Employing rapid, accurate, high-precision phenotyping in poplar, switchgrass, and bacteria

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Project Goals: The Center for Bioenergy Innovation (CBI) vision is *to accelerate domestication of bioenergy-relevant, non-model plants and microbes to enable high-impact innovations at multiple points in the bioenergy supply chain.* CBI addresses strategic barriers to the current bioeconomy in the areas of 1) high-yielding, robust feedstocks, 2) lower capital and processing costs via consolidated bioprocessing (CBP) to specialty biofuels, and 3) methods to create valuable byproducts from the lignin. CBI will identify and utilize key plant genes for growth, composition, and sustainability phenotypes as a means of achieving lower feedstock costs, focusing on poplar and switchgrass. We will convert these feedstocks to biofuels using CBP with cotreatment at high rates, titers and yield in combination with catalytic upgrading into drop-in hydrocarbon fuel blendstocks.

Traditional plant phenotyping relies on manual measurement of traits, which can be time-consuming, labor-intensive, subject to human error, and often destructive to the samples being scored. Thus, we aim to resolve such bottlenecks by developing field-ready devices (using edge computing and field digitization) and computational tools (deep learning and explainable AI) to facilitate population-scale analyses like GWAS. We apply these methods to data arising from the field and greenhouse in conjunction with ORNL's high performance computing (HPC) resources (e.g., Oak Ridge Leadership Computing Facility).

Edge computing and phenotyping devices: Field-ready devices for switchgrass and poplar feedstocks are developed and deployed that utilize (i) edge computing (e.g., GPU-accelerated computing, real-time machine learning, sample tracking, data storage, etc.) for measuring plant traits and (ii) field digitization (e.g., RFID tagging, QR codes, barcodes, plant wearables, soil probes, electrolytic readers, in-situ monitoring devices, etc.) for wireless data capture. This includes the development of handheld phenotyping devices like the Diameter at Breast Height Camera, Rapid Thermal Imager, and μ-tablet, which utilize automated data capture, processing, and storage within the same device. For bacteria, hardware and computational tools are developed for fast and accurate feature extraction from scanned images of bacterial colonies on culture plates.

Image processing: We use deep learning and explainable AI to extract and analyze biologically relevant plant features from multimodal image data captured from field devices (cameras, tablets, drones, etc.) and phenotyping facilities (e.g., the Advanced Plant Phenotyping Laboratory at ORNL). Deep learning is used to identify salient image features while explainable AI relates such features to complex plant traits (e.g., environment, biomass yield and composition, etc.).

Project Impact: This work enables fast and accurate plant phenotyping in the field and greenhouse, in which a single individual can collect high-precision phenotypes at population scale in a fraction of the time and energy compared to traditional strategies.

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