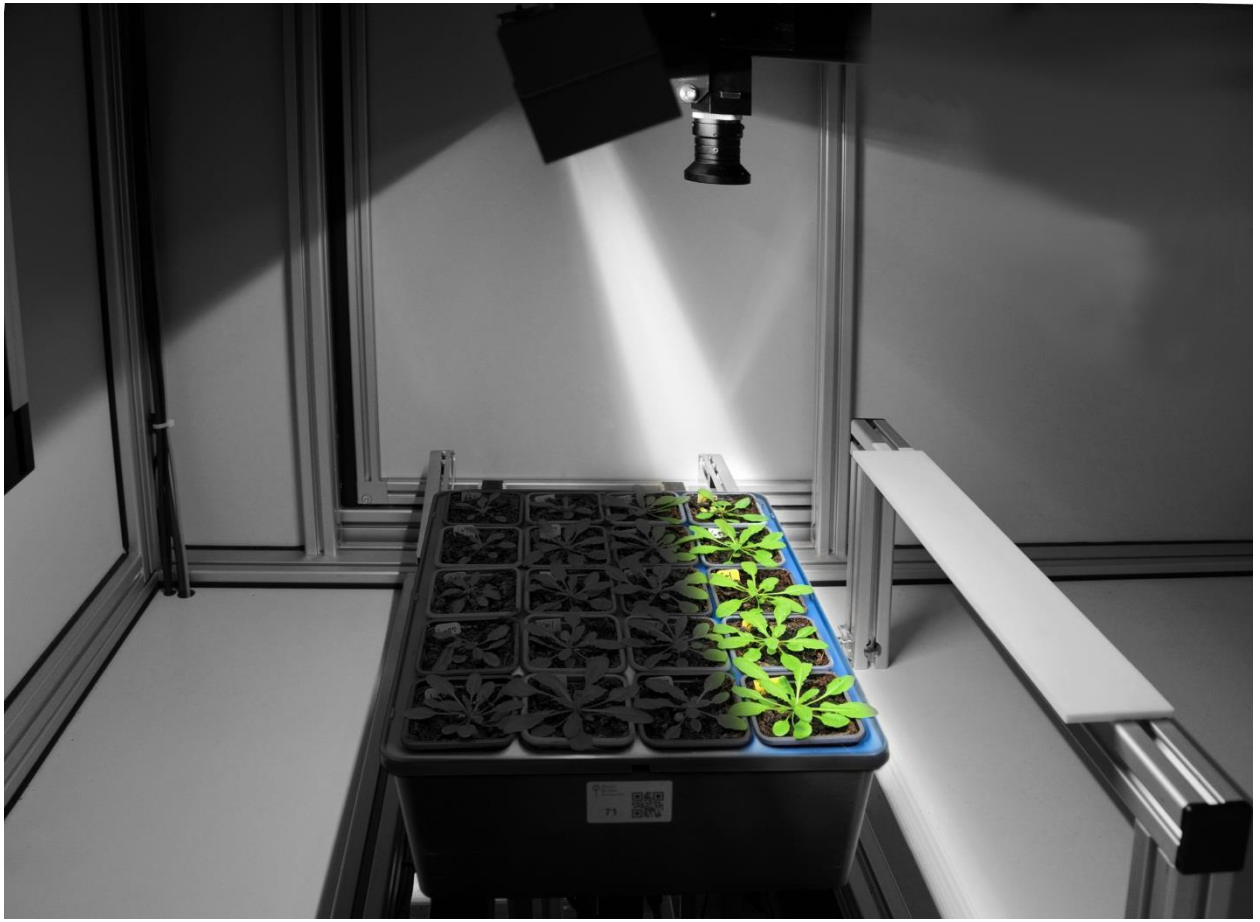
Hyperspectral Imaging in Plant Phenotyping



Jiří Fajkus, PSI

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- Fluorescence imaging
- Plant and algae cultivation
- Portable field devices
- Photobioreactors
- LED light sources
- Spectrometres
- PlantScreen Phenotyping platforms

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PlantScreen Installations

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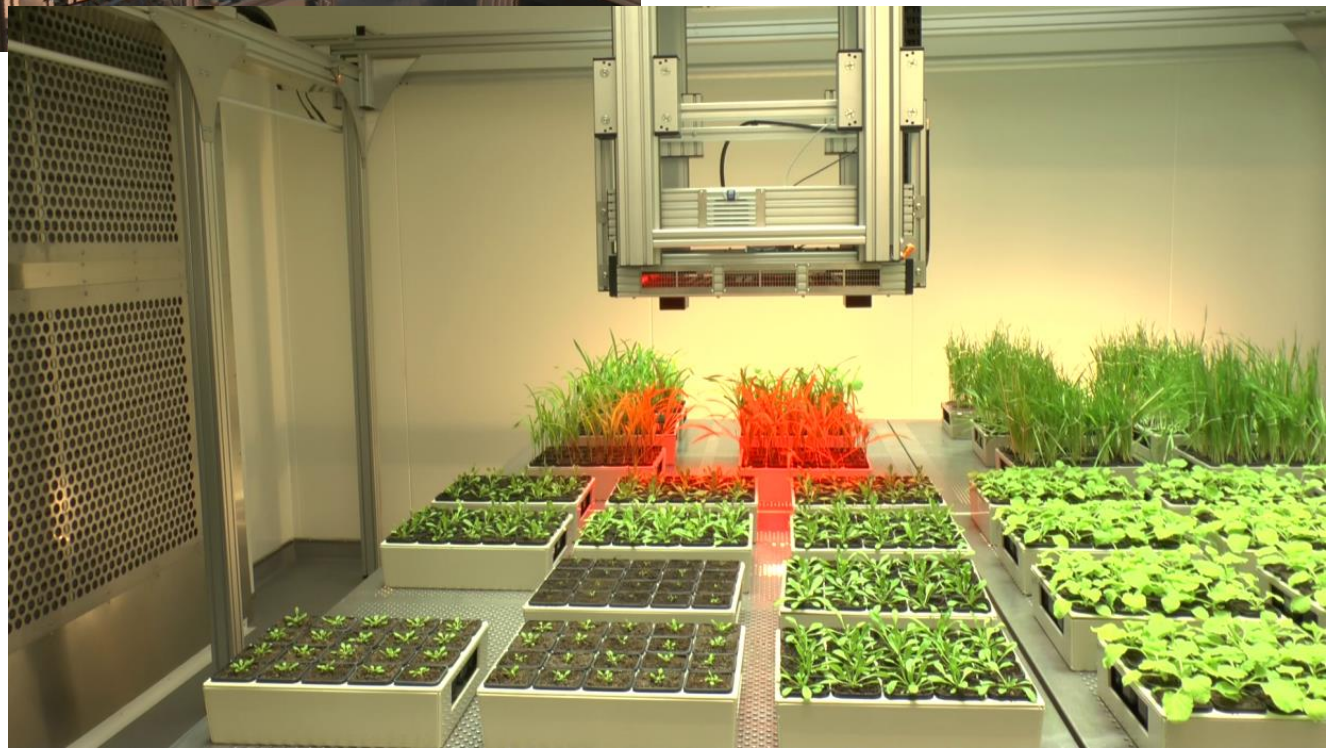

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PSI research center

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Introduction

- Remote, quantitative measurements of spectral characteristics of each pixel across imaged scene
- Narrow bands (<= 10 nm) providing information about continuous part of electromagnetic spectrum
  - VNIR (400-1000nm)
  - SWIR (1000-2500nm)
- Construction
  - Spatial scanning (Push broom)
  - Wavelength scanning – tunable filters
  - Others (Whisk-broom, SS scanning…)

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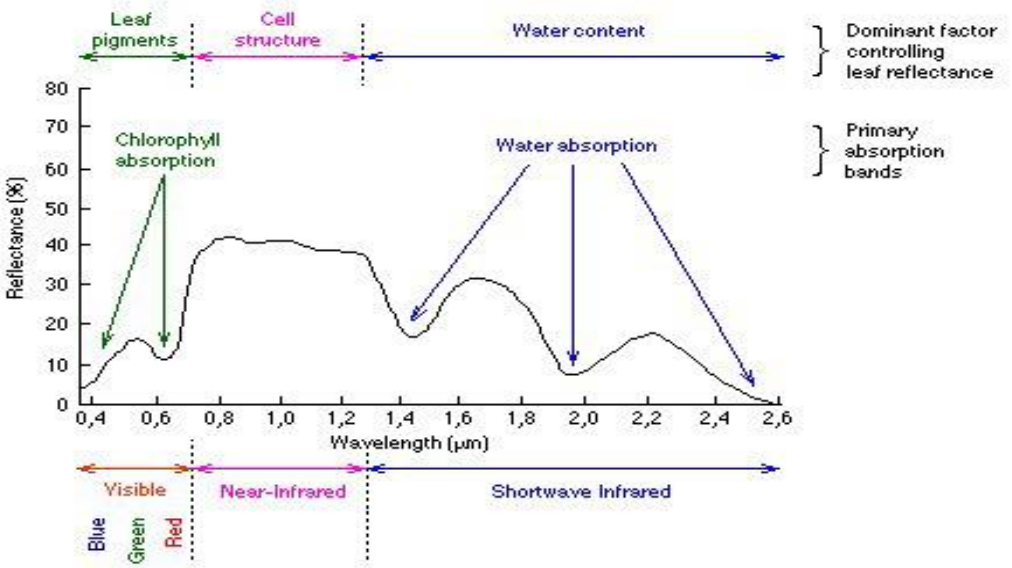
- Material identification
- Astronomy
- Environmental
- Precision agriculture
- Homeland security
- Health care
- Mining…



- PSI high-throughput phenotyping platforms
  - Biochemical composition, fitness determination, seed quality analysis
    - VNIR – vegetation indices (NDVI, PRI, SRI…)
    - SWIR – water content estimation

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Data acquisition

- Setting of hyperspectral imaging system
  - Speed/integration time/frame rate
- Radiometric calibration of data
  - Removes influence of spectral inhomogeneities and drifts caused by CCD sensitivity, illumination spectrum,
    - Calibration reflectance standards (teflon, spectralon)
    - Dark current calibration
  - Calibration data for each measurement
- Chromatic aberration correction

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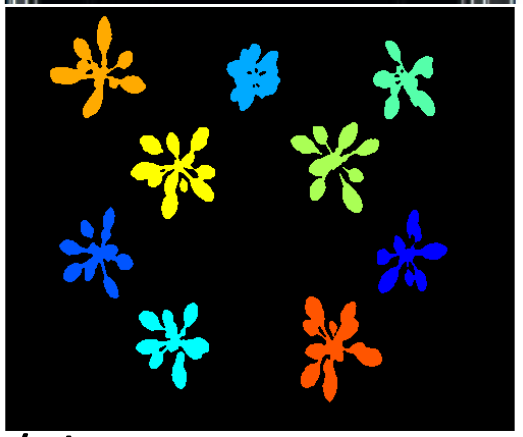
“Hypercube” processing



- RGB image for visual inspection
  - selected wavelengths (VNIR)
  - Simultaneously captured RGB (SWIR)
- Background subtraction
- Mask / labeling / manual selection
- Results
  - Average spectra for each object
  - Calculated vegetation indices for each pixel/object
  - Data visualization and basic statistics
- Export

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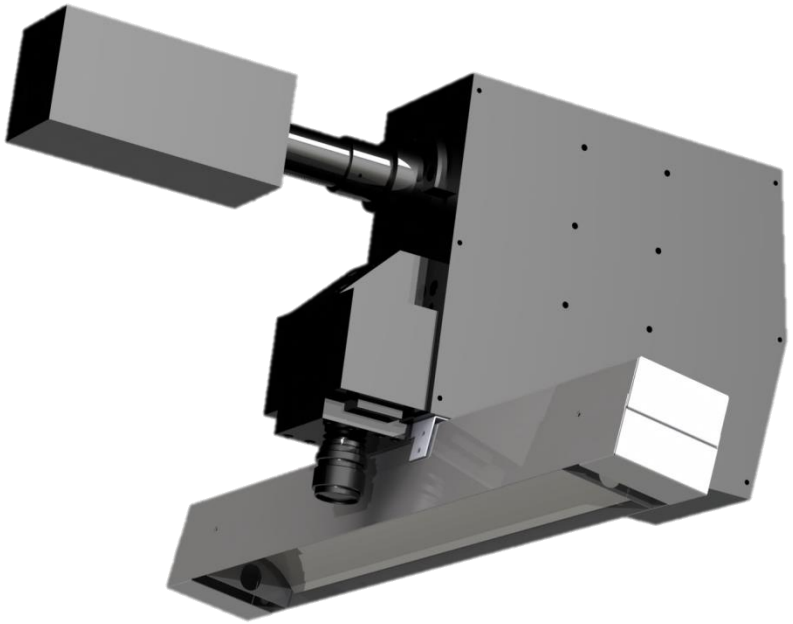
PSI HC 900 Series

- Spectral range: 350-900nm
- Spatial resolution: 1000px
- Spectral bands: 1920
- Spectral resolution: 0,8nm FWHM
- Dispersion: 0.28nm/px
- Detector: CMOS
- Frame rate: 45fps
- Dynamic range: 67dB
- Bit depth: 12bit



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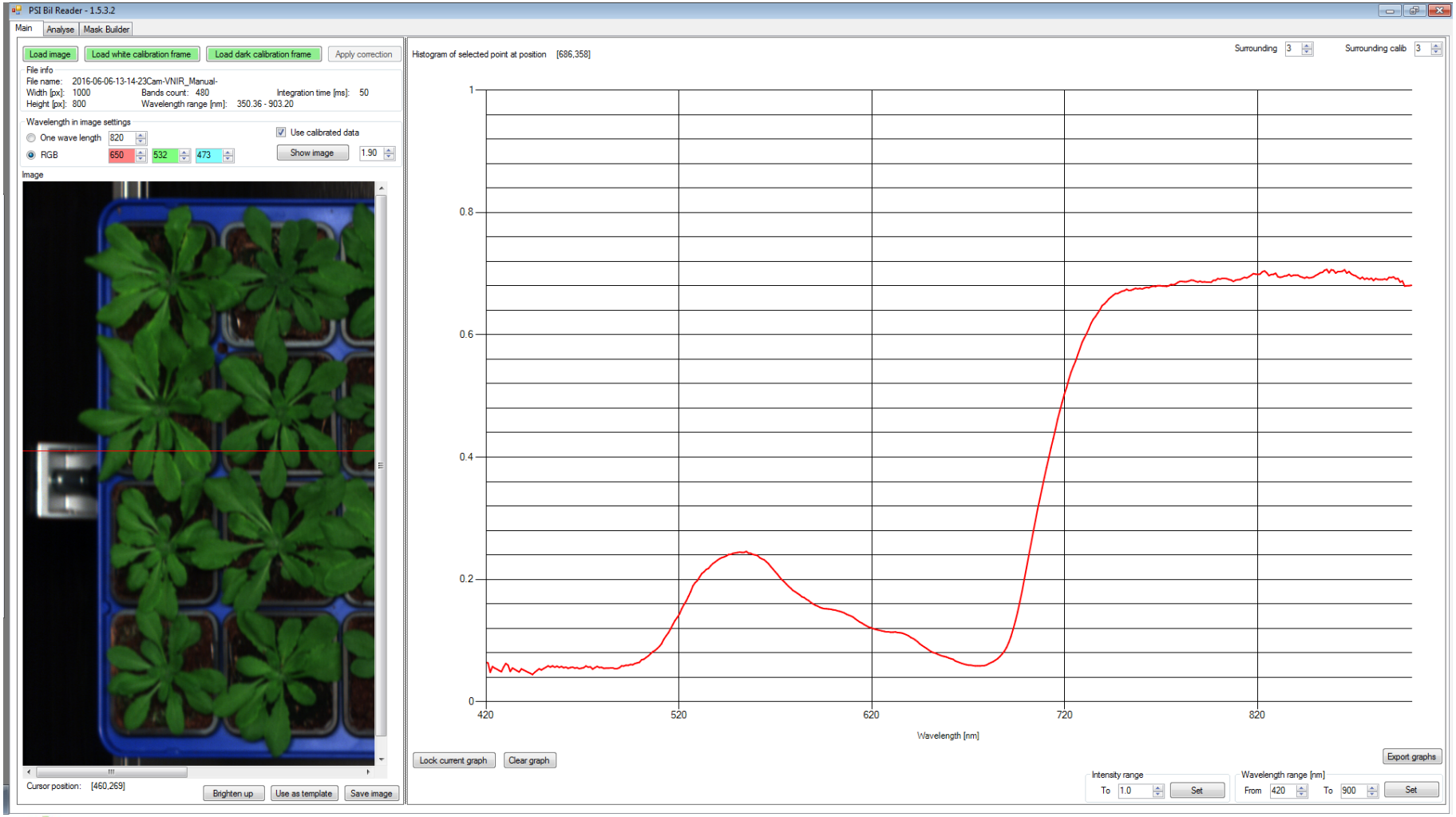
Software



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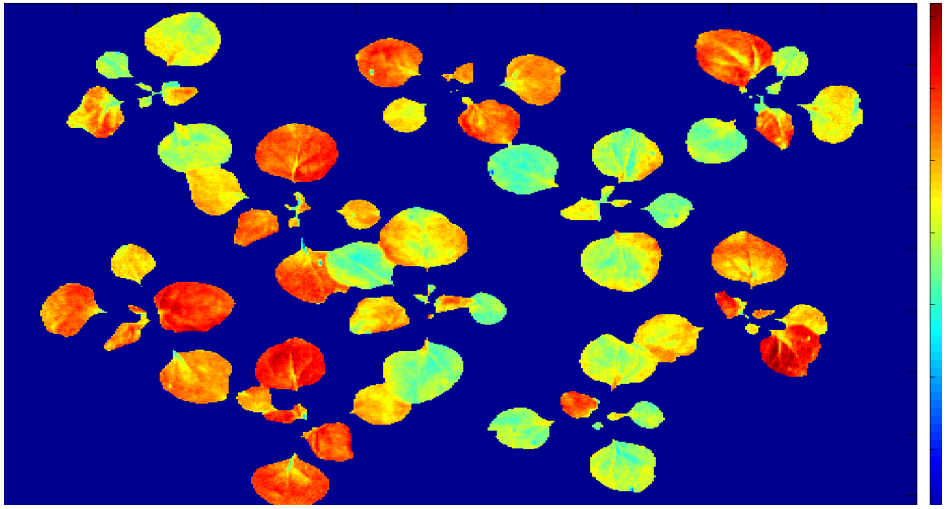

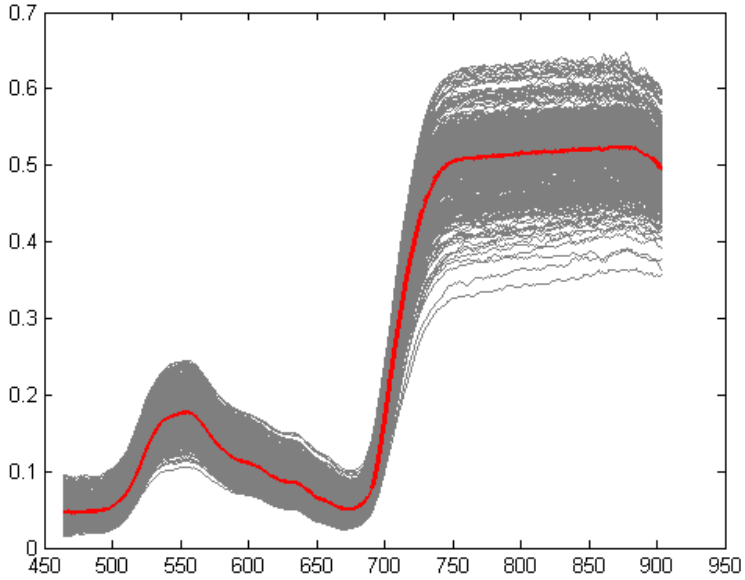

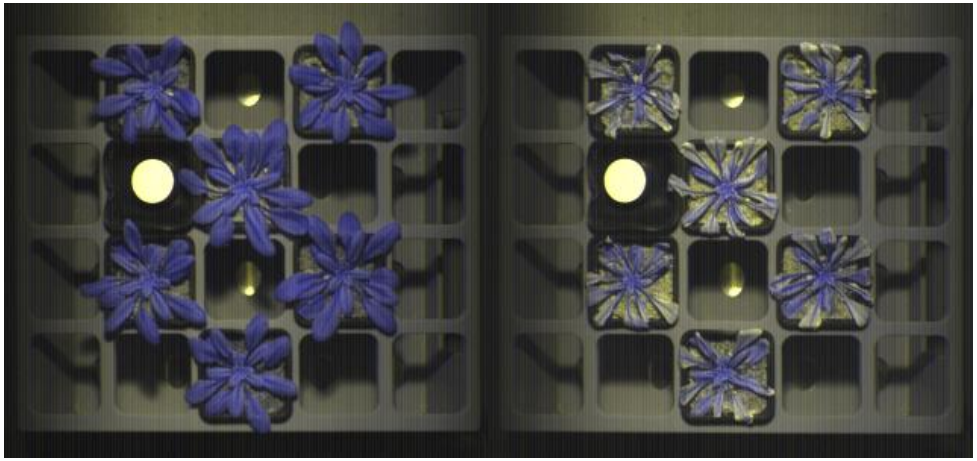

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Experiment

- 22 days old A.thaliana Col-0
  - 12h/12h light regime 22°C(day) / 20°C(night)
  - Low Light 100µE High Light 600µE
  - Relative humidity 60%
  - RGB, Hyperspectral and HPLC
  - measurements after 0, 4, 8 and 24 hours

HL	LL			
T0A1	T4A1	T8A1	T24A1	A1LL
T0A2	T4A2	T8A2	T24A2	A2LL
T0A3	T4A3	T8A3	T24A3	A3LL
T0A4	T4A4	T8A4	T24A4	A4LL

- 3 trays
  - 4 HL plants removed for HPLC

  Each measurement
  - LL HPLC after 24 hours

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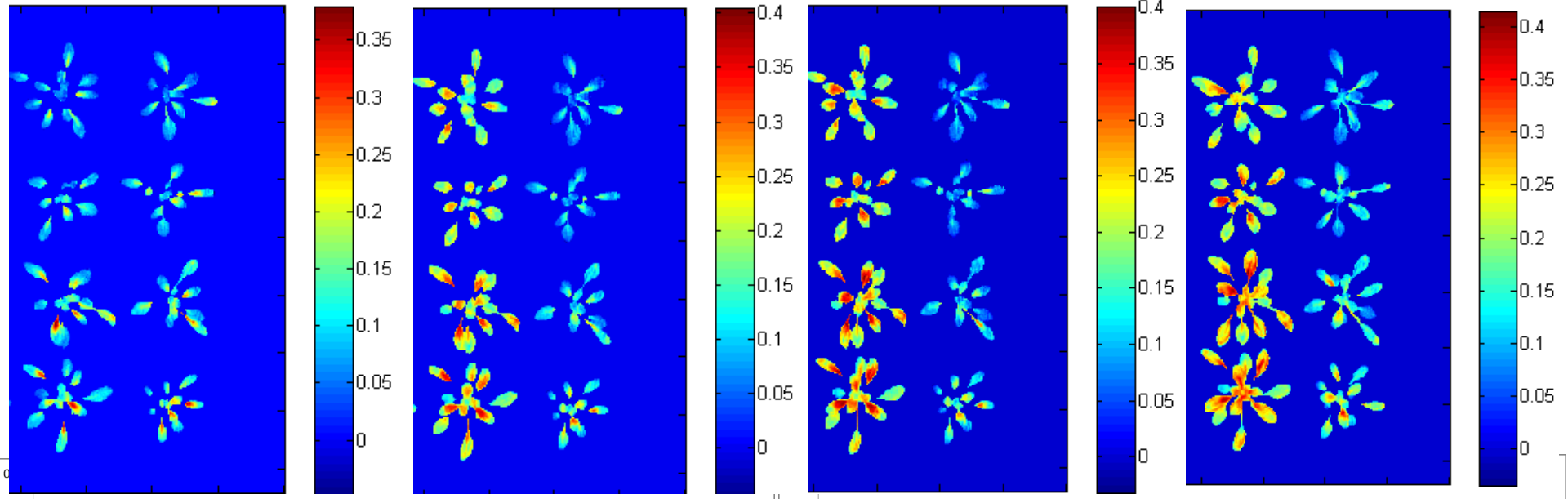
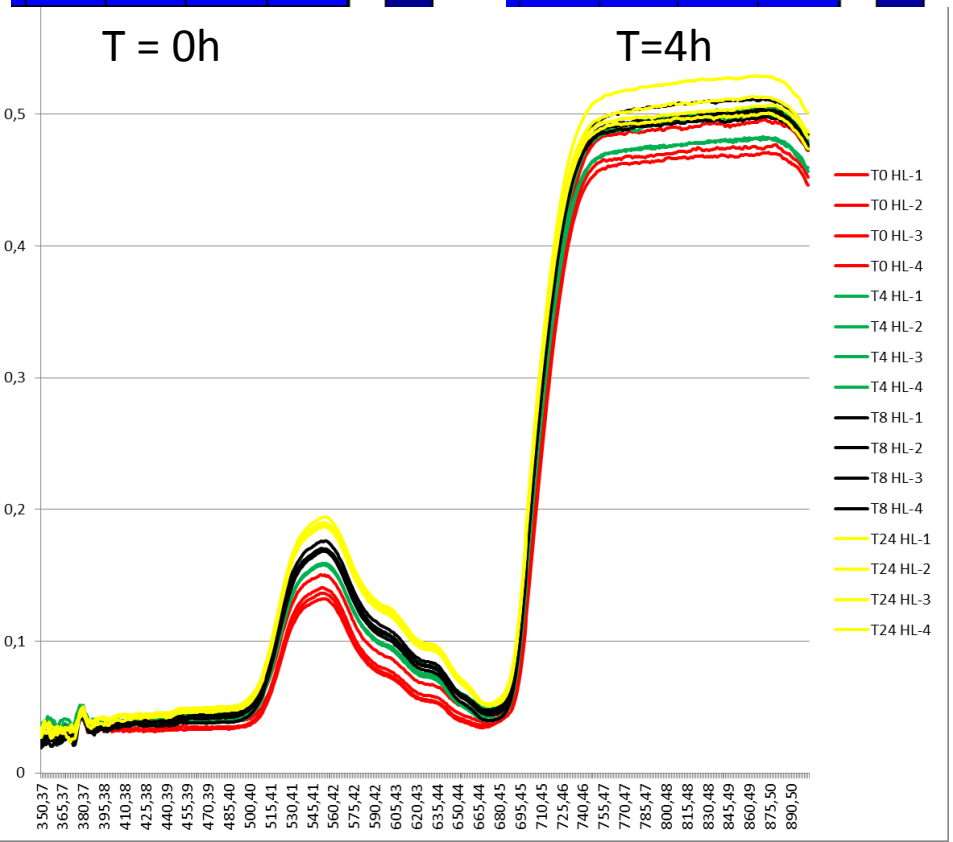
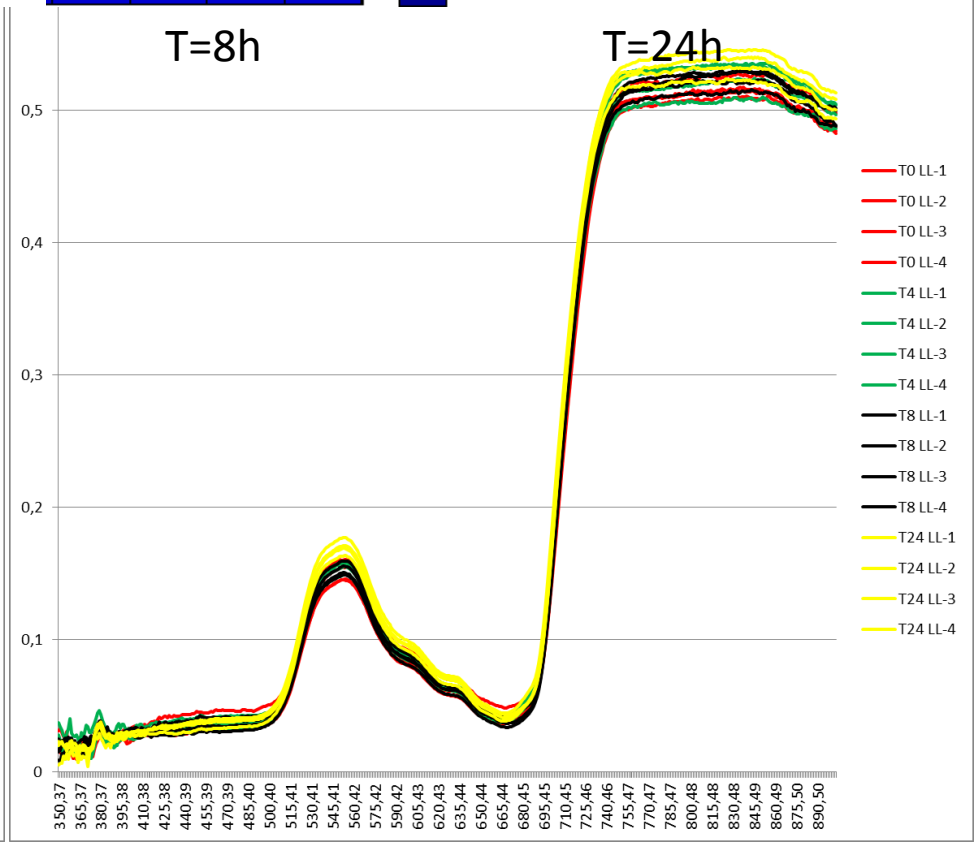
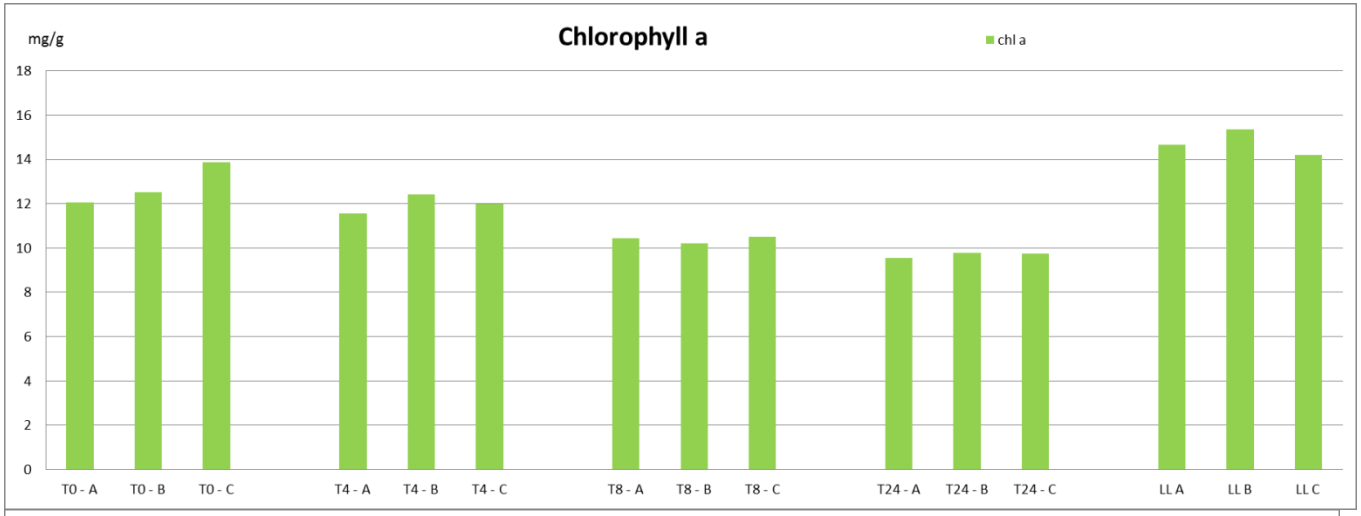

0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0

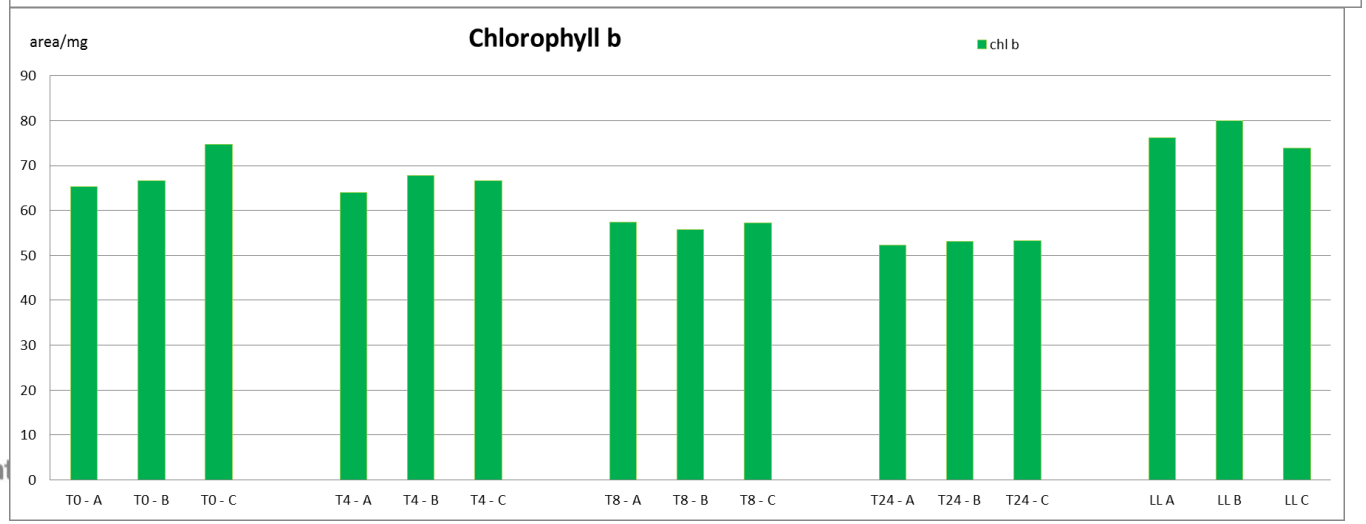

T = 0h
T=4h
0,5
0,4
0,3
0,2
0,1
0
T0 HL-1
T0 HL-2
T0 HL-3
T0 HL-4
T4 HL-1
T4 HL-2
T4 HL-3
T4 HL-4
T8 HL-1
T8 HL-2
T8 HL-3
T8 HL-4
T24 HL-1
T24 HL-2
T24 HL-3
T24 HL-4
350,37
365,37
380,37
395,38
410,38
425,38
440,39
455,39
470,39
485,40
500,40
515,41
530,41
545,41
560,42
575,42
590,42
605,43
620,43
635,44
650,44
665,44
680,45
695,45
710,45
725,46
740,46
755,47
770,47
785,47
800,48
815,48
830,48
845,49
860,49
875,50
890,50


T=8h
T=24h
0,5
0,4
0,3
0,2
0,1
0
T0 LL-1
T0 LL-2
T0 LL-3
T0 LL-4
T4 LL-1
T4 LL-2
T4 LL-3
T4 LL-4
T8 LL-1
T8 LL-2
T8 LL-3
T8 LL-4
T24 LL-1
T24 LL-2
T24 LL-3
T24 LL-4
350,37
365,37
380,37
395,38
410,38
425,38
440,39
455,39
470,39
485,40
500,40
515,41
530,41
545,41
560,42
575,42
590,42
605,43
620,43
635,44
650,44
665,44
680,45
695,45
710,45
725,46
740,46
755,47
770,47
785,47
800,48
815,48
830,48
845,49
860,49
875,50
890,50

Supplementary HPLC measurements

- Chlorophyll a, b, Carotenoids, Anthocyanins





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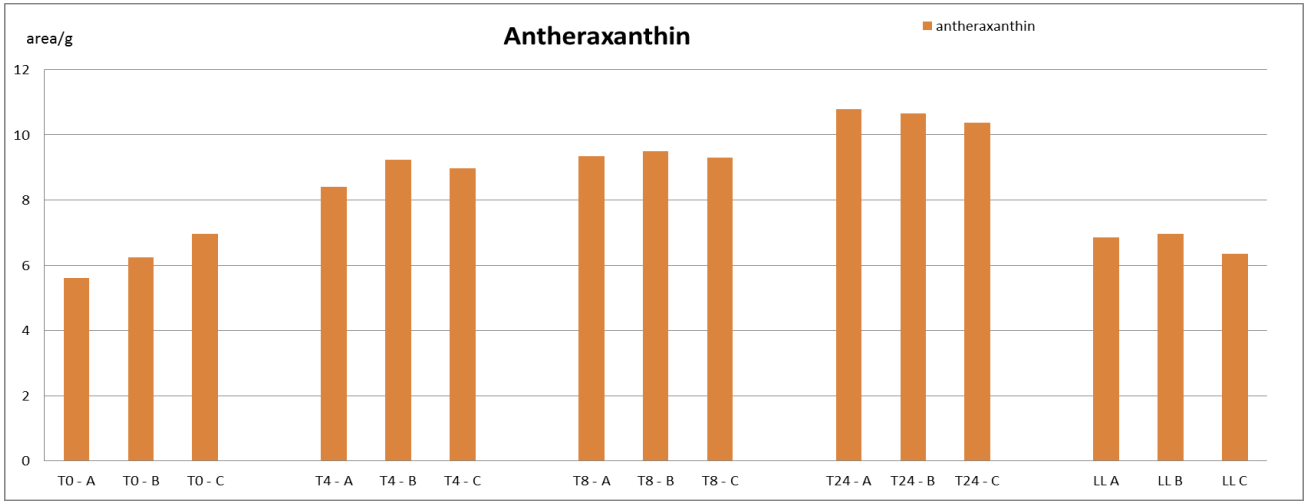

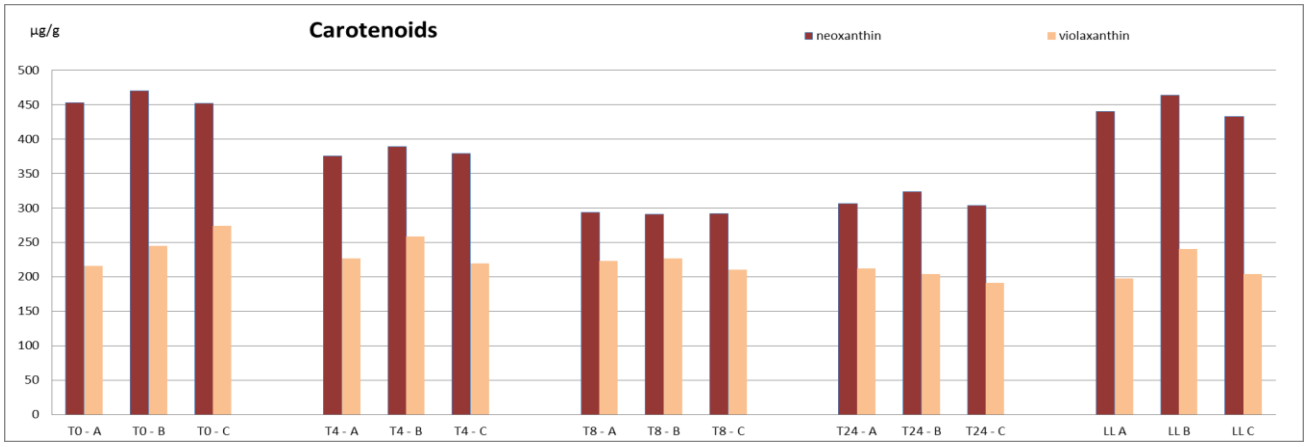

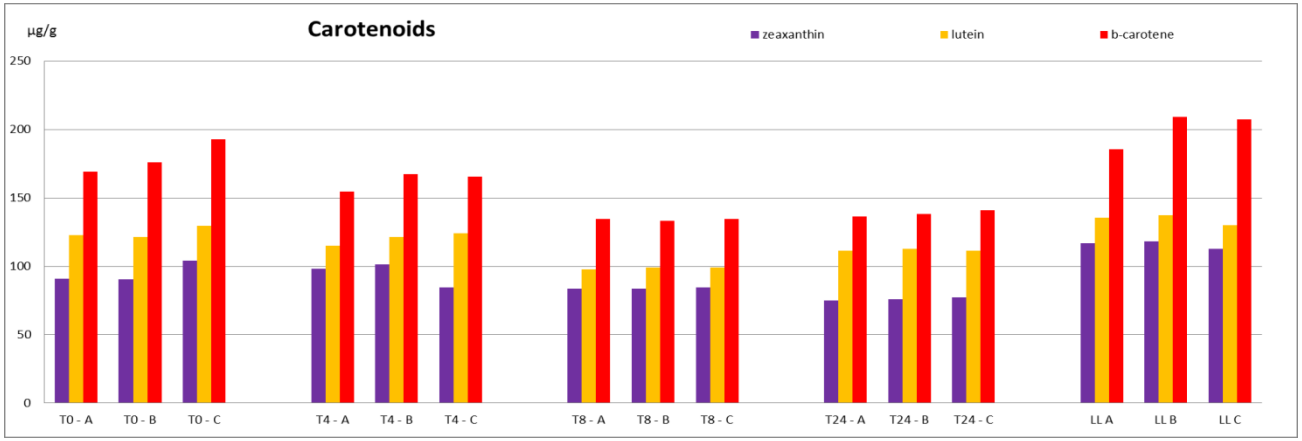

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Future perspective

- Multimodal measurements of various species under different conditions
  - HS, HPLC, RGB, FC…
- Implementation of sophisticated models inside PSI PlantAnalyser
  - MLP, PCA…
- UAV scanning
- Full frame
- Multispectral

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Thank you for your attention

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