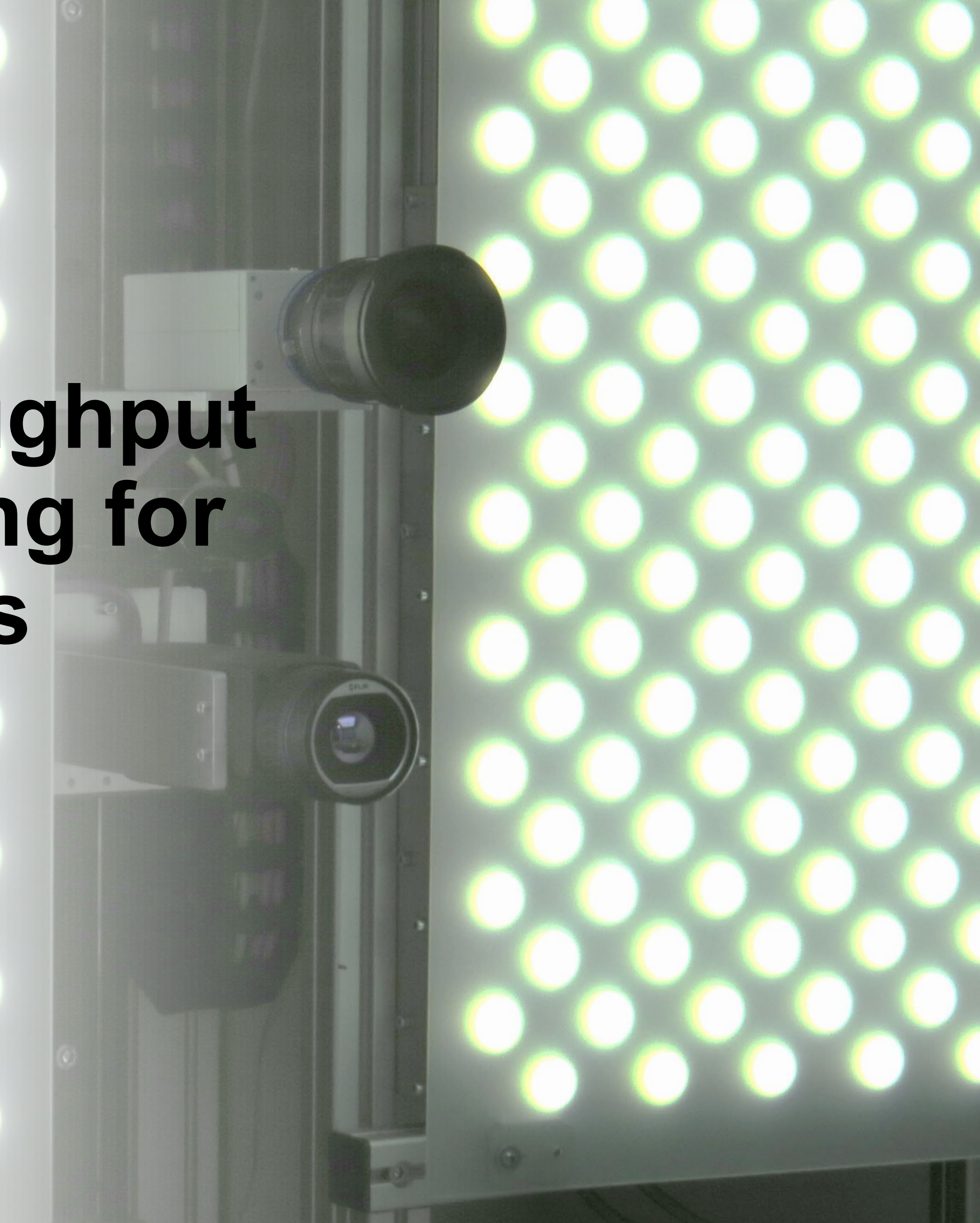


PHOTON SYSTEMS INSTRUMENTS

Application of high throughput technologies in screening for stress-tolerant crops

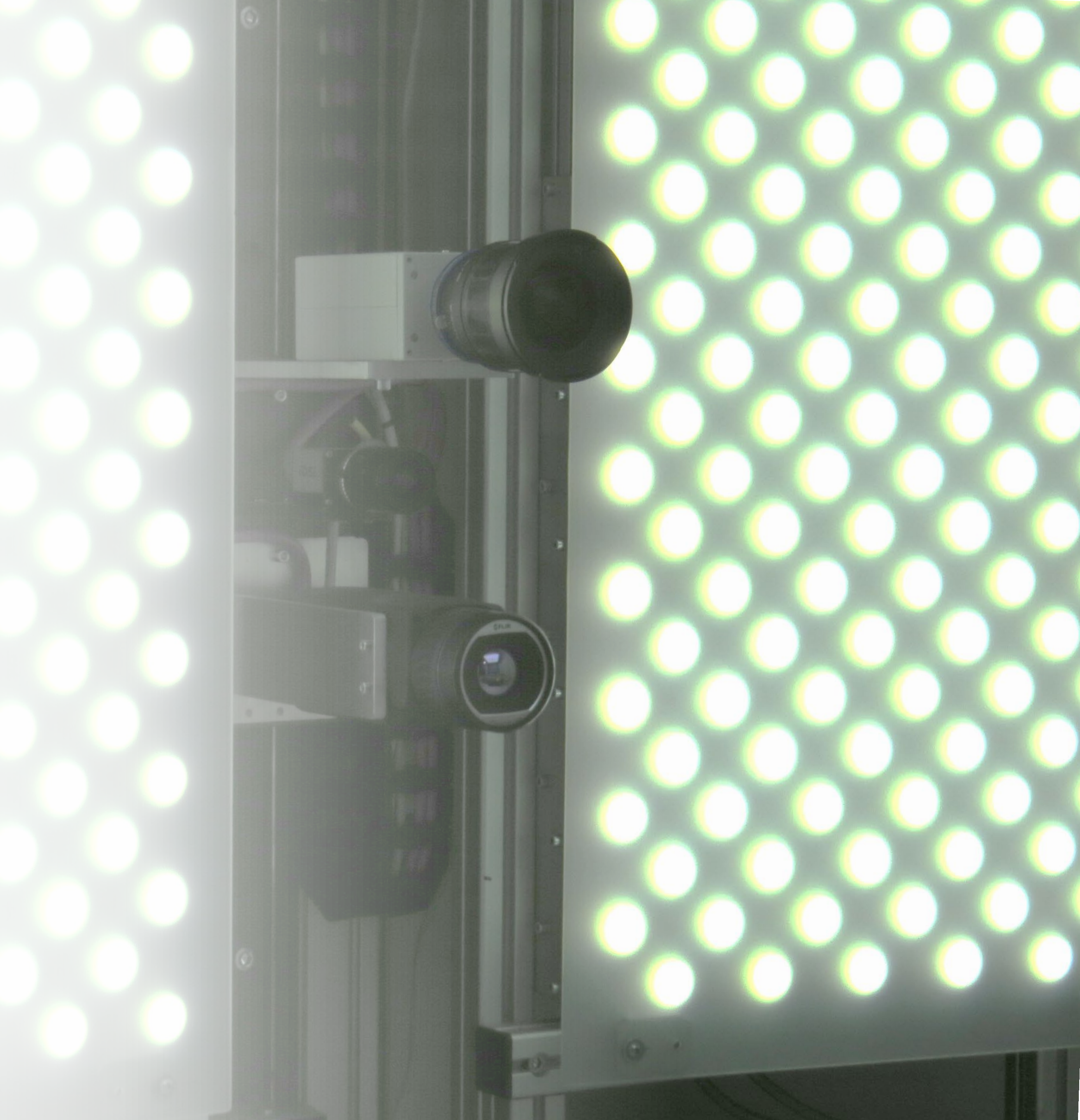
Lamis Abdelhakim

Postdoc researcher

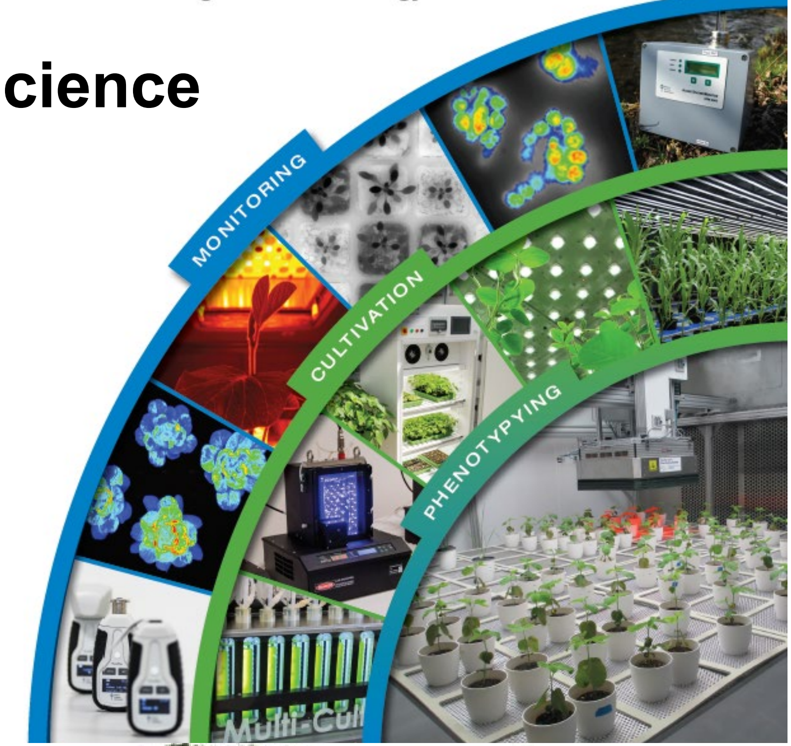
18th NSTDA Annual Conference 2023

Outline

- Overview
- PlantScreen™ systems
- PlantScreen™ imaging sensors
- Case studies in screening for stress-tolerant crops



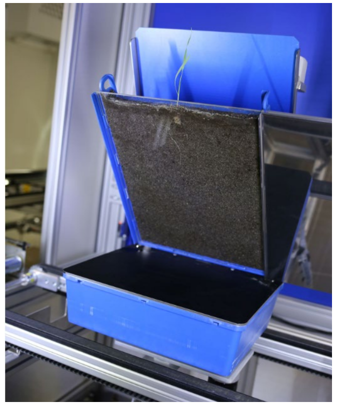
Professional Instruments for Plant Science and Algae Biotechnology



PSI headquarters and production site

Professional Instruments for Plant Science and Algae Biotechnology




Cultivation facilities & Indoor and outdoor phenotyping facilities

PSI Research Center

High-throughput Phenotyping

- **Non-invasive rapid** measurements
- Investigation of various plant **traits of interest over time**
- Through digital color images to determine plant **growth dynamics** and overall plant **performance**

PlantScreen™ systems

Professional Instruments for Plant Science and Algae Biotechnology

PlantScreen™ Robotic XYZ system

PlantScreen™ SC system

PlantScreen™ Compact system

PlantScreen™ Modular system

PlantScreen™ Root system

PlantScreen™ Field system

Multi-sensory platform towards the plants at defined intervals

Digital data are acquired from top view

Professional Instruments for Plant Science and Algae Biotechnology

PlantScreen™ Robotic XYZ system

PlantScreen™ SC system

PlantScreen™ Compact system

PlantScreen™ Modular system

PlantScreen™ Root system

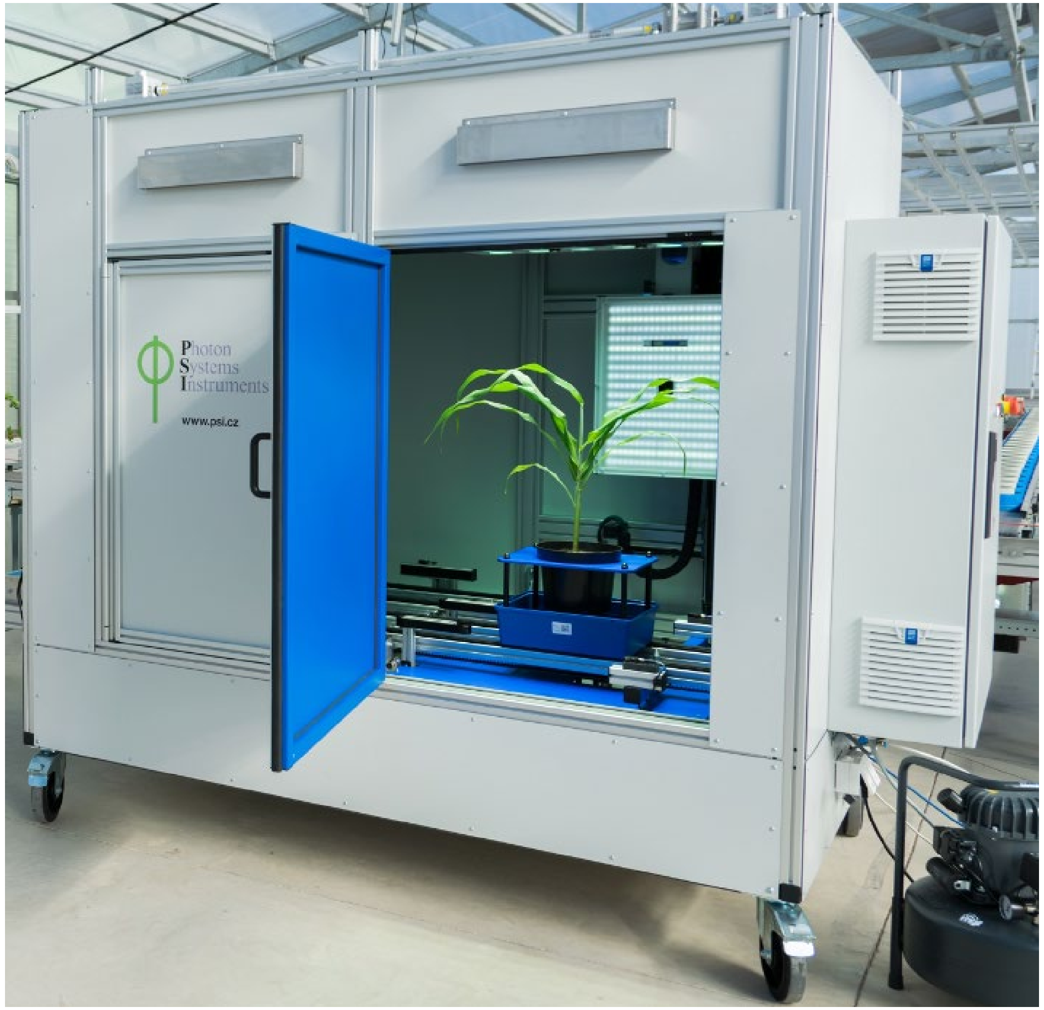
PlantScreen™ Field system

“PhenoCrane” (sensor-to-plant) high-throughput phenotyping systems

PHOTON SYSTEMS INSTRUMENTS

Professional Instruments for Plant Science and Algae Biotechnology

- PlantScreen™ Robotic XYZ system
- **PlantScreen™ SC system**
- PlantScreen™ Compact system
- PlantScreen™ Modular system
- PlantScreen™ Root system
- PlantScreen™ Field system



Compact design systems with different imaging sensors

Professional Instruments for Plant Science and Algae Biotechnology

PlantScreenTM Robotic XYZ system

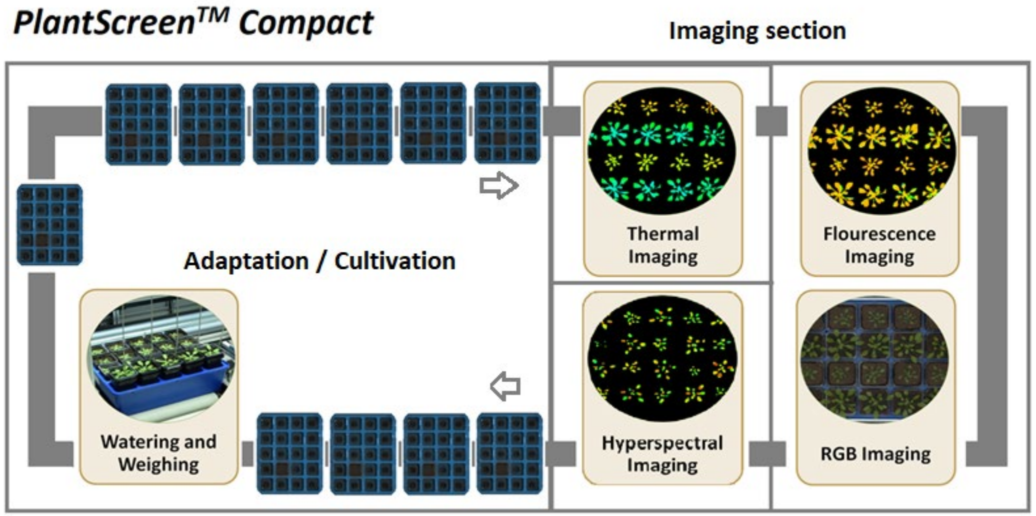
PlantScreenTM SC system

PlantScreenTM Compact system

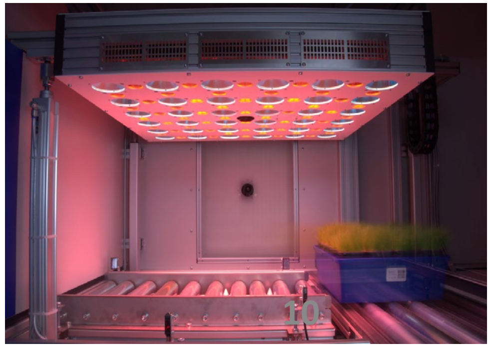
PlantScreenTM Modular system

PlantScreenTM Root system

PlantScreenTM Field system



Small and mid-size scale plants up to 40 cm in height



Professional Instruments for Plant Science and Algae Biotechnology

PlantScreen™ Robotic XYZ system

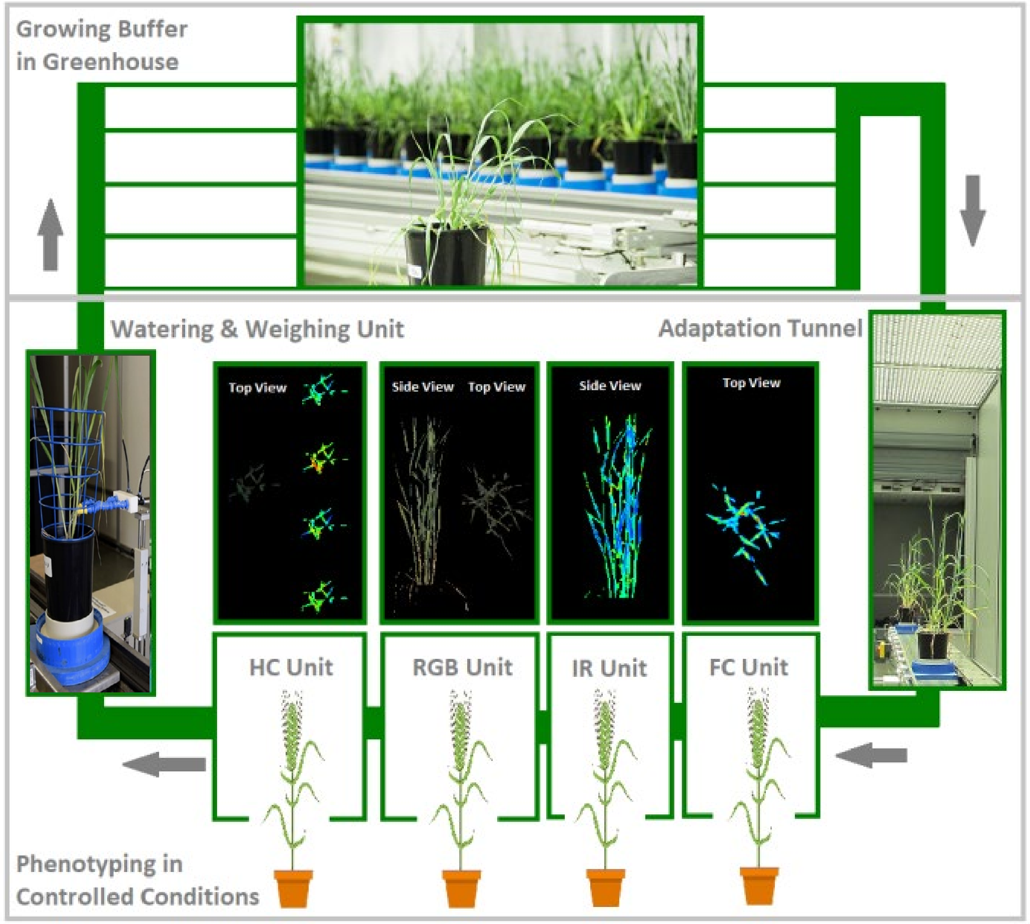
PlantScreen™ SC system

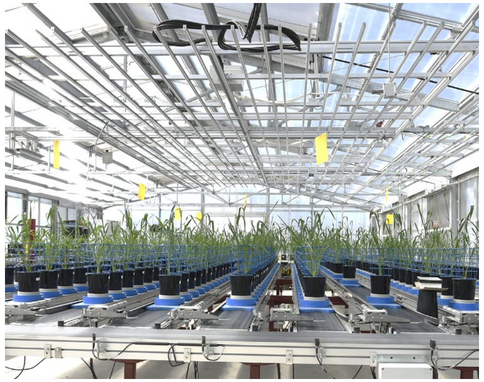
PlantScreen™ Compact system

PlantScreen™ Modular system

PlantScreen™ Root system

PlantScreen™ Field system





Larger scale plants up to 1.2 m

Monitor the entire life cycle

PHOTON SYSTEMS INSTRUMENTS

Professional Instruments for Plant Science and Algae Biotechnology

PlantScreen™ Robotic XYZ system

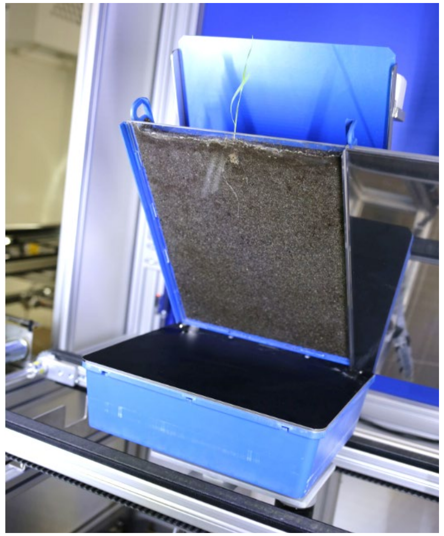
PlantScreen™ SC system

PlantScreen™ Compact system

PlantScreen™ Modular system

PlantScreen™ Root system

PlantScreen™ Field system



Scale plants up to 50 cm in height
in the rhizotron system

Professional Instruments for Plant Science and Algae Biotechnology

PlantScreen™ Robotic XYZ system

PlantScreen™ SC system

PlantScreen™ Compact system

PlantScreen™ Modular system

PlantScreen™ Root system

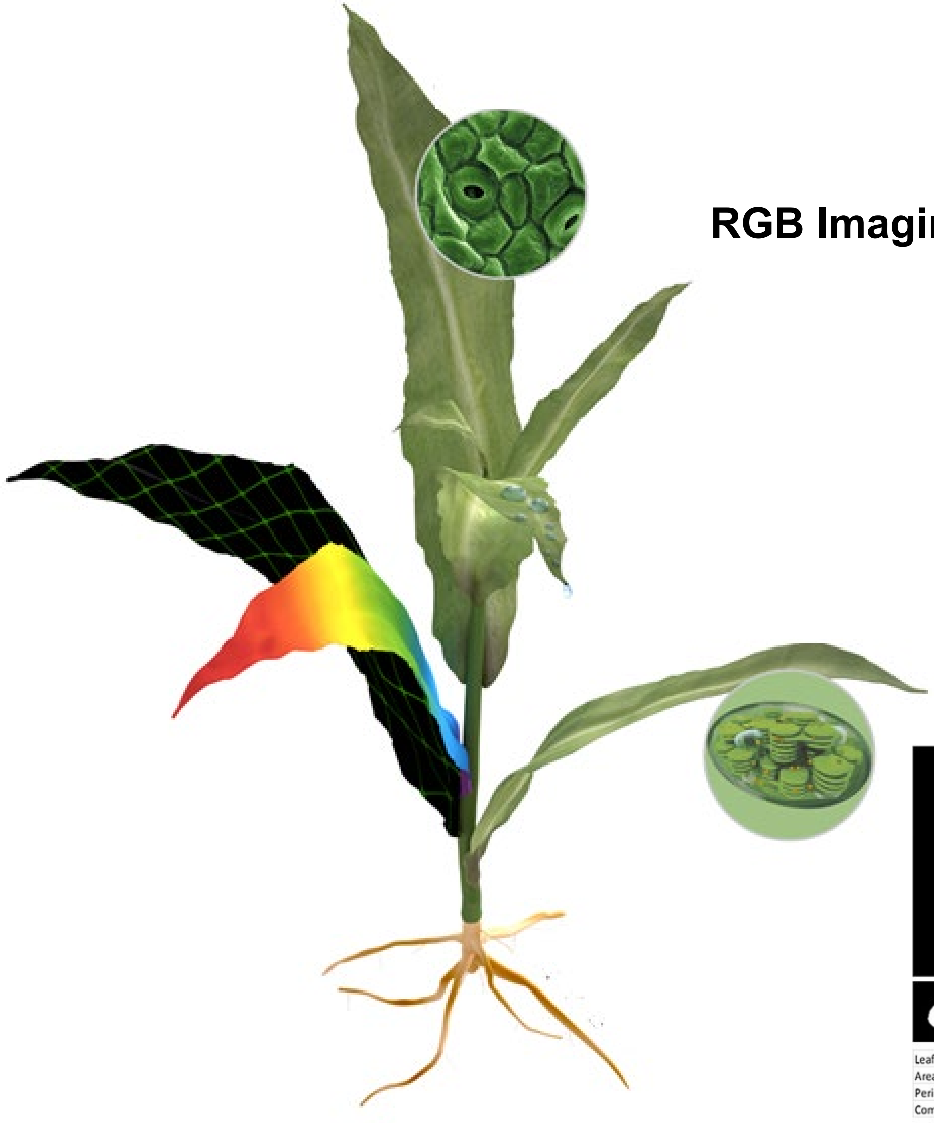
PlantScreen™ Field system

Autonomous, semi-autonomous and manual mobile platforms

PlantScreen^{TM} imaging sensors

PlantScreen^{TM} imaging sensors

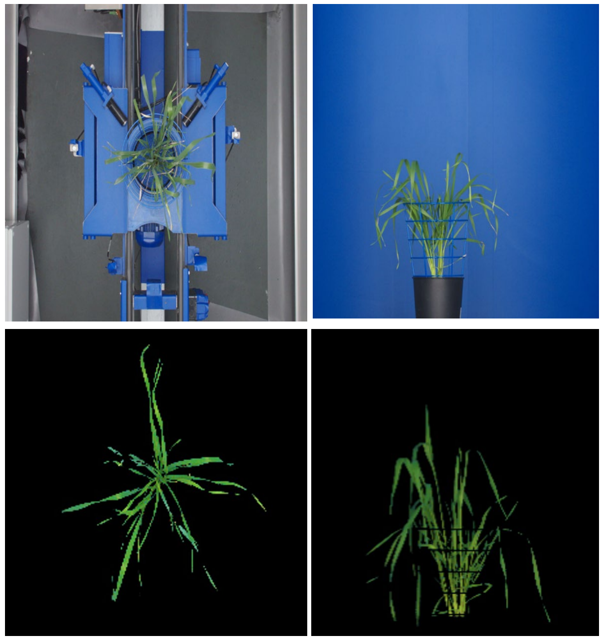
Morphological and Developmental Analysis

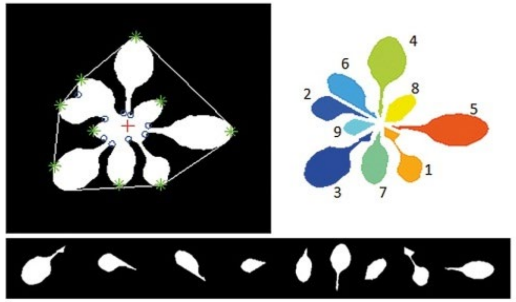


RGB Imaging

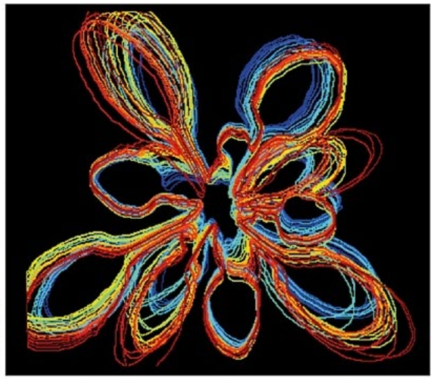
Top view

Side view





Leaf	1	2	3	4	5	6	7	8	9
Area(px)	1511,00	684,00	890,00	295,00	885,00	1478,00	539,00	694,00	1699,00
Perimeter	202,89	134,95	150,27	73,01	134,23	205,92	95,50	164,27	215,10
Compactness	0,79	0,81	0,90	0,94	0,92	0,77	0,95	0,61	0,84



Analyzed parameters

TOP VIEW

- Area [pixel count/mm^2]
- Perimeter [pixel count/mm]
- Roundness
- Compactness
- Eccentricity
- Rotational Mass Symmetry
- Slenderness of leaves
- Color index
- Leaf tracking and leaf analysis

SIDE VIEW

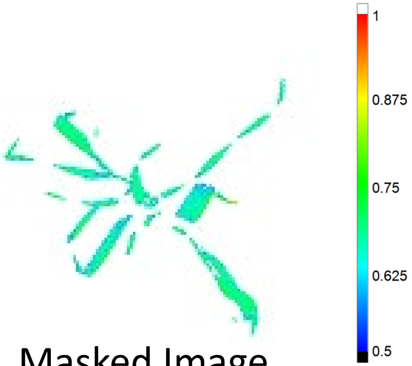
- Growth height [pixel count/mm]
- Growth width [pixel count/mm]
- Area [pixel count/mm^2]
- Perimeter [pixel count/mm]
- Compactness
- Number of leaves
- Leaf movement

COMBINED TOP & SIDE VIEW

- Biomass assessment
- Leaf movement
- Relative growth rate

PlantScreen^{TM} imaging sensors

Photosynthetic performance

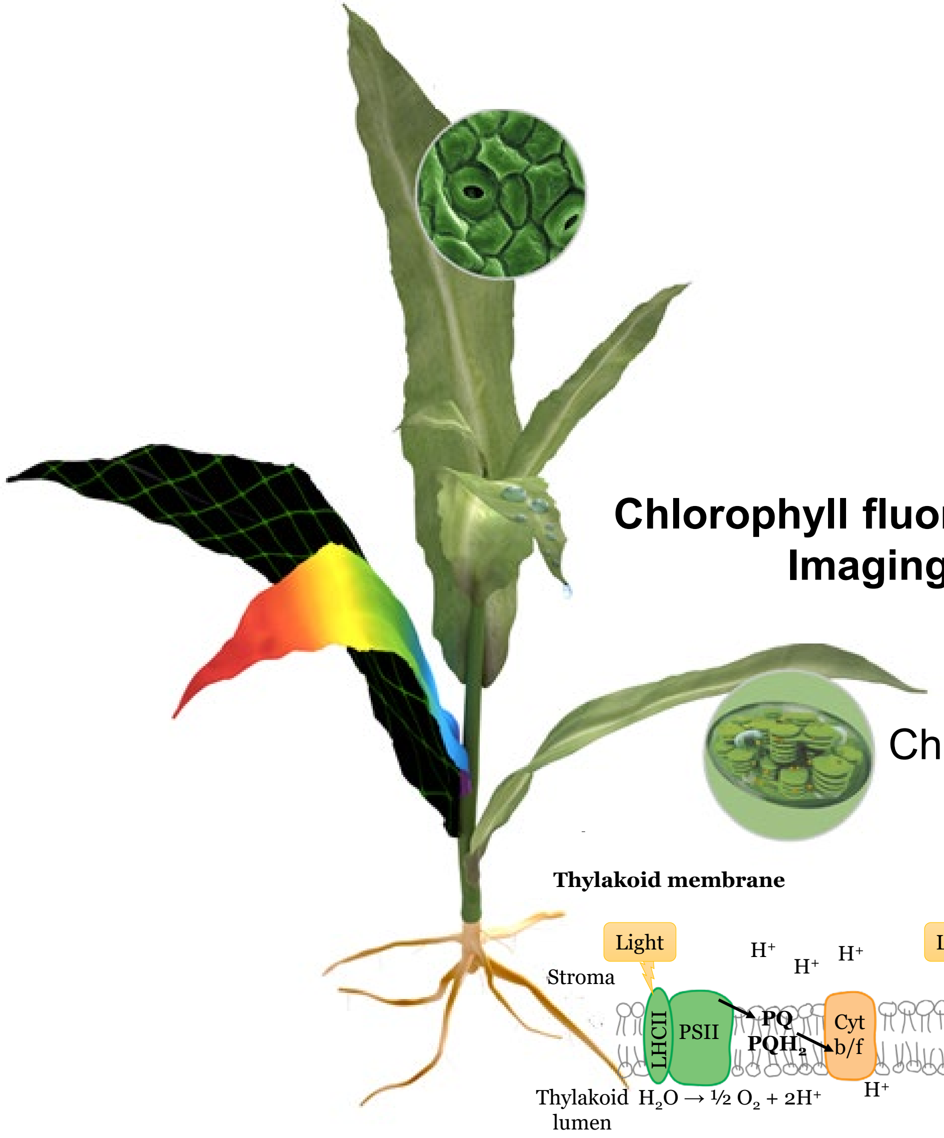


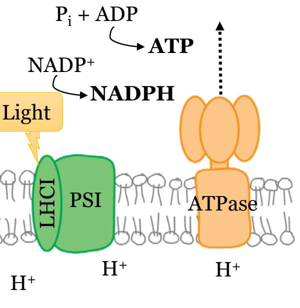
Masked Image

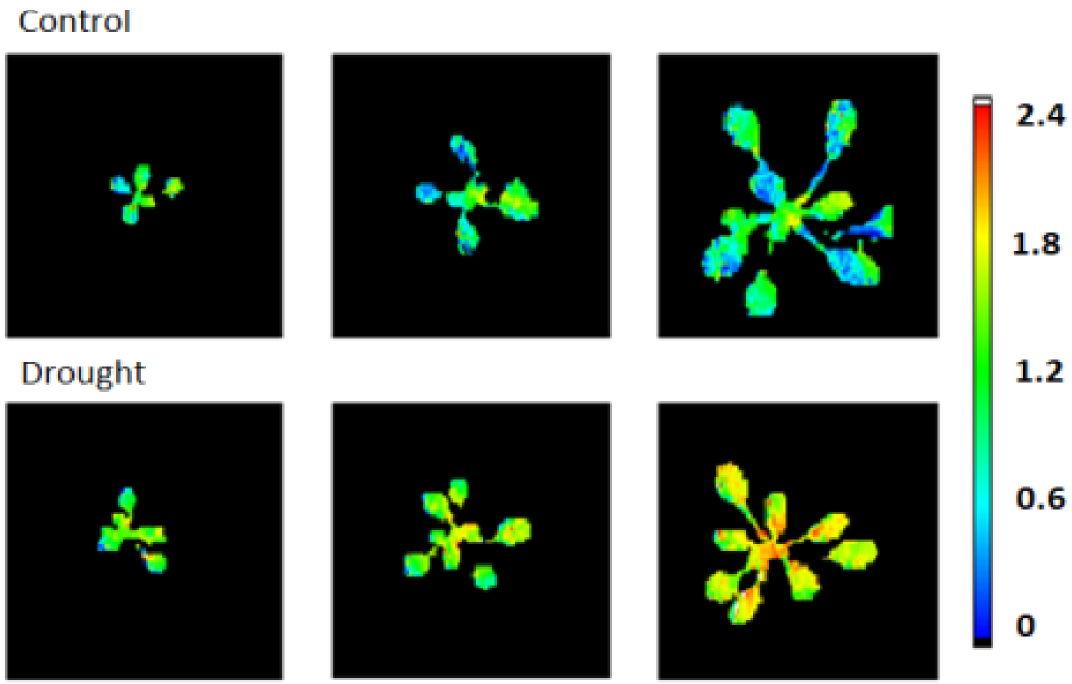
Analyzed parameters

- Measured parameters
  FO, FM, FV, FO´, FM´, FV´, FT
- Calculated parameters
  FV/FM, FV´/FM´, ΦPSII, **NPQ**, qN, qP, Rfd, ETR

Chlorophyll fluorescence Imaging



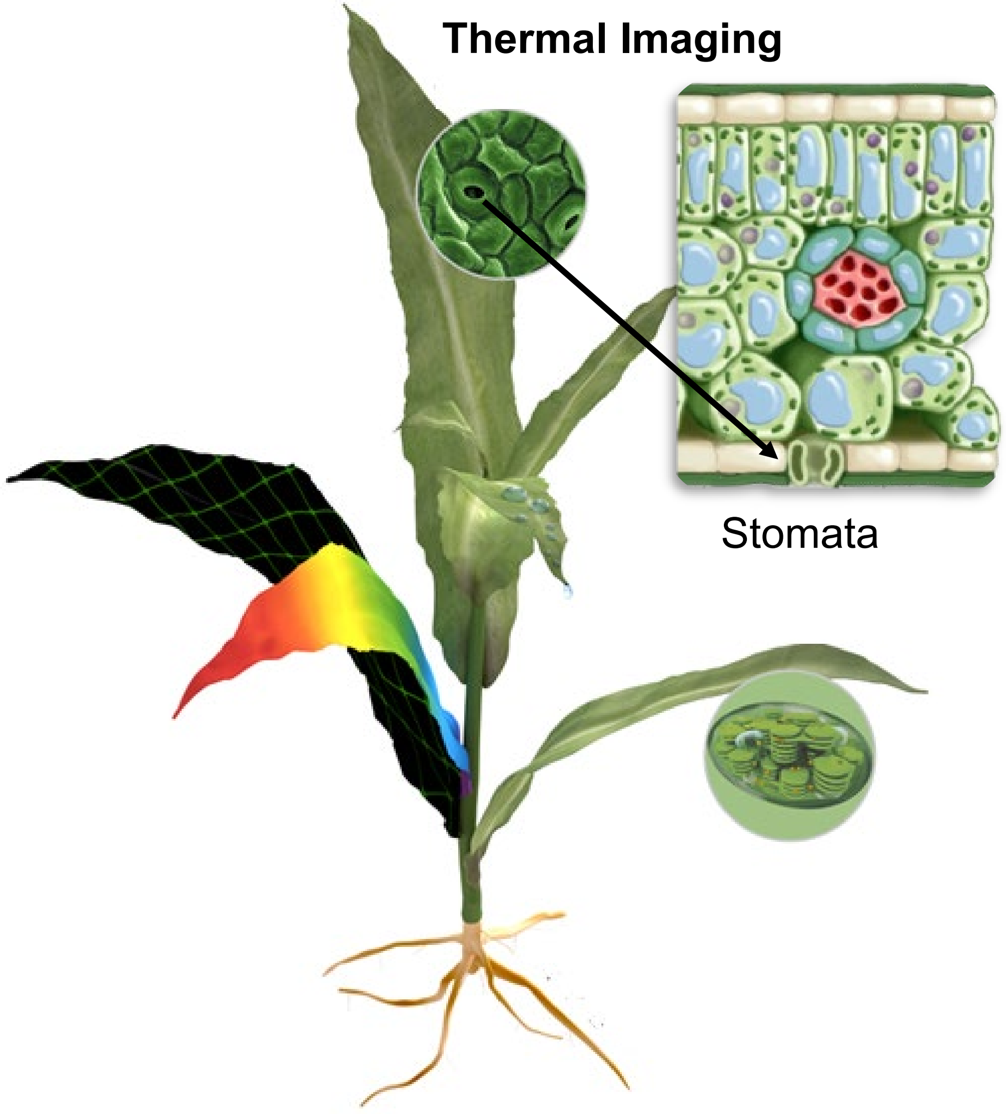


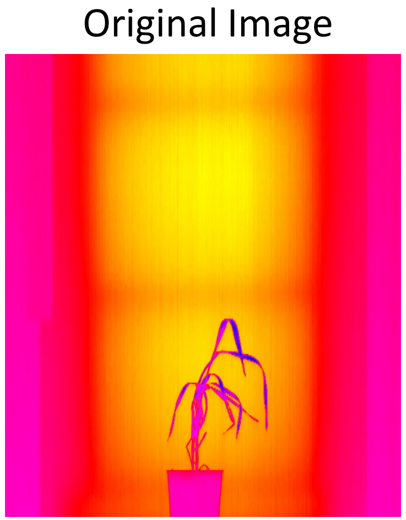


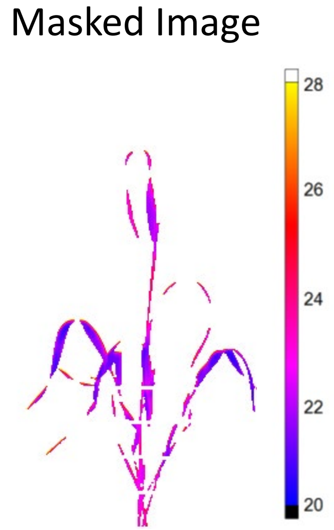
1st day of phenotyping | 5th day of phenotyping | 12th day of phenotyping

PlantScreen™ imaging sensors

Regulation of stomatal aperture

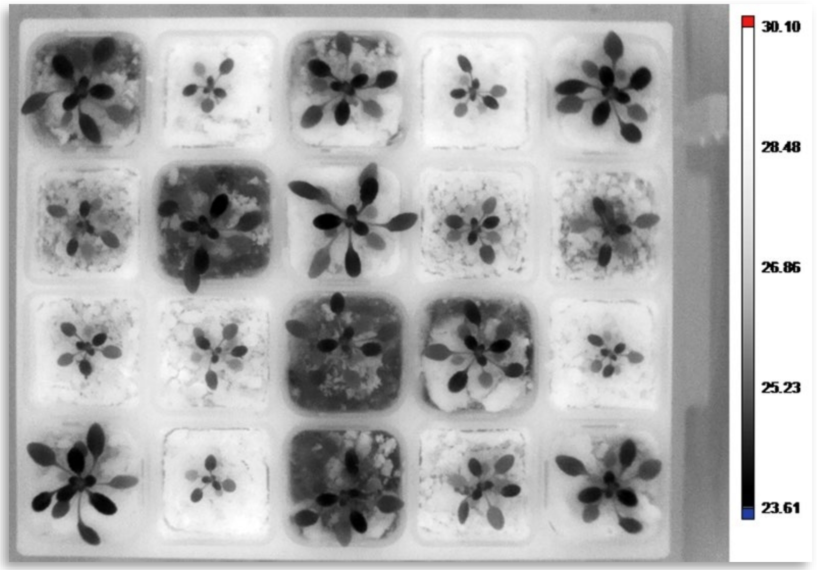






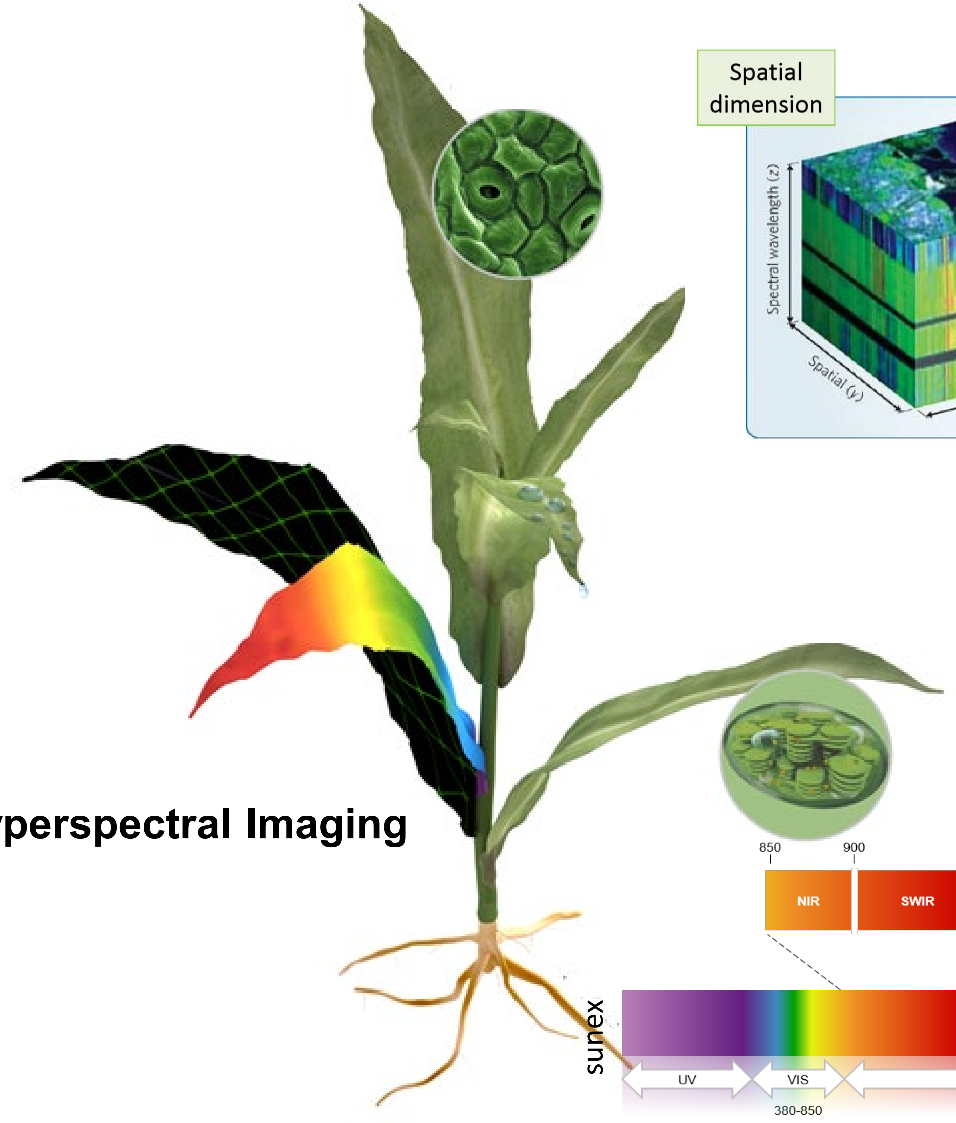
Analyzed parameters

- Leaf temperature
- Canopy temperature

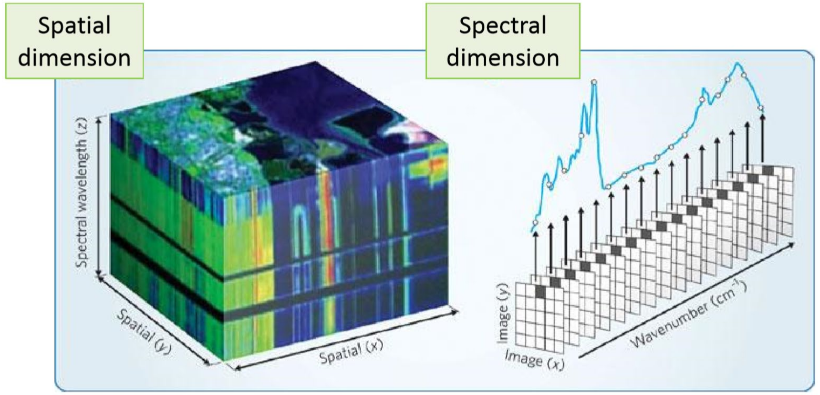


PlantScreen™ imaging sensors

Reflective indices, pigments, leaf water content



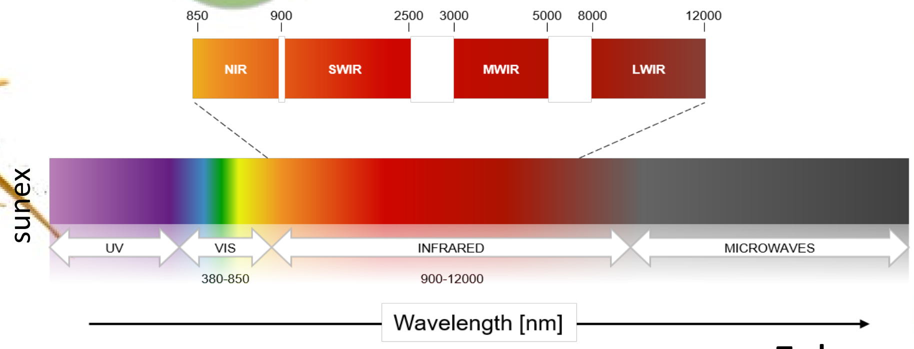
Hyperspectral Imaging

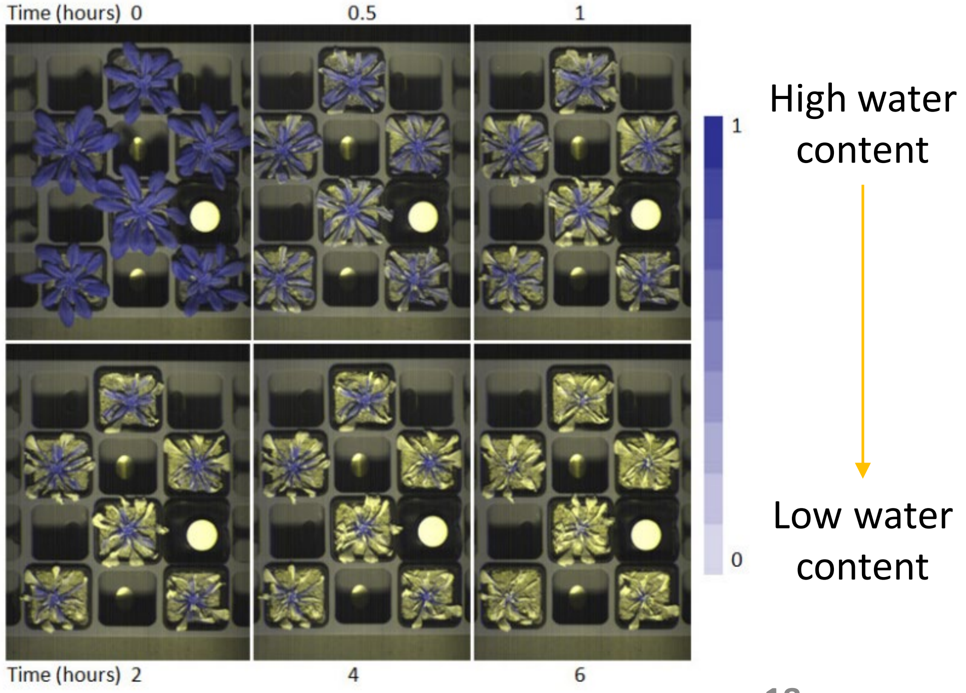


Modified from Nature Photonics 3, 627 - 629 (2009)

Analyzed parameters

- Normalized Difference Vegetation Index (NDVI)
- Photochemical Reflectance Index (PRI)
- Optimized Soil-Adjusted Vegetation Index (OSAVI)
- Modified Chlorophyll Absorption in Reflectance Index (MCARI1)
- Nitrogen status
- Water content



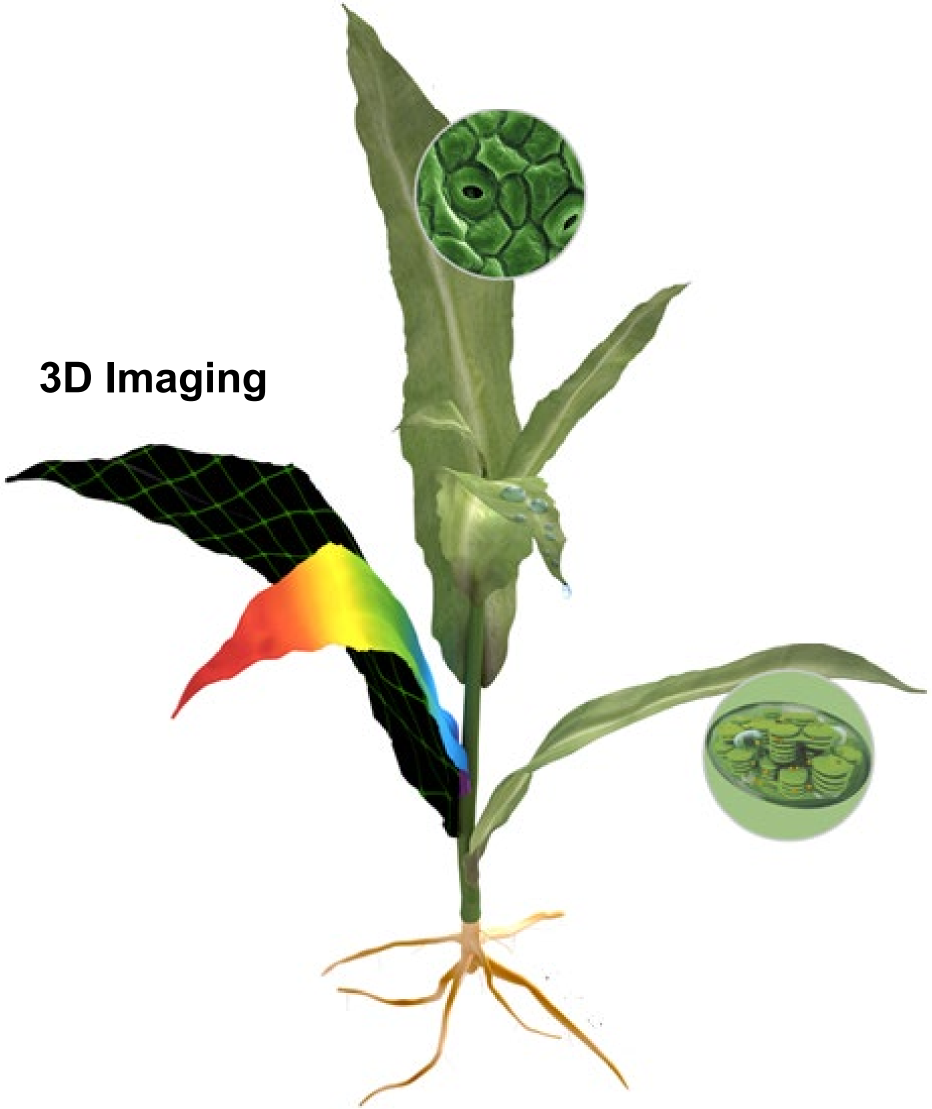


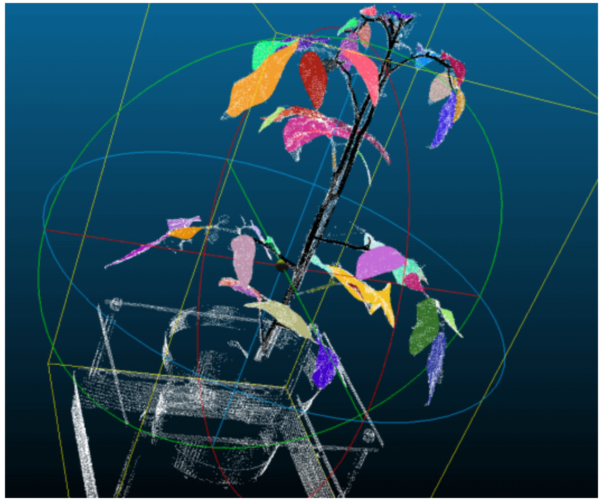
False color images of water index at 1400 nm

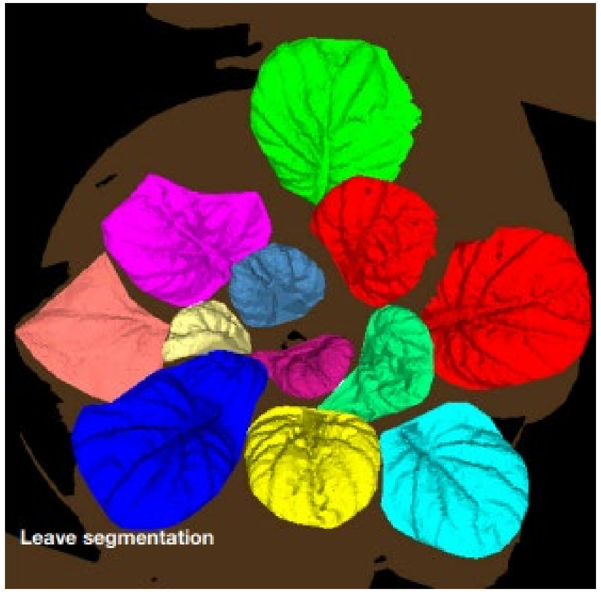
PlantScreen™ imaging sensors

Structural plant phenotyping

3D Imaging







Analyzed parameters

- Plant architecture assessment
- Biomass assessment
- Leaves count
- Individual leaf area
- Leaves angle measurement

Apply 3D model

Registered with other imaging sensors such as chlorophyll fluorescence and hyperspectral imaging

Case studies

Main environmental stress

Heat

Drought

Salinity

Heavy metals

Cold

Flooding

Screen for tolerant & robust varieties in crops

Characterization of adaptive responses to single and combined stresses in Desirée

Accelerated Development of Multiple-stress tolerant potato



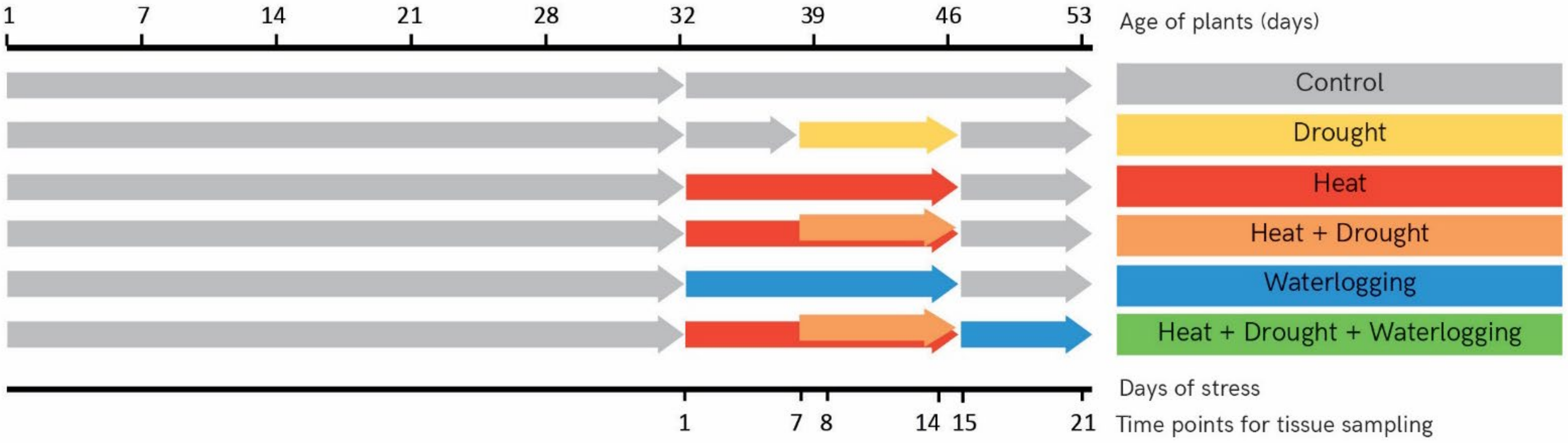
Coordinated by Dr. Markus Teige

Funded by the European Union's Horizon 2020 research and innovation programme; grant agreement No GA 2020 862-858

Characterization of adaptive responses to single and combined stresses in Desirée

Overview of experimental design

Cultivation
150 *in-vitro* plantlets of
Solanum tuberosum cv Desirée
available from HZPC
(Marijke Woudsma)



Timeline of applied treatments

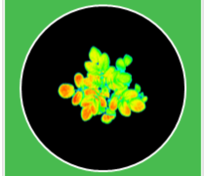
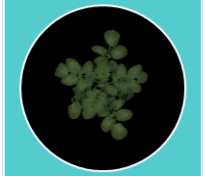
- Control: 60% field capacity
- Drought: 30% FC for 1 week
- Heat at 30/28 °C: 60% FC for 2 weeks
- Heat + Drought: 60% FC for 1 week, then 30% FC for 1 week
- Waterlogging watered up to 130% FC for 2 weeks
- Heat + Drought + Waterlogging: 60% FC for 1 week, then 30% FC for 1 week, then 130% FC for 1 week

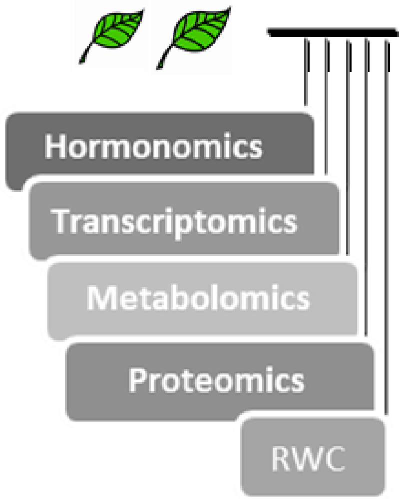
(Unpublished)

Characterization of adaptive responses to single and combined stresses in Desirée

Overview of experimental design

Dynamic morpho-physiological analysis of Desirée stress responses

Phenotyping protocol	 **Chlorophyll fluorescence imaging**	 **Thermal imaging**	 **Top and multi-angle side RGB imaging**	 **Weighing and Watering**	 **Enviro Data**
Measured parametres	*Size F0 Lss Fm Lss Ft Lss Fv Lss Fq Lss qL Lss Fv/Fm Lss qP Lss QY Lss*	*Temp-avg Temp-stddev Temp-median Temp-min Temp-max Size-avg*	*Area MM Perimeter MM Height MM Width MM Compactness Roundness Eccentricity RMS SOL Volume RGR Leaf colors*	*Weight Weight after watering Water consumption WUE*	*Temperature Humidity Light intensity Light spectra*



Tissue sampling for further Omics data analysis

(Unpublished)

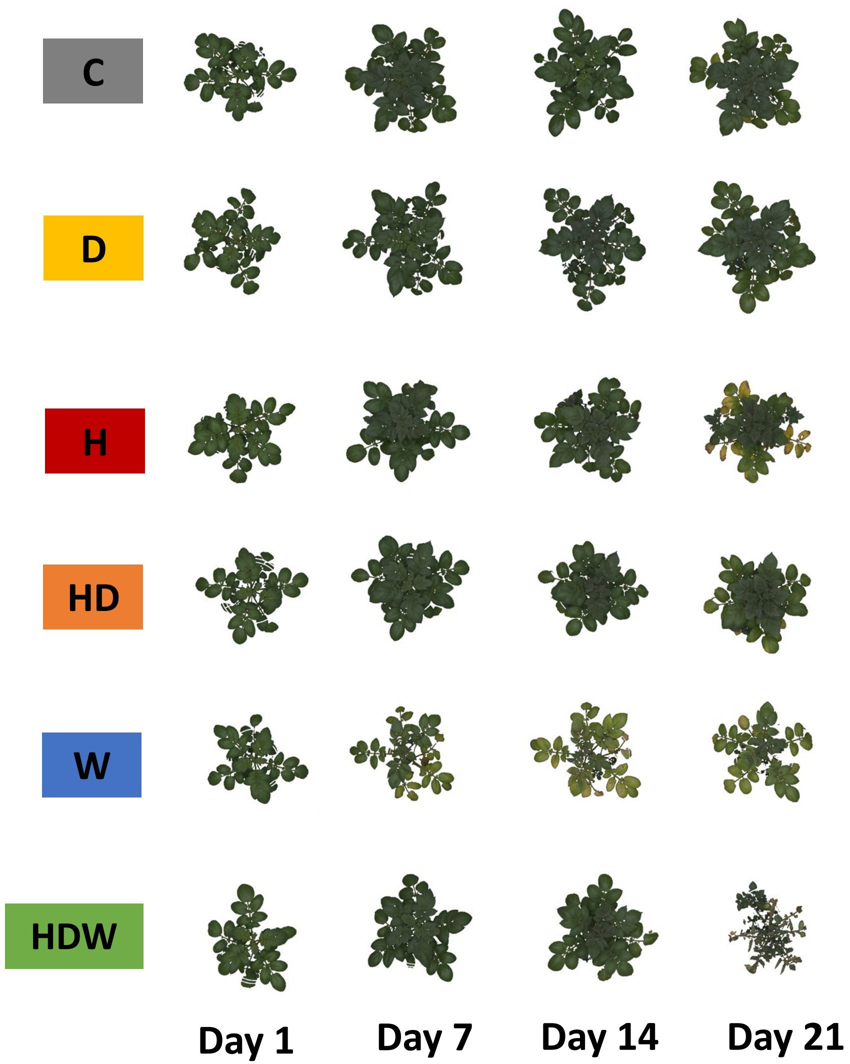
PHOTON SYSTEMS INSTRUMENTS

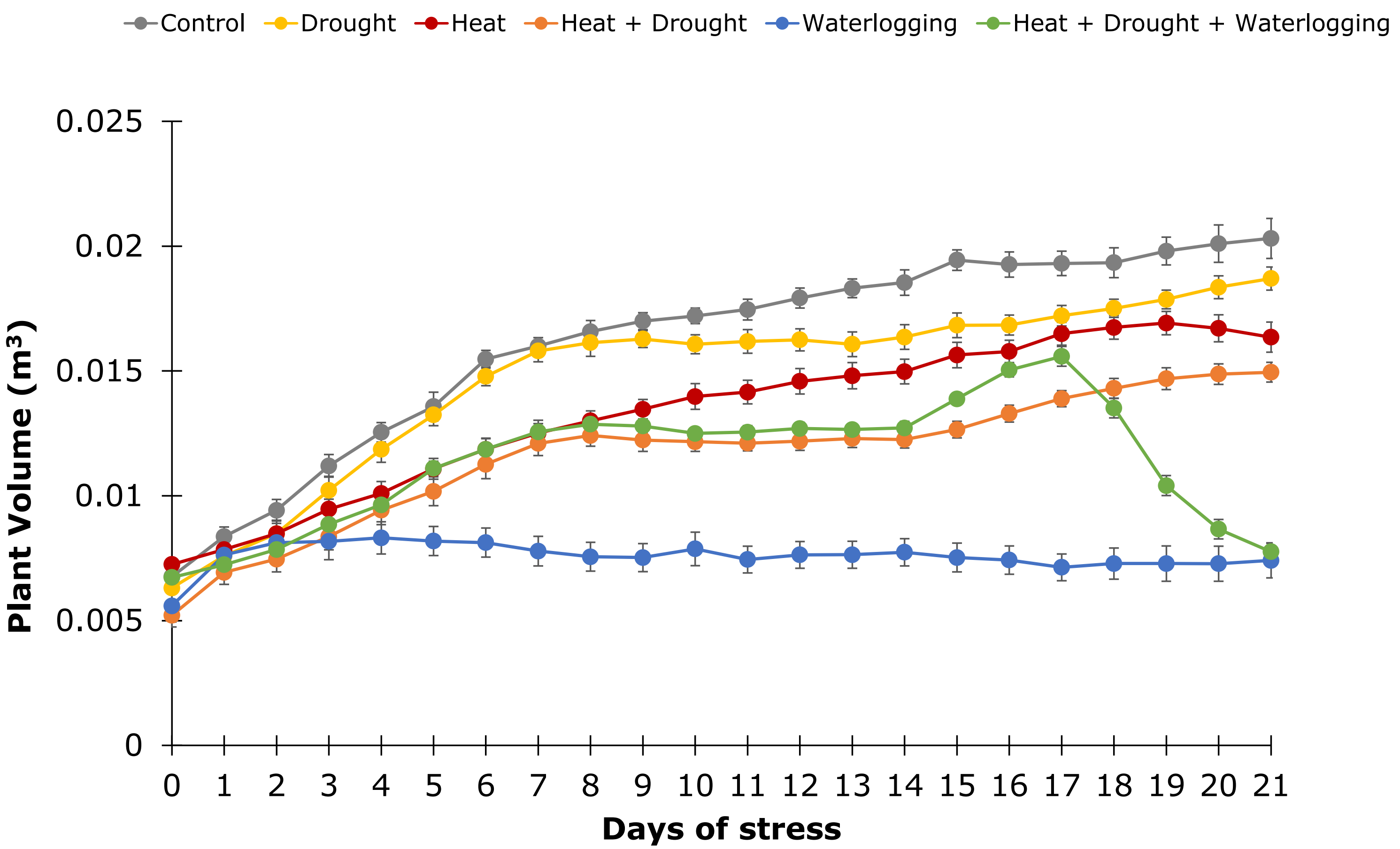
Developing heat-and drought-stress tolerant potatoes

Characterization of adaptive responses to single and combined stresses in Desirée

Plant growth

Top view RGB images



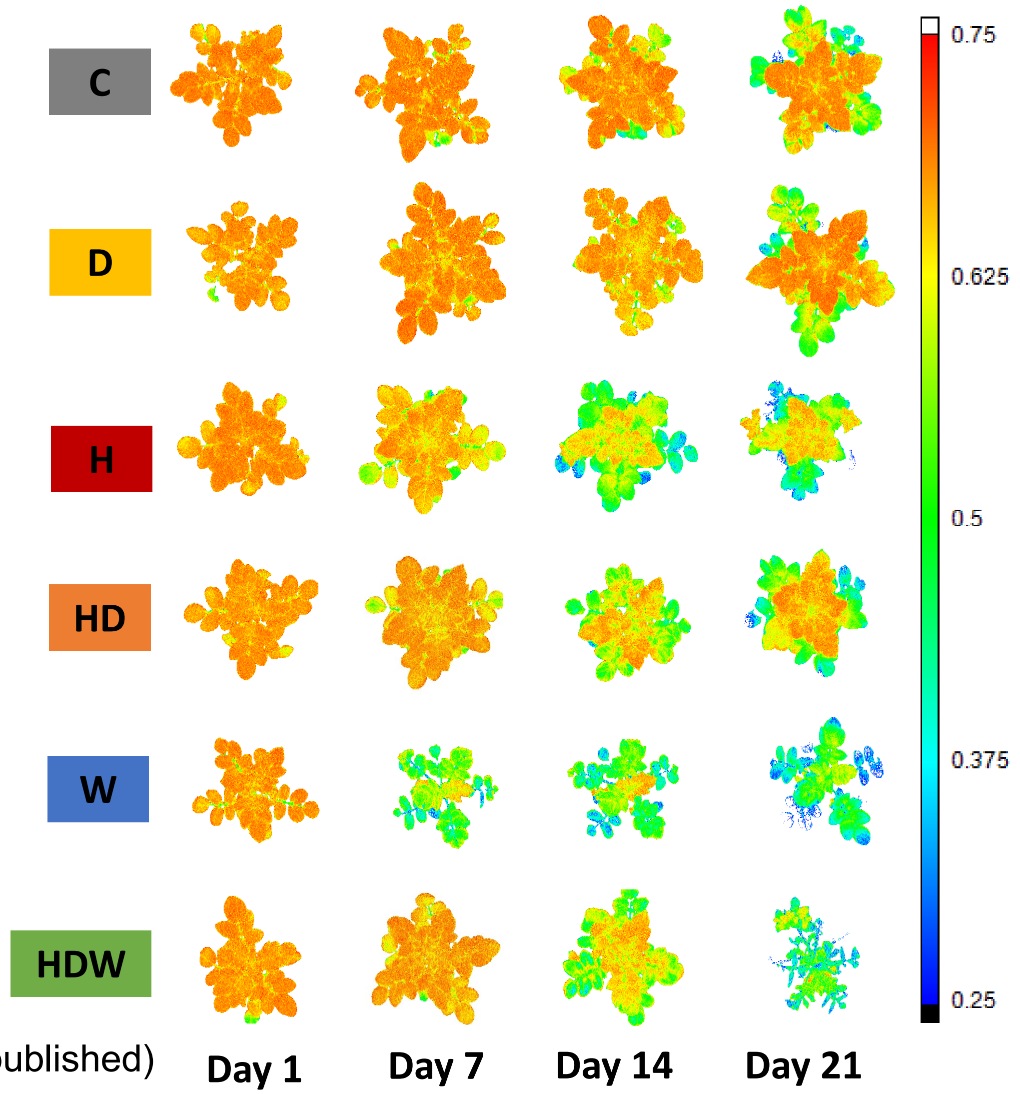


(Unpublished)

Characterization of adaptive responses to single and combined stresses in Desirée

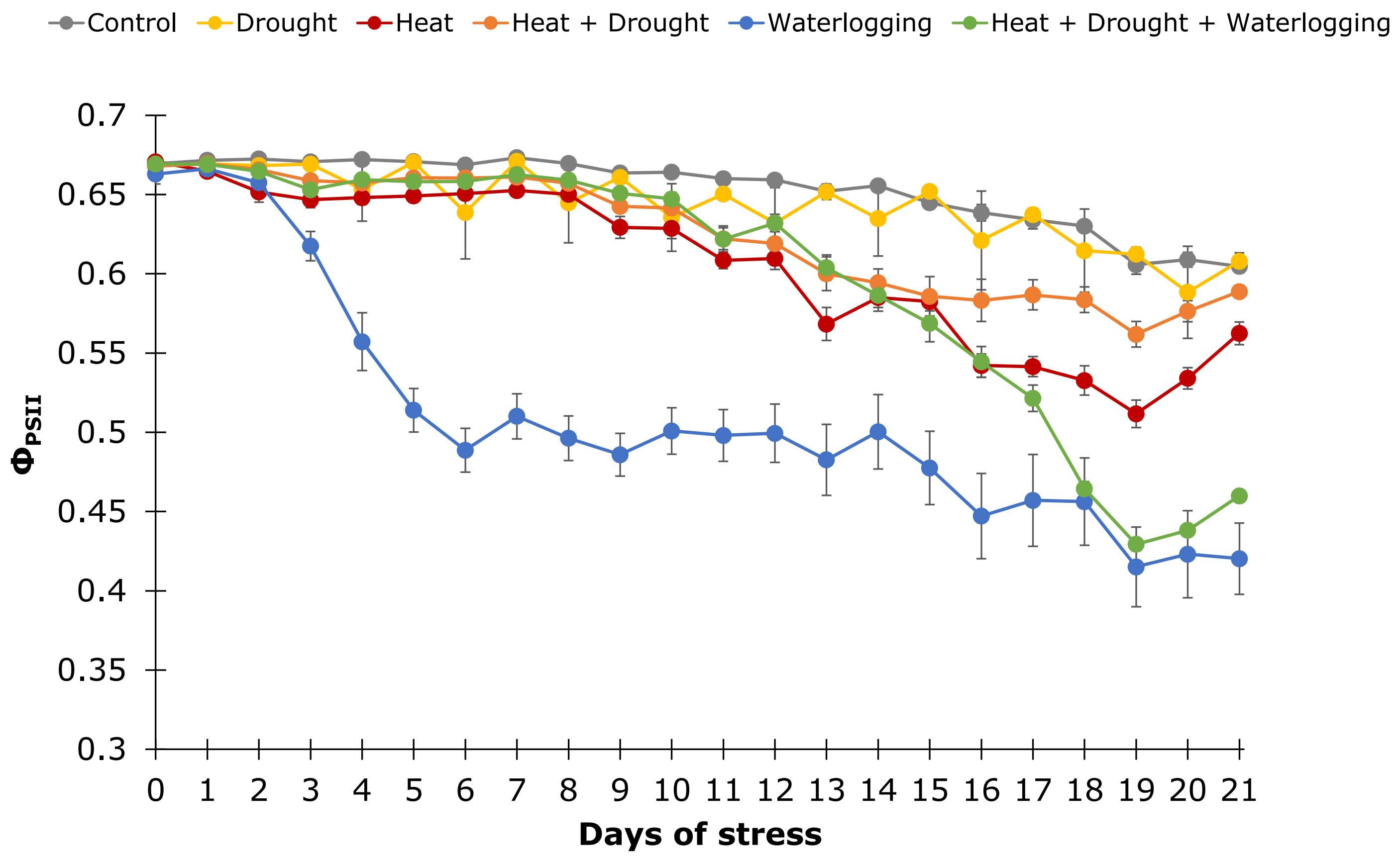
Photosynthetic efficiency

False color Φ_{PSII} images



(Unpublished)

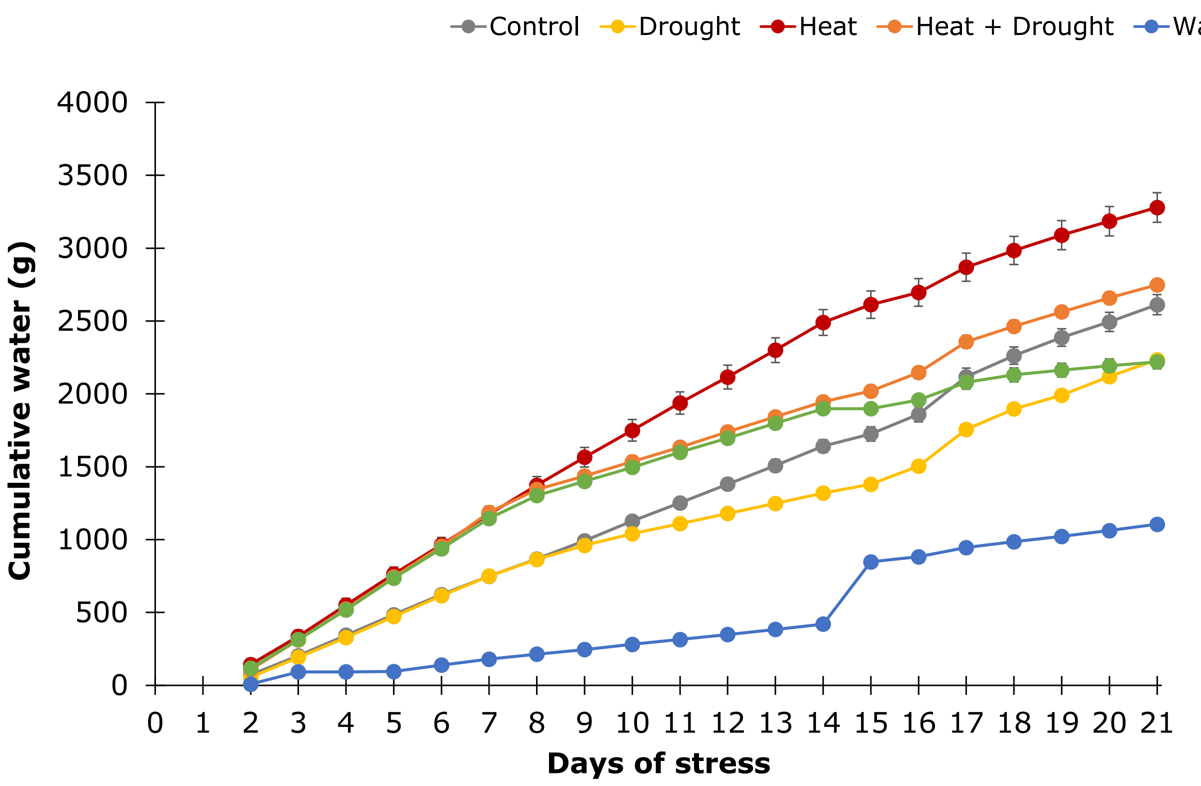
Operating efficiency of photosystem II on light-adapted plants



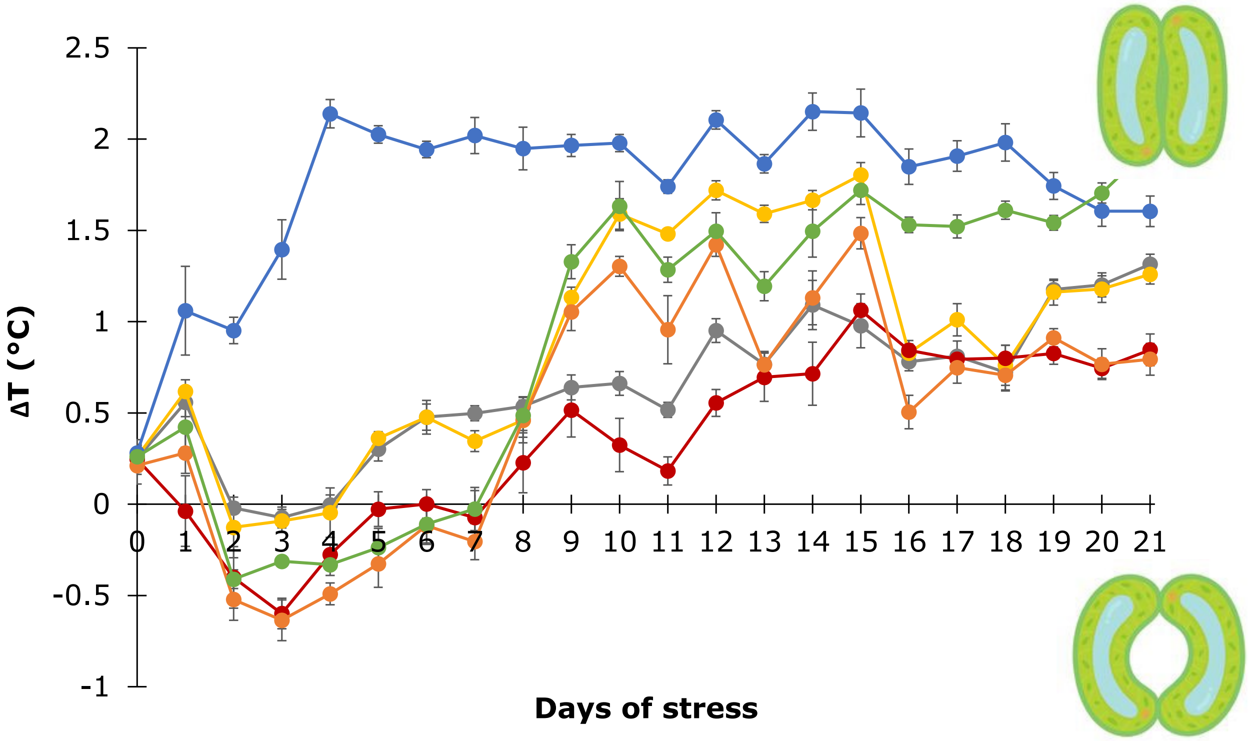
Characterization of adaptive responses to single and combined stresses in Desirée

Stomatal regulation

Water consumption along plant development



Difference between canopy average and air temperature measured in the thermal IR imaging



Stomata

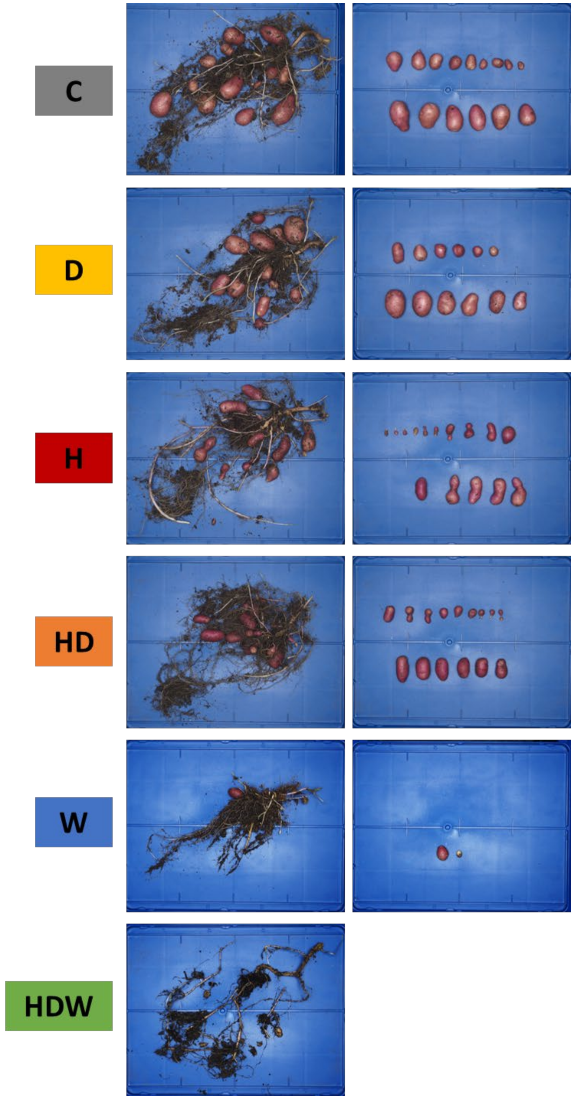
(Unpublished)

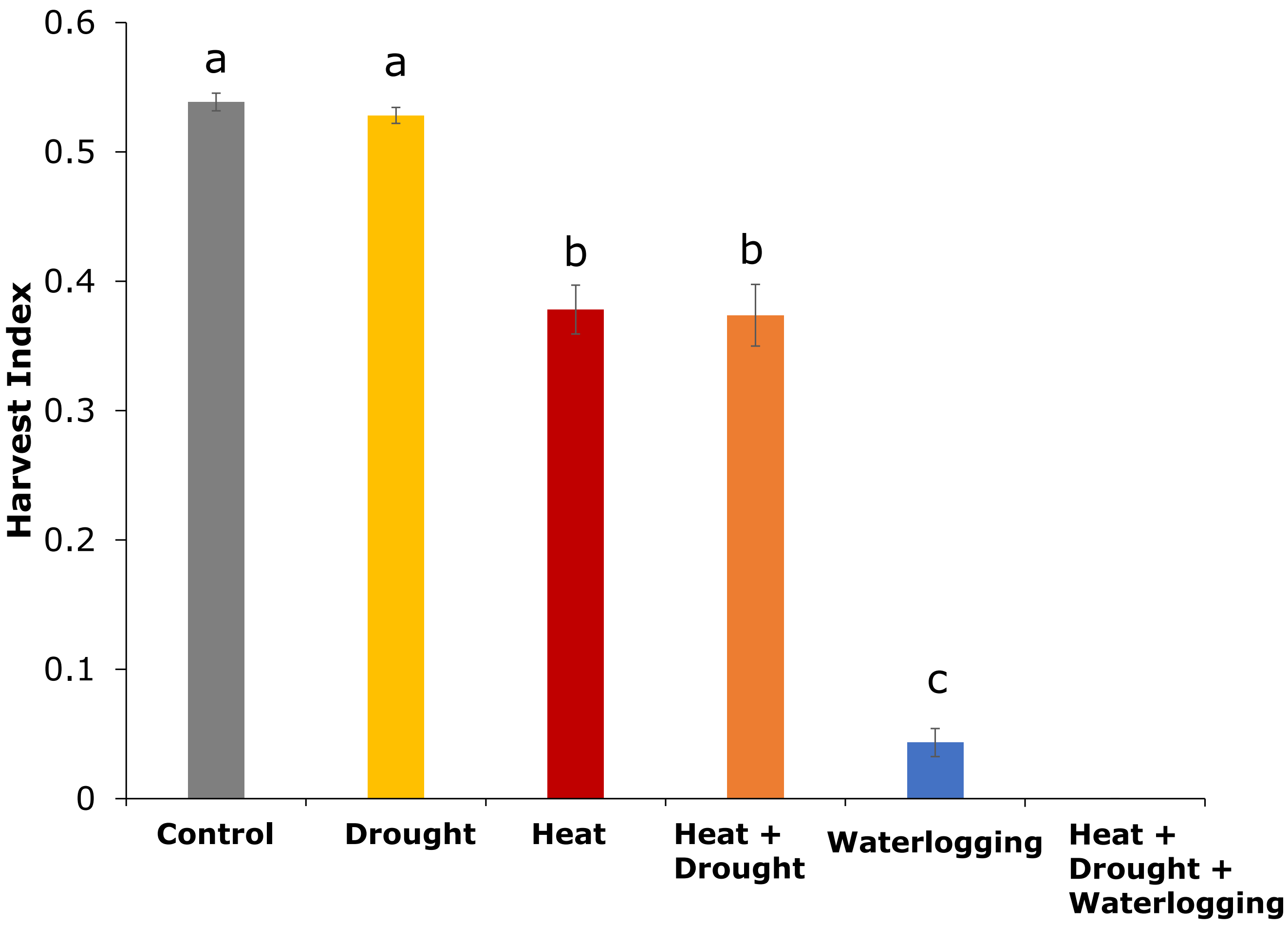
PHOTON SYSTEMS INSTRUMENTS

Characterization of adaptive responses to single and combined stresses in Desirée

Yield

Root biomass and tubers per plant

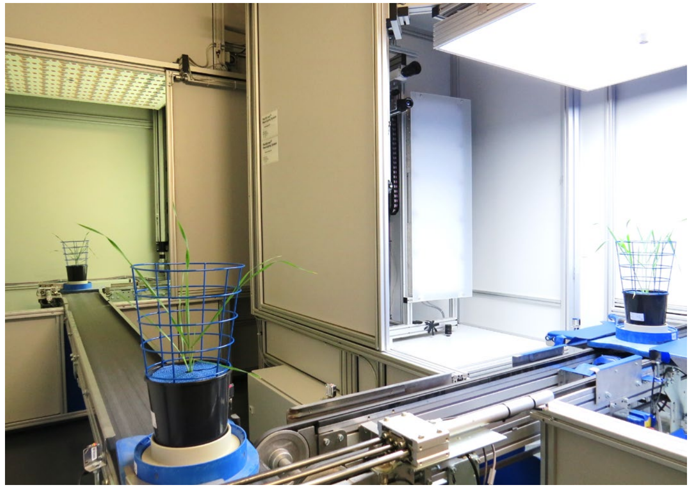
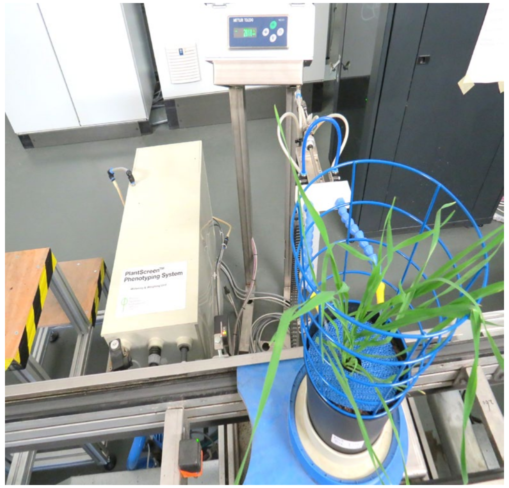




(Unpublished)

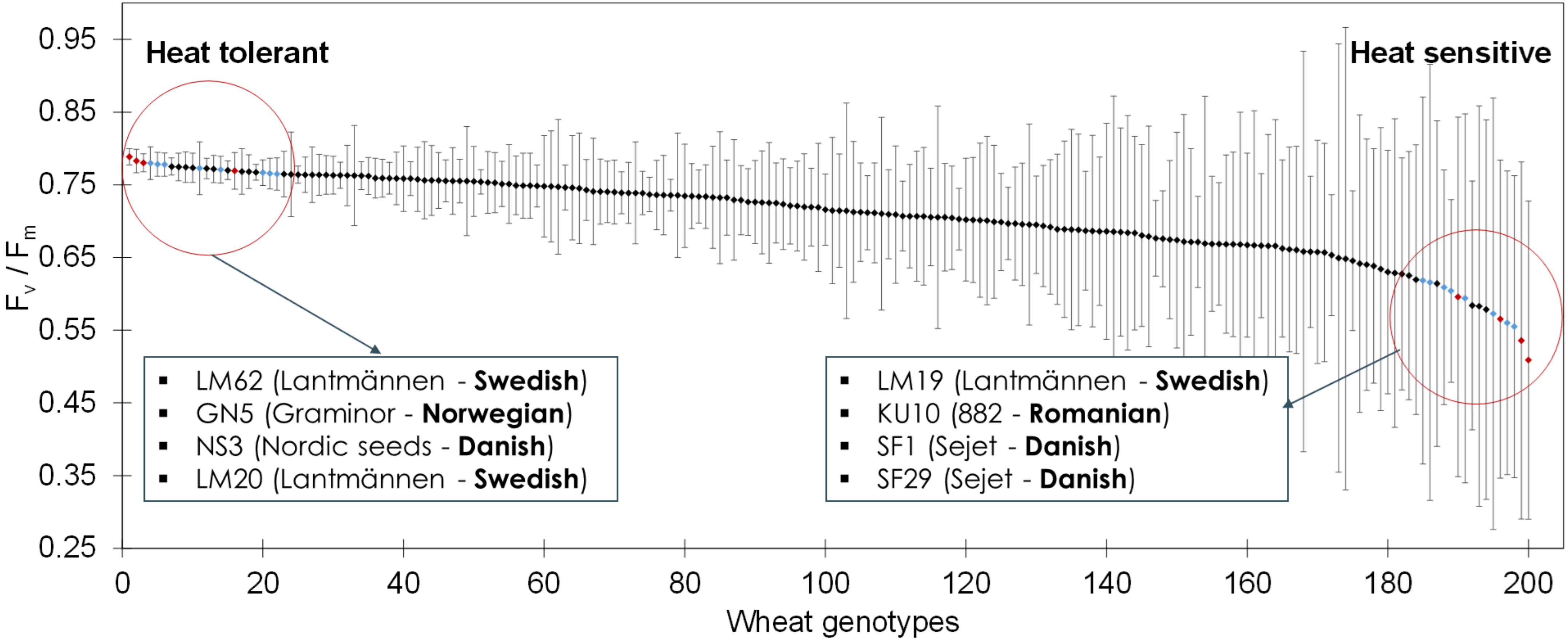
Investigating the combined drought and heat stress effect on physiological traits in spring wheat by using dynamic image-based phenotyping

Abdelhakim L. et al. (2021), Agronomy

Investigating the combined drought and heat stress effect on physiological traits in spring wheat by using dynamic image-based phenotyping

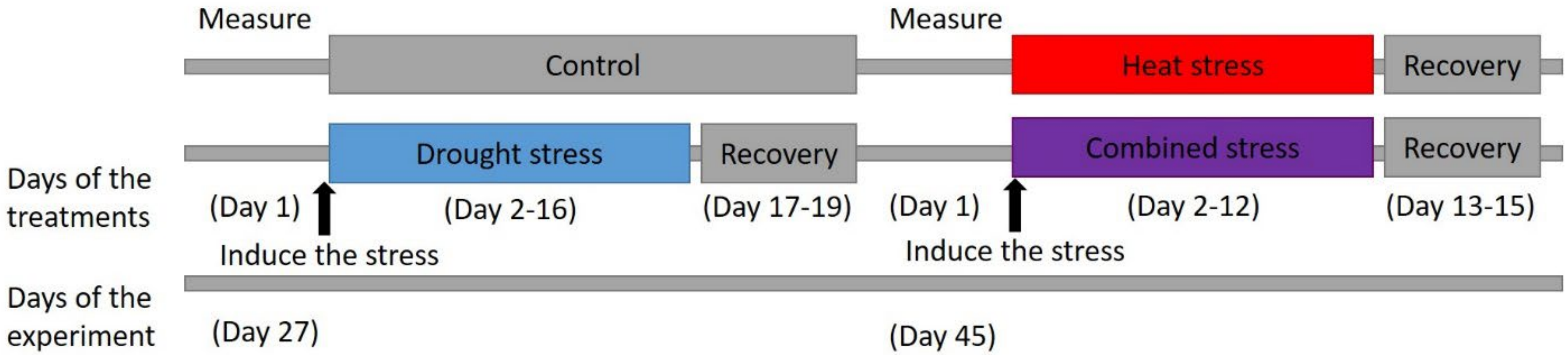
Heat screening experiment 200 Nordic wheat genotypes at 40°C using maximum quantum efficiency of PSII (Fv/Fm)



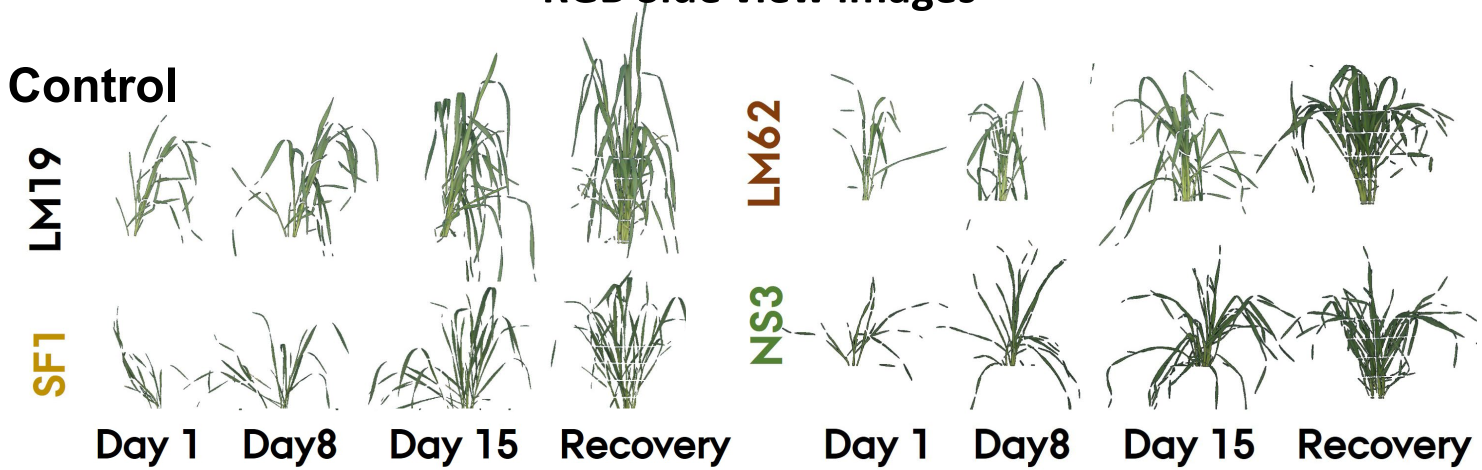
Sensitive indicator of plant photosynthetic performance under heat stress

Investigating the combined drought and heat stress effect on physiological traits in spring wheat by using dynamic image-based phenotyping

Experimental design



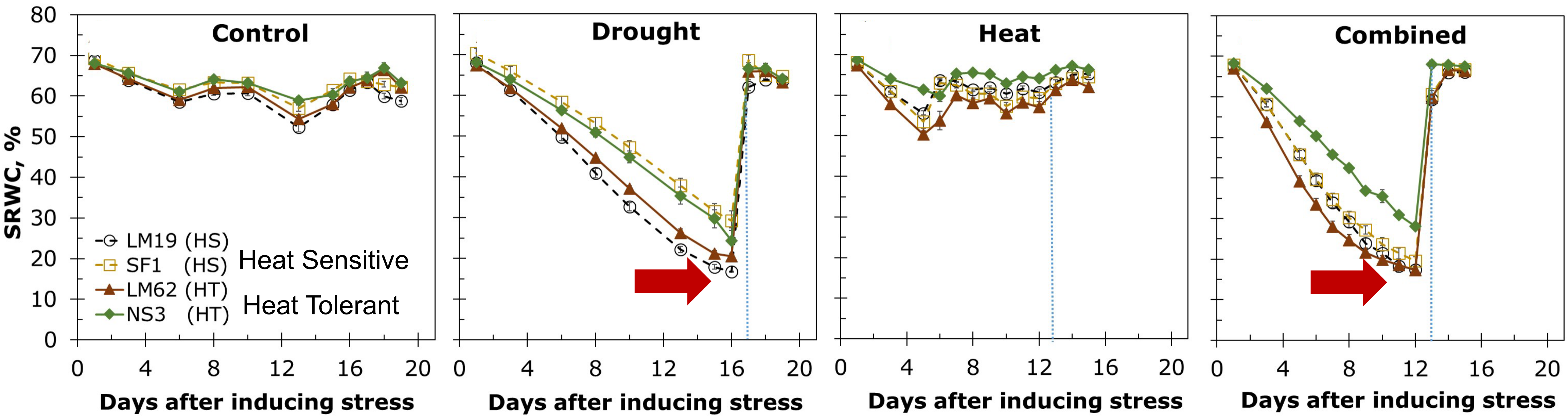
RGB Side view images



Abdelhakim L. et al. (2021), Agronomy

Plant growth dynamics

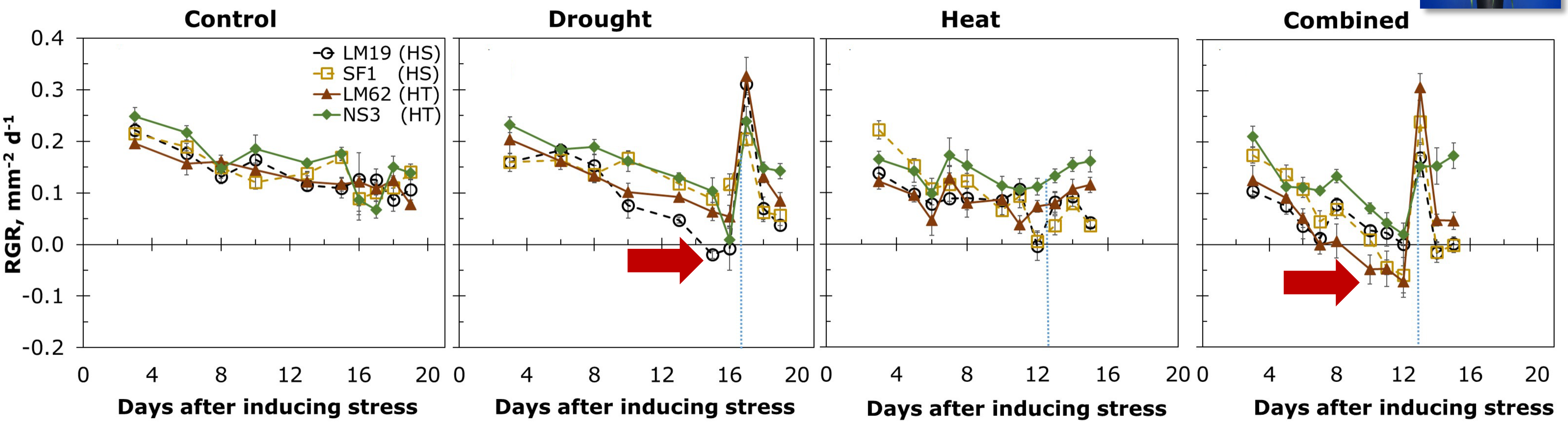
Soil Relative Water Content



The water consumption of genotypes under drought stress varied under combined stress reflecting different regulations and susceptibility to stresses

Plant growth dynamics

Relative Growth Rate

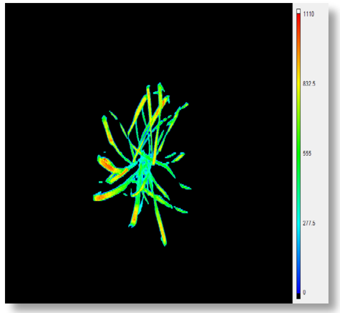


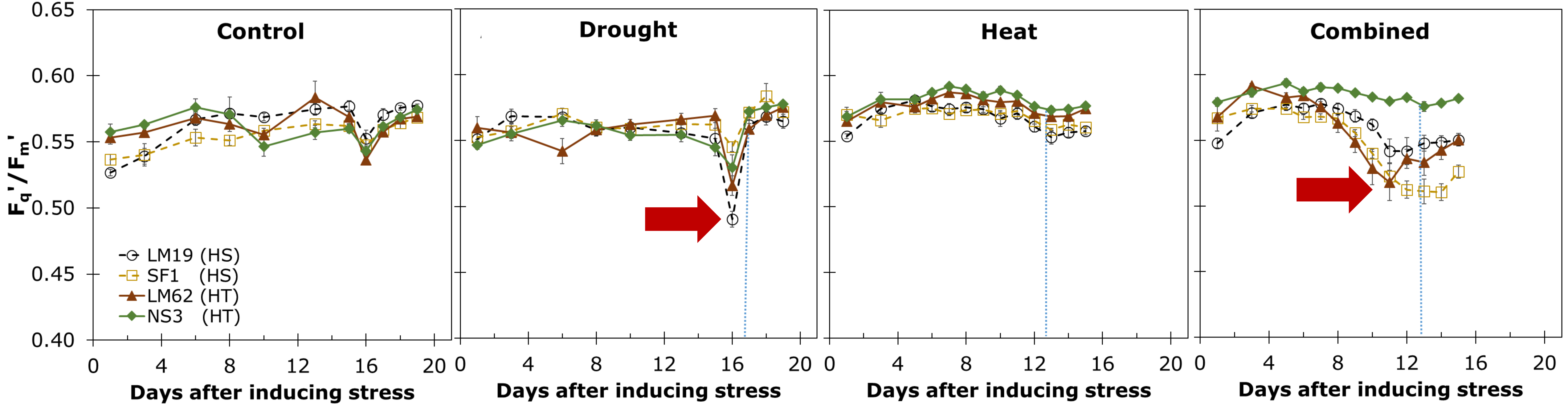
Genotypes that consumed more water were more susceptible to stress severity and enhanced adaptive stress was observed in heat sensitive genotype (LM19) under combined stress

Photosystem

Operating efficiency of Photosystem II

Reflects efficiency of the conversion of absorbed light into photochemistry



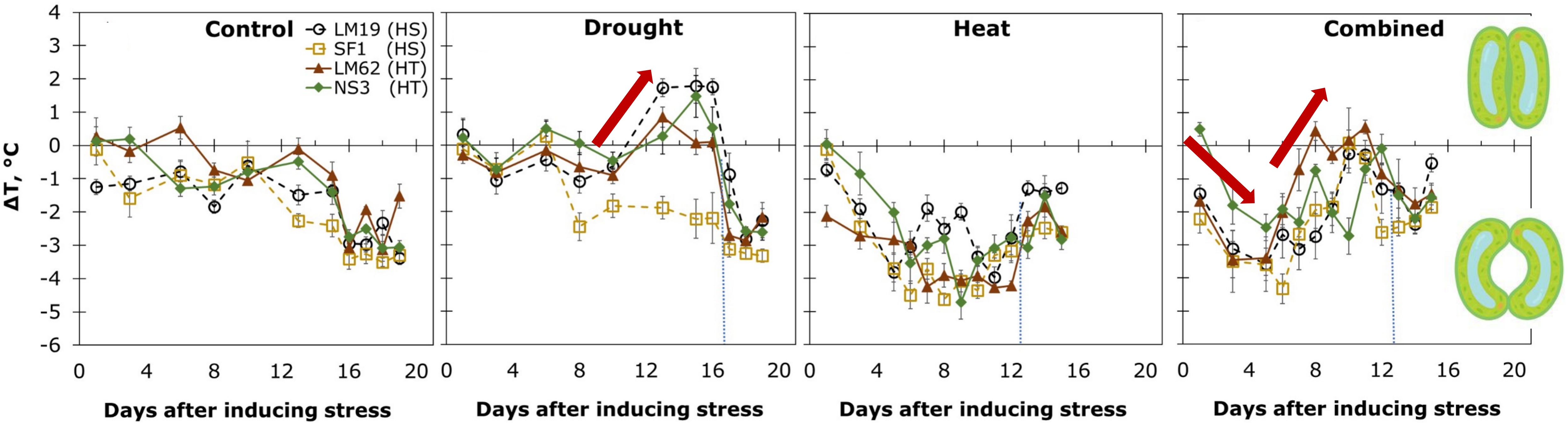


Such enhanced adaptive stress under combined stress reflected in protected photosynthetic apparatus

Transpiration efficiency

Canopy temperature

Difference between leaf and air cuvette temperature (ΔT)



Heat tolerant (**LM62**) leaf cooling efficiency was less under combined stress as observed in high ΔT highlighting the importance of investigating the potential of genotypes under the combination of stresses

Other applications of plant screen technology with different stresses and crops

frontiers in Plant Science
ORIGINAL RESEARC
published: 08 February 20
doi: 10.3389/fpls.2019.000

Understanding the Biostimulant Action of Vegetal-Derived Protein Hydrolysates by High-Throughput Plant Phenotyping and Metabolomics: A Case Study on Tomato

OPEN ACCESS

Kenny Paul[1†], Mirella Sorrentino[1†], Luigi Lucini[2], Youssef Rouphael[3], Mariateresa Cardarelli[4], Paolo Bonini[5], Hélène Reynaud[6], Renaud Canaguier[7], Martin Trtílek[1], Klára Panzarová[1] and Giuseppe Colla[8,9*]*

the plant journal — SEB

The Plant Journal (2021) 107, 544–563 doi: 10.1111/tpj.15310

Genetic mapping of the early responses to salt stress in *Arabidopsis thaliana*

Mariam Awlia[1], Nouf Alshareef[1,2], Noha Saber[1], Arthur Korte[3], Helena Oakey[4], Klára Panzarová[5], Martin Trtílek[5], Sónia Negrão[1,6], Mark Tester[1] and Magdalena M. Julkowska[1,*]

Article — EMBO reports

Glucose uptake to guard cells via STP transporters provides carbon sources for stomatal opening and plant growth

Sabrina Flütsch[1,2,†], Arianna Nigro[2,†,‡], Franco Conci[2], Jiří Fajkus[3], Matthias Thalmann[2,§], Martin Trtílek[3], Klára Panzarová[3] & Diana Santelia[1,2,*]

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Seed Priming With Protein Hydrolysates Improves Arabidopsis Growth and Stress Tolerance to Abiotic Stresses

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PHOTON SYSTEMS INSTRUMENTS

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