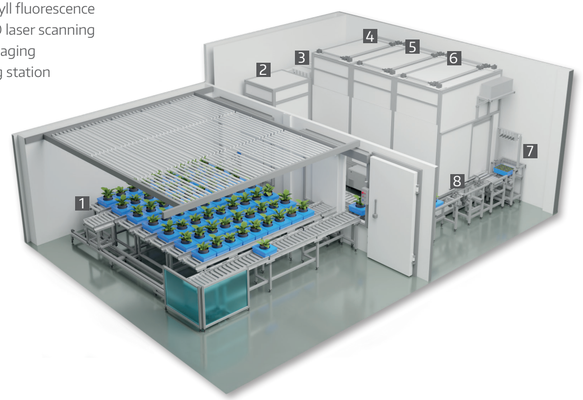
The Shoot Phenotyping System is designed for non-invasive, morphometric and physiological high-throughput phenotyping of mid-size crop plants with dimensions up to 1,000 × 50 cm (H × W). Helios system is fully integrated into a state-of-the-art walk-in FytoScope chamber providing highly homogeneous plant growth condition in two individually controlled compartments, i.e. cultivation area and imaging area. The Helios system is customized for efficient operation with modular PlantScreen transportation trays and it can accommodate a maximum of 1,260 pots with small size plants as *Arabidopsis* at full capacity.

Within the HELIOS infrastructure, plants are transported on conveyor belts from the growth area to the imaging area equipped with automatically operated state-of-the-art sensors integrated into light-insulated imaging cabinets. Cutting-edge imaging sensors include multispectral chlorophyll fluorescence, RGB, VNIR/SWIR hyperspectral, thermal and 3D. The imaging units are physically separated from the growth area facilitating the parallelization of measurements via a sample loop and thus improving the throughput, flexibility and sensor utilization.

Layout Schematics

1. Cultivation area
2. Pre-adaptation with laser height bar
3. Light/dark adaptation tunnel
4. Multispectral chlorophyll fluorescence
5. Multiangle RGB and 3D laser scanning
6. VNIR Hyperspectral imaging
7. Watering and weighing station
8. Imaging area



PHOTON SYSTEMS INSTRUMENTS

SEEING BEYOND THE SURFACE

PLANTSCREEN™

Shoot Phenotyping System HELIOS

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UNIVERSITEIT UTRECHT, UTRECHT, NETHERLANDS

PlantScreen™

Shoot Phenotyping System (Helios)

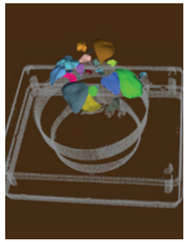
UNIVERSITEIT UTRECHT, UTRECHT, NETHERLANDS

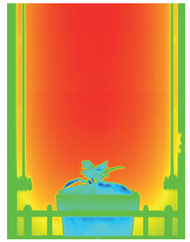
Description: PlantScreen™ Modular System
Location: Universiteit Utrecht, Utrecht, Netherlands
Installed: 2023

Helios is designed as modular fully autonomous front-to-end solution for phenotyping of above-ground properties of plants from *Arabidopsis* to crops. Between 63 and 1,260 plants can be grown on soil pots from 250 ml to 5L with a maximum height of 100 cm under controlled environmental conditions with automated plant handling, precise irrigation, and phenotyping via 3D laser scanning triangulation and RGB, fluorescence, and VNIR hyperspectral imaging.

System overview

Type of the system	PlantScreen™ Modular Systems
Capacity of the system	63 trays accommodating 1,260 pots
Tray types	PlantScreen trays with modular lid system to accommodate 1x5L pot, 2x 3L pots, 4x 2L pots, 4x 1L pot, 20 x 250 ml pot
Cultivation area type	Growing buffer with 7 lines, 9 trays per line with state-of-the- art illumination in the ceiling, providing high intensity and homogeneity over entire cultivation area
Cultivation lights	LED with independently controlled setting for each color channels
Light quality & intensity	Cool white (5,700 K), up to 500 µmol/m²/s at 50 cm distance + deep red (660 nm) + far red (735 nm) optimal R:F ratio 0.50 – 0.82
Application station	Automated watering ad weighing station
Adaptation tunnel	Cool white (5,700 K), up to 500 µmol/m²/s at 50 cm distance
Rating and applications stations	RGB Morphometric imaging, 3D laser scanning, Multispectral chlorophyll fluorescence imaging, VNIR hyperspectral imaging





Biosafety Walk-in Climate Chamber

The Helios Phenotyping System is installed inside a FytoScope controlled environment with GMO containment zone. The FytoScope chamber regulates temperature (+10 to +40 °C), relative humidity (40 % to 80 %) and CO_2 (ambient – 1,500 ppm). Actual inside conditions and target values for temperature and relative humidity are permanently displayed on the touch-screen controller. All monitored data may be downloaded to a PC and accessed remotely.

Cutting-Edge Imaging Sensors

PlantScreen™ Imaging Sensors are complete integrated solutions for non-invasive analysis of plant specific patterns of absorption, emission and reflection. Digital trait assessment is based on analysis of wide range of electromagnetic radiation wavelength bands: visible range of spectra is detected by RGB cameras for structural and color analysis, hyperspectral cameras in visible, near-infrared and short wavelength infra-red range of spectra are used for reflectance-based analysis of plants, thermal imaging cameras are optimized for leaf temperature and stomata conductance analysis, kinetic chlorophyll fluorescence imaging sensors for analysis of plant photosynthetic performance and multicolor fluorescence signals.
An integral part of the process involves the automated image analysis pipeline on the level of each individual plant object.

Optimized Growth Environment

High-precission irrigation system is integral part of the system for programable delivery of both water and nutrients to the plants throughout growth and/or measurement cycles. Watering and nutrient delivery may be combined with programmable regimes of automated weighing of plants in pots. These regimes may be used to impose, e.g. drought stress or waterlogging of varying degrees of severity, imposed rapidly or gradually. Water application is gentle, without spillage or splashing of soil, and is adjustable for the different pot sizes. Schemes for watering to exact volume, relative volume or predefined weight can be set for single plants or groups of plants.
In addition comprehensive suite of environmental sensors (humidity, temperature, light intensity, light quality, CO_2 concentration, pH) is available for the PlantScreen™ Phenotyping Systems. The parameters deduced from the measurements acquired by imaging units can be correlated with the environmental parameters acquired from a number of environmental sensors implemented.

Experimental Management SW toolbox

Comprehensive software package has been developed for system control, data acquisition, image analysis and database configuration. A user-friendly graphical interface has been designed to manage and control all actions of the hardware system components, tomonitor environmental conditions and to design experiments with an extremely high level of flexibility. High-end industrial PC with a touch screenis used for system control. Scheduling assistant with calendar function allows running multiple experiments simultaneously, provides different modes for experiment randomization, for treatment per plant or group of plants with different experimental protocols and plant handling regimes including dark/light adaptation or watering and nutrient delivery schemes.

UNLOCKING THE FEASIBLE STUDY OF PLANT-MICROBE INTERACTIONS

ADVANCED HIGH-CONTENT IMAGING OF CHLOROPHYLL FLUORESCENCE AND FLUORESCENT PROTEINS

STATE-OF-THE-ART DYNAMIC MEASUREMENTS OF PLANT PHENOTYPES

FULLY AUTOMATED MODULAR SHOOT SCREENING SYSTEM OF SOIL CULTIVATED PLANTS