PhenomUK

Current UK Phenotyping Platforms

A UKRI Infrastructure Scoping Project.
Integrating state-of-the-are national facilities in plant and crop phenotyping and connecting the UK phenomics community

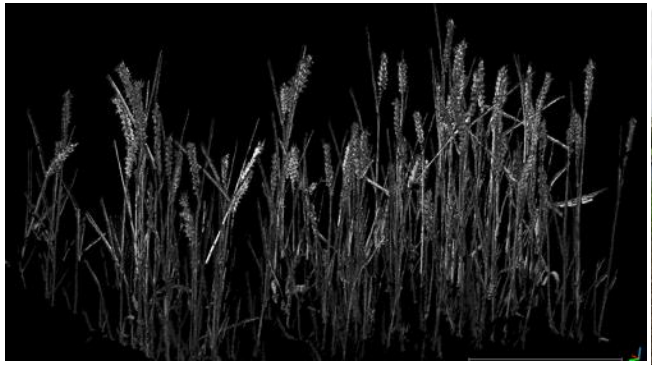
www.phenomuk.org

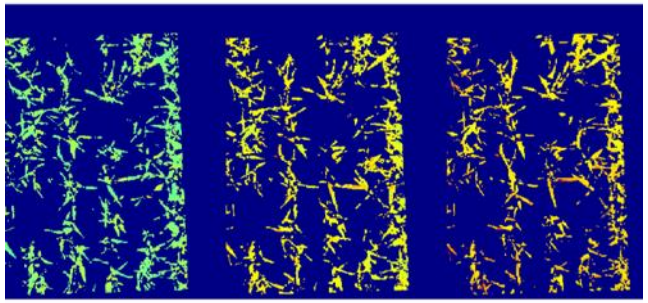
PhenomUK Research Infrastructure

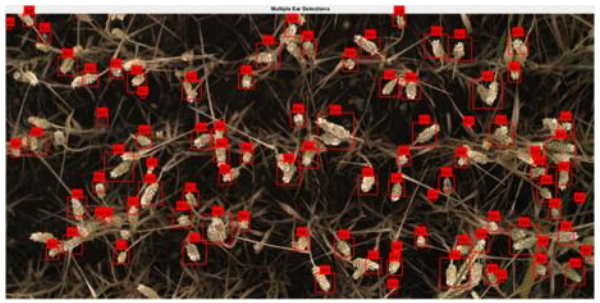
HTP in the field

Malcolm Hawkesford

Field scanalyzer

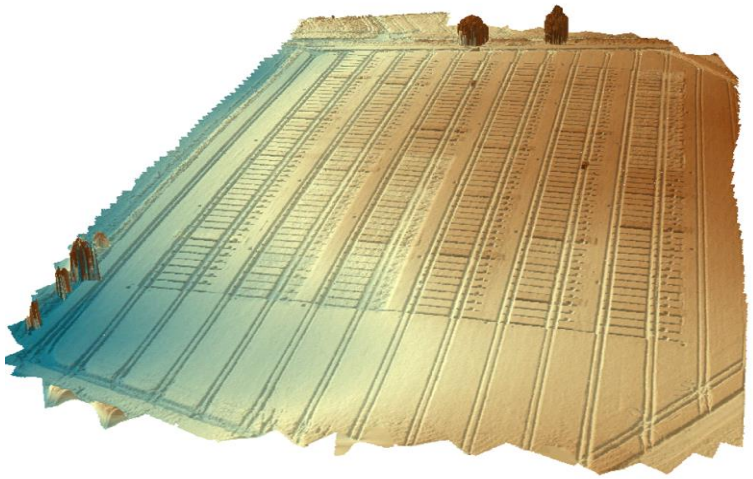




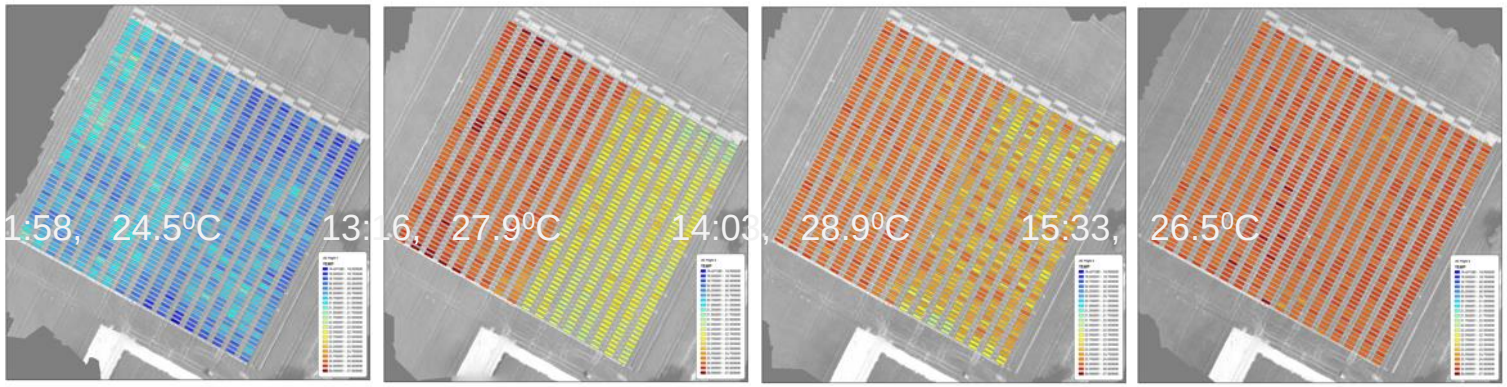


- **Programmable,** 24/7 operation, **fully automated**
  - High throughput
  - High spatial and dense temporal information capture
  - Accurate X, Y Z positioning
- **Range of sensors** to measure crop/individual plant growth, development and health
  - RGB (x3)
  - Thermal
  - Laser scanner
  - Fluorescence
  - Hyper-spectral
- **Non-invasive**
- **Useful for germplasm screening and sensor/method development**
- **Plots or pots!**
- **Lots of feature recognition/data workflows**

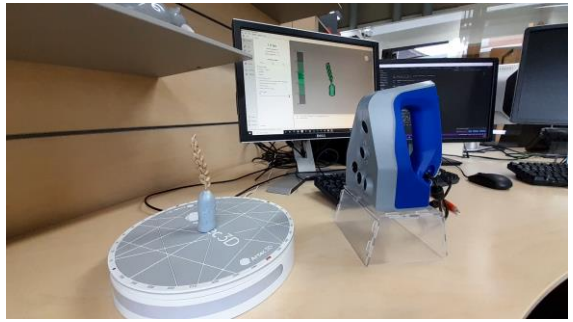
Drones



- Multiple drone platforms
- RGB (high resolution possible)
- Thermal
- Multispectral
- Hyperspectral
- 3D, e.g. for crop height
- Work-flows
- Licenced and insured pilots
- Any site depending on flying restrictions



3D imagery



- Range of surface scanners for different scales/resolutions (e.g. canopies, spikes)
- Feasible in the field, including off-site
- Segmentation of features for wheat

Contacts at Rothamsted

Drone work

Andrew Riche

March Castle

Parul Sehrawat

Field Scanalyzer

Nicolas Virlet

Latifa Greche

malcolm.hawkesford@rothamsted.ac.uk

The Advanced Plant Growth Centre at the James Hutton Institute

The Advanced Plant Growth Centre seeks to use **next generation controlled pre- and post-harvest environments** combined with **high throughput phenotyping** to deliver the **underpinning science** for the development of resilient **crop varieties.**

It additionally aims to support technologies that provide farmers and growers with tools to advance both **precision** and **controlled environment agriculture**.

Example projects

- H2020 ADAPT – Accelerated development of multiple stress tolerant potatoes
- BBSRC PACE – Optimising genetics by management (G x M) interactions to enhance productivity and quality in indoor lettuce cultivation
- IUK KTP – Development of molecular markers for accelerated breeding of medicinal cannabis

The Advanced Plant Growth Centre

Available facilities

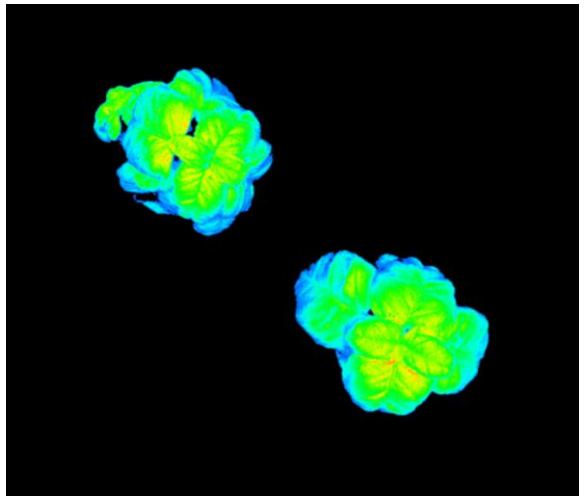
- 137 individual glasshouse compartments including >3000 m^2 modern Venlo facilities
- 675 m^2 (24 cubicles) licensed for GMO
- 1280 m^2 (37 cubicles) including quarantine for pathogens
- 1500 m^2 (30 cubicles) air conditioned including entomological facility
- 15 walk in growth rooms
- Various age and quality
- Size range 8 – 12 m^2
- 34 growth cabinets
- Range of environmental control sub-zero to +40^oC
- Fluorescent and LED lighting

The Advanced Plant Growth Centre

Available facilities

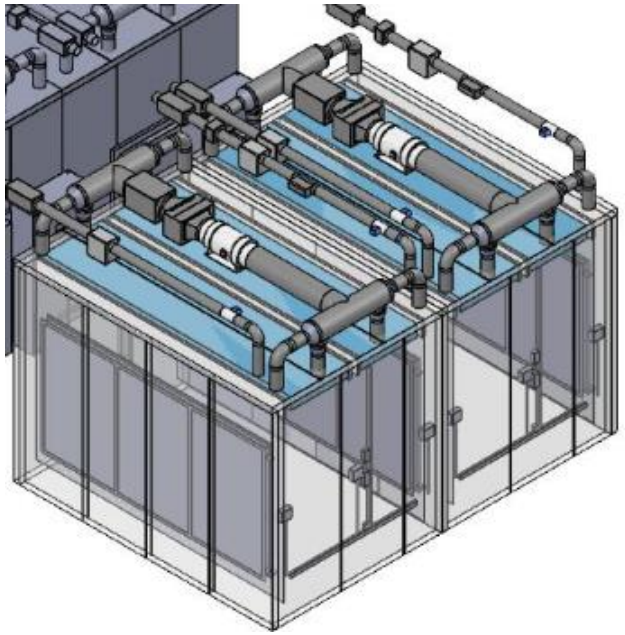
PSI PlantScreen semi-automated phenotyping platform

- Accommodates up to 5 plant trays (5 – 100 plants)
- RGB top
- RGB side with multiangle view
- 3D laser scanning and segmentation
- Kinetic chlorophyll fluorescence imaging (QY PSII, NPQ, qN, qP, qL, ETR)
- VNIR top view hyperspectral imaging (380 – 900 nm)
- PRI, NDVI, SRI, MCARI, OSAVI



The Advanced Plant Growth Centre

Upcoming facilities – July 2024

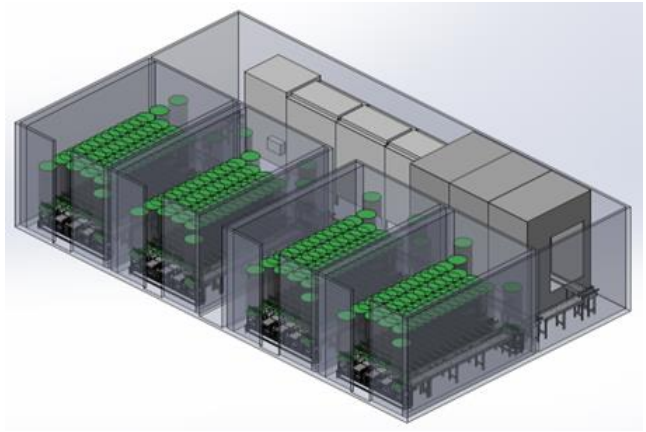


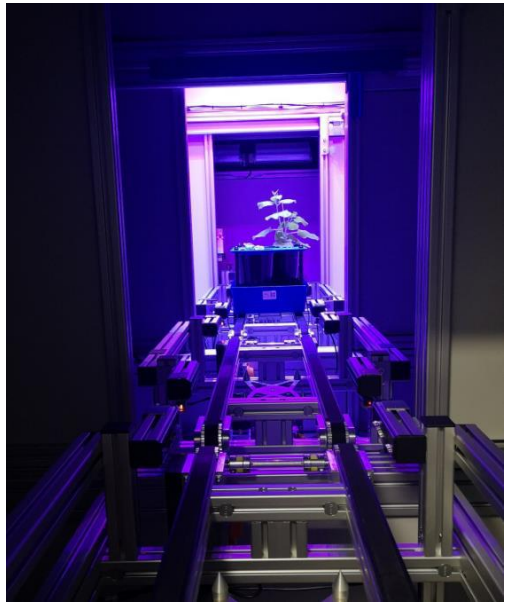
12 new high quality growth rooms

- Internal dimensions 12 m^2 x 2.4 m height
- Glycol cooled 5 to 40^oC +/- 0.5^oC
- Ultrasonic humidification (30-95%)
- CO_2 ambient to 1500ppm
- Sunlight spectrum LED's up to 1500 μmol m^{-2} s^{-1} at 50cm above bench
- Variable spectrum LED's up to 1000 μmol m^{-2} s^{-1} at 50cm above bench
- UVB (310nm), Cool white, Blue (450nm), Green (550nm), Red-orange (630nm), Ref (660nm), Far-red (730nm)
- Four rooms connected by automated conveyor to phenotyping platform

The Advanced Plant Growth Centre

Upcoming facilities – July 2024





Automated High-Throughput Phenotyping Platform

- 4 independent growth rooms with conveyor system for plant transport
- Flexible system 52 trays per room (52 – 1040 plants)
- Maximum plant size 1.5 (h) x 0.6 (w) m
- Automated watering/weighing station
- Automated plant height measurement for optical optimisation
- RGB top + side view
- 3D laser scanning
- Kinetic chlorophyll fluorescence
- VNIR hyperspectral imaging (380 – 900 nm)
- SWIR hyperspectral imaging (900 – 1700 nm)
- Dedicated experimental support team

Raul Huertas

Ray Campbell

The Advanced Plant Growth Centre

Contact

www.apgc.org.uk

rob.hancock@hutton.ac.uk

info@apgc.org.uk

PhenomUK

Lincoln Institute for Agri-Food Technology (LIAT)

UNIVERSITY OF LINCOLN

Plant Phenotyping Facilities at LIAT, University of Lincoln

Ravi Valluru
rvalluru@Lincoln.ac.uk

Robotic Phenotyping Platform

Specifications:

Weight:	200 kg
Size:	3 m Long x 1.5 m wide
Battery:	6-8 h

Operation: Joystick

Components:	Mini-PC, network module
Sensors:	3D scanners, Multispectral camera, Hyperspectral camera, Thermal camera, and RGB camera

Dual set-up of multispectral 3D laser scanners (F500-PlantEye, Phenospex Ltd)

- Dual sensors (reflectance at 940 nm)
- Dense 3D point-cloud
- HortControl software
- Spectral sensitivity: 380-900 nm
- Spectral data: R (624-634 nm); G (530-540 nm), B (460-485 nm), and NIR (820-850 nm)

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Hyperspectral camera (Senop)

- **Spectral capability:**

- Wavelength area
  - 500nm – 900nm
  - Up to 1000 spectral bands (normal, narrow and wide FWHM selectable per wavelength)

- Spectral FWHM bandwidth:
  - Narrow <10nm
  - Normal <15nm
  - Wide <20nm
- Spectral accuracy over operating ambient temperature range <2nm
- All pixels are true pixel, no interpolation used

Multispectral camera (RedEdge, Micasense)

- **Spectral capability:**

- Wavelength area
  - Red: 668 nm
  - Green: 560 nm
  - Blue: 475 nm
  - Red edge: 717 nm
  - NIR: 842 nm

PhenomUK

Thermal camera (FLIR A35)

- **Spectral capability:**
  - Accuracy: ±5°C
  - Temp. range: -25°C to 135°C
  - Focal length: 9 mm
  - Resolution: 320 x 256 pixels

In-situ root imager (CI-600)

- **Spectral capability:**
  - Resolution: up to 23.5 million pixels
  - 100, 300, 600, and 1200 DPI scanning resolutions
  - 360-degree scans (21.59 X 19.56cm)
  - Live-updating root images

University of Essex

Plant Productivity Group

- High/low res chlorophyll fluorescence whole plant imaging
- Thermal imaging of stomatal conductance
- Imaging plant Water Use Efficiency
- Infra-red gas exchange analysis – inc whole plant chambers
- Dynamic lighting platforms
- Spectral reflectance

Research areas:

- Plant photosynthesis
- Abiotic stresses
- Impact of climate change on plant performance

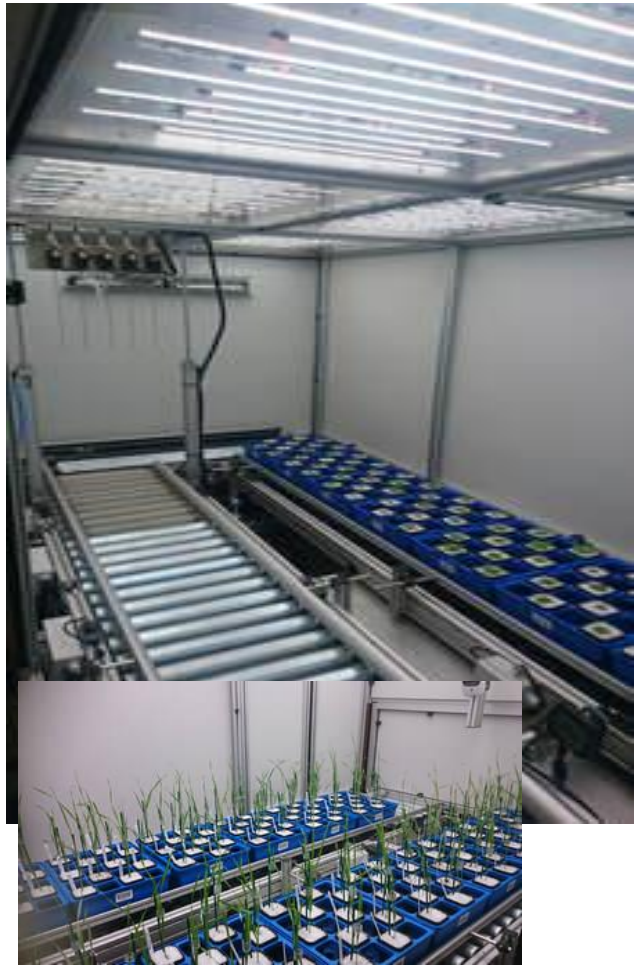
Contact: Prof Tracy Lawson, School of Life Sciences

For further information please go to:
The Plant Productivity Group

University of Essex

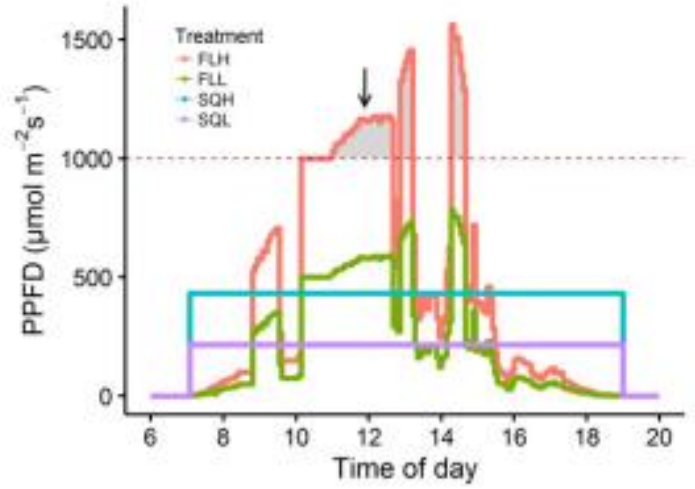
Plant Productivity Group – Range of growing environments

Watering and weighing platform
- controlled drought experiments.



State of the art growing rooms and light environment, both spectral and dynamic PPFD

Hight light intensity dynamic platforms that can be programmed on sec basis.



University of Essex Coming soon March 2024

Plant Productivity Group – Wolfson Smart Technology Experimental Plant Suite (STEPS).

New state-of-the-art facilities:

- Climate controlled environments capable of mimicking those in the natural environment - “the field”
- Future climate conditions including CO_2 and temperature
- Dedicated watering and balancing platform for WUE
- Vertical farm – IAG Grow Frame.

Dynamic Plant Phenotyping for future proofing crop productivity - DynSCREEN

University of Essex Coming soon March 2024

Plant Productivity Group – Wolfson Smart Experimental Technology Plant Suite.

PlantEye F600

Drought spotter

University of Essex

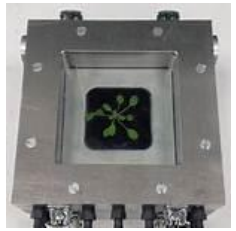
Plant Productivity Group – Infra-red gas exchange analyses

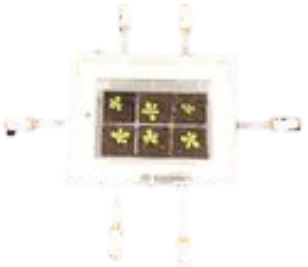
A suite of IRGAs for leaf level measurements

- 8 Licor6800
- 5 Licor 6400
- 3 ACD pros.
- Walz 300

For use in the field, lab or controlled environment. Facilitates high through capacity of “gold standard” measurements of photosynthesis.

Bespoke chambers: Whole Plants, split chamber, pod chambers, imaging chambers

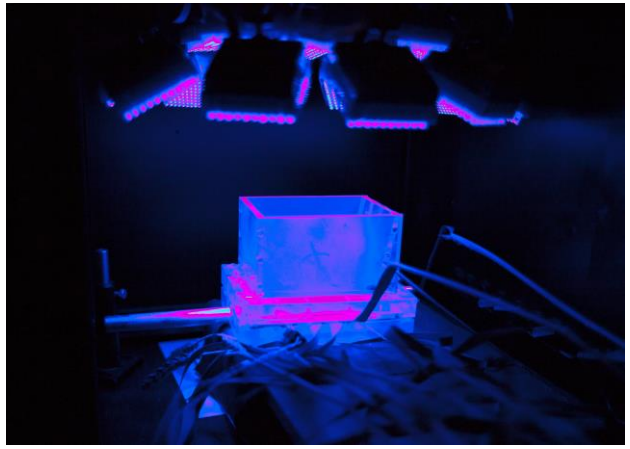


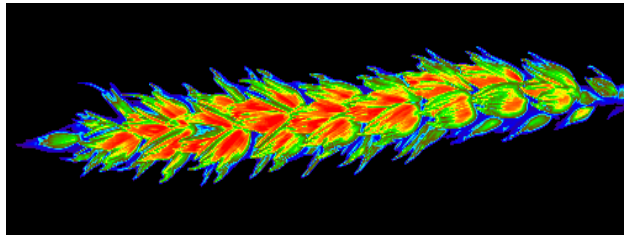


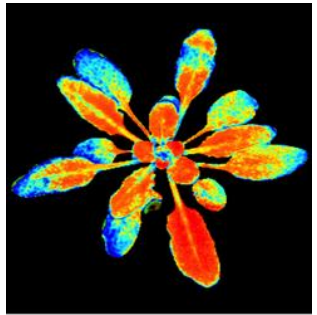
University of Essex

Plant Productivity Group – Plant imaging

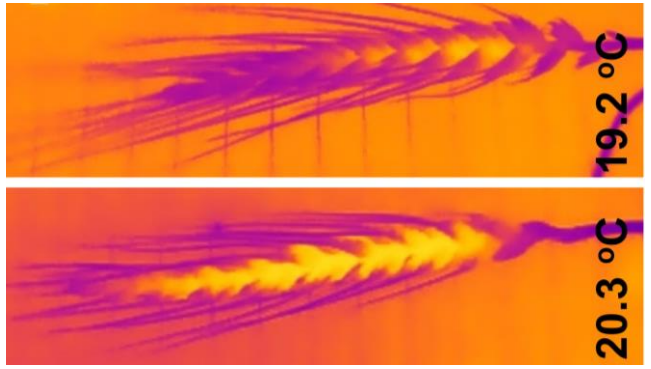
Chlorophyll fluorescence

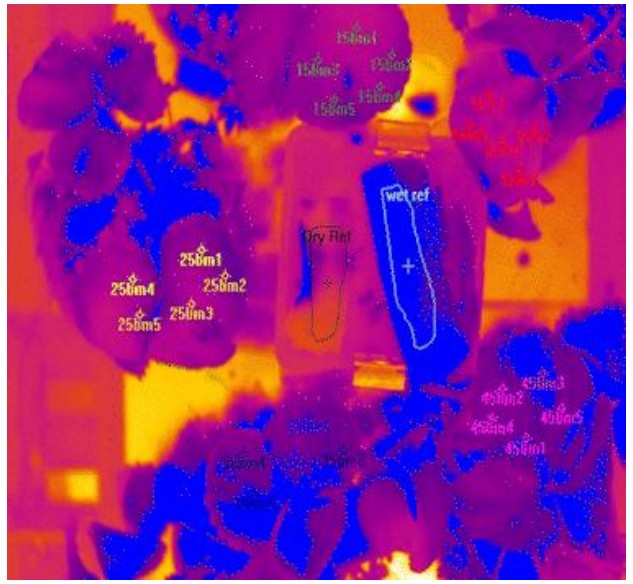




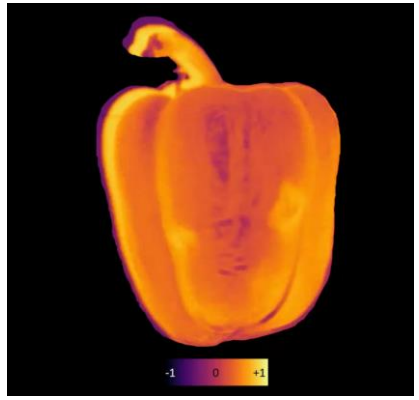


Thermography – dynamic and static.





Inexpensive NDVI imaging device



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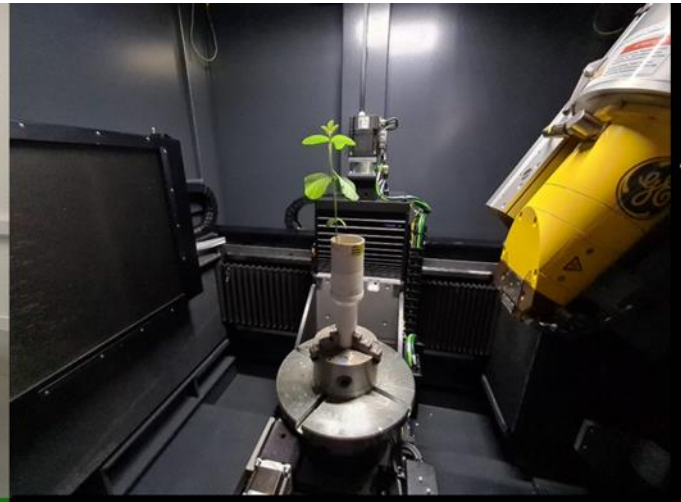
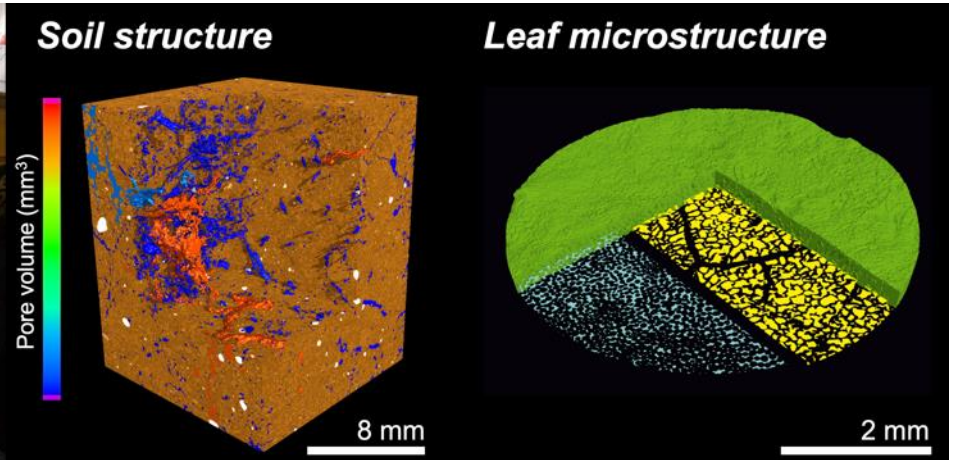
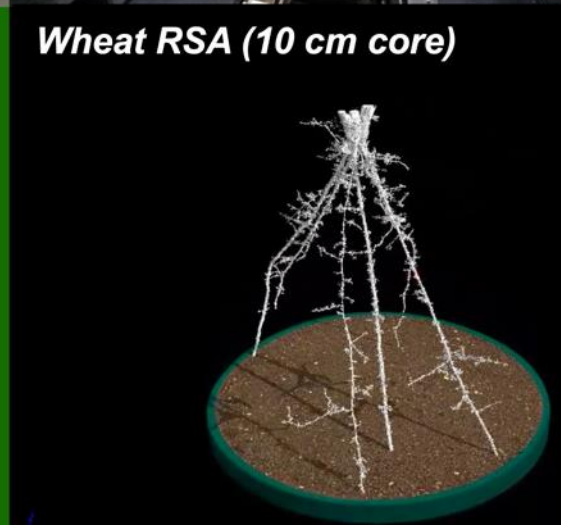
X-ray CT at the Hounsfield Facility

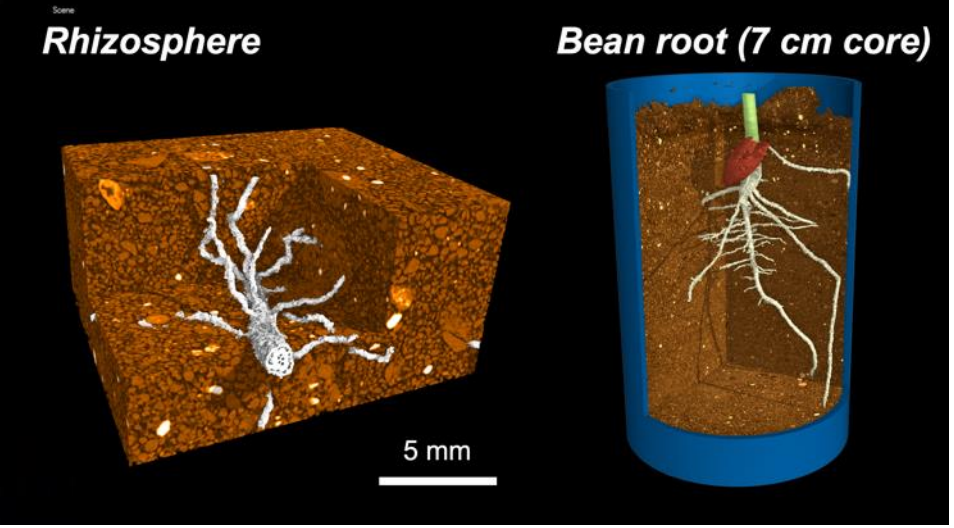




A non-invasive technique for visualizing & quantifying the interior of a solid object in 3D

www.nottingham.ac.uk/microct/





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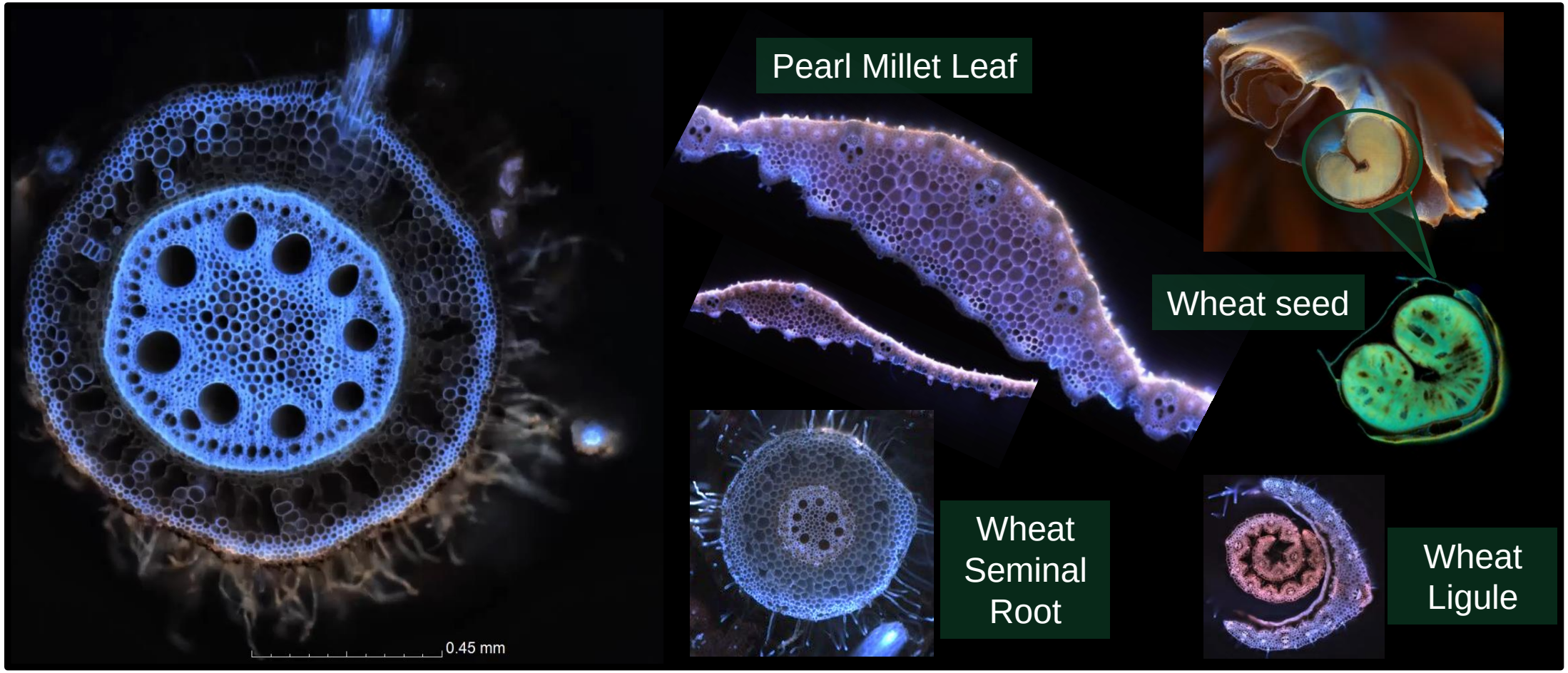
Laser Ablation Tomography

- **Destructive sampling for 2D and 3D anatomical traits**



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Laser Ablation Tomography

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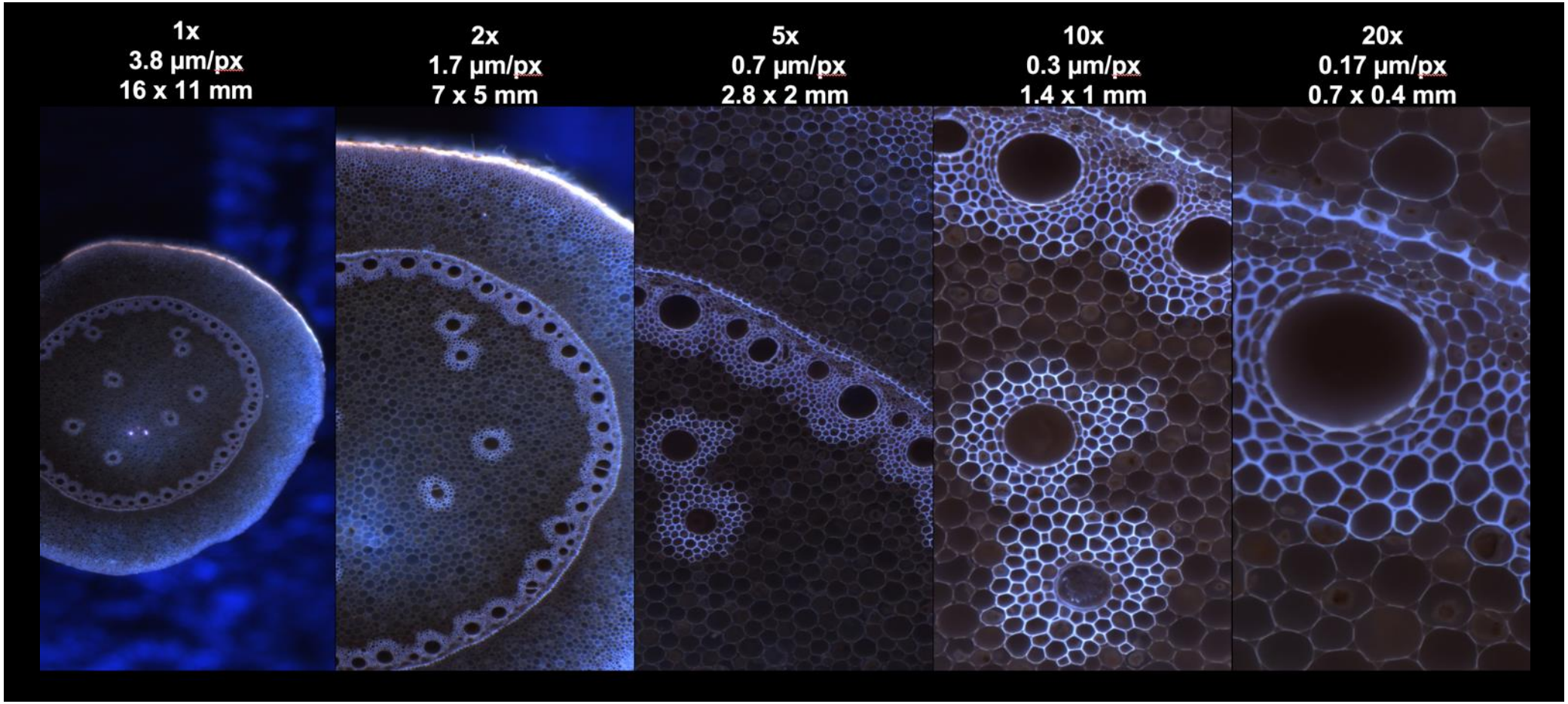

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2D RSAT seedling root architecture phenotyping

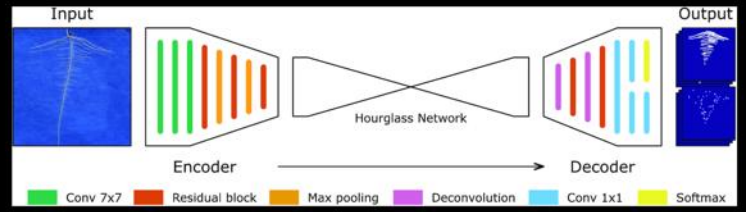
- 560 plants per experimental run, 10 days per experiment

Visitors & publications: Andras Cseh (EPPN2020), Passot et al (2016), De la Fuente et al (2023)

RootNav – user-assisted image analysis

Pound *et al.* (2013)

RootNav2 – automated



Yasrab *et al.* (2019)

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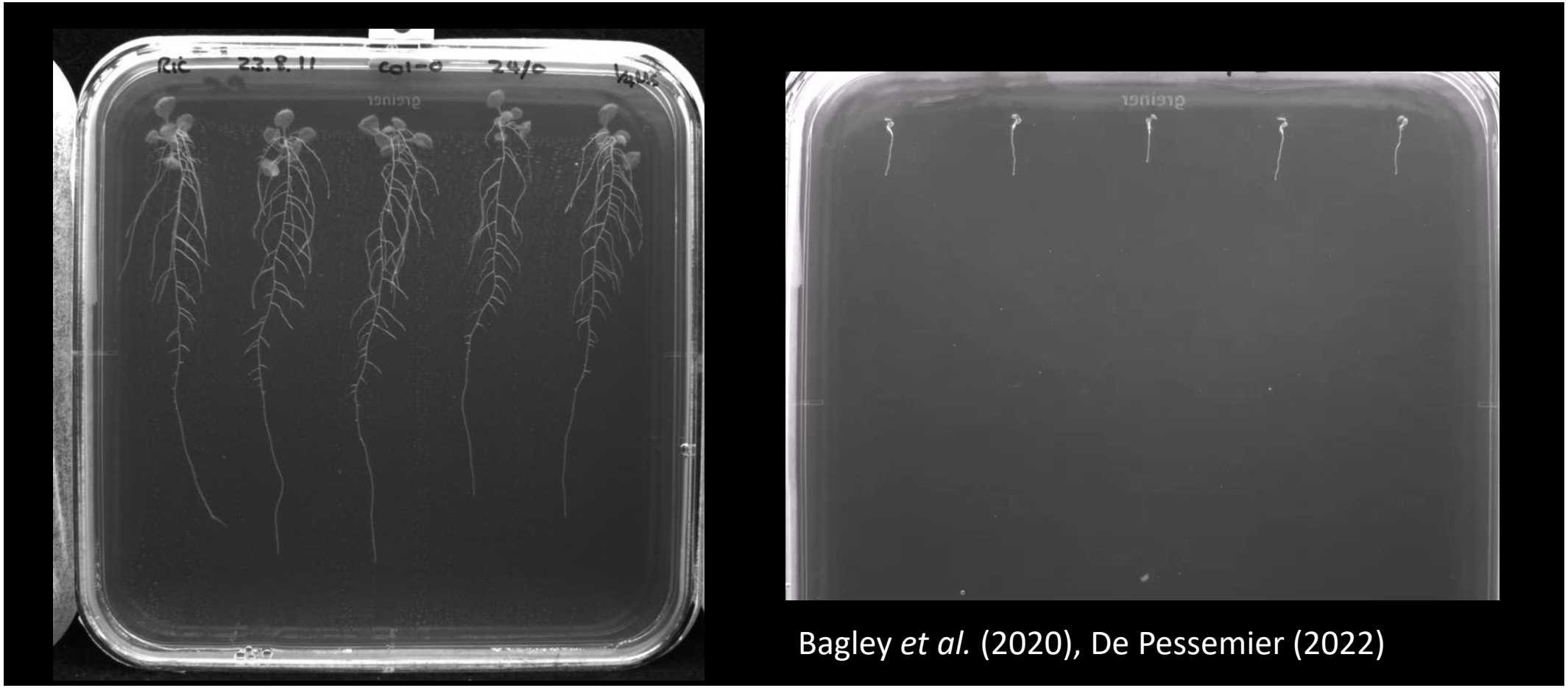
Automated plate imaging robots

- ***Arabidopsis*** **or other smaller species**



Bagley *et al.* (2020), De Pessemier (2022)

Samuel Taylor (s.taylor19@lancaster.ac.uk)

Opportunities

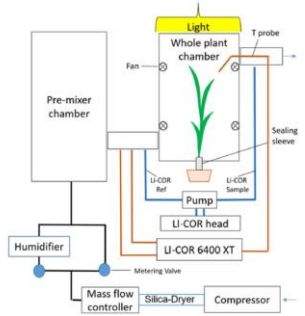
Method	Gas	PPFD	Temperature	Throughput	No. devices
Whole plant chamber	+ control	+ control	+ control	1 - 10s plants/day	1
Photosynthesis system	++ control	++ control	++ control	1 - 10s plants/day	~4 (portable)
Hand-held CF (field)	− control	− control	− control	10s - 100s plants/day	~4 (portable)
Imaging CF (lab)	+ control	+ control	+ control (custom)	10s - 100s plants/day	1 (static)
Drops platform	- control	- control	· control	100s plants continuous	1
Hormone analysis – ABA/ethylene					

Samuel Taylor (s.taylor19@lancaster.ac.uk)

Gas exchange

Field/Lab - LI-6800F

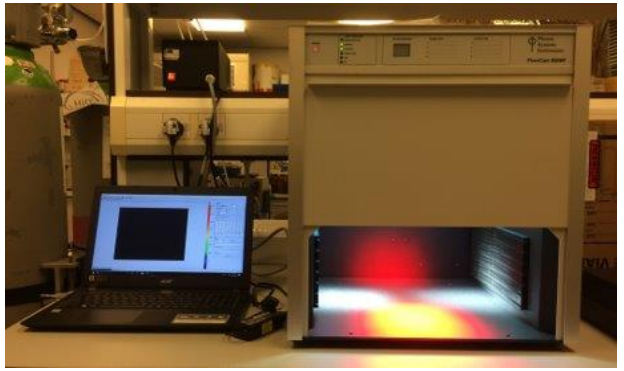
Lab – Whole plant chamber



PSII fluorescence

Field/Lab - MultispeQ

Lab – Closed Fluorcam



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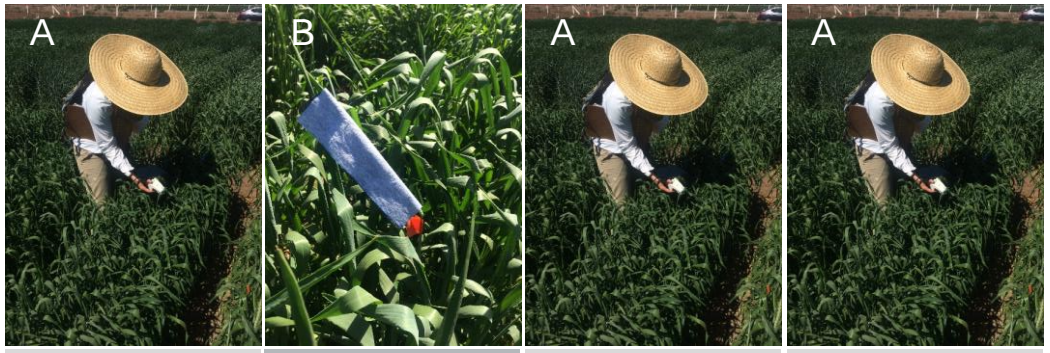
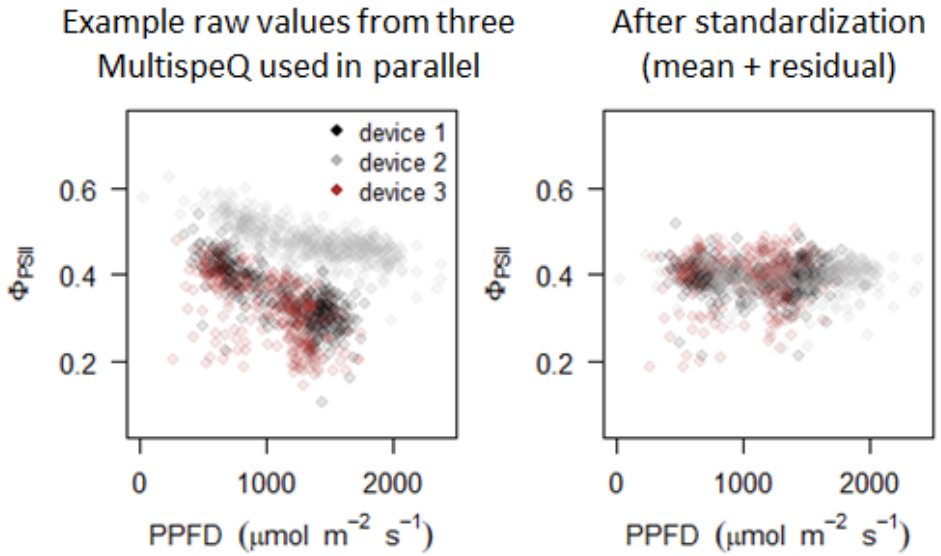
MultispeQ



Midday Φ_{PSII} reference	20 min	+ 2 min	+12 min
	Shade	Induction ($\Delta\Phi_{PSII}$)	

Induction phenotype: change in photochemical efficiency during 10 min after shade

$$\Delta\Phi_{PSII} = \Phi_{PSII,12} - \Phi_{PSII,2}$$



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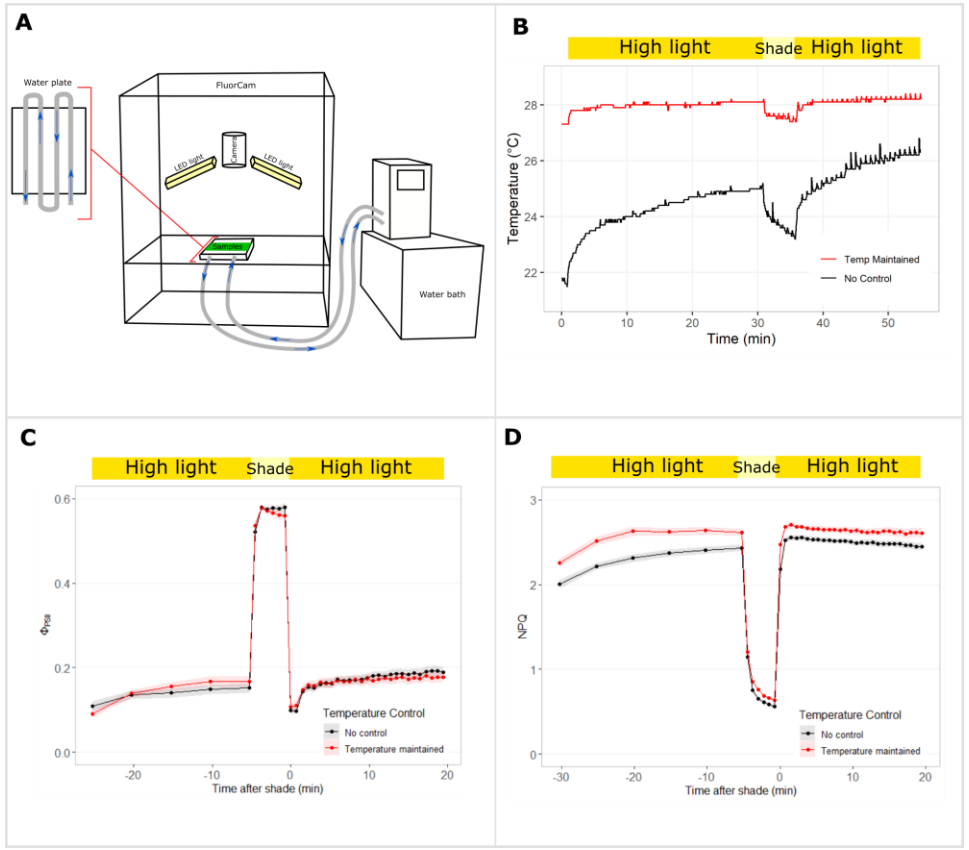
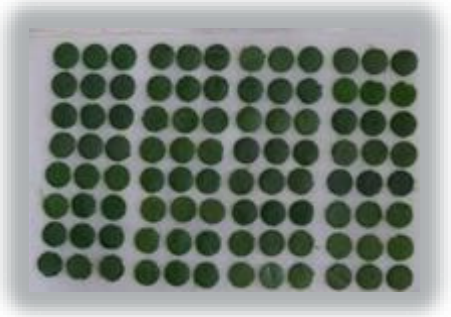
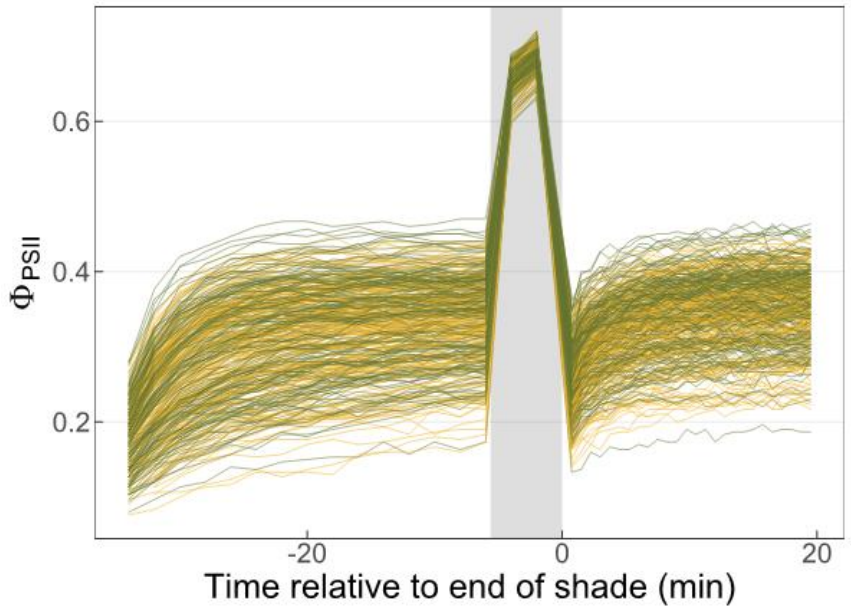
Closed fluorcam

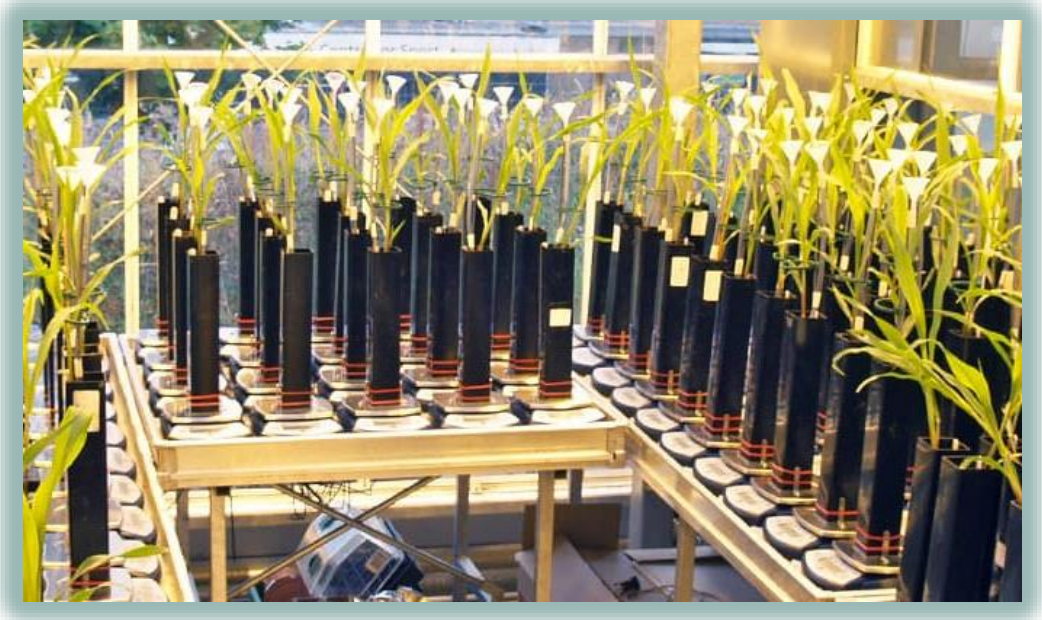




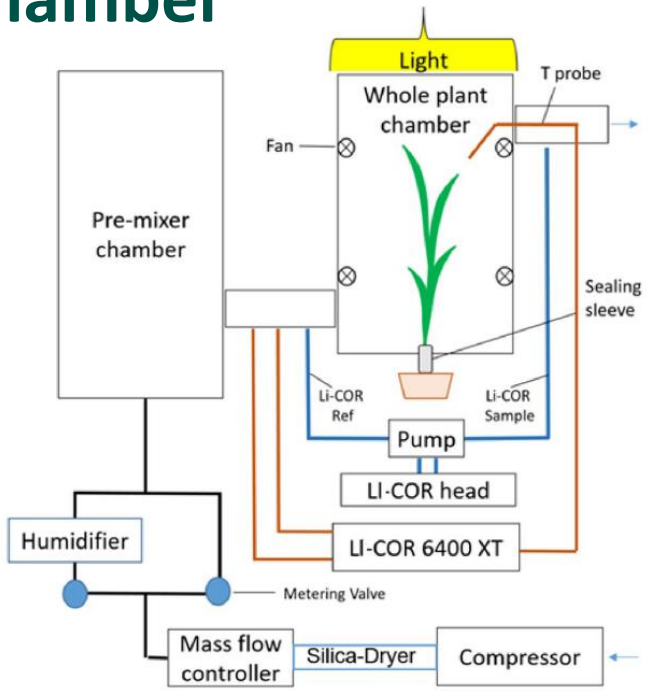


Samuel Taylor (s.taylor19@lancaster.ac.uk)

‘Drops’



‘Whole plant chamber’



NIAB AI and machine learning

Ji Zhou
Head of Data Sciences

Greg Deakin
Senior Statistician EMR

Felipe Pinheiro
AI Data Scientist

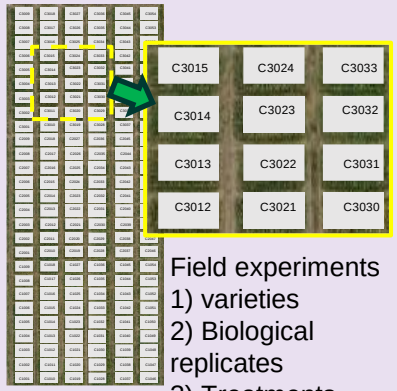
Arthur Mitchell
AI Data Scientist

Robert Jackson
Senior Data Scientist

Liyan Shen
Visiting PhD student

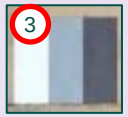
NIAB drone phenotyping pipeline

Wheat field layout



Field experiments
1) varieties
2) Biological replicates
3) Treatments

In-field setups



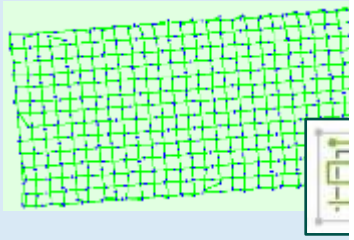
Calibration mats

GCPs

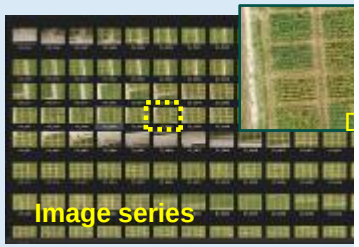
Height reference

In-field RTK station

Double-grid mission for automated aerial imag



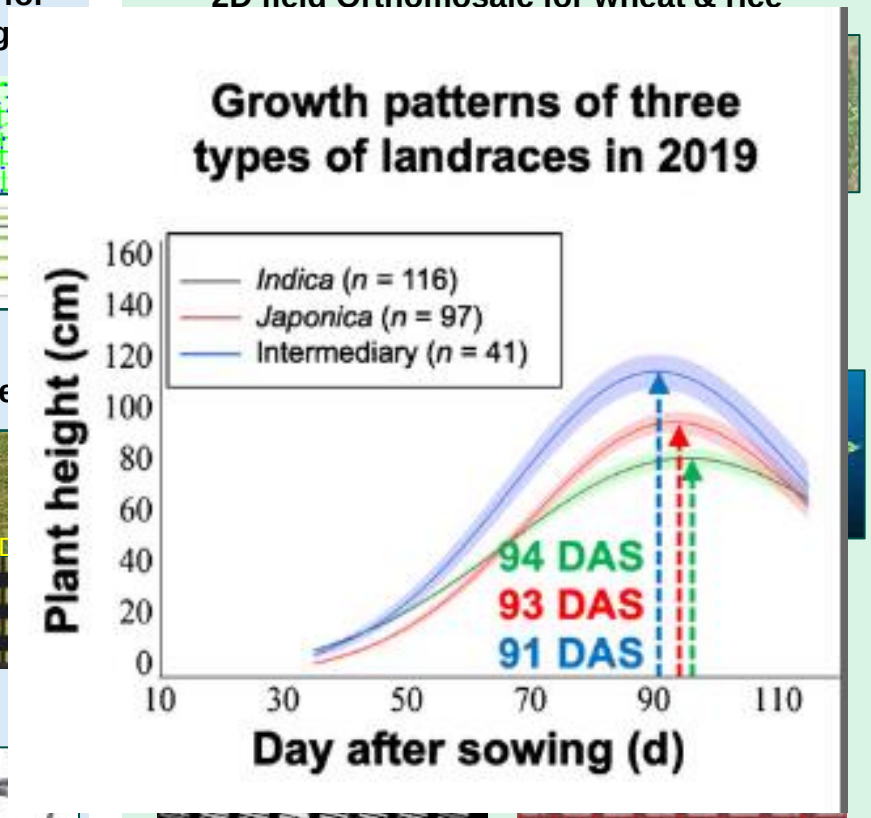
Acquired image serie



Multi-spectral UAV

Low-cost UAV

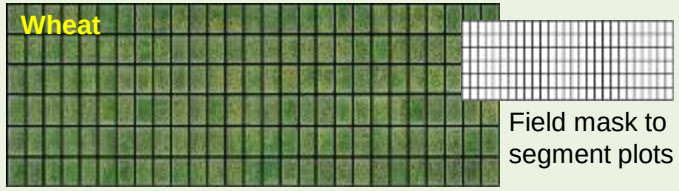
2D field Orthomosaic for wheat & rice



Canopy height model

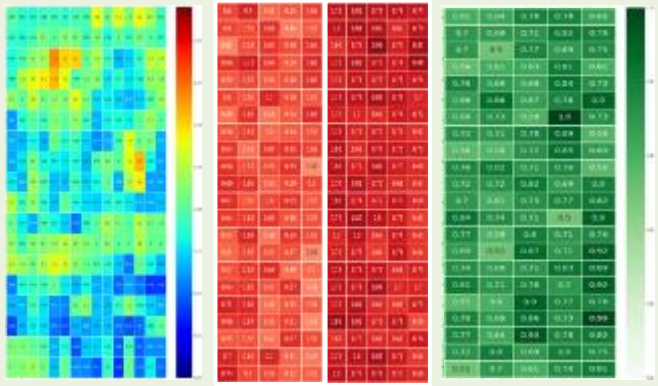
Plot segmentation

Plot segmentation with plot masks



AirMeasurer

Plot level traits measurement



Canopy height | Yield est. (NDYI) | Veg. greenness

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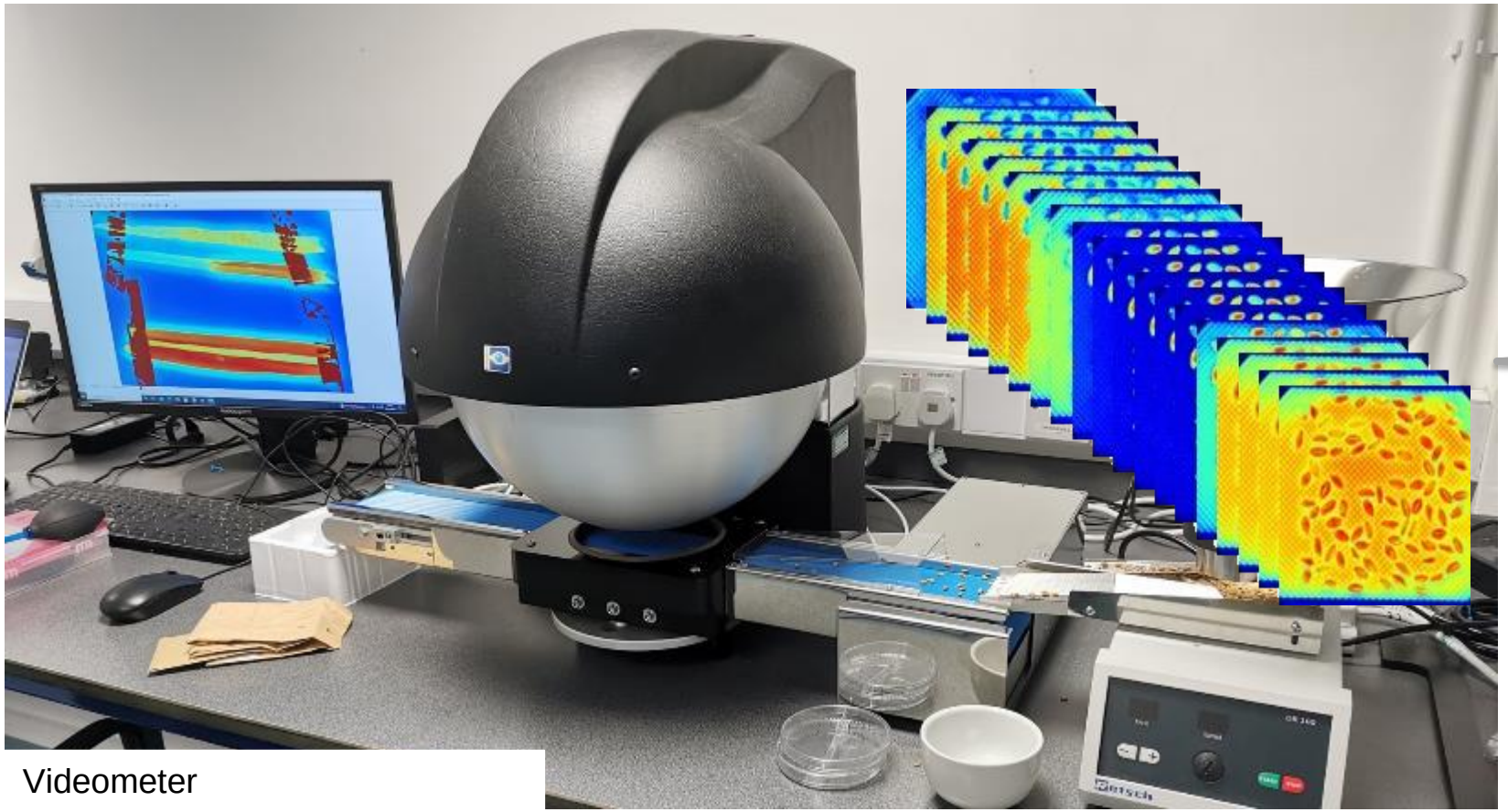
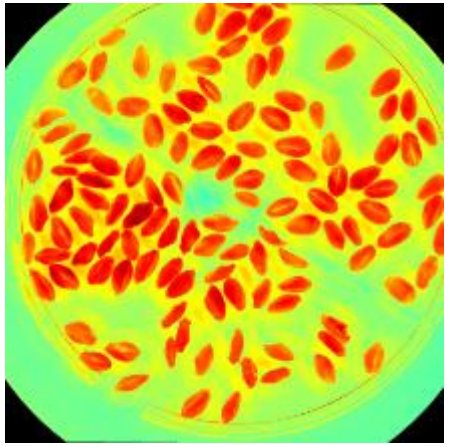
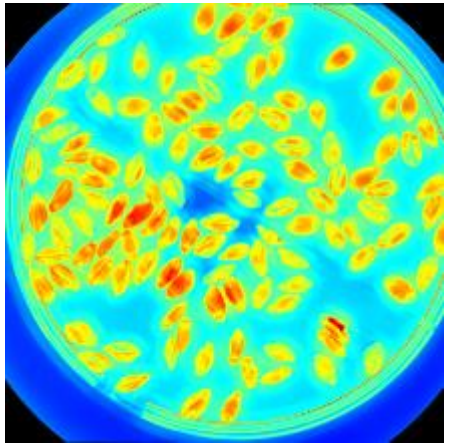
NIAB seed to seed



Videometer



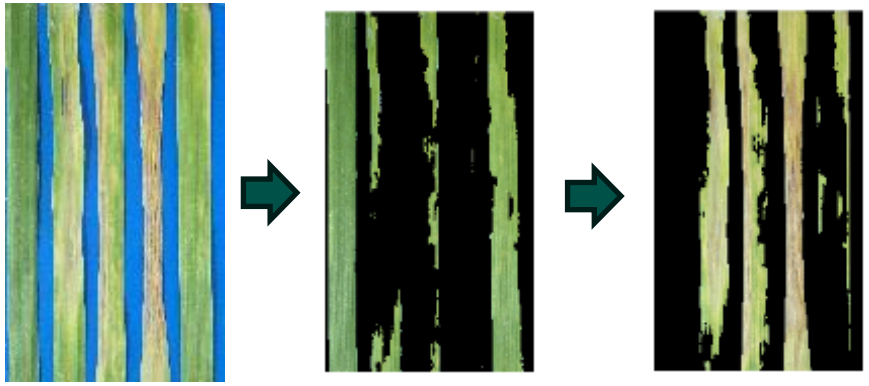
880 nm NIR



590 nm Amber

NIAB cell (organ) to county

Liyan Shen, Kostya Kanyuka, Anissa Blower



Felipe Pinheiro, Dan Sargent

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NIAB handheld trait detection