

PLANTSCREEN™

Agar Root Phenotyping System



Fully automated root and shoot
screening system on agar plates

Agar Root Phenotyping System (Hades)

UNIVERSITEIT UTRECHT, UTRECHT, NETHERLANDS

Description: PlantScreen™ Robotic Root System

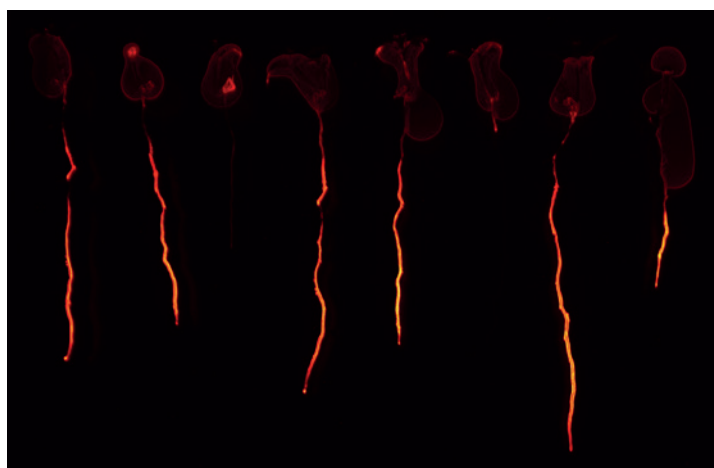
Location: Universiteit Utrecht, Utrecht, Netherlands

Installed: 2023

The Agar Root Phenotyping System is a groundbreaking solution that redefines approaches to root research. Powered by cutting-edge robotic technology, the system seamlessly handles PSI-developed Petri plates 24/7 throughout the entire phenotyping process, from pouring agar and robotic seed sowing to application of bacteria at the root-stem interface, to phenotypic evaluation at different imaging stations.

System overview

Type of the system	Automated robotic platform
Capacity of the system	2,160 Petri plates
Tray types	PSI Petri plates square format 129 x 129 x 16.5 mm
Cultivation area type	Growth Hotel: 4 shelves/hotel, 9 cassettes/shelf, 20 plates/cassette
Cultivation layout	3 x Growth Hotels with total capacity of 2,160 plates
Cultivation lights	LEDs with independently controlled color channels, independent control in each shelf
Light quality & intensity	Cool white, up to $400 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ at 30 cm distance Deep-red & FAR - optimal R:F ratio 0.50 – 0.82
Sample preparation station	Plate Preparation Table: fully automated agar pouring and integrated seed sowing robot
Application station	Liquid Handling: automated bacteria pipetting and dispensing
Rating stations	Morphometric imaging, 2x Chlorophyll and multispectral fluorescence imaging, Transmission and fluorescence VNIR hyperspectral imaging

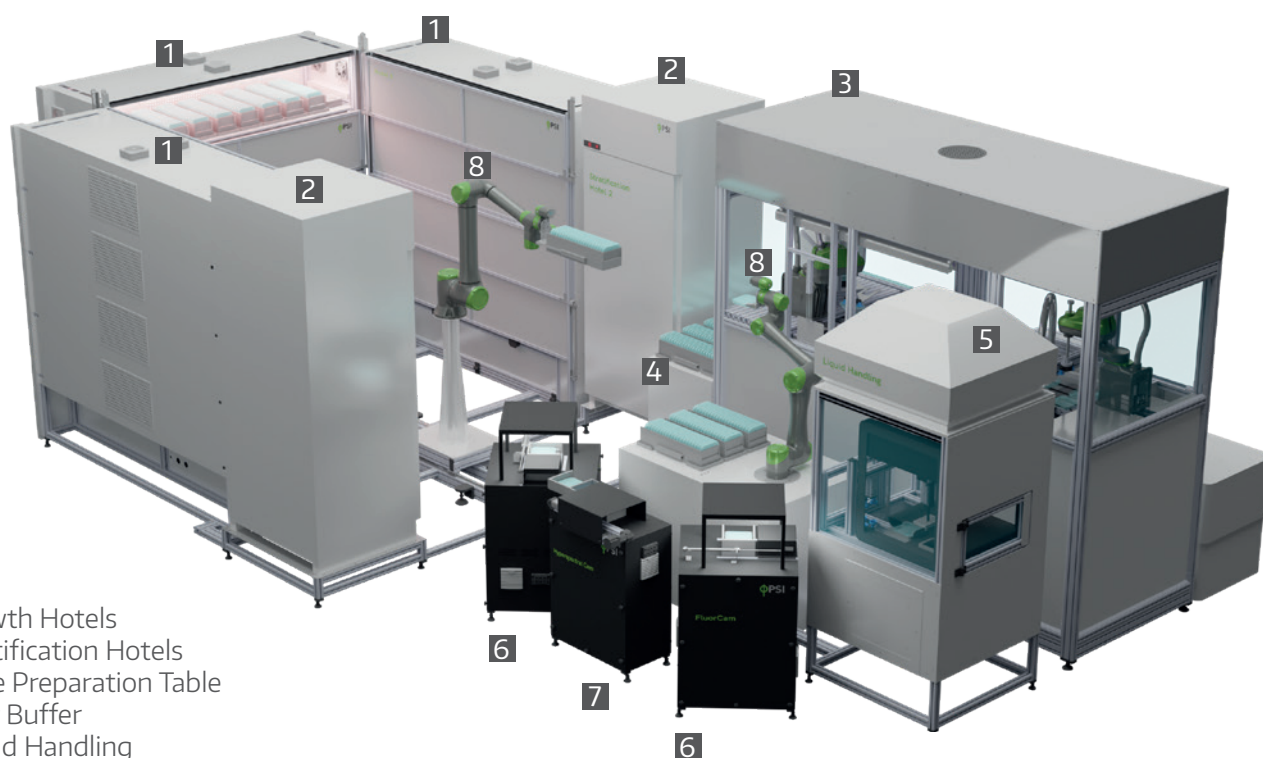


The Agar Root Phenotyping System is designed for high-throughput, automated, software-controlled phenotyping of plants grown *in vitro*. The Hades system is customized for efficient operation with PSI developed square Petri plates, and can accommodate a maximum of 2,160 plates at full capacity.

The Agar Root Phenotyping System is engineered to offer a comprehensive end-to-end workflow solution requiring no human intervention. The process initiates with sample preparation and cultivation, encompassing tasks such as media pouring and automated robotic seeding. It progresses through stratification at 5 °C to long-term cultivation of

samples in “Growth Hotels”. Complete automation through robotic manipulation facilitates the integration of multiple imaging stations. These enable continuous non-invasive monitoring of root morphology, the detection of expression of various fluorescent proteins in plant roots, and the measurement of chlorophyll fluorescence kinetics in plant shoots. Uniquely, the system also includes fluorescence hyperspectral imaging of coumarins production. Additionally, it incorporates an application station that enables the sterile application of bacteria to a specified root site. The entire system is designed with an emphasis on sterility, and manipulation with GMO plants and bacteria.

Layout Schematics



- 1 Growth Hotels
- 2 Stratification Hotels
- 3 Plate Preparation Table
- 4 User Buffer
- 5 Liquid Handling
- 6 Chl & Multispectral Imaging
- 7 VNIR Hyperspectral Imaging
- 8 Robotic arm



Biosafety Walk-in Climate Chamber

The Agar Root Phenotyping System is installed inside a FytoScope controlled environment with a GMO containment zone. The FytoScope chamber regulates temperature (+10 to +40 °C), relative humidity (40 % to 80 %) and CO₂ (ambient – 1,500 ppm). The conditions inside, and the target values for temperature and relative humidity are permanently displayed on a touch-screen controller. All monitored data may be downloaded to a PC and accessed remotely.

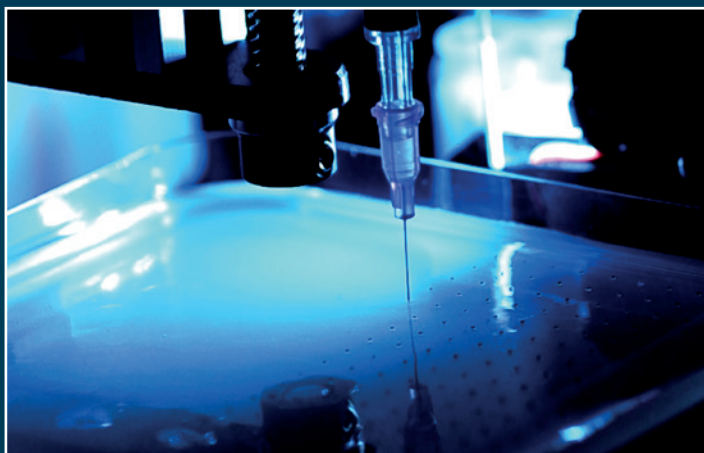


Unique Bacterial Inoculation

The Hades system maintains exceptional chamber sterility, and facilitates direct pipetting of bacteria onto plant roots. This opens up a new frontier in research, enabling automated exploration of plant-microbe interactions.

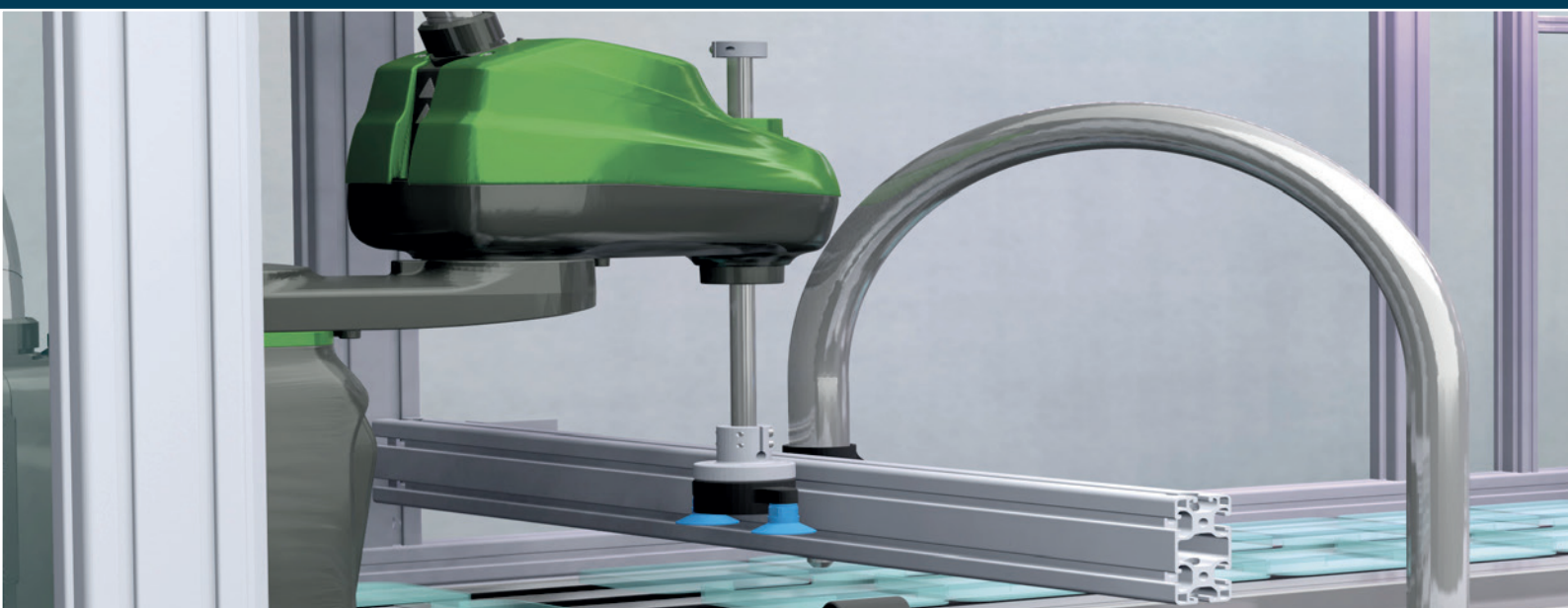
Effortless Plate Preparation

A crucial component of the Hades system is the Plate Preparation Table. This remarkable engineering achievement provides seamless, fully automated sample preparation in a sterile atmosphere established through HEPA-based air filtration and UV-C sterilization. The table is capable of accommodating up to 1,500 sterile Petri plates. The cutting-edge platform is equipped with an automated agar pouring mechanism, guaranteeing precise filling of media from a commercial media preparation device. The station relies on two SCARA robots and conveyor belts to manage all aspects of sterile plate handling, eliminating the need for human intervention. Additionally, the platform includes a seeding robot, Boxeed, which sows seeds onto the agar in precise accordance with predefined parameters. The process involves image analysis of each seed to identify and select viable individuals.



**UNLOCKING THE FEASIBLE STUDY OF
PLANT-MICROBE INTERACTIONS ETC.**

**HIGH-CONTENT IMAGING OF MULTIPLE
FLUO PROTEINS & CHLOROPHYLL**

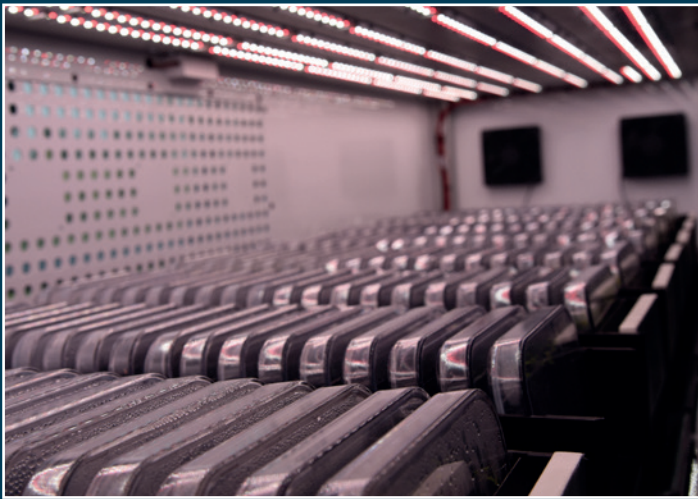


Optimized Growth Environment

A dedicated shelving cultivator (Growth Hotel), was designed for the cultivation plant material on Petri plates. Within each Hotel, there are 4 shelves, each accommodating transport cassettes that each hold 20 plates. With the ability to hold 9 cassettes on each shelf, the total capacity of each Growth Hotel is an impressive 720 Petri plates.

The Growth Hotel is equipped with multichannel LED illumination. Irradiance (up to $400 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$), spectral quality and specific light regimes are adjustable for each shelf and each color channel separately via a user-friendly interface.

A dedicated section within the growing space is responsible for controlling seed stratification at a precisely maintained temperature of 5°C .



Cutting-Edge Imaging Technology & Analysis

Guided by robotic arms, the samples are moved from the cultivation hotels to imaging stations for the study of root and shoot development. These stations capture chlorophyll fluorescence data, and compounds such as fluorescent proteins (GFP, YFP, RFP, mCherry) and coumarins are visualized without sample disruption. Hyperspectral cameras provide an extra layer of imaging sophistication, revealing the biochemical status of samples.

The state-of-the-art AI technology is utilized to analyze traits from the acquired images. The software employs one of the most renowned computer vision methods, Convolution Neural Networks (CNNs), to effectively segment root objects from the background.



REVEALING MOLECULAR INSIGHT WITH SPECTRAL METABOLITE IMAGING

CUTTING-EDGE NEURAL NETWORKS BASED IMAGE ANALYSIS



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