PHENOSPEX

PHENOSPEX

a new PERSPECTIVE in PLANT PHENOTYPING

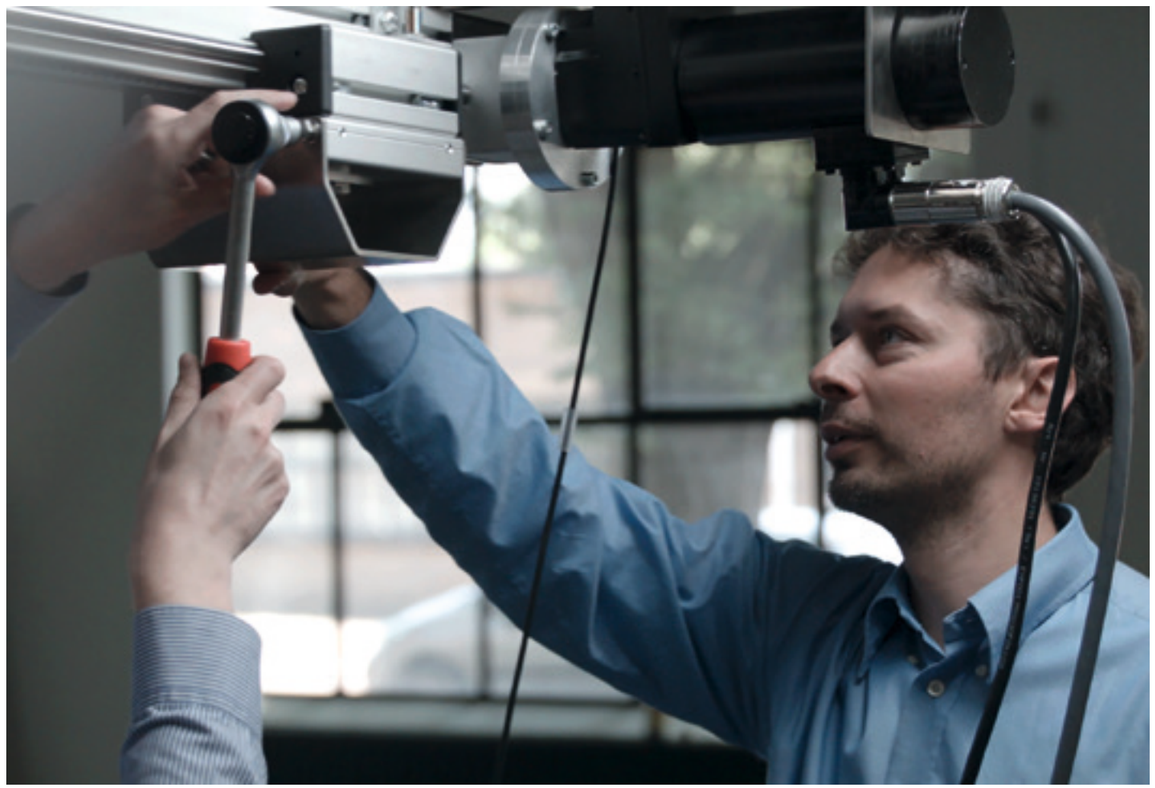
Why we develop tools for automated plant phenotyping

Thanks to the genomic revolution, we now know that the function and interaction of genes is much more complex than we had ever expected. This insight has been terrifying and fascinating, because it reveals to us – in far greater detail than we had ever known before – the nature of the problem that we as a species must solve if we are to feed the people of our planet in the years to come.

It is our belief that only by pursuing knowledge gained through plant phenotyping, and by asking the right questions, can we come up with an appropriate response. We provide plant phenotyping tools and data analysis capabilities to the biologists, breeders and growers who are daily seeking answers to the most important biological questions. Our key objective, therefore, is not to develop technology by itself and for itself, but to provide scientists with the tools and the necessary infrastructure to extract meaningful information from the data they collect.

To meet this challenge, we work closely with our customers and partners, whose expertise spans a wide range of disciplines, to come up with the best new ideas. We optimize our products so they are useful, not only now, but in the future. We believe it's time for a new perspective in plant phenotyping.

Our aim is to provide you with automated phenotyping tools that will help to answer your biological questions.



Connecting plant science with quality engineering

Phenospex was founded by Grégoire Hummel, Philipp Tillmanns and Uladzimir Zhokhavets in 2011. Grégoire Hummel is a plant ecophysiologist. He earned his PhD at the Research Center in Jülich, where he examined plant growth and function in dynamically changing environments. Uladzimir Zhokhavets is a physicist who specializes in optics and semi-conductors. Prior to Phenospex, he worked at Philips Research in Aachen. Philipp Tillmanns, an economist, was at the Boston Consulting Group before he joined our team. Today, we are an intercultural team with a diverse set of expertise. Our competencies include plant biology, agronomy, physics, computer science and even psychology.

What we provide for you

We provide state of the art technologies and know-how for phenotyping applications ranging from indoor phenotyping to fully automated field platforms. With our core expertise in 3D scanning, gravimetric systems and data analysis, we provide simple but functional solutions to improve your research and plant breeding activities.

Phenospex products are made and optimized for automated plant phenotyping in challenging environments. We keep our products simple to ensure high reliability, easy handling and cost-efficient operation. Since most of our customers are breeders or scientists, rather than focus on the technology by itself, we focus on the specific applications of our products. For us, phenotyping is a tool. It should, therefore, be easy to use and should exist to solve a problem. In other words, we believe that it should be highly automated, easily integrated into existing platforms, and designed for open access to the data that it stores – on any level.

In order to maintain the highest standards of quality, all of our products are designed and manufactured in house. Our commitment to the entire product development process has led to us having a unique understanding of the advantages of different concepts in plant phenotyping and to the creation of a truly outstanding product portfolio. In just a few short years, we have extended our core expertise from 3D screening with Phenospex PlantEye in greenhouses and growth rooms to large-scale screening platforms in the field, with FieldScan. Using our unique and highly automated DroughtSpotter platform, which uses a gravimetric approach to track the loss of water, we have been able to assess water use efficiency and other drought relevant traits in controlled environments and in the field.

We believe in the future of advanced data analysis for plant phenotyping, as raw data acquisition is not the key for better plant phenotyping. All of our parameters are validated in scientific experiments and provide meaningful information. We support data flow in any direction and can provide advanced statistical analysis tools in the R-Project.

We focus on the research question, not simply the technology.

PHENOSPEX **PRODUCTS**

01

PlantEye
is a high-resolution 3D laser scanner specially designed for plant phenotyping in all environments. PlantEye follows the sensor-to-plant-concept, allowing the phenotyping of plants growing in fields or in any other setting where plants can't be moved.

02

FieldScan
is a high-resolution and high-throughput field phenotyping machine that can screen thousands of plants or plots per hour. Its sensor carrier device moves dedicated sensors across the field and measures plant parameters in combination with environmental parameters.

03

FieldScale
allows you to measure transpiration rates of large potted plants in greenhouses or in the field. Hundreds of scales can be installed to screen large populations every 5 minutes.

04

DroughtSpotter
combines gravimetric measurements with precision irrigation. The table-based system precisely weighs and waters each plant individually according to the experimental protocols of your research.

05

HortControl
collects data from various sensors and stores it in one central, easily accessible database. Access your data from any browser within your network at all times.

PLANTEYE
HIGH-RESOLUTION 3D LASER SCANNER FOR PLANT PHENOTYPING

PlantEye is a high-resolution 3D laser scanner specially designed for plant phenotyping in challenging environments. PlantEye follows the sensor-to-plant concept, allowing you to make assessments of plants growing in fields or in any other setting where plants cannot be moved. PlantEye is also fully sunlight resistant and temperature controlled and is fully operational in harsh and hot environments.

PlantEye automatically computes a diverse set of morphological plant parameters and provides raw information as 3D point clouds. It's effective not only on dedicated sensor-to-plant platforms, where it's able to screen thousands of plants per hour, but also on existing conveyor based phenotyping platforms, where it can easily be retrofitted for use.

PlantEye F400, high-resolution laser scanner for all environments.

WHY WE DEVELOPED PLANTEYE

Various 3D technologies are available on the market. However, none are fully capable of assessing plants in high resolution and in harsh and bright environments, which are key requirements for field phenotyping. Moreover, most 3D sensors deliver only 3D point clouds, leaving users with the challenge to derive meaningful parameters from large data sets. Our idea was to provide a sensor that can easily be integrated into screening routines, used under any environmental conditions, and which can also deliver morphological information quickly and efficiently. PlantEye was specially developed for plant phenotyping applications in breeding, science and production.

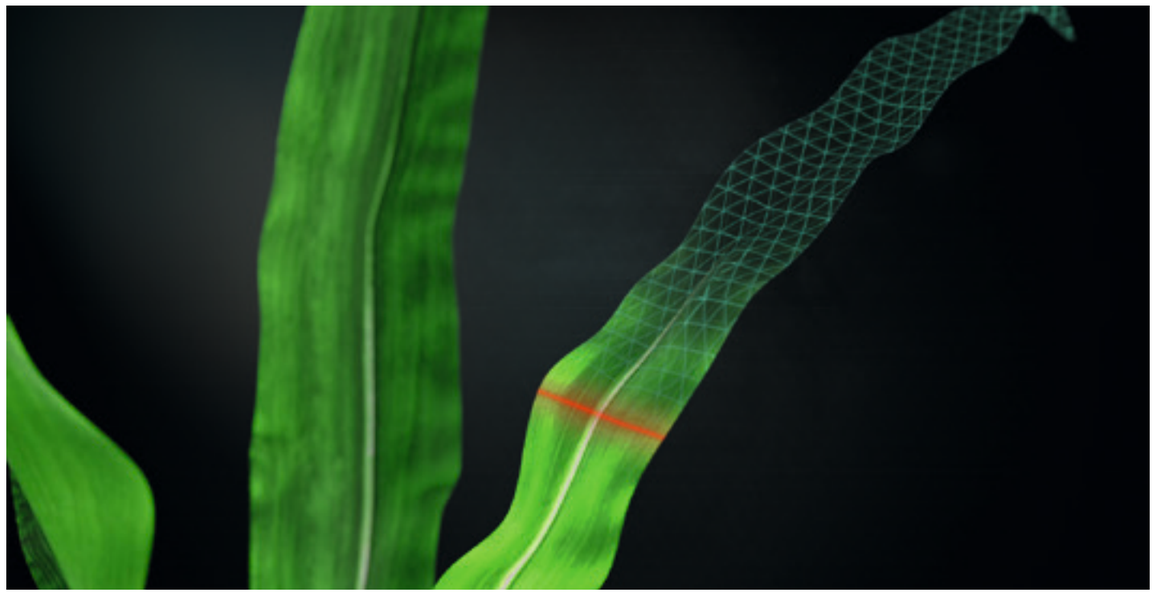
How PlantEye works

PlantEye uses a laser light section to acquire 3D point clouds of plants. It projects onto the plant or plant canopy a very thin near-infrared laser line, which is reflected and captured with an integrated camera that is mounted at the other end of the PlantEye sensor. The projected laser line shifts based on its distance towards the sensor, and a record of those shifts is then used to generate a height profile of the plant. By moving the sensor over the plant, or by moving the plant relative to the sensor, you get multiple height profiles which are merged together to form a 3D model of the plant. In a second step, the sensor segments this 3D model, recognizes plant organs and computes a diverse set of morphological plant parameters within less than a second.

Plug and play – Automated computation of plant parameters

Deriving parameters can be a challenge when using standard sensors that haven't been developed for plant phenotyping. PlantEye automatically computes a diverse set of morphological plant parameters, such as height, 3D leaf area, projected leaf area, ground coverage or leaf angle distribution – no computational skills are required. If the parameter that you are seeking to measure is not available, we are more than happy to work with you to develop new ones: we develop, you validate! All parameters are calculated in real time and on the sensor, with no need for complex and expensive server solutions.

PlantEye – the first laser scanner designed for plant screening.



HOW PLANTEYE HELPS YOUR RESEARCH

Plants cannot walk – Sensor-to-plant concept

In many cases, plants cannot be moved to imaging stations, either because they are growing in the field, or because movement would affect plant growth. It may also simply be the case that space or financial resources are not available for the installation of conveyor belt systems. Following the sensor-to-plant concept, PlantEye opens up a lot of new applications at a competitive cost and with a possible throughput of more than 5,000 plants/h. PlantEye is an autonomous sensor containing a high grade of intelligence and can be operated independently from any carrier device. This makes it easy to test the system or to integrate it into your phenotyping platform – it is even possible to integrate PlantEye into conveyor-based platforms. All data is transferred via Wi-Fi that can handle multiple sensors and environmental stations at the same time.

Hard times: sensors under stress – How we screen from Saudi Arabia to Norway

Phenotyping sensors have to perform under any conditions, as breeders and plant biologists cannot wait for the right conditions to arrive when they are phenotyping plants in the field. However, most optical sensors are simply unable to do this because of their susceptibility to sunlight and heat. PlantEye overcomes this common shortfall by fully conditioning and containing the phenotyping sensor in a protective sunlight filter, thus enabling phenotyping to occur under any environmental conditions and without any safety hazard for the users or plants, as demonstrated by Katarin Kjaer from Aarhus University. Its housing consists of a robust UV-proof POM case with a 10mm aluminium lid. All components are IP67 resistant to dust and precipitation.

Nobody wants a black box – Open platforms for seamless access

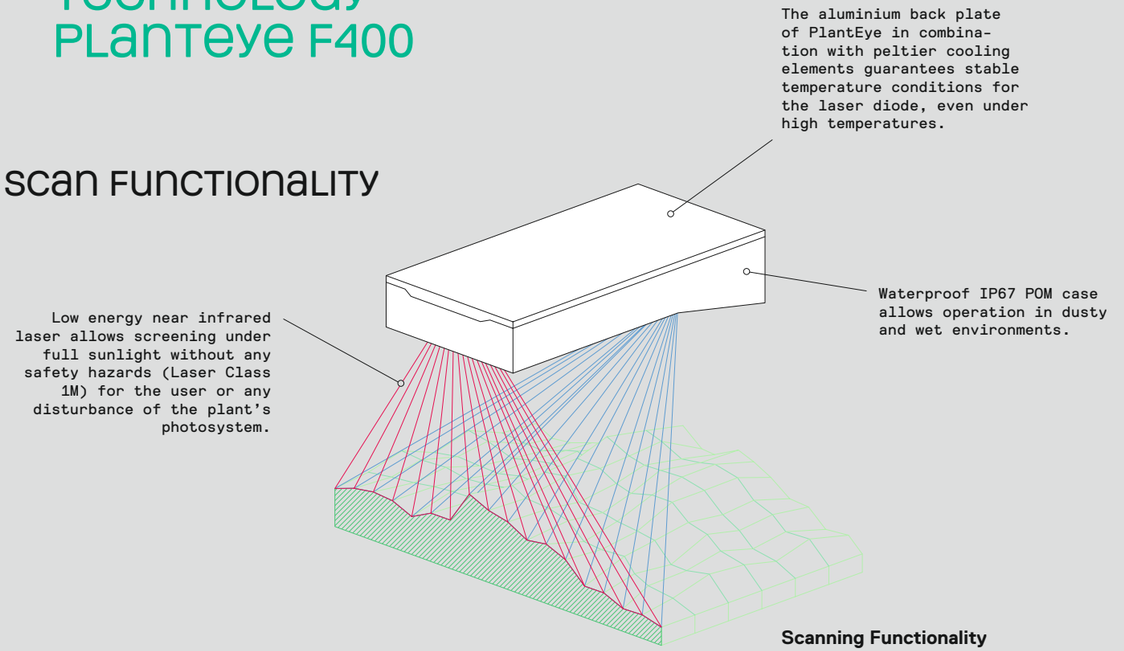
We all know how difficult or inconvenient it can be to access data from technical devices, especially when proprietary protocols are used. PlantEye is an open system that allows users to access RAW data or analyzed plant parameters at any level. Direct access to the embedded PlantEye computer can be set up with a public SSH protocol in order to download RAW data, point clouds or derived parameters. Data can also be stored in our HortControl database and accessed through a web interface from any computer or tablet in your network.

Plants aren't composed of pixels – High-resolution 3D measurements in metric numbers

PlantEye doesn't provide cryptic data sets that have to be calibrated or recalculated. We provide data that is ready for interpretation. All of our 3D point clouds are calibrated. This means that leaf area is no longer measured in pixels as a 2D projection that varies with distance and angle, but is measured as a real area that is reported in millimeters. With a maximum resolution of up to 0.2 mm in height, PlantEye is able to measure even small plants, such as Arabidopsis, in very high precision. Our large-scale calibration can also measure mature corn plants from top to bottom. And the good thing is 1 mm is always 1 mm.

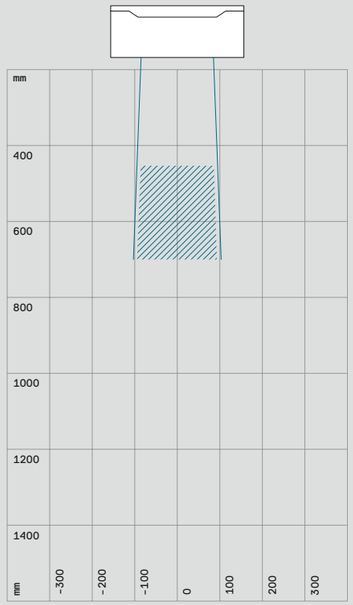
TECHNOLOGY PLANTEYE F400

SCAN FUNCTIONALITY

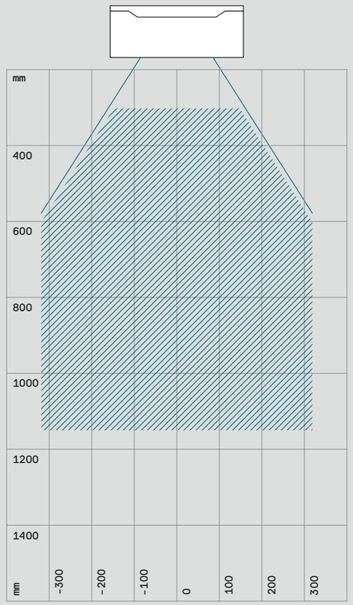


Scanning Functionality
PlantEye projects a near infrared laser line onto the plant. The integrated camera measures the reflected line to calculate height information. By moving PlantEye over the object, a full 3D model is generated.

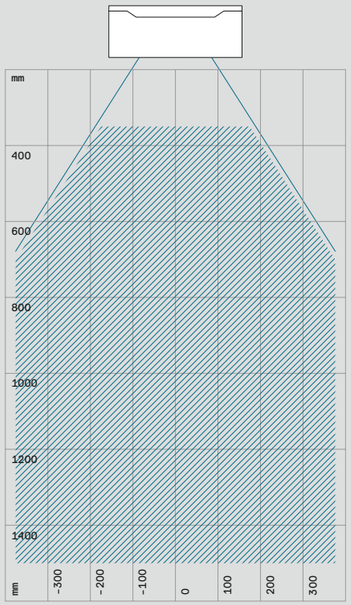
SCAN RANGES



PlantEye High Resolution (< 0.2 mm)

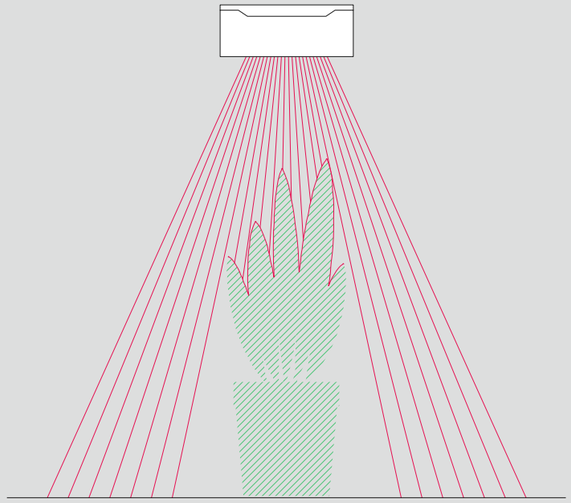


PlantEye Standard (0.8 mm)

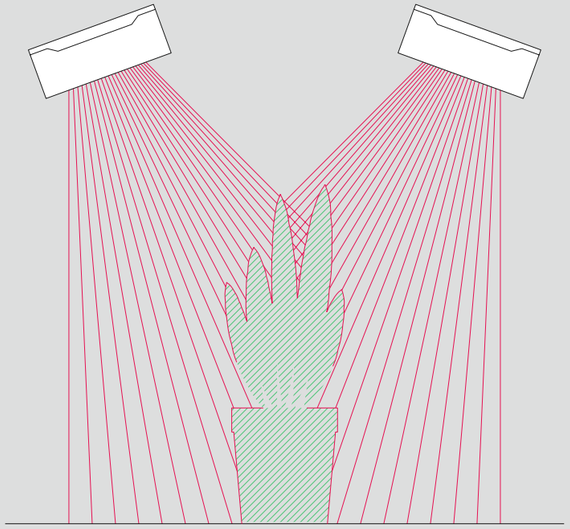


PlantEye Long Range (1.5 mm)

SCANNING OPTIONS

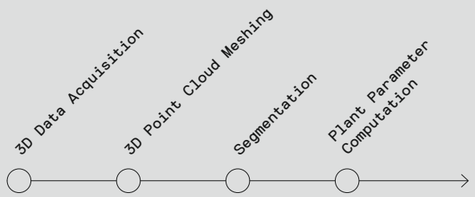


Single Scan
For small plants up to 60 cm or plants with a simple architecture, a single scanner can provide a very good 3D representation of the plant. With increasing complexity and more occlusion, the correlation of detected and real leaf area will decrease slightly with time.



Dual Scan
Two PlantEyes see more than one PlantEye! This is the principle of the Dual Scan. Several PlantEye sensors can be synchronised to scan the same plant from different angles. Their data is merged into one 3D point cloud with less occlusion. This allows high quality data sets for plants with difficult architectures and more overlapping leaf area.

SCAN WORKFLOW



The integrated workflow fully and automatically derives validated parameters from the acquired point clouds. All calculations are performed on PlantEye's embedded computer in real time. For later recalculation, raw data can be accessed directly and parameter extraction can be reconfigured and repeated on any other machine.

TECHNICAL DATA

Computed plant parameters	Height, leaf area (3D), coverage, leaf angle distribution, leaf/plant count
Measurement rate	50 XY-Profiles/s
Data processing	in parallel with measurement
Temperature range	0–40°C
Humidity	<90% rel.
Power requirements	24 VDC or 230 VAC
Laser class	1M
Dimensions	420 × 200 × 92 mm
Weight	5.2 kg
Light environment	sunlight resistant
Enviromental protection rating	IP67
Data transfer	WiFi

FIELDSCAN
ULTRA HIGH-THROUGHPUT PHENOTYPING

Phenospex FieldScan is a platform for ultra-high-throughput plant phenotyping under field- or semi-field conditions. A carrier device transports dedicated sensors over the plants or plots and performs measurements 24/7. The platform enables capacities of tens of thousands of plants or plots with throughputs of 5,000 plants or higher per hour. FieldScan is designed to screen big populations used for breeding or research and combines high-precision phenotyping with high throughput. Irrigation units can be added to the carrier device for top-down irrigation with a diverse set of nozzles.

FieldScan – the ultra-high-throughput phenotyping platform.

WHY WE DESIGNED FIELDSCAN

Environmental information is key to analysing and interpreting phenotypic data. Environmental stations closely monitor growing conditions within FieldScan.

Throughput and precision at affordable costs

Automated high-throughput plant phenotyping is mostly limited to controlled environments like greenhouses or climatic chambers where space, and the possibility of expansion, is often limited by finances. But research shows that traits discovered under controlled environments can often be reproduced with only low correlation in the field; hence, there is a strong need for platforms that allow for the direct assessment of plants under field conditions. Mobile platforms or UAVs have been developed and tested for these applications, but precision and payload has been limited. In addition, the operation of such platforms requires a lot of effort, and automation is challenging.

Our solution to these problems is FieldScan. Using our expertise in horticultural production, we developed a precision carrier device that moves a diverse set of sensors over plants to gather relevant environmental information, according to your needs. The platform can easily achieve throughput of several thousand plants or plots per hour and has been proven to work reliably under harsh conditions, such as those in central India. It can easily be scaled up and extended, it is cost efficient, and it allows for the new dimension of throughput. With FieldScan, we close the gap between the controlled environment and the field.

HOW FIELDSCAN HELPS YOUR RESEARCH

Is low-tech better than high-tech? Simplicity is the ultimate sophistication

Automating the measurement of plants in fields is a big challenge. Humid, dusty, hot, cold and windy environments strongly increase the cost of high-tech solutions. Some of the machinery that might be used in such weather, such as irrigation systems and spraying robots, is readily provided by suppliers, who in many cases offer horticultural expertise and decades of experience. In order to provide tools for plant phenotyping, however, where high reliability needs to be coupled with high precision, we drew from the expertise of our partners in the horticultural industry and developed a one of a kind sensor carrier device. Following the maxim to remove the inessentials, we simplified the technology while cutting costs, and were able to achieve full automation and millimetre precision with little downtime and almost no maintenance requirements – over thousands of square meters.

In-field screening needs calibration – Integrated identification and quality control

Often, approaches using cameras in-field require a complicated calibration for both colour and size measurements. In addition to the uncertainty of the camera, the carrier device can cause problems when it is not positioned accurately. Our plant sensors also rely on the precision of the carrier device. However, despite the high accuracy of our carrier device, we have a diverse set of calibration targets in the field that increase reliability and precision. Our PlantEye sensors do not require any colour calibration because they are able to operate in full sunlight. For later quality control, a diverse set of parameters like carrier speed or target height and size is constantly recorded.

Experimental layouts will change – From pots to plots

The design of field experiments might change from year to year. The experimental design, the amount of plants, or even the crop itself – all might change. FieldScan allows researchers to either scan and integrate over plots or to consider individual plants. Sensor height and position can be adapted to accommodate various layouts and to use the available area as efficiently as possible.

How do you control irrigation of your experiments in the field? – Irrigation and weighing systems

For drought stress experiments, rainout-shelters are commonly used to avoid unwanted precipitation. However, when using such shelters, some experiments need artificial irrigation systems. Irrigation nozzles can be added to FieldScan directly to be used as an irrigation system for your plants. These nozzles allow you to irrigate individual areas and to apply different drought scenarios. The combination of FieldScan with analytical balances (FieldScale) also allows you to assess transpiration dynamics gravimetrically.

Phenotype = G x E – Environmental monitoring is key

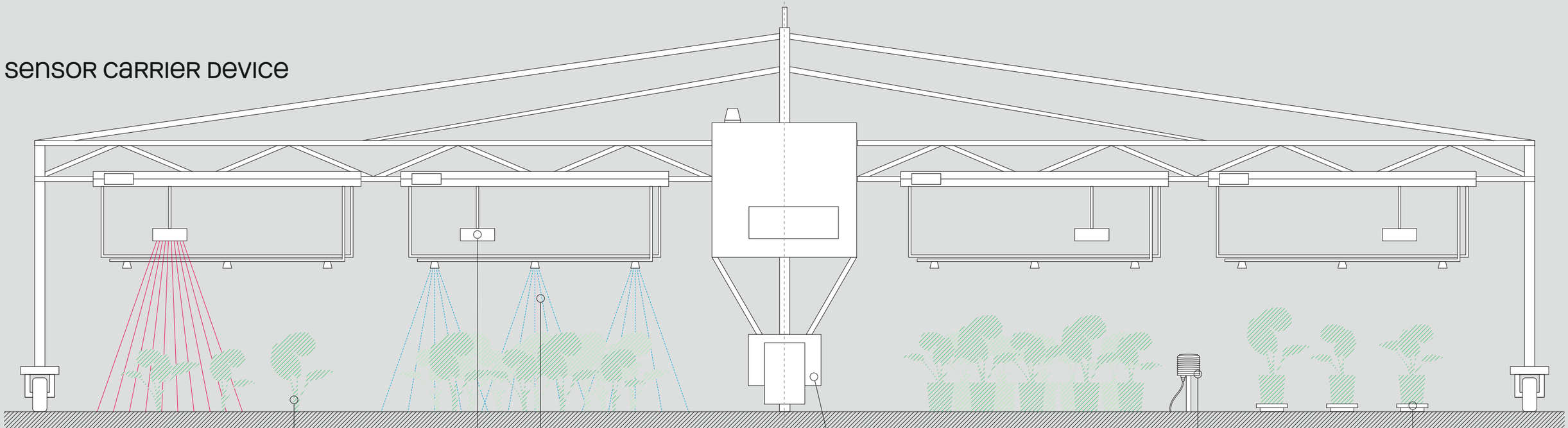
In many cases, phenotyping data is assessed without sufficient information about the environmental condition in which the phenotype was expressed (even in controlled environments). To properly interpret the data, and to be able to link the data to other data sets or experiments, precise information about the environment is key. For this reason, we track all environmental information with a sensor grid over the entire platform. Light, wind, temperature, relative humidity, leaf area, CO_2 and other parameters are tracked following the requirements of your research.

Data is not knowledge – Open data analysis pipeline

Still, the best automation is not useful if you can't make any sense of it. We bring all of your data together with open databases and interfaces to R to help you better understand how drought is influencing plant growth and transpiration rates. In addition, FieldScan and PlantEye are open platforms that allow users to access RAW data or analyzed parameters at any level. Direct access to the embedded PlantEye computer can be set up with a public SSH protocol in order to download RAW data, 3D point clouds or computed parameters. In addition, the data can be stored in our HortControl database and accessed through a web interface from any computer or tablet in your network.

TECHNOLOGY FIELDSCAN

SENSOR CARRIER DEVICE



Plants can be assessed growing in pots or in the soil as single rows or plots.

Sensor mounting for various plant sensors such as PlantEye.

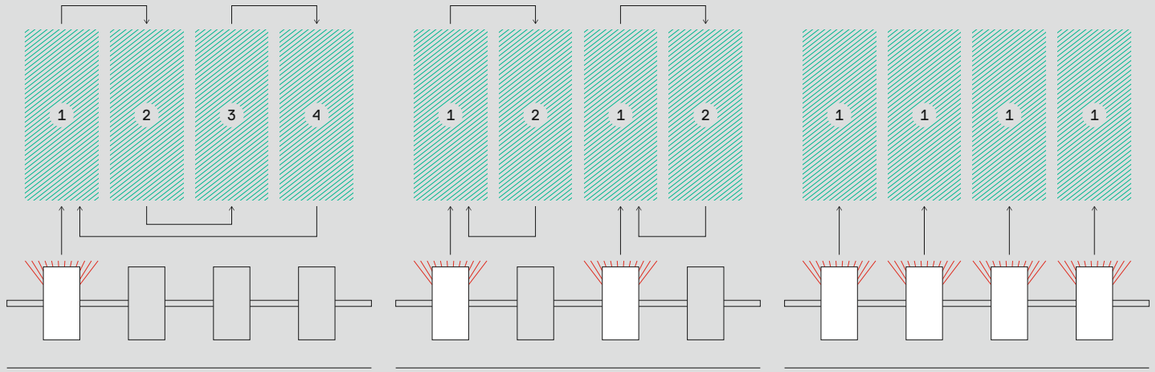
Integrated irrigation systems allow application of water to all plants or individual regions.

A central rail is used to position the sensor carrier device with high precision over distances up to 250m in length.

Distributed climate sensors in the whole platform continuously record environmental information such as relative humidity and temperature at various positions and combine it with the acquired growth information in a central database.

When using plants in pots, rugged load cells allow you to measure water loss over the day and compute individual transpiration rates for thousands of plants.

SENSOR ARRAY



1 PlantEye
4 Scanning positions
Approx. 300 plants/h

2 PlantEye
2 Scanning positions
Approx. 600 plants/h

4 PlantEye
1 Scanning positions
Approx. 1.200 plants/h

TECHNICAL DATA

Scanning Speed	50mm/s
Max. moving speed	250mm/s
Operating temperature	0–40°C
Operating relative humidty	<95%rel.
Power supply	3 phase, 230VAC, 16A
Protection class	IP65
Data transfer	WiFi
System width	8–30m
Sensor height	1–3m
System length (rail length)	Up to 250m
Environmental sensors	Wind, PAR, Rainfall, RH, Temperature
Environment measurement frequency	5min
FieldScale max weight	5–1,000kg

The central piece of our FieldScan system is the Sensor Carrier Device (SCD). Its main task is to move all sensors and other equipment, such as the irrigation system, to the plants. To provide a simple yet reliable working system, we took advantage of our horticultural experience and made it precise enough for science. Our solutions are scalable in any direction and can later be extended at an affordable cost. Other than large-scale gantry systems, our SCD is designed in such a way that it will not shade any plants. As we do not need to stop to measure plants and therefore are constantly driving over the platform, we avoid any local effects even while scanning. In parking position, our SCD will be located off the growing space and will not influence plant growth.

FieldScale
Monitor transpiration in greenhouses or the field

FieldScale is a scalable weighing system designed to assess transpiration rates for pots and containers ranging from 5 to 1,000 kg. FieldScale is placed directly on the ground where plants growing in pots or crates are positioned on the scales to track weight loss in high temporal resolution. The scalable design allows you to arrange FieldScale in multiple arrays with up to 320 plants per array and total capacities of up to 10,000 plants or more. FieldScale offers fast reading protocols and temperature compensation, which reduces errors due to high temperature changes to 0.02 %. With its flexible weighing range, FieldScale can be adapted to each specific application and to the required resolution.

FieldScale allows to assess transpiration rates of plants at high precision outside or in greenhouses. Its IP67 protection and stainless steel design protect it even in harsh environments.

How FieldScale helps your research

Providing genotypes with improved tolerances towards drought has become a major focus in science and breeding programs around the world. Assessing water status has become a basic research method, which is increasingly performed by gravimetric measurements. The power of gravimetric measurements lies in its simplicity and the ability to gain integrated and resilient data over the day. We developed FieldScale as a robust and affordable solution for assessing the transpiration rates of hundreds of plants.

Transpiration is not steady– Assess transpiration dynamics over the day

Plants dynamically adjust (within minutes) their transpiration rates in response to changes in environmental parameters like vapor pressure deficit (VPD), soil moisture, light and CO_2. Yet, transpiration rates are typically only measured on a daily basis, especially in plant phenotyping. To better understand the dynamics of such changes, FieldScale tracks transpiration in intervals of 5 minutes or less. Typically, such accuracy would require investment in either a lot of labor or expensive conveyor belts, and researchers still would not be able to achieve the same precision (down to 1g in high temporal resolution) as they could with FieldScale.

Nobody wants a black box– Open platforms for seamless access

We all know how difficult or inconvenient it can be to access the data of technical devices, especially when proprietary protocols are used. FieldScale is an open system that allows users to access RAW data or analyzed parameters at any level. Direct access to the embedded FieldScale computer can be set up with a public SSH protocol in order to download RAW data or calculated transpiration rates. In addition, the data can be stored in our HortControl database and accessed through a web interface from every computer or tablet in your network.

Hard times– sensor under stress– Easy to run and maintain system

FieldScale was designed to the IP67 standard to work in greenhouses and in the field. The system is built on individual mechanical platforms that can accommodate a single plant, multiple pots or large-scale containers. Depending on your experimental design, the pot size or number of plants per pot might vary. FieldScale can be built to accommodate pots from only 5 kg – 1,000 kg containers.

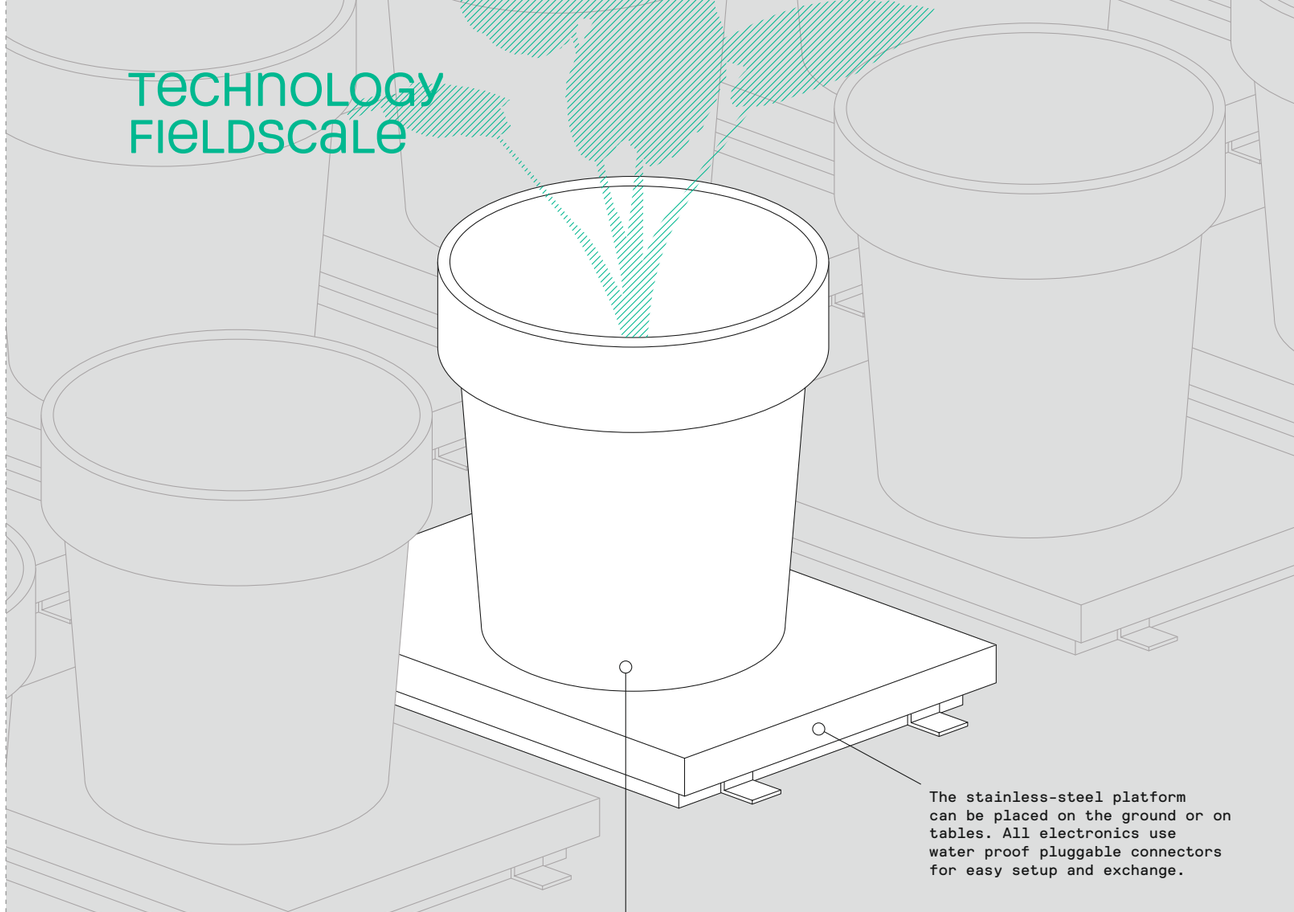
Size does matter– Include leaf area in your equation

In combination with Phenospex FieldScan, using PlantEye, the drought performance of various genotypes in field conditions can be linked to growth dynamics. Integrating leaf area can be important when calculating and normalizing transpiration rates independent of plant size. By estimating plant biomass, water use efficiency can be estimated. With integrated environmental sensors, transpiration rates can be directly associated with environmental factors such as VPD or else transferred into thermal time.

Data isn’t knowledge– Data analysis pipeline

Still, the best automation is not useful if you can’t make any sense of it. We bring all of your data together with open databases and interfaces to R to help you better understand how drought is influencing plant growth and transpiration rates.

Technology FieldScale

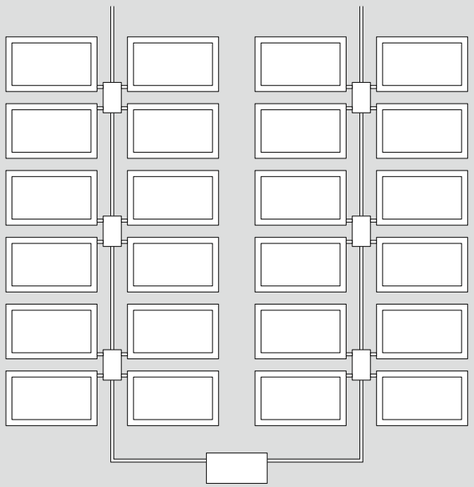


Technical data

Maximum load per scale	5–1,000 kg
Reproducibility (weight deviation due to long term drift)	<0.02% of max. load
Power supply	110–230 VAC
Operating temperature	0–40 °C
Operating relative humidty	<95%
Degree of protection	IP67

FieldScale is arranged in scalable arrays with up to 320 scales per array. From the central control box, sub-stations are connected that control individual arrays and read out hundreds of load cells within 5 minutes. Each array is surge protected to avoid major damage in case of lightning strike. Components are also temperature compensated, strongly reducing the effects of temperature on load cell accuracy.

Setup



DROUGHTSPOTTER
FOR DROUGHT RESEARCH AND BREEDING

DroughtSpotter is a fully automated gravimetric platform that was made to assess the transpiration dynamics of plants with a precision of up to 1g. The integrated irrigation units allow precise and reproducible water application for drought stress or related experiments requiring accurate control of water volume to 1ml. DroughtSpotter can easily be adjusted to accommodate various pot sizes and pot designs. Watering protocols or drought scenarios can quickly and easily be customized via the DroughtSpotter software web interface. The designed irrigation events maintain the target weight of each individual plant pot according to the researchers' experimental protocol and provide plant transpiration rates at high temporal resolution calculated by the loss of weight. Combined with PlantEye's growth measurements, the weight increase due to plant biomass accumulation can also be considered.

A DroughtSpotter gravimetric platform provides fully automated precision irrigation and assesses transpiration rates in a growth chamber.

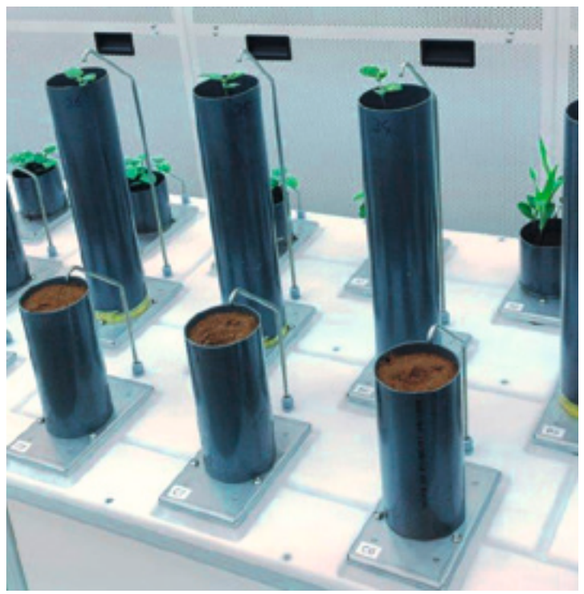
WHY WE DEVELOPED DROUGHTSPOTTER

The beauty of using manual gravimetric measurements to assess transpiration rates lies in the simplicity of the method and its ability to provide you with incorruptible and resilient data. Although simple, it is nonetheless a very labor intensive protocol! Spurred into action by this challenge, we decided to engineer a solution that was simple but professional and specially made for high-throughput phenotyping. Why professional? Homemade solutions have provided good results and have been proven to be useful for drought research and breeding, but for those who want to focus less on technical development and more on research, DroughtSpotter is a better tool. Design your drought scenarios with our software, position your plants on the system, and all of your measurements and irrigations will be performed fully automated.

What is drought? More than one definition.

Research on drought stress has strongly increased over the last decade, as water shortage is one of the key limiting factors in global crop production. Many breeding and scientific projects aim to deliver knowledge, traits and chemical agents that will help to provide better resistance to drought scenarios. However, the term “drought stress” is broadly defined and covers many different ways that plants might be affected. For instance, drought stress differs depending upon the site of the action, its strength and its dynamics, which may be integrated by plants and might also trigger different coping mechanisms in plants for dealing with the stress. This fact has to be considered in experimental designs and breeding programs, and the mode of stress has to be controlled and reproducible.

Flexible use with various pot sizes and species.



Automated high precision irrigation systems guarantee reproducible drought stress scenarios for each individual pot.

HOW DROUGHTSPOTTER HELPS YOUR RESEARCH

Transpiration is not steady– Assess transpiration dynamics over the day

Despite the fact that transpiration is dynamically controlled by soil moisture, vapor pressure deficit and other environmental parameters, transpiration rates are typically only measured on a daily basis. To better understand the dynamics of these processes, DroughtSpotter tracks transpiration in intervals of 5 minutes or less. Typically, such accuracy would require investment in either a lot of labor or expensive conveyor belts, and researchers still would not be able to achieve the same precision (down to 1 ml in high temporal resolution) as they could with DroughtSpotter.

Nobody wants a black box– Open platforms for seamless access

We all know how difficult or inconvenient it can be to access the data of technical devices, especially when proprietary protocols are used. DroughtSpotter is an open system that allows users to access RAW data or analyzed parameters at any level. Direct access to the embedded DroughtSpotter computer can be set up with a public SSH protocol in order to download RAW data or calculated transpiration rates. In addition, the data can be stored in our HortControl database and accessed through a web interface from every computer or tablet in your network.

Hard times–sensor under stress– Easy to maintain system

DroughtSpotter was designed to the IP65 standard to work in controlled environments and in greenhouses. The system is built with separate tables, so-called units, that can accommodate up to 24 plants per unit. Central valves enable the user to shut down water supplies for maintenance or whenever experiments are not running. DroughtSpotter units have an integrated drainage system for preventing damage if and when the soil is overwatered. As a solid-state system without any moving parts, DroughtSpotter needs very little maintenance and is not susceptible to hardware failures.

Each drydown is different– Flexible experimental protocols and weighing ranges

Depending on what you want to test, the pot size, or the number of plants per pot, the way you want to irrigate may vary strongly. DroughtSpotter offers different watering modes that allow the user to apply specific behavior to each pot. Besides holding a predefined target weight, plants can be given fixed dosages of water, or the conditions of a specific pot can be replicated for all plants as in the field. For all events, you can define whether watering is performed at defined times, or even dynamically, whenever a certain minimum threshold is reached. With tool-free adjustable irrigation tubes, pot sizes from 10 to 50 cm can easily be handled. DroughtSpotter can be built to accommodate pots from 1 kg to 15 kg large-scale containers that can be placed either on tables or directly on the ground. The system can also be used outdoors in combination with Phenospex FieldScan in order to measure the drought performance of various genotypes in field conditions.

Even the best climate chamber is not homogeneous– Control edge effects on each individual plant

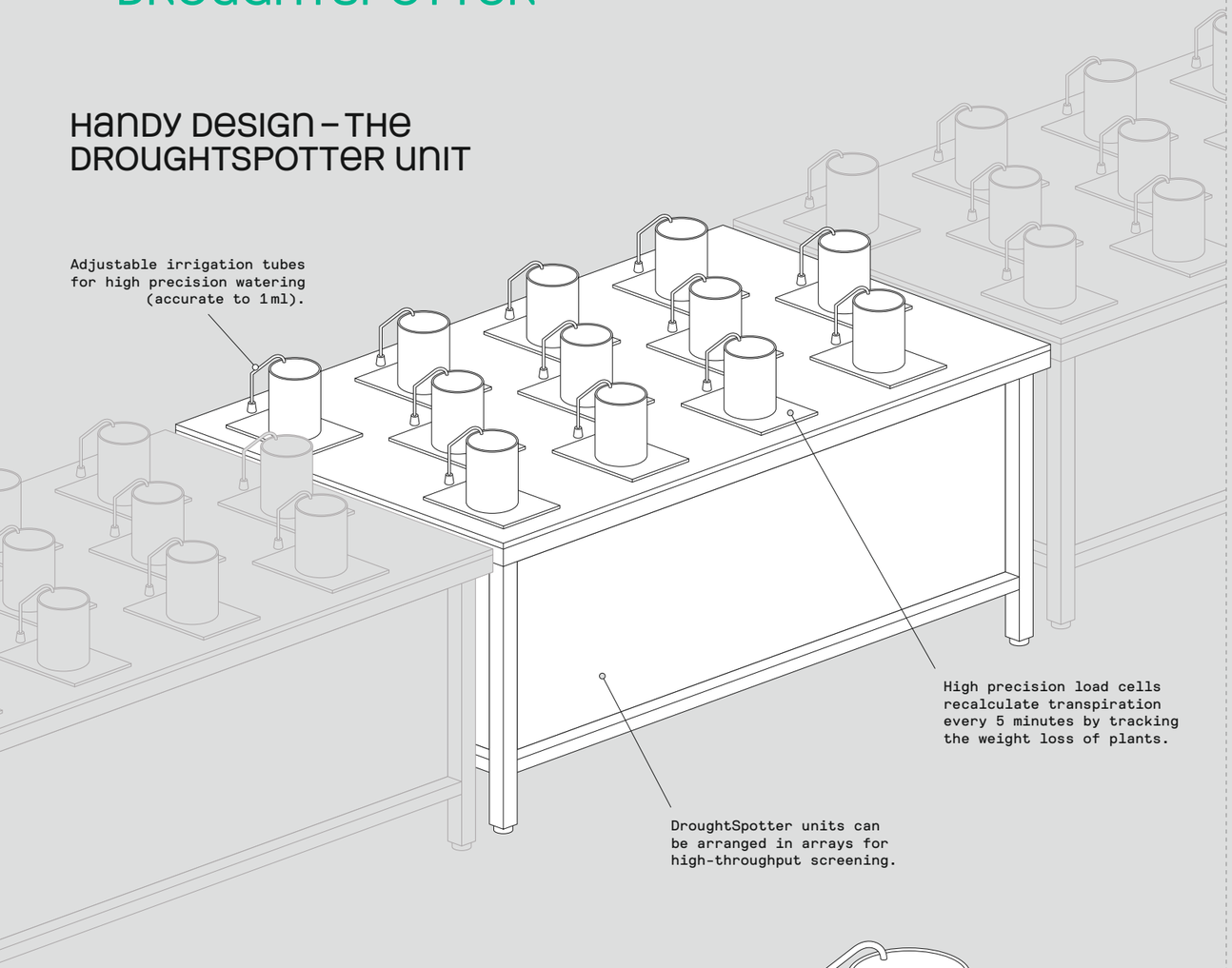
Everybody knows how difficult it is to control and reproduce a drydown, since even in climate chambers, environmental conditions are not homogenous. Border effects, different growth rates and many other factors influence the soil water content to which the plants react. DroughtSpotter takes care of this by tracking and controlling the water amount in each pot. Moreover environmental conditions, such as temperature and light intensity, that affect transpiration are constantly monitored. Hence, even the transpiration rates of small plants can be controlled and tracked, thereby keeping variability low. DroughtSpotter is easily combined with data loggers from various suppliers to monitor climate conditions (T, RH, PAR, CO_2) and manage data in one central place.

Data isn’t knowledge– Data analysis pipeline

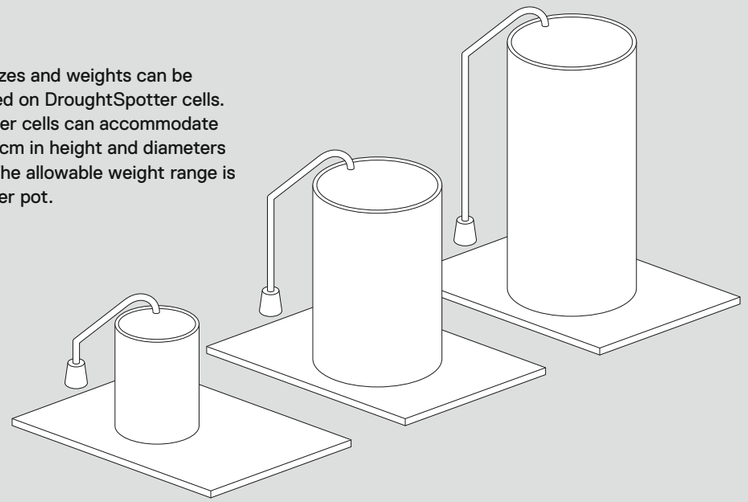
Still, the best automation is not useful if you can’t make any sense of it. We bring all of your data together with open databases and interfaces to R to help you better understand how drought is influencing plant growth and transpiration rates.

TECHNOLOGY DROUGHTSPOTTER

HANDY DESIGN – THE DROUGHTSPOTTER UNIT

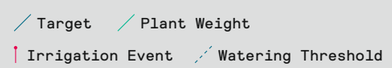


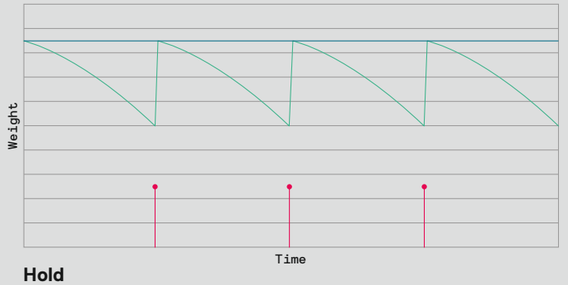
Cells
Various pot sizes and weights can be accommodated on DroughtSpotter cells. DroughtSpotter cells can accommodate pots up to 50 cm in height and diameters up to 15 cm. The allowable weight range is 1 kg to 15 kg per pot.



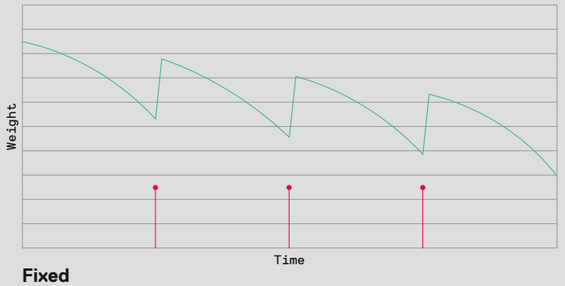
IRRIGATION MODES

The following irrigation modes can be applied to each individual plant on the system: **Hold:** target weights are held by watering at fixed time points. **Fix:** fixed water amounts are given independent of actual water consumption. **Deviation:** plants are rewatered as soon as a lower threshold is reached, independent of time. **Copy:** a plant imitates the drydown pattern of another plant and gets dynamically rewatered to the master plant's target weight. **None:** when no irrigation is applied, only the drydown data is recorded.

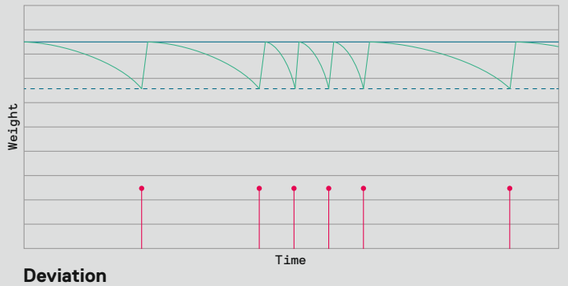




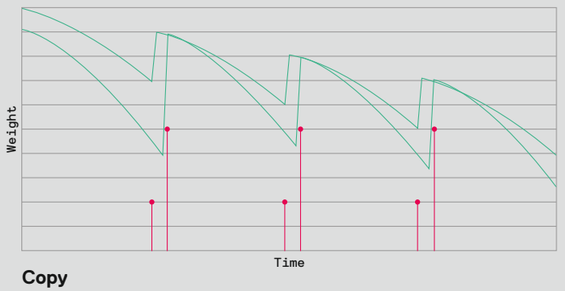
Hold



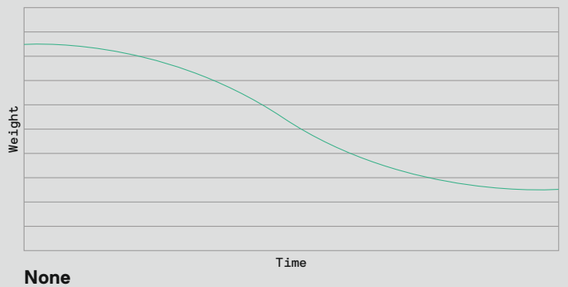
Fixed



Deviation



Copy



None

TECHNICAL DATA

Unit dimensions without irrigation tubes (L×W×H)	1000×760×650 mm
Unit weight	65 kg
Pot height range	100–500 mm
Supply voltage	110–230 VAC
Power consumption (max)	120 W
Inlet pressure range	1.5–7.0 bar
Nominal system pressure	0,5 bar
Water flow at nominal system pressure	3.0 g/s
Temperature drift for temperature rise/drop of 10 °C, typical	<2.5 g

Reproducibility (weight deviation due to long term drift)	<0.2%
Operating temperature	0–40 °C
Operating humidity	<95%
Degree of protection scale	IP66
Maximum load per cell	1–15 kg
Watering precision	<2 ml
Hold deviation	Fix

HORTCONTROL
DATA MANAGEMENT SOFTWARE

Phenospex provides a complete data solution for all data acquired by PlantEye, DroughtSpotter, our environmental stations and other plant sensors. All data – RAW and tabulated – is stored in our Hort-Control database. We provide the highest standard of security combined with intelligent quality management and analytics to secure online access from your designated hardware – on-site and on the road. Our data warehouse provides sufficient storage capacity to save and backup your experimental data for comparisons and analyses that might be made over several cycles and years.

HortControl can be accessed from any browser within your network and on various devices to check data quality, to set up your experiments and to analyze your data.

HOW HORTCONTROL HELPS YOU MANAGE YOUR DATA

HortControl infrastructure (using PostgreSQL) enables the real time combination of RAW data, plant parameters and associated climate data (via a pre-installed interface to major climate systems) and additional plant sensors. Our browser-based interface to the HortControl database can be used on almost any operating system (Microsoft Windows, Apple Mac OS and iOS, Linux). If needed, tailored solutions can integrate your existing interfaces for climate data and other sensors. High data volume is stored on a secure proprietary server that is accessed only through your individual Security-ID. Start monitoring and analyzing your experiments on-site, from the computer in your office, at home or on your mobile device.

Using HortControl– Software should make life easier

When it comes to software, ease of use and design simplicity are key for a good user experience. We believe in simple solutions for multiple users across any operating system.

Unlimited Access– Connect as many users as you need

For us, science is not a single player game. With today's interdisciplinary teams, access to data from researchers and workgroups in different locations is needed. That's why we have unlimited user access to HortControl, which can also be established from remote locations using a safe connection ID. Different users can access the information they need with different dashboards.

'R' you ready for data analysis?– Using the statistical power of the R-Project

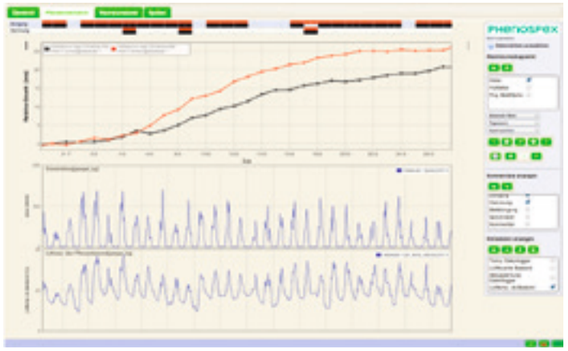
Modern phenotyping tools produce more data than ever. However, data itself has little value for plant scientists and breeders. The data still need to be combined and analyzed before we can learn from it. Instead of reinventing the wheel, we decided to draw from the power of one of the most widely used statistical tools in the world: the R-Project. That's why we developed an easy to use direct interface from our database into R, so that people can apply various scripts directly onto the data that we produce.

Quality is key– Checking data acquisition on the fly

No machine is perfect, and neither are the people using it. Often, a fast and simple look into the data can give you a good impression of the status of your experiments. HortControl allows you to graphically check the whole status of the phenotyping equipment and also to visualize the acquired data with less than three clicks from your computer, laptop or tablet.

Small is beautiful– Integrated data storage without IT skills

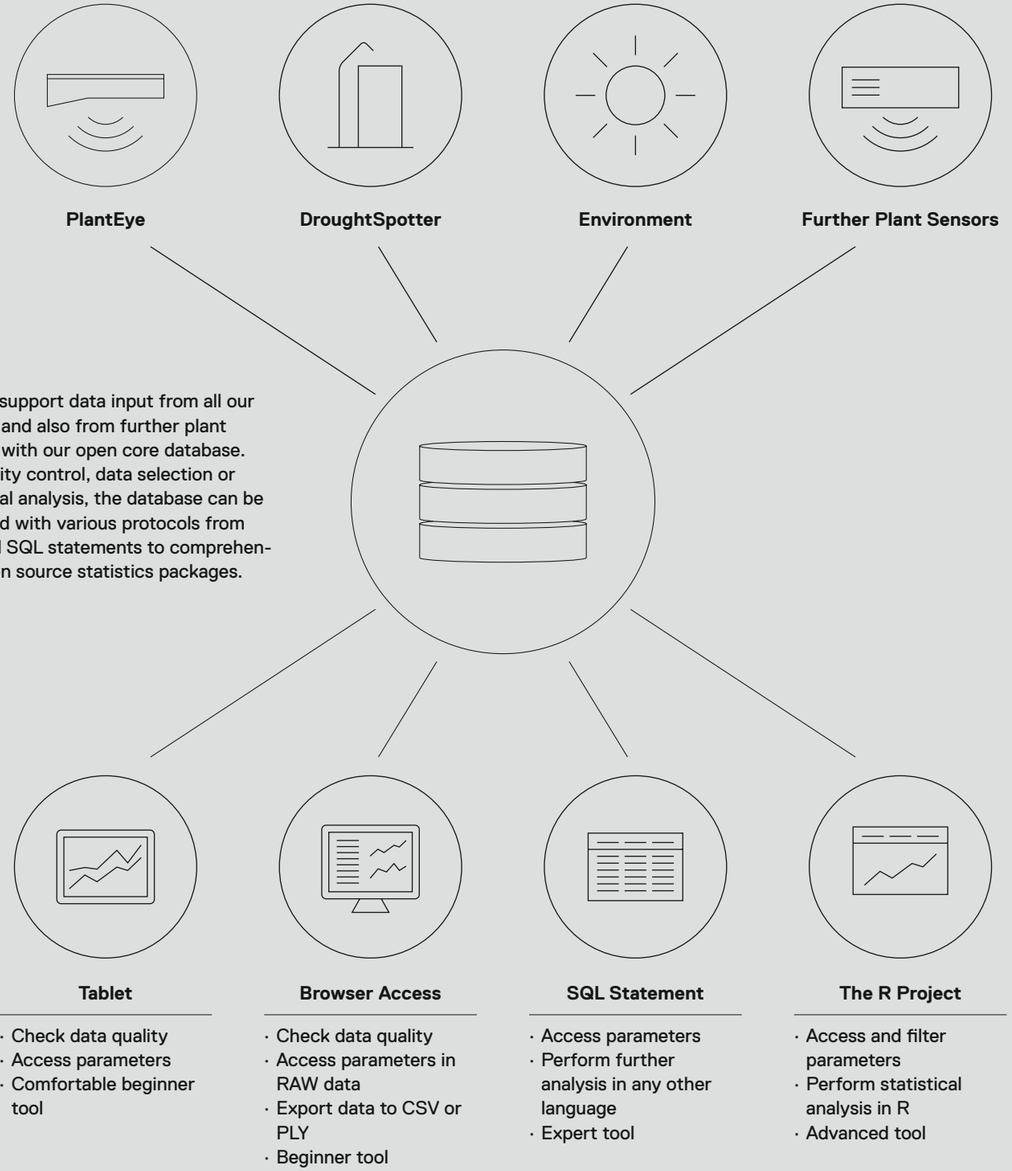
Large-scale systems can produce Terabytes of data in short amounts of time. Nevertheless, as a scientist you want to focus on analyzing the data and not maintaining it. HortControl can perform that task for you, automatically storing and handling all data in the background. Even backup solutions can be integrated with no need for any IT interaction. If you want, you can still access all data as HortControl is completely open.



HortControl gives you fast feedback on the acquired data and connects it with climatic data.

All connected sensors can be monitored in real time.

TECHNOLOGY HORTCONTROL



We can support data input from all our sensors and also from further plant sensors with our open core database. For quality control, data selection or statistical analysis, the database can be accessed with various protocols from classical SQL statements to comprehensive open source statistics packages.

Tablet

- Check data quality
- Access parameters
- Comfortable beginner tool

Browser Access

- Check data quality
- Access parameters in RAW data
- Export data to CSV or PLY
- Beginner tool

SQL Statement

- Access parameters
- Perform further analysis in any other language
- Expert tool

The R Project

- Access and filter parameters
- Perform statistical analysis in R
- Advanced tool

Can Field Phenotyping **improve the livelihood** of millions of households?

Dr. Jana Kholova describes her research at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and how we established a unique field phenotyping platform together to support research on crops for the semi-arid tropics.

Why the semi-arid tropics should get more research attention

Climate change projections for the already harsh conditions of the semi-arid tropics (SAT) point to potentially severe outcomes for the region's agriculture. These changes will affect millions of the most vulnerable households, many of whom are already living deeply below the poverty line. One way to change, if not reverse, this dire outlook for the future of SAT farming systems is to enhance its production and resilience. However, in the last decades, there has been only marginal progress in this task because of the region's harsh environmental constraints (mainly drought) and very low crop production. Maybe for these reasons, SAT agro-ecosystems have received only limited scientific attention and negligible investment from the public-private sector.

Acceleration of breeding: a viable way to improve adaptation of cropping systems in SAT

Since 2006, the main effort of the research team formed around Dr. V. Vadez at ICRISAT has focused on bringing together a wide range of multidisciplinary and international experts to improve SAT agro-ecosystems (with a focus on the adaptation of cropping systems to drought). Since then, a lot of evidence has accumulated showing what options are available for the improvement of agricultural production in the SAT. One of the key recommendations resulting from this research includes accelerating crop improvement efficiency. This requires accurately defining the screening criteria that are relevant to improving crop production in specific agro-ecologies. These criteria have been well defined and are basically linked to the physiological mechanisms influencing water use (WU) during the crop cycle.

Jana Kholova and her team at ICRISAT doing manual measurements in the field for her sorghum breeding program.

TOP 10 Reasons WHY PHENOSPEX COULD HELP

The main reasons why Phenospex's proposed solution was chosen to be a part of ICRISAT research.

01 Our ICRISAT team was given the opportunity to test the prototype and validate the relevance of Phenospex technology for ICRISAT research.

02 Phenospex had the flexibility to develop the technology and facility based entirely on ICRISAT requirements.

03 Phenospex eagerly committed to the continuous development of technology accurately targeting ICRISAT research goals.

04 Phenospex was absolutely committed to pursuing a flexible, transparent, open and fair-play approach.

05 Phenospex has a dynamic multidisciplinary team that is able to understand the research question from every possible angle.

06 Phenospex is capable of working efficiently and providing solutions under difficult conditions, such as those in developing countries around the world.

07 Phenospex has outstanding maintenance services and quickly resolves problems that occur after the installation of the HT-platform.

08 Phenospex is already developing technology in line with the research objectives of ICRISAT.

09 Phenospex developed the tools for data management/analysis according to ICRISAT needs.

10 Phenospex has kept costs down by pursuing design simplicity and efficiency in all areas.

If this approach were to be brought into practice, it would require huge quantities of breeding material accurately screened and evaluated for the identified WU-related traits (generally populations of 1000s of lines). Such a task would be close to impossible without an automated system, and that is where the idea of an HT-phenotyping platform arose. However, most of the currently available market options have little or no relevance to carrying out the above-defined scientific task (i.e., evaluation of germplasm for the main components of WU):

1. Canopy size & canopy growth dynamics (plant vigor)
2. Canopy conductivity (H2O transpired per unit of LA per unit of time)
3. Plant water use & water use dynamics (transpiration in time)
4. Interaction of plant WU components with environmental stimuli (e.g., drought, VPD, salinity, micronutrient deficiencies ...)
5. All across the crops species, in outdoor conditions and within short time intervals

Installation of an HT-phenotyping platform at ICRISAT in 2013 was a clear milestone in the "research for development" (R&D) approach. The phenotyping concept itself is very unique – it brings the technology to the plants in the field, rather than bringing plants to technology – which finally resulted in a tremendous improvement of phenotyping throughput (currently, the information from 5000 micro-plots can be accessed every 2h along with meteorological data). The analysis of phenotypic information should provide the means to bring precision agriculture into practice in the near future. It seems likely, then, that rigorous conceptual research paired with highly focused technology should lead to the improved livelihood of millions of households depending on agricultural production in (not only) developing countries.

Dr. Vincent Vadez, a principal scientist at ICRISAT, leads the research team using FieldScan

PHENOSPEX
WORLD WIDE ACTIVITIES

PARTNERS AND DISTRIBUTORS

In modern plant science, research is not limited to one location but is carried out worldwide. We see ourselves in that worldwide context. With our interdisciplinary team from various nations, we try to understand not only scientific requirements, but also cultural differences and serve the best possible solution for each individual client.

To be able to deliver and service systems globally, we have created close partnerships with service and distribution providers all around the world. We want to offer fast response times through remote and on-site service no matter where we are working. Our distributors share our vision of plant phenotyping and share our passion for answering questions with our clients.

Besides our distribution and service partners, we deeply believe in the concept of industry cooperation. We will not be able to offer every solution you might ask for, but we want to be able to refer you to a reputable company that can help. That's why we collaborate closely with our partners in plant phenotyping, automation and horticulture to deliver the best possible solution in all contexts, even if it exceeds our core strengths. Only by working together can we make plant phenotyping an even bigger success in the future.

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