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 CRN 53999983
 All currencies in Euros (Ex VAT, Ex Works)

Description of PlantExplorer XS

The PlantExplorer XS has a 5-megapixel high-resolution CMOS- camera to image the efficiency of photosynthesis. By using the two individual blue led strings a saturation and measuring pulse of 4000 $\mu\text{mol m}^{-2} \text{s}^{-1}$ can be produced.

Camera Version

The PlantExplorer XS is equipped with a 5-megapixel (2464 x 2056 pixels), global shutter CMOS- camera. At full resolution the maximum frame rate of the camera is 37.5 images per second. At 2x2 binning this will be 134 frames per second.

Software

The control software is installed on the internal computer to capture different images using pre-defined protocols.

Remote control software is supplied for remotely controlling the PlantExplorer XS using an ethernet connection. By using the remote-control software, the system can be easily integrated into a phenotyping system.

Principles of measurement:

1. **Chlorophyll Fluorescence**
 - a. *Direct CF imaging*
 - b. *PAM Imaging (Pulsed Amplitude Modulation)*
 - c. *Kautsky OJIP Induction Curve Imaging*

a) Direct chlorophyll fluorescence imaging is used to determine the amount of chlorophyll in seeds and plants. The used intensity of the red/amber LEDs can be varied by the user combined with the integration time of the camera to obtain high quality fluorescence images. These chlorophyll fluorescence images are used for correlating chlorophyll with maturity status of seeds and physiological status of plants. Furthermore, these images are used in the analysis software for thresholding objects from the background.

b & c) For imaging photosynthesis, two basic measuring principles can be applied: Pulsed Amplitude Modulation and Kautsky. These two measuring principles can be selected independently of each other. a) During short pulses of measuring light with amber LEDs F_0 is being determined by capturing images during the measuring pulse. A saturating pulse is applied for capturing the maximum fluorescence yield, F_m . From this data different photosynthesis parameters are calculated like F_v/F_m . Actinic light is turned on to measure F_i with the PAM method and applying saturation and short measuring pulses, F_m is being measured in the light. This yields for instance ϕPSII .

c) The Kautsky principle can be applied as a second method to capture chlorophyll fluorescence images of the OJIP induction curve like F_0 , F_i and F_m and calculate different photosynthesis parameters. Before each induction curve is being imaged, the background image is being captured and subtracted from the images captured during the induction curve.

Dark adapted: Plants are measured when they are dark adapted. This yields F_0 and F_m . From this data the parameter that correlates with the maximum efficiency of photosystem II, F_v/F_m , is calculated and presented as an image.

Measured parameters: For PAM F_0 and F_m are being imaged for dark adapted plants. For Kautsky the induction curve is being imaged. This yields F_0 , F_i and F_m images of the OJIP induction curve (F_i depending on used frame rate).

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PhenoVation B.V. is a spin-off company of Wageningen UR and is specialised in the domain of phenotyping imaging equipment.

Light adapted: The same measuring procedure is used for plants in the light to measure parameters that correlate with the effective efficiency of photosystem II, ϕ PSII, ABS and ETR image. Actinic light provides control over the applied spectrum and intensity.

Kinetic analysis: For time resolved kinetic analysis plants are first dark adapted. After the adaptation procedure plants are first being measured in the dark. Then they are continuously illuminated by LEDs. The camera measures the plant when the plant is adapting to the light intensity: induction analysis. Then the actinic light is turned-off and the recovery is measured in time. Images of F_0 , F_m , F_m' , F_t and F_0' are being recorded in time and F_v/F_m , F_v'/F_m' , ϕ PSII, NPQ, q_N , q_P , Rfd, ETR are being calculated.

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Highlights

- PAM- and Kautsky-principle chlorophyll fluorescence imaging
- Single leaf (macro) and whole plant imaging both at 5 Mp
- Provides: F_0 , F_m , F_v , F_0' , F_s' , F_m' , F_v' , F_t
- Kinetic chlorophyll fluorescence images are provided from light adaptation and dark adaptation protocols
- High signal-to-noise ratio of chlorophyll fluorescence images
- Blue 450 nm LED measuring light source used for measuring F_0 and so on;
- pulse width: 10 – 100 μ s / DC
- Blue 450 nm LED saturating light source used for measuring F_m and so on;
- pulse width: 10 – 100 μ s / DC
- LED light source with 730 nm far-red for measuring F_0' etc.
- Measuring distance between plant and camera ranges over a distance from 10cm– 30cm
- Effective imaging area of 18x18 cm²
- High quality Mp lens, with broad band visible and NIR coating
- No visible lens distortion, no correction needed

Acquisition protocols

$F_v/F_m=(F_m-F_0)/F_m$ image that correlates with the maximum quantum yield of PSII photochemistry

ϕ PSII= $F_q'/F_m'=(F_m'-F_s')/F_m'$ image that correlates with the effective quantum yield of PSII photochemistry

NPQ= $(F_m-F_m')/F_m'$ image that correlates with non-photochemical quenching

ABS=image of the absorption coefficient of chlorophyll

ETR = image that correlates with the electron transport rate.

Rfd image

Chfl image: the chlorophyll fluorescence image at relative long exposure time for thresholding plant material from background

Light adaptation curves

Dark adaptation curves

Delivered images by controller software of PlantExplorer XS in raw data 16-bit format

F_0 minimum chlorophyll fluorescence image in dark adapted state

F_m maximum fluorescence image in dark adapted state

F_s' steady state minimum chlorophyll fluorescence image in light adapted state

F_t' instantaneous chlorophyll fluorescence image during light adaptation

F_m' steady state maximum fluorescence in light state

F_m' maximum fluorescence during light adaptation

F_0' minimum chlorophyll fluorescence image during dark relaxation after applying farred

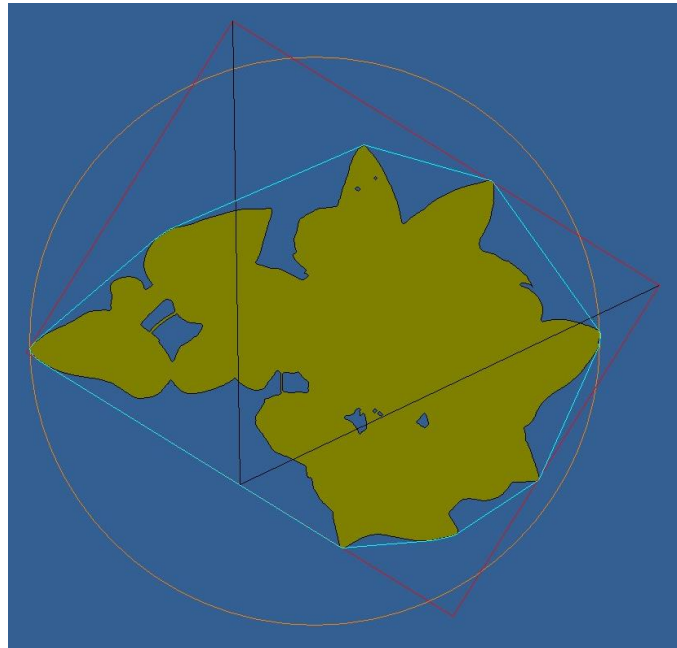
$F_{background}$ for all fluorescence images

R_{NIR} reflectance image at NIR wavelength, 730nm

R_{Red} reflectance image for red at 660nm

Morphological parameters

- **Convex hull**
 - Border
 - Mask / Border
 - Points
 - Area
 - Mask / Area
- **Minimal Circle**
 - X- centre
 - Y- centre
 - Radius
 - Area
 - Mask / Area
- **Minimal Rectangle**
 - Width
 - Height
 - Area
 - Mask / Area
 - Alpha
- **Skeleton**
 - Size
 - Junction
 - Endpoint
 - Path



Specifications of PlantExplorer XS

Image acquisition time

Single chlorophyll fluorescence image	10-100 μ s (or up to 20 seconds depending on application)
Total induction curve	1000 ms yielding 35 images

PAM

Two independent sets of blue LEDs for pulsed modulated measuring and saturating light pulse imaging

Measuring Light

Type	LED (light emitting diodes)
Wavelength	450 nm
Intensity	0-4000 μ mol m ⁻² s ⁻¹ , controllable in intensity and pulse width

Saturating Light

Type	LED (light emitting diodes)
Wavelength	450 nm
Intensity	0-4000 μ mol m ⁻² s ⁻¹ , controllable in intensity and pulse width

Kautsky measuring light

Type	LED (light emitting diodes)
Wavelength	450 nm
Intensity	0-4000 μ mol m ⁻² s ⁻¹ , controllable in intensity and pulse width

Actinic light for time resolved kinetic analysis

Type	LED (Light Emitting Diodes)
Wavelength	660 nm,
Intensity	0-800 μ mol m ⁻² s ⁻¹ controllable in intensity

Farred light source

Type	LED
Wavelength	735 nm

Imaging area

Imaging area	18cm x 18cm
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Camera

Type of sensor	monochrome CMOS global shutter
Number of pixels	5 Mp
Number of grey values	12-bit or 4096 grey values per pixel
Standard frame rate	37.5 fps
Format	16-bit RAW format
Spectral range	350-1000 nm
Interface	USB 3.0

Lens

Type of lens	high quality Megapixel lens
Lens mount	C-mount
Focal length	8 mm
Spectral range	400-1000 nm; high transmission from visible to NIR

Remote control

Connection	RJ45 TCP/IP
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Dimensions and mass

Width x depth x height
frame)

26cm x 26cm x 27cm (63cm when used as standalone system including bottom

Weight

20 kg

Electrical power camera

Requirements

AC Voltage from 110-230

Consumption

Peak: 1000 W during measurement of CF images

Standby

35 W