Zealquest Asia

Zealquest Group Company

LemnaTec
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PHENOAIXPERT HT

High Throughput Plant-to-Sensor Phenotyping

LemnaTec AIxpert Product Family

Documentation, Phenotyping, Seed Testing and more

PHENOAIXPERT HT

The Automated Conveyor-Based Multi-Sensor Phenotyping System

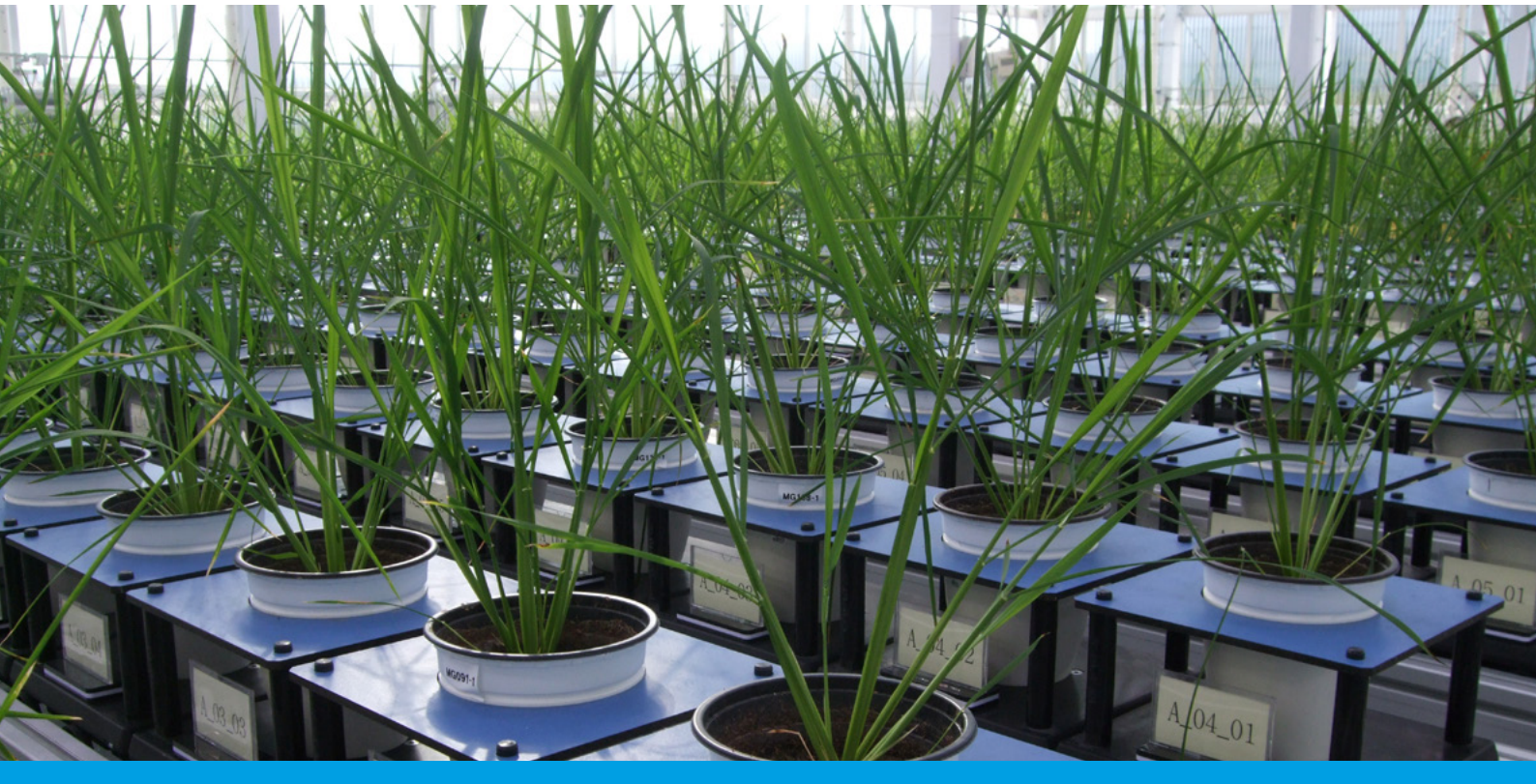
PhenoAIxpert HT is LemnaTec's flagship phenotyping system with highest flexibility in capabilities for phenotyping applications. Over 20 installations worldwide and more than 200 scientific publications referring to applications illustrate the range of capabilities of the system.

PhenoAIxpert HT is a high-throughput plant-to-sensor phenotyping system with conveyors that move plants through imaging cabinets and weighing/watering units. With large sample numbers, advanced statistical analyses, and comparisons across genotype- and treatment-groups are enabled. Systems are customized according to the customers' measuring demand, plant properties, and edificial conditions[1]. Systems have been built for plants as small as Arabidopsis up to the range of fully-grown maize and sugar cane plants.

PhenoAIxpert HT Key Facts

- Automated high-resolution plant phenotyping at high throughput
- Large portfolio of cameras available
- Phenotyping software for comprehensive trait analysis
- Machine learning available for complex traits
- Large sample numbers facilitate enhanced statistics
- Plants in pots, boxes, or trays on carriers
- Conveyors move samples through imaging cabinets
- More than 1000 sample carriers possible in one system
- Horizontal and/or vertical imaging of shoot system
- Automated Weighing and watering
- Optional supply of liquid fertilizer[2]
- Root imaging options with transparent pots, columns, or boxes with transparent plates

[1] A technical feasibility check is required before installation.
[2] Chemical properties of liquids must be compatible with the technical equipment.



Applications

The broad options for imaging in PhenoAIxpert HT, combined with the comprehensive capabilities of image analysis in the corresponding LemnaTec software package enables several applications in research, product development, or monitoring. Typical application cases are:

- Studies on growth and development
- Genotype-phenotype relations
- Genetic screening
- Treatment screening
- Environmental responses
- Stress- and disease assessments
- Root-shoot-relations
- Root interactions

Technical Features

- High-resolution cameras and sensors[3], combined with customized illumination (if applicable)
  - Visible light imaging
  - Dynamic chlorophyll fluorescence imaging
  - Fluorescence imaging
  - NIR imaging
  - IR imaging
  - Multispectral imaging
  - Hyperspectral imaging
  - Laser scanning
- Turner-units for multi-view imaging
- Horizontal and vertical scanning units to operate hyperspectral cameras and laser scanner
- Conditioning tunnel for pre-darkening or pre-illumination before chlorophyll fluorescence imaging
- Conveyors to move samples through imaging cabinets and weighing/watering stations
- Cabinets and conveyors available in a range of dimensions adapted to sample sizes
- Carriers for a range of pot sizes and geometries, for trays, or root-view enabling containers
- Database for plant data and metadata
- Software package for system control, data recording, and image analysis

[3] The full set of desired sensors should be considered before installation – even if not all are acquired in the beginning – as mounting space and technical requirements must be planned. It is not guaranteed that additional sensors can be added to an existing system.

Size Ranges of Samples Suitable for Conveyor Systems and Cabinets in PhenoAIxpert HT

The technology of PhenoAIxpert HT – namely the imaging cabinets and conveyors – can accommodate a broad range of sample sizes. When planning a PhenoAIxpert HT system, it is important to know about the expected range of sample dimensions, as these determine the size of the conveyor system and the footprint and height of the imaging cabinets. In addition, sample dimensions are important to correctly choose the optics for the camera systems.

As the PhenoAIxpert HT normally is used for plants in pots or trays, the dimensions of the potted plants are important. The following parameters are key for system determination:

- Sample height – from bottom of the pot (or tray) to the tip of the plant
- Sample width or diameter – width of pot or tray, and of the outgrowing plant, particularly if this exceeds the width of the pot itself
- Weight of the sample, mainly determined by the weight of moist soil filled into the pot/tray. Here it is important to know the weight of the water-saturated soil filled into the pots

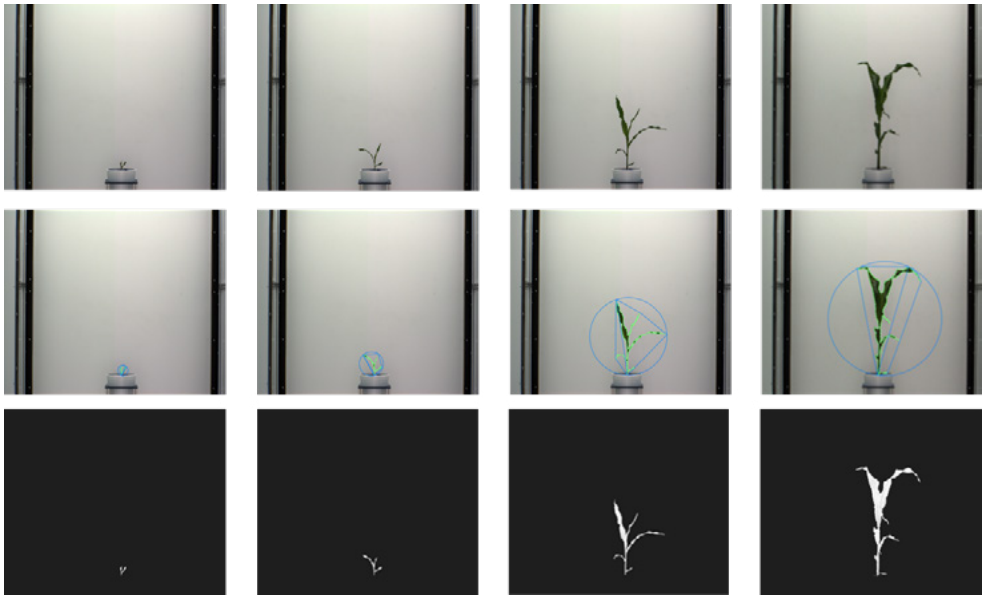
Image Recording and Processing

PhenoAIxpert HT can accommodate a large selection of imaging and scanning devices. Images and scans taken with the hardware of PhenoAIxpert HT can be processed with system's software package. Each camera type delivers a typical set of parameters through image processing. The parameters depend on the physical sensing principle of the camera/sensor system and relate to the bio-physical properties of the sample. These parameters can be interpreted for biological features of the sample. For proper interpretation, background information on the samples is required, so the given interpretation examples may differ from the data interpretation in the users' work. In many cases, interpreting parameters is not a direct measurement of a sample's feature, but an indirect indication that requires a mathematical model for relating measured parameters with sample properties. Therefore, calibration experiments are required that deliver information how to interpret the parameters with the given samples.

Imaging Options, Image Processing Parameters, and Application Examples

Imaging and image processing with hardware and software		Data use in applications (examples) - derived biological information
Sensor	Measured parameters	
RGB VIS	count size shape colour	growth biomass development stress activity
Laser scanners	3D point cloud	height growth three-dimensional structure
Hyperspectral cameras	spectrally resolved images (VNIR, SWIR)	physiology pigments water status stress diseases vegetation indices
Multispectral cameras	images of reflectance by wavelength	physiology pigments stress diseases vegetation indices
PAM camera	chlorophyll fluorescence	photosynthetic parameters
Fluorescence cameras	emission of fluorescence light after excitation	abundance, localization of fluorescence pigments or fluorescence-labelled material
IR camera	surface heat emission / temperature	water stress transpiration
NIR camera	spectral reflectance at water band	water content

Images can be taken in time courses so that developmental stages of the plants can be monitored. For each plant at each recording time, the system provides phenotypic traits according to the image analysis carried out with the analytical software.

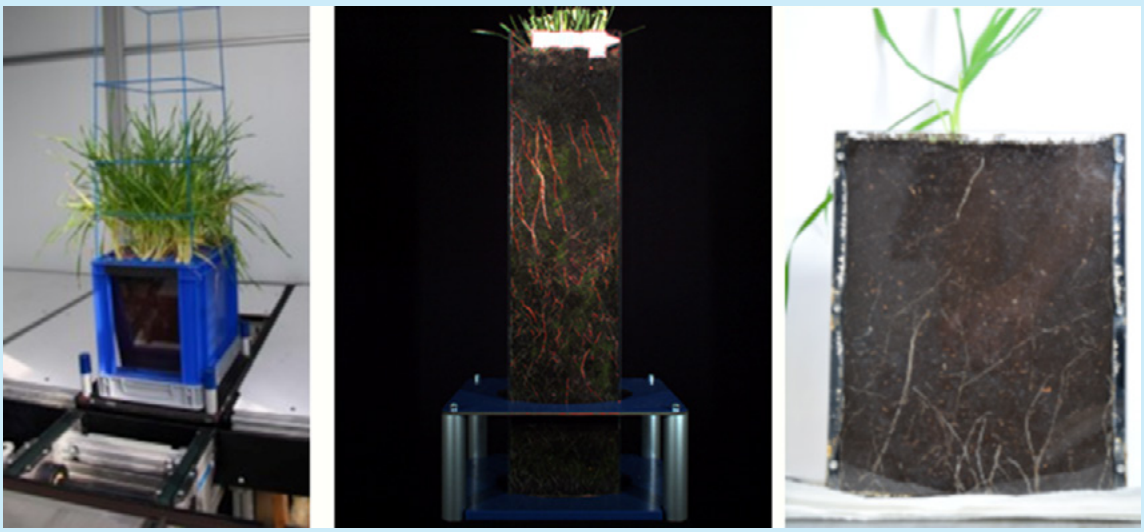


Samples Suitable for PhenoAIxpert HT

The PhenoAIxpert HT is designed for plants in pots. The pots are placed on carriers that are moved by conveyors from the growth area to the imaging cabinets. Conveyors and carriers are available in different size[4] ranges, according to the plant species and growth stages that are analyzed with the system. Pot carriers standardly harbour one pot, but adaptors are available that allow inserting multiple pots or trays. In configurations for more than one pot, or for a tray with more than one plant, it is not guaranteed that all plants are completely visible to the cameras.

Pots in carriers on conveyor systems with imaging cabinets; carriers can have adaptors for one or more pots.

For root measurements, PhenoAIxpert HT can carry different types of sample containers, including transparent pots, transparent columns, mini-plot boxes with transparent sides, or flat rhizoboxes. Each of these requires specific carriers and imaging systems[5]. The choice of the root-displaying container depends on the intended application case.



Containers dedicated for root imaging: miniplot box (left), transparent column (center), rhizotron box (right).

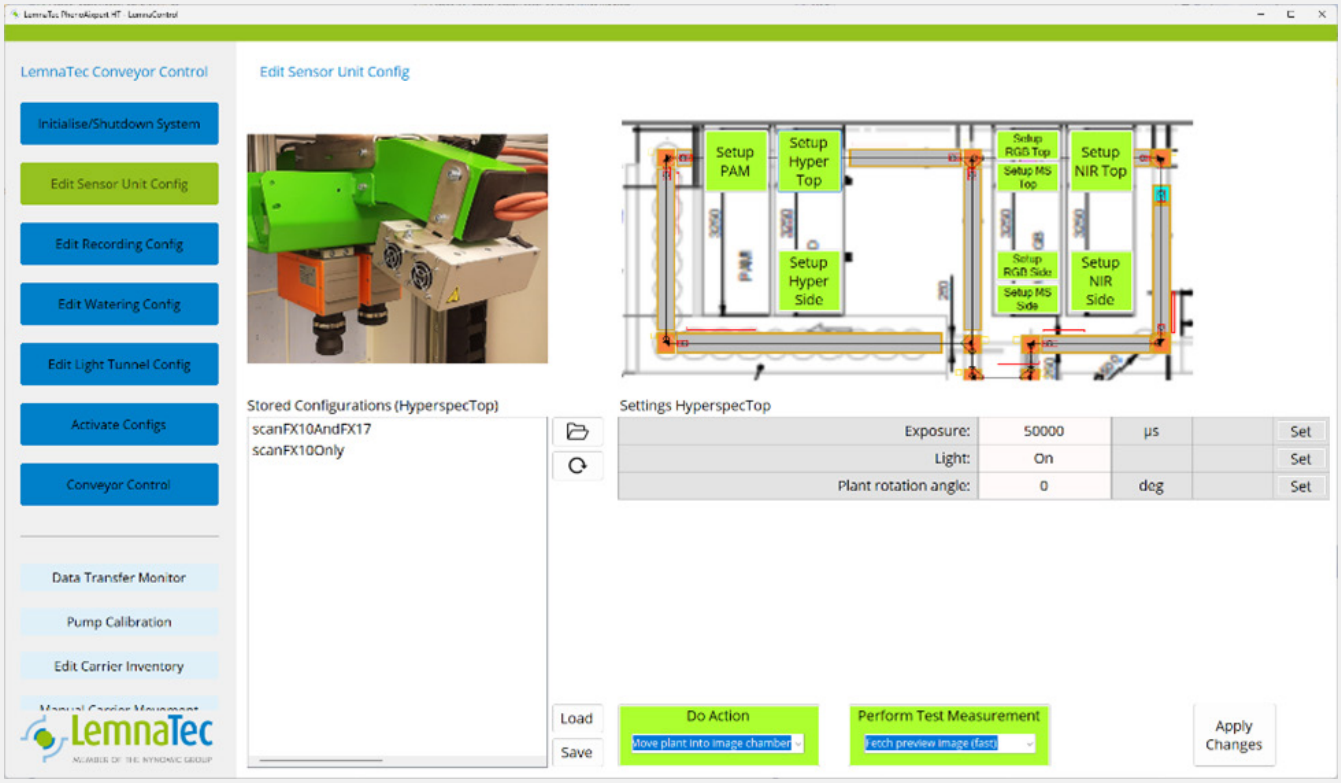
[4] Sizes must be determined before ordering the system.
[5] Root imaging capabilities should be considered before installation, because technical constraints might prevent adding root imaging capabilities to existing systems.

Weighing and Watering Options

With automatic weighing and watering together with fertilizer supply any plant in the system can be provided with pre-defined amounts of water and nutrients. A gravimetric monitoring of water use is provided. Moreover, it is possible to set customized irrigation- and nutrition- scenarios, e.g., for stress assessments that rely on water- or fertilizer-shortage. For growth containers enabling root view, the water supply might require specific technical adaptations.

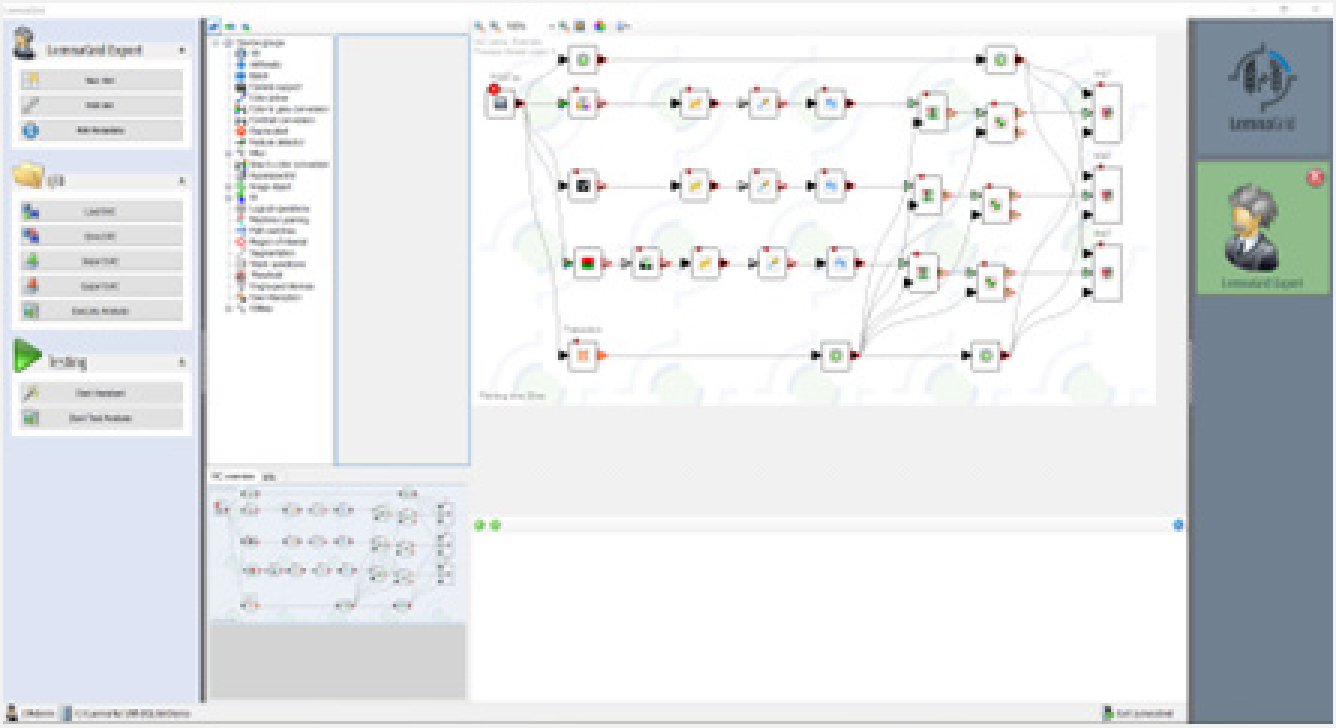
Software Package Provided with the System

Beyond system control and technical settings in LemnaControl, the software[6] enables comprehensive management of experiments and analyses via LemnaExperiment. Analyses can be programmed using LemnaGrid and Lemna 3D, and analysis results can be visualized and exported using LemnaExperiment.

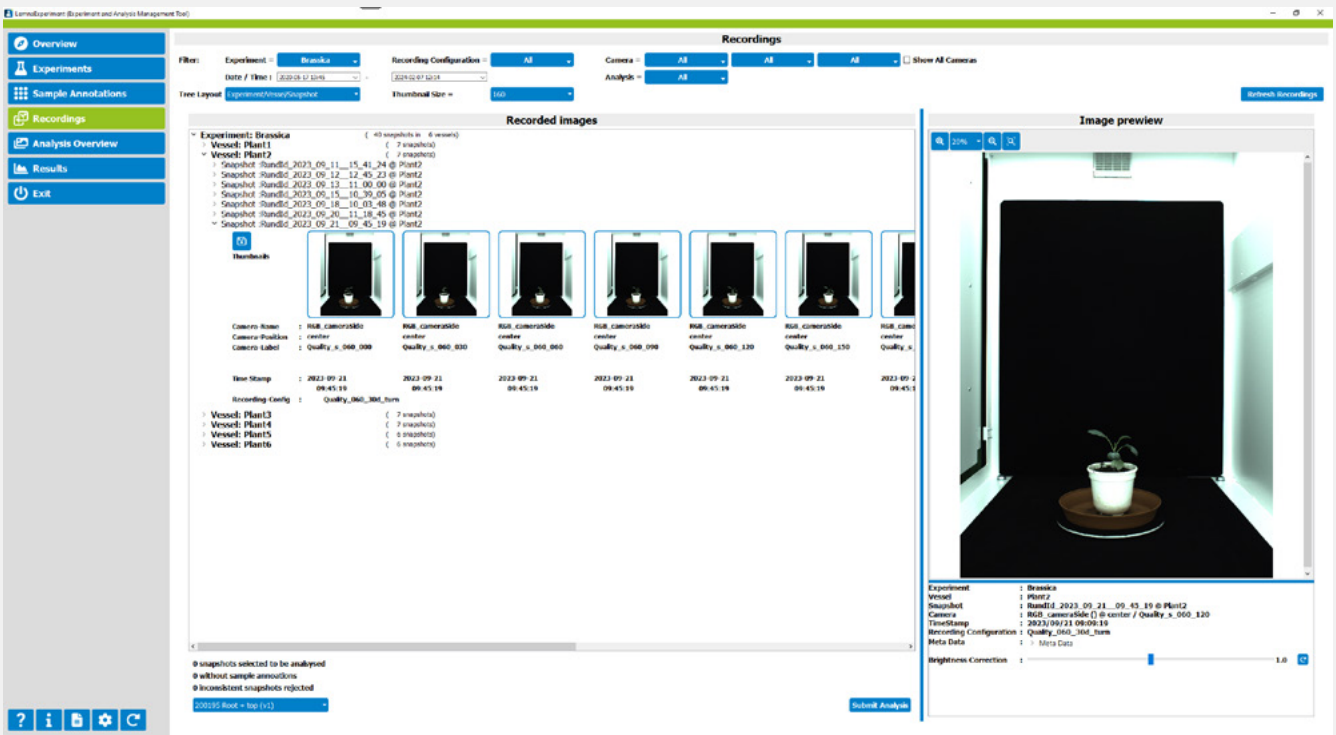


LemnaControl enables settings for cameras, lights, moving parts, weighing, and irrigation systems. With these settings, users can control image recording with all cameras and sensors in the system, combined with transporting the plants to the imaging stations. Moreover, supply of water and fertilizer can be controlled and scheduled at weighing and watering stations.

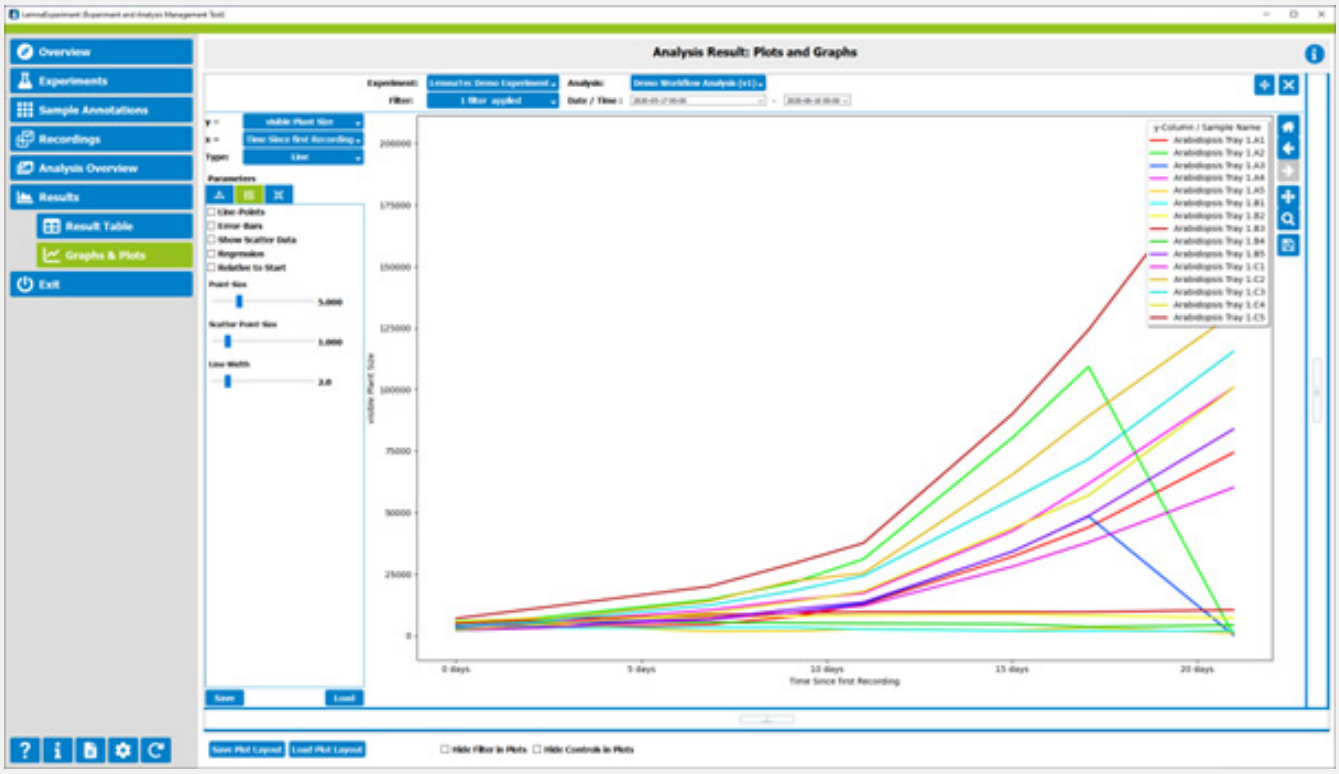
[6] For details on software, see our Software Brochure



In LemnaGrid, image processing pipelines can be programmed and modified using a broad range of devices. These devices can be combined on a graphical interface to set up processing steps that convert recorded images into numerical values. The programmed pipelines are called by LemnaExperiment to process sets of recorded images.



In LemnaExperiment, recordings and experiments can be managed and reviewed. Annotations can be provided to experiments, samples, and recordings. The core function is defining and running image analyses. Therefore, image processing pipelines – programmed in LemnaGrid – can be called to run with defined sets of recordings.



Results of image processing can be visualized in graphs and exported numerically as csv-tables. Transfer of data to common database formats is available.

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