CHANGING WHAT'S POSSIBLE

AUTOMATED SORGHUM PHENOTYPING PLATFORMS

Updated: December 21, 2017

TITLE: Automated Sorghum Phenotyping and Trait Development Platform

PROGRAM: Transportation Energy Resources from Renewable Agriculture (TERRA)

AWARD: $6,662,287

TEAM: Purdue University, IBM, University of Queensland

TERM: August 2015 – August 2018

PRINCIPAL INVESTIGATOR (PI): Mitch Tuinstra

MOTIVATION

As global energy demand increases, bioenergy remains an important fuel alternative. However, current yields of bioenergy crops, like biomass sorghum, are insufficient to produce large volumes of domestic biofuel. High-throughput strategies that can identify improved crop genotypes earlier in the growth cycle are needed to quickly develop new, high-yield varieties. Greater knowledge of factors that influence crop development can improve breeding. Genomics tools have advanced, and the pace of genotyping has accelerated exponentially while the cost of sequencing has dramatically decreased. The technological challenge has shifted from understanding the genotype to understanding the phenotype – the traits exhibited by the plant as a result of its genotype and its environment (Figure 1). Because traditional breeding approaches are slow and labor-intensive, new approaches to accelerate phenotyping are needed.

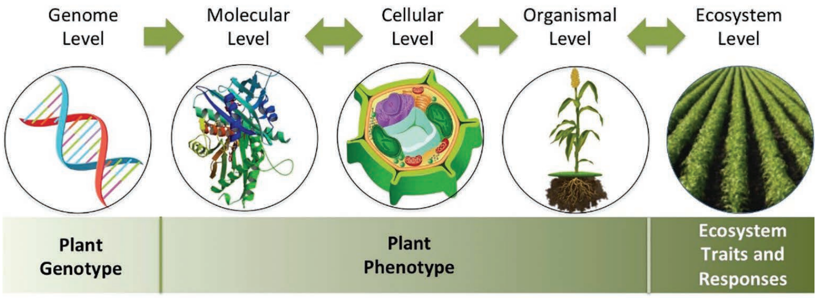

Figure 1. Information in the plant genome interacts with biotic and abiotic factors to inform emergent properties across scales.

TECHNICAL OPPORTUNITY

Sorghum plants possess many valuable attributes, including high biomass-yield potential, drought tolerance, and a sequenced genome. Advanced phenotyping could lead to the identification of new sorghum variants with even higher biomass or increased tolerance. Advances in robotics, remote sensing, and software allow for extraction of massive volumes of data from crops, allowing high-throughput evaluation of traits throughout the growing season. When combined with next-generation DNA sequencing and molecular profiling, these advances enable breeders to rapidly develop crops with desired traits. Nevertheless, complexities in data processing, feature extraction, and data analytics make predictions of crop performance challenging.

INNOVATION DEMONSTRATION

Purdue seeks to optimize sorghum energy yield for transportation fuel. The team uses advanced sensors mounted on ground-based systems (Figure 2) and unmanned aerial vehicles (UAVs) to monitor several traits throughout the growing season, including plant height, canopy cover, leaf-area index, spectral indices, and leaf number. The data are combined with traditional measures of productivity and agronomic performance to develop trait indices for high-throughput phenotyping.

The team developed an integrated calibration procedure for various sensors onboard the UAV and PhenoRover systems. The calibration process has demonstrated accuracy near the pixel resolution of the sensor. This resolution enables an unprecedented level of automatic analysis—from entire plots all the way down to individual plants and leaves (Figure 3).

Figure 2 (left): The PhenoRover integrates visible, multispectral, ranging, and hyperspectral sensors. Figure 3 (right): Automated plant identification.

Purdue developed machine learning algorithms to identify plots of field trials, identify centers of all plants in each plot, and estimate plant and leaf counts, plant height, panicle counting, and canopy cover. The team then combines these measurements with visualization tools to provide interactive analytical capabilities. Algorithm users can investigate which varieties are similar according to selected plant traits, discovering genes for plant performance, architecture, and composition in diverse collections of sorghum. The team is working to identify genes and alleles that can be used to enhance the bioenergy value of sorghum feedstock. The team has already identified 22 mutants with modified lignin content and composition and improved efficiency in biofuels production. They also identified genetic loci that contribute to sugar release during ethanol production, enabling potentially higher yields in biofuel conversion. To enable applications beyond sorghum, the team is working to ensure its tools can be used in other remote sensing platforms.

IMPACT PATHWAY

The team received approximately $200,000 in follow-on funding from the United Sorghum Checkoff to develop and deploy a platform of sensors and algorithms to identify reproducible, physiologically relevant changes in crop plant tissues under stresses. Additionally, a major agricultural corporation has provided $150,000 to develop new phenotyping technologies for maize breeding and genetics.

In 2016, Purdue University devoted $15 million in a new field phenotyping facility, the Indiana Corn and Soybean Innovation Center, which brings together Indiana farmers, industry, university faculty and students. By using state-of-the-art technology to measure and analyze characteristics of crops, the Center seeks to translate information about individual plants to field scale.

In August 2017, the project leads launched CROPi Analytics, a company that provides data processing software for remote sensing applications in agriculture. In October 2017, CROPi Analytics agreed to commercialize two patents from the Purdue Research Foundation related to remote plant sensing and improved algorithms.

LONG-TERM IMPACTS

Previously, the difficulty of identifying relevant information from plant data limited the application of whole genome data to sorghum breeding. Thanks to the remote sensing tools and data processing systems developed in this project, breeders now have detailed, precise measurements of plant performance. These data, coupled with genomic technologies and new algorithms, will enable the development of bioenergy crops that can sustainably generate a large supply of biomass for biofuel production.

INTELLECTUAL PROPERTY AND PUBLICATIONS

As of December 2017, the project has generated five invention disclosures to ARPA-E. One U.S. Patent and Trademark Office (PTO) patent application has been filed on the disclosed inventions. The project has also published the scientific underpinnings of this technology five times in open literature and presented at conferences around the world.