



PhotosynQ

Accelerate your crop advancements

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oQulus

An open space phenotyping platform

A phenotyping system for greenhouses or growth rooms which includes a custom sensor platform with multiple modes of imaging mounted on an XYZ gantry.

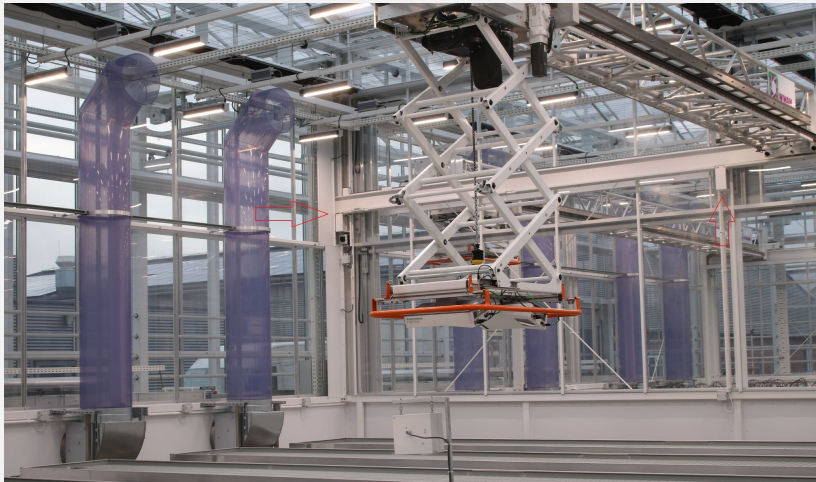
Modes of imaging include: Chlorophyll fluorescence, High resolution RGB imaging and 3D laser scanning



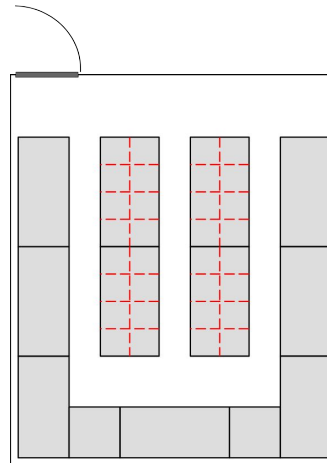
Gantry

Specifications

Computer-controlled
XYZ-gantry for positioning
sensor platform above plants



- Assumes plants or groups of plants in a fixed position
- Will cover the 2 central benches in the greenhouse space (each 168 inches long x 45 inches wide).
- Propose 16 fixed positions per bench in a 2 x 8 grid.

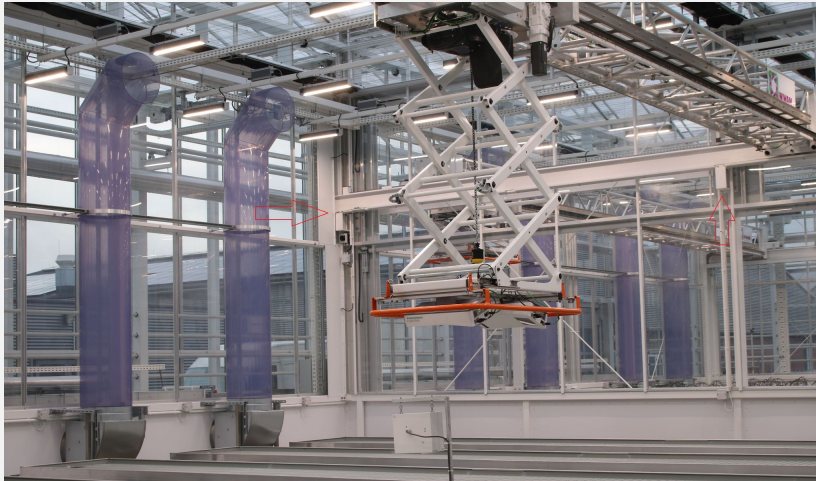


16 positions

Dimensions of each
section: 22.5" x 22"

Gantry

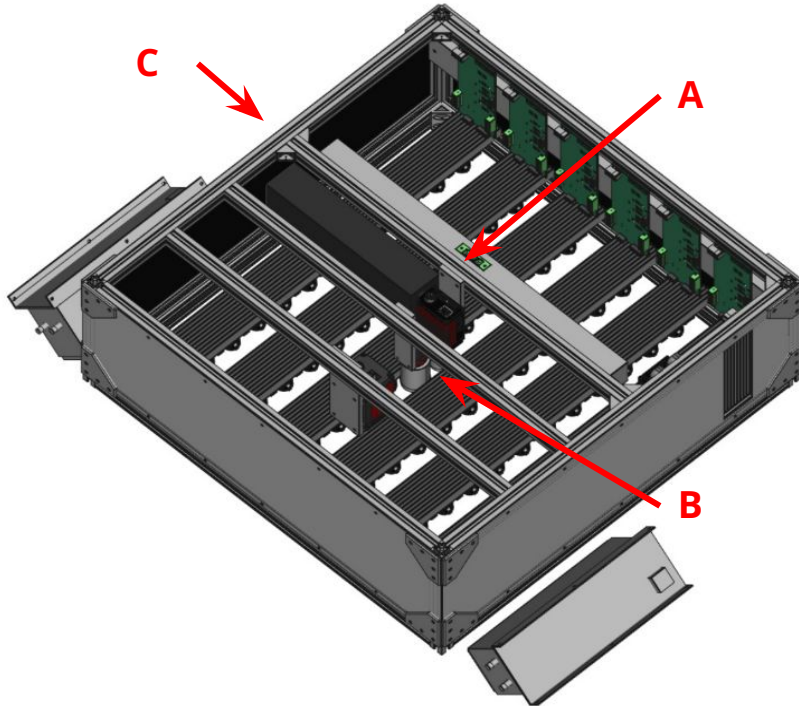
Specifications



- Four to Six support columns will need to be installed if the gantry trusses are not to be supported from the ceiling tied into existing structure (space?, floor strength?)
- User will need to move overhead lighting before starting experiment.
- Maximum plant growth height of 40 to 60 cm. May depend on imaging mode.

Sensor Platform

Layout



- Chlorophyll a Fluorescence (A)
- High resolution RGB (B)
- 3D Laser Scanning (C)
- Room for additional sensors

Chlorophyll a fluorescence

Specifications

Based on DEPI platform

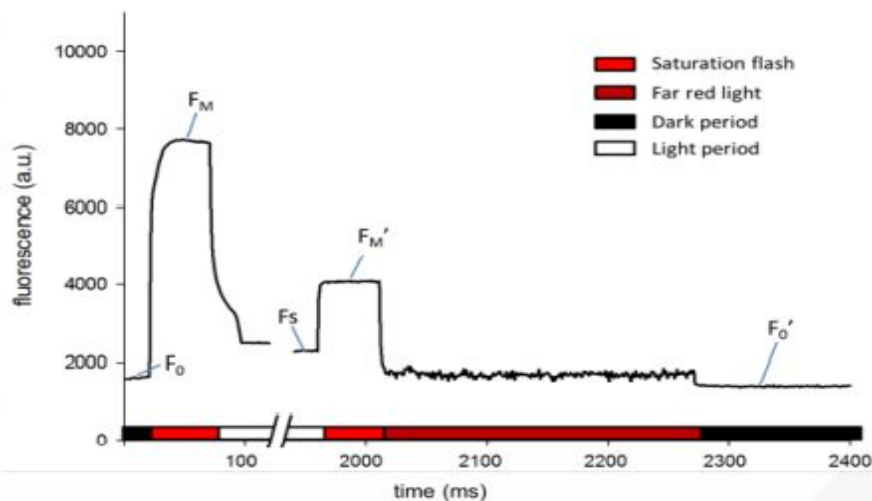


- Cool white LEDs with a color temperature of 5700K and a PAR of 2000 $\mu\text{mol photons m}^{-2}\text{s}^{-1}$
- Maximum steady state actinic intensity >2,000 $\mu\text{mol photons m}^{-2}\text{s}^{-1}$
- Saturating light intensity 10,000 to 12,000 $\mu\text{mol photons m}^{-2}\text{s}^{-1}$
- Even light distribution across the plant growth area (>3% difference from center to edge)
- Rapid light intensity changes (within 1 ms or less)
- Far-red light supplied by 730 nm LEDs with an emission spectrum allowing oxidation of Q_A^- at 720 nm and phytochrome activation at 735 nm

Chlorophyll a fluorescence

Method

- A 50 μ sec excitation pulse provided by an array of red (635 nm) LEDs
- Images of chlorophyll a fluorescence (at >720 nm) for all plants in the imaging area are captured by a GigE 1.4 megapixel CCD camera.
- FOV (8mm lens) @ 60cm: 67.1cm x 50.2cm
- Captures chlorophyll a fluorescence parameters F_0 , F_M , F' , F_M' , F_0' and F_M'' from which standard photosynthetic parameters (F_V/F_M , ϕ_{II} , NPQ, q_E , q_I , NPQ_t, q_{Et} , q_{It}) are provided.



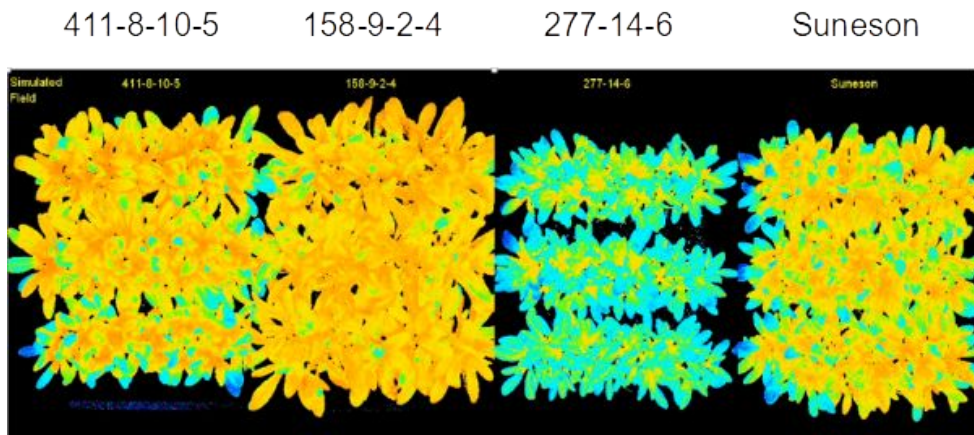
Chlorophyll a fluorescence

DEPI data

- Photosynthetic efficiency (F_V/F_M , ϕ_{II})
- Photoprotection (NPQ, q_E , q_I)
- Photosynthetic performance strongly tied to the health of the plant.



Cruz et al., 2016

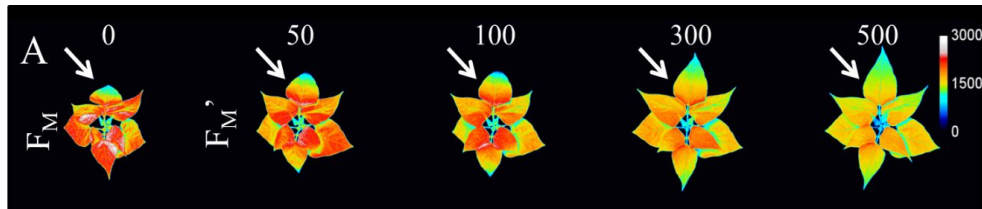


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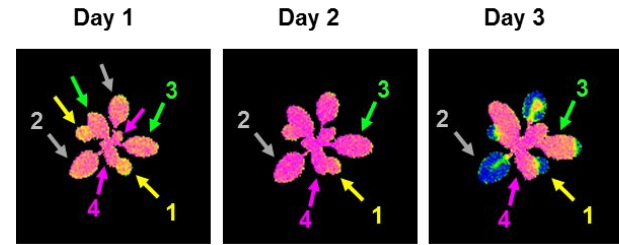
Chlorophyll a fluorescence

DEPI data

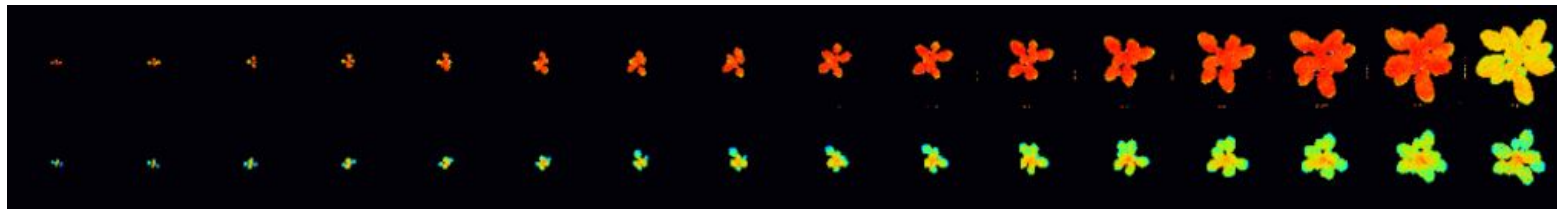
- Daytime movements
- Leaf response heterogeneity
- Growth



Tietz et al., 2017



Cruz et al., 2016



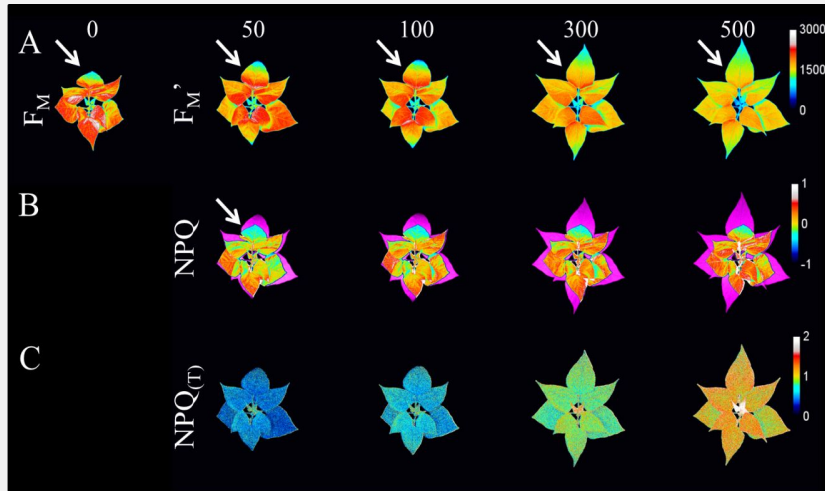
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Chlorophyll a fluorescence

Data



Tietz et al., 2017

Parameter	Description	Measurements
F_V/F_M	Maximum quantum yield	F0, FM
ϕ_{II}	Steady-state quantum yield	FS, FM'
NPQ	Total quenching	FM, FM'
q_E	Energy dependent quenching	FM, FM', FM''
q_I	Inhibitory (irreversible) quenching	FM, FM''
NPQ_t	Total quenching	FM', F0'
q_{Et}	Energy dependent quenching	FM', FM'', F0', F0''
q_{It}	Inhibitory (irreversible) quenching	FM'', F0''

Chlorophyll a fluorescence

Concerns

- Minimizing light leakage through benches
- Baffles, shields, & light absorbing surfaces can be used for this purpose

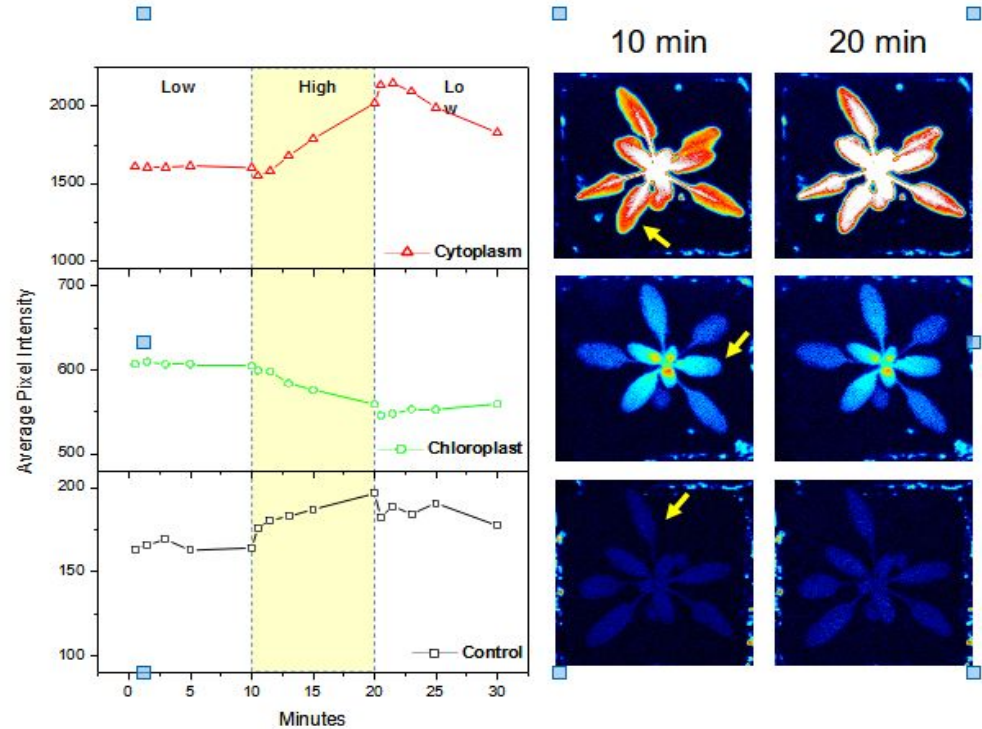
Controlling stray light to mimic the DEPI enclosed environment



DEPI variants

DEPI data

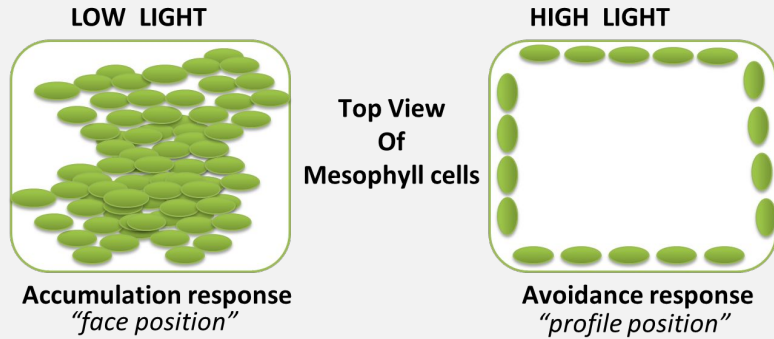
- R-Modified lighting system to detect GFP
- Matryoshka ATP biosensor



Unpublished

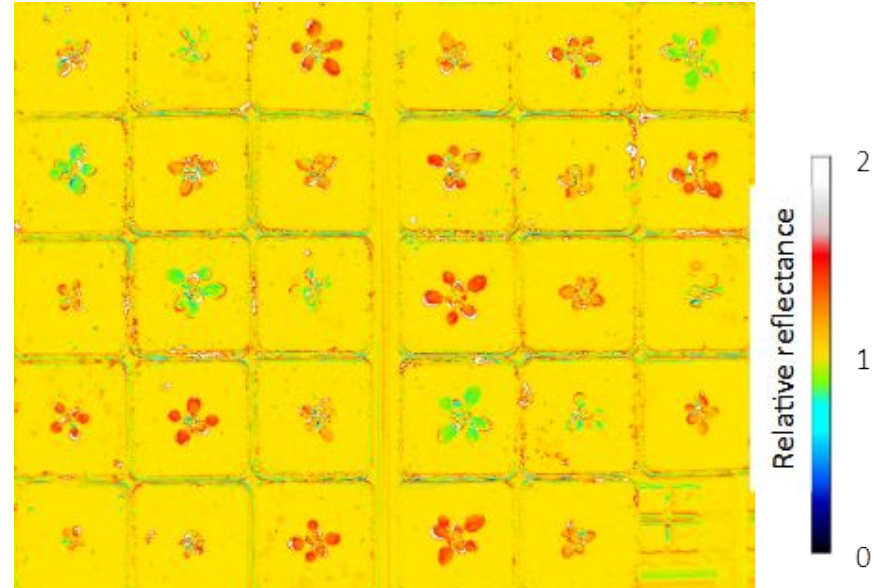
DEPI variants

DEPI data



Dutta et al., 2015

Red reflectance to track chloroplast movements



DEPI Literature

- Cruz et al., 2016. "Dynamic Environmental Photosynthetic Imaging Reveals Emergent Phenotypes." *Cell Systems* 2: 365–77. <https://doi.org/10.1016/j.cels.2016.06.001>.
- Dutta et al., 2015. "Non-Invasive, Whole-Plant Imaging of Chloroplast Movement and Chlorophyll Fluorescence Reveals Photosynthetic Phenotypes Independent of Chloroplast Photorelocation Defects in Chloroplast Division Mutants." *The Plant Journal* 84: 428–42. <https://doi.org/10.1111/tpj.13009>.
- Hoh et al., 2022. "Genetically-Determined Variations in Photosynthesis Indicate Roles for Specific Fatty Acid Species in Chilling Responses." *Plant, Cell & Environment* 45: 1682–97. <https://doi.org/10.1111/pce.14313>.
- Kanazawa et al., 2017. "Chloroplast ATP Synthase Modulation of the Thylakoid Proton Motive Force: Implications for Photosystem I and Photosystem II Photoprotection." *Frontiers in Plant Science* 8.
- Li, Jiyang et al., 2019. "Photometric Screens Identified Arabidopsis Peroxisome Proteins That Impact Photosynthesis under Dynamic Light Conditions." *The Plant Journal* 97: 460–74. <https://doi.org/10.1111/tpj.14134>.
- Major et al., 2020. "A Phytochrome B-Independent Pathway Restricts Growth at High Levels of Jasmonate Defense1 [OPEN]." *Plant Physiology* 183: 733–49. <https://doi.org/10.1104/pp.19.01335>.
- Oakley et al., 2017. "Genetic Basis of Photosynthetic Responses to Cold in Two Locally Adapted Populations of Arabidopsis Thaliana." *Journal of Experimental Botany* 69: 699–709. <https://doi.org/10.1093/jxb/erx437>.
- Tietz et al, 2017. "NPQ(T): A Chlorophyll Fluorescence Parameter for Rapid Estimation and Imaging of Non-Photochemical Quenching of Excitons in Photosystem-II-Associated Antenna Complexes." *Plant, Cell & Environment* 40: 1243–55. <https://doi.org/10.1111/pce.12924>.

High resolution RGB

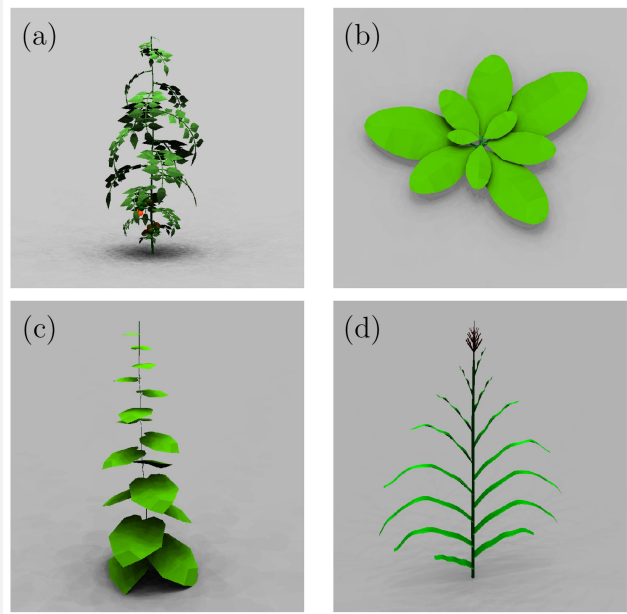
Specifications

- Light provided by a high power array of white LEDs
- Images captured using a gigE 20.4 megapixel color CMOS.
- 12-bit pixel depth
- FOV (12 mm lens) @ 60cm: 61.8cm x 61.8cm
- Other lens options available



3D scanner

Specifications

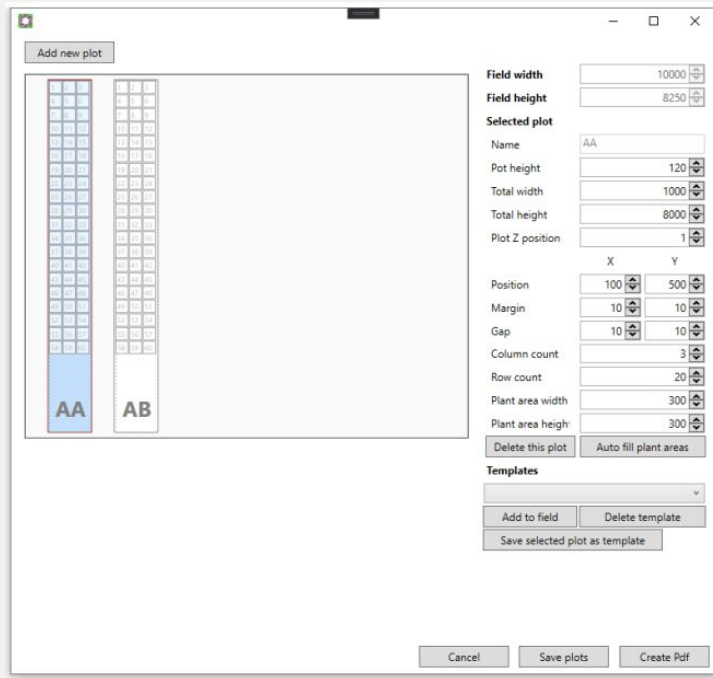


- Red laser line scanner
- Vertical range 800mm, clearance 350mm
- Vertical resolution: 0.092mm to 0.488mm
- Horizontal resolution: 0.375mm to 1.10mm
- FOV: 29cm to 126cm (~59.3cm @ 60 cm)
- Top mounted

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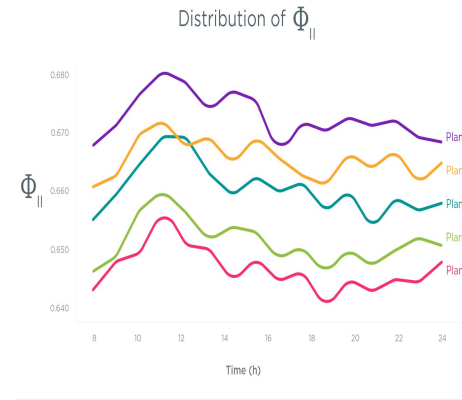
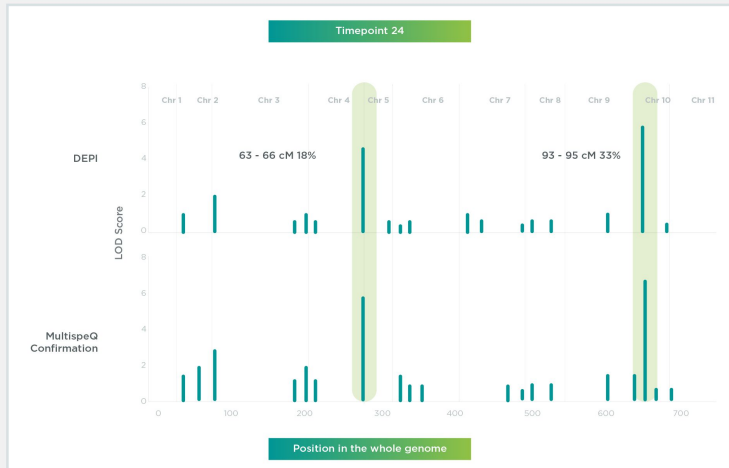
Control Software

Graphical user interface



- Allows flexible experimental design, mapping of plant positions, and scheduling experiment runs.
- Built in application programming interface (API) allows addition of other sensors if required
- Route experiment data to external storage
- Display the data using an API for data analysis

Data Collection and Visualisation



- Quantitative Trait Loci Mapping aided through Photosynthetic analysis
- Conceptualize the variability of parameters such as Φ_{II} over time and treatments and create statistic comparisons and charts

Hoh et al., 2022

Questions?