# New Plant Phenotyping Capabilities to Drive Scientific Discoveries

Oak Ridge National Laboratory is installing a unique high throughput, high-resolution plant phenotyping system with a more diverse suite of imaging capabilities than any other systems worldwide.

Integrating these capabilities with the wealth of genomic data on plants and microbes generated through, for example, the DOE Center for Bioenergy Innovation or the DOE Plant-Microbe Interfaces Scientific Focus Area at ORNL will enable new avenues for scientific discovery. The new system will have five image capture stations—dynamic chlorophyll fluorescence imaging system, thermal imaging, near-infrared, 3D plant modeling, and hyperspectral imaging—which will be combined to provide the user with daily leaf-level spectra across a 90 day period.

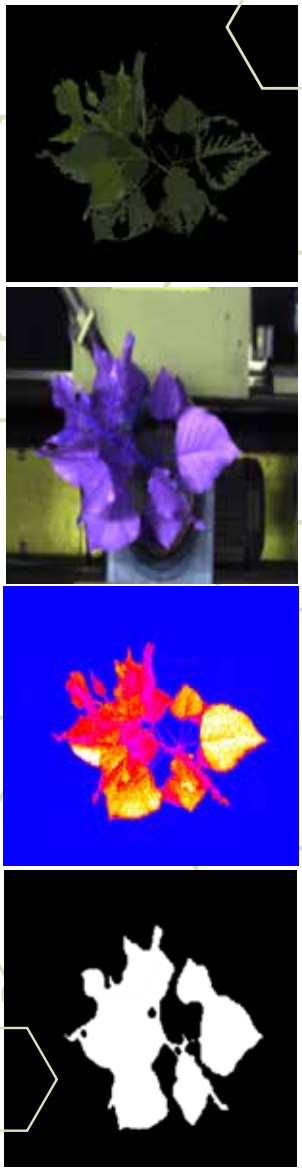
## Capturing Critical Data

Measuring multiple key plant characteristics and processes across various plant populations takes speed and accuracy to capture data for hundreds of plants before internal and external conditions change. The new automated system achieves high throughput with higher-resolution measurements than possible through traditional, manual methods.

### Research and Development

Users interested in plant growth characteristics, photosynthetic activity, biochemical status, and response to stress will be able to associate changes in leaf-level spectra with changes in pigment composition, biochemical composition, nitrogen content, leaf water status, plant growth dynamics, plant morphology, etc. This new high-resolution data will accelerate fundamental science investigations, connecting genotypes to phenotypes with applications for bioenergy, agriculture, and beyond. The system uses sophisticated robotics and sensors to capture day and nighttime images, automating the measurement of:

- Plant morphology
- Biomass accumulation
- Photosynthetic activity
- Physiological status
- Relative water content and distribution
- Stomatal movement
- Stress response
- Biochemical composition



*Multiple plant phenotypes can be gathered at the same time on a single plant.*

# System Capabilities

**Dynamic chlorophyll fluorescence imaging system**—Uses pulse amplitude modulated (PAM) technology which allows the full range of chlorophyll fluorescence parameters to be measured. PAM fluorescence systems measure fluorescence resulting only from excitation of the sample from the measuring light (flashes) while ambient light has no effect.

**Thermal imaging station**—Average, standard deviation, median, and minimal and maximal temperature are obtained across the whole plant surface. Housed in a light-proof cabinet with automatic doors, it includes a light source to induce dynamic responses so that the camera can be used to assess stomatal activity and/or water distribution within plants.

**Near-infrared camera**—Images light absorption by water. Monitors water at the 1450 nm absorption peak and monitors a reference at 940 nm. A homogenous LED light source, optimized for NIR measurements, provides the required irradiance conditions.

**3D plant modeling camera**—Morphometric and color analyses may be con-ducted with equal effectiveness on monocotyledonous and dicotyledonous plants, with both top-view and side-view image acquisition and processing.

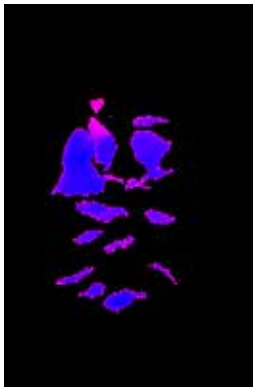
**Hyperspectral imaging station**—Includes a visible and near-infrared (VNIR) camera with a range from 350–900 nm and a short-wave infrared (SWIR) camera with a range of 900–1700 nm. The cameras allow the user to acquire a full scan across the entire spectral range for each pixel of the image.

**Automated conveyor system**—For growth, randomization, watering and weighing of plants in the greenhouse and for transport of plants from the cultivation zone in the greenhouse to the imaging circle in the headhouse. Plants may be in pots or trays and may have dimensions up to 1.3 meters tall and 0.5 meters wide. Watering and weighing may be done with or without imaging.

**Additional capabilities**—System is expandable with potential additional capabilities including anomaly detection and the ability to automate sample collection with the system using lasers to cut sections of leaves and drop them into solution to initiate 'Omics analyses.

## Thermal Infrared

*Without Mask*



*With Mask*

Thermal infrared cameras detect long-wave infrared (LWIR) light that is emitted by leaves in a temperature-dependent intensity.

**APPLICATIONS**

- Leaf surface temperature visualization
- Transpiration over plant surface
- Stomatal activity

## RGB

*Without Mask*

*With Mask*

The mask for any image is used to calculate parameters based solely on plant area; this eliminates the background. The mask can be adjusted to only analyze a specific leaf, etc.

**APPLICATIONS**

- Plant growth dynamics
- Plant morphology (shape, structure)
- Color properties of each plant

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