



Imaging-Based Phenotyping Technologies for Accurate Assessment of Plant Growth

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DESCRIPTION

Crop phenotyping technologies have become an important part of modern agricultural research because they provide detailed information about plant characteristics, growth patterns, and responses to environmental conditions. Crop phenotype refers to the observable characteristics of a plant that result from interactions between its genetic composition and surrounding conditions. These characteristics include plant height, leaf area, biomass, flowering time, root development, canopy structure, fruit size, and responses to water availability, temperature, nutrients, pests, and diseases. Accurate measurement of these characteristics is essential for selecting suitable crops and improving production systems.

Conventional phenotyping frequently depends on direct field observations and manual measurements. Researchers may measure plant height with rulers, count leaves, collect biomass by hand, or evaluate disease symptoms through visual inspection. Although these methods can provide useful information, they require substantial labor and may be influenced by differences between observers. Measurements taken from a limited number of plants may also fail to represent conditions across an entire field. Digital phenotyping technologies provide an alternative by collecting large quantities of information rapidly and consistently.

Digital cameras are among the simplest tools used in crop phenotyping. Images captured from fixed cameras, mobile devices, drones, or other platforms can be processed to measure plant characteristics. Image analysis software can identify plant boundaries, estimate canopy area, measure plant height, and evaluate changes in vegetation over time. Repeated imaging provides a record of plant development from early emergence through maturity. Such records can help researchers compare different varieties under the same environmental conditions.

Unmanned aerial vehicles have expanded the use of image-based phenotyping in agricultural research. Drones can collect high-resolution images over experimental plots and commercial fields

within relatively short periods. Different cameras can record visible light, near-infrared wavelengths, thermal information, or other spectral regions. These data can reveal differences in plant vigor, canopy structure, water status, and disease development. Because drones can repeatedly survey the same locations, researchers can monitor plant responses throughout a growing season without disturbing the crop.

Multispectral imaging provides information beyond what the human eye can observe. Plants interact with different wavelengths of light according to their physiological condition and structural characteristics. Sensors that record several spectral bands can therefore provide useful indicators of vegetation health. Vegetation indices calculated from these measurements can be used to estimate canopy density, chlorophyll-related properties, and plant stress. Researchers can compare these measurements among crop varieties to identify plants that perform well under particular environmental conditions.

Hyperspectral imaging provides an even larger range of spectral information. Instead of recording only a few broad wavelength bands, hyperspectral systems collect information across numerous narrow bands. This creates detailed spectral profiles for individual plants or sections of a crop canopy. These profiles can support identification of subtle changes associated with nutrient deficiency, water stress, disease, or changes in plant development. Hyperspectral systems are particularly useful in research settings where detailed physiological information is required.

Thermal imaging is another useful method for evaluating plant responses. Leaves lose water through transpiration, and this process influences canopy temperature. When plants experience water shortage, stomatal activity may change, affecting leaf temperature. Thermal cameras can detect these temperature differences across plants or field areas. Researchers can use thermal maps to compare water-use responses among crop varieties and identify plants that maintain suitable physiological activity under limited water conditions.

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Received: 29-Aug-2025, Manuscript No. AGT-25-32494; **Editor assigned:** 01-Sep-2025, Pre QC No. AGT-25-32494 (PQ); **Reviewed:** 15-Sep-2025, QC No. AGT-25-32494; **Revised:** 22-Sep-2025, Manuscript No. AGT-25-32494 (R); **Published:** 29-Sep-2025, DOI:10.35248/2168-9881.25.14.420

Citation: Freitas F (2025) Imaging-Based Phenotyping Technologies for Accurate Assessment of Plant Growth. Agrotechnology. 14:420.

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CONCLUSION

Crop phenotyping is increasingly connecting biological observation with digital measurement. By combining imaging, sensors, automated analysis, and environmental records, researchers can examine plant characteristics across different scales, from individual leaves to entire fields. This information

can contribute to improved crop selection, efficient resource management, and better understanding of plant responses to changing growing conditions. As digital agricultural systems continue to develop, reliable phenotyping methods will remain an important component of research focused on productive and resource-efficient crop production.