres and continuously across the diurnal cycle (Figure 2). Currently the sensor-head assembly incorporates an active MSI and photometric stereo detector, as developed by the research team in partnership with the Bristol Robotics Lab (University of the West of England), the underlying research having also catalysed at least two of the first round Phenom-UK activities.

Additional above canopy sensing may be incorporated, as dictated by the community's needs, whilst controlled spectrum lighting and programmed foliar application of chemistries is scheduled for commissioning mid-2021. The system has been scoped, as a Phase-2, to accept below ground imaging of up to 24 plants, using the new EIT engineering (Figure 3).

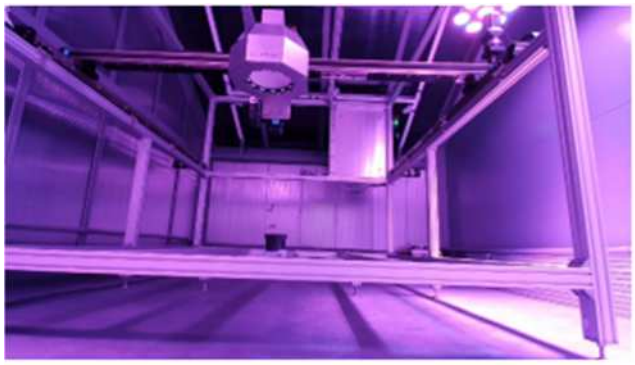

Fig.2: *Existing Robotic gantry and AMSI Sensor head*

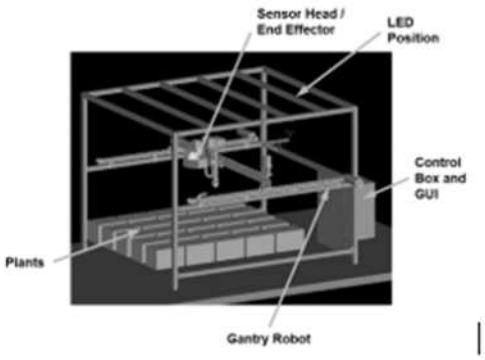

Fig.3: *Proposed Phenotyping Assembly*

Conceptual designs for the structure of the 'intelligent' soil imaging pots have been produced (Figure 4) and the electronics and sensor array restructured from a laboratory concept unit (Figure 5) to now be a none labour-intensive scalable module, suitable for manufacture at just a few hundred pounds. The aim of this project is to take those conceptual CAD designs into a reality by implementing an array of 24 modules operating in parallel in the Fallowfield facility, suitable for below ground phenotyping of soils and root-bundles up to 10 litres in capacity and so launch a Phase-3 of machine learning insights from roots-to-shoots.

Fig.4: Laboratory Proof-of-Concept EIT unit

Fig.5: Proposed Value-Engineered Module

The Phenom-UK pilot project would fund the consumable materials in order to build the 24 EIT modules, the Bill-of-Materials for these being £25,846. If the bid is successful, then the UoM will support the shortfall of £5,846 in non-recoverable outgoing costs associated with the consumables being charged at 100% FEC versus the Phenom-UK grant recovery rate of 80% and the £25K @ 100% FEC cap on expenditure. In addition, the design, tooling and ancillaries' costs for the EIT infrastructure (£17,052 at 100% FEC) will also be borne by the UoM on a related supporting budget.

In return, once commissioned, during the life of the live project 'free usage' of the complete whole-plant phenotyping system will be made available to any member of the Phenom-UK membership to access, in notional 4–6-week blocks, i.e. plant science consumables and labour supplied by the user whereas the system support and engineering developmental resources would, again, be provided by the UoM team as in-kind support. It is proposed that each use-case would:

- Be prioritised and selected by Phenom-UK management group with respect to the potential for research and / or commercial impact.
- Require the Plant Science user to commit to leading on drafting and submitting a peer reviewed paper to a high impact journal. If the user is a commercial partner, relevant IP may be secured in advance of publication provided the EIT system and prior Phenom-UK research input is cited.

Following this half-year inauguration period, it is anticipated that the system would continue to be provided to the Phenom-UK membership and broader community on a similar but at-cost basis, i.e. not-for-profit.