CHANGING WHAT'S POSSIBLE

LOW-COST ROBOT FOR CROP IMPROVEMENT

Updated: January 29, 2018

TITLE: TERRA Mobile Energy-Crop Phenotyping Platforms (MEPP)

PROGRAM: Transportation Energy Resources from Renewable Agriculture (TERRA)

AWARD: $5,100,000

TEAM: University of Illinois at Urbana-Champaign (Lead), Cornell University, and Signetron, Inc.

TERM: October 2015 – December 2019

PRINCIPAL INVESTIGATOR (PI): Stephen Long

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.

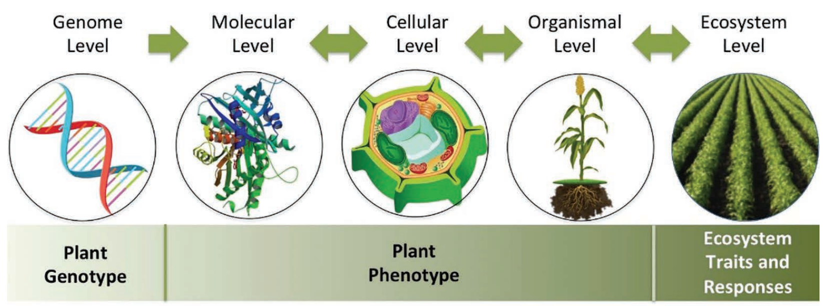

Figure 1. Information in the plant genome interacts with biotic and abiotic factors to inform emergent properties across scales.

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

The University of Illinois, Urbana-Champaign (UIUC) project aims to: (1) develop low cost, autonomous robots with sensors to rapidly collect phenotypic information within large field trials (Figure 2); (2) develop software to deliver high-throughput phenomics from the sensor data; (3) use a model-based data synthesis system to capture physiological parameters and predict yield; and (4) integrate this diverse information with whole-genome DNA sequencing technologies to identify genes underlying the traits and their genetic markers that will maximize the pace of trait discovery.

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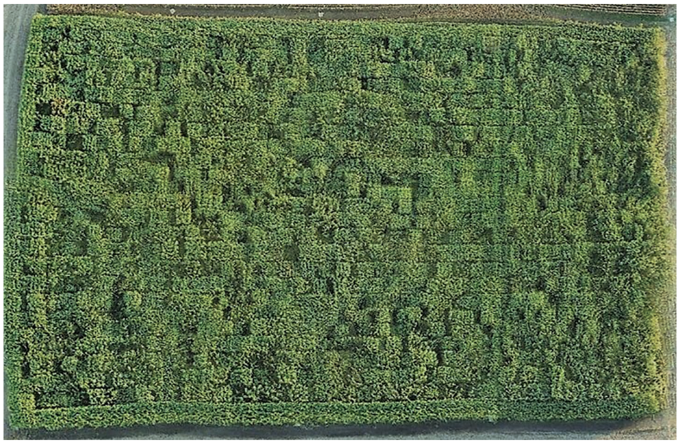

Figure 2 (left): One trial at UIUC. Ground robots collect sensor data from sorghum varieties at a rate of one acre every two hours.
Figure 3 (right): TerraSentia is an ultra-compact 3D-printed robot.

To improve accuracy for automated phenotypic data processing, the team developed point cloud algorithms to identify individual stems and age-adaptive algorithms to estimate stem width and plant height. These algorithms can be applied to field data with over 80% accuracy. The team used the data to develop a model able to predict end-of-season performance of individual plants.

The team created a high-throughput sequence data analysis pipeline for whole-genome resequencing to identify genes underlying specific traits. Some traits, such as plant height, were found to be highly heritable, and a number of genetic markers have been linked to these traits. High quality genetic markers allow researchers to determine the best crosses to make between sorghum varieties, and then select the plants with the highest yield potential early in the season. As a result, the team also developed germplasms, living genetic resources, such as seeds, that are maintained for plant breeding and other research uses.

The team also developed TerraMepp, an over-canopy, high-payload robot for versatile phenotypic measurements, and TerraSentia (Figure 3), a low cost, under-canopy robot for early adoption in commercial applications. Whereas manual phenotyping of a single field requires several days, a single TerraSentia can survey a trial plot in just one day. Fleets of TerraSentia robots can operate as a team to offer nearly unlimited scalability.

IMPACT PATHWAY

Potential commercial products from this project include the autonomous robots, novel algorithms for analyzing plant data, and new germplasms with crop-improving genetic markers. Through an early adopter program, the TerraSentia robots are already available to industry, academia, and others at a cost of $5,000.

LONG-TERM IMPACTS

The difficulty of identifying relevant plant data limits the application of whole genome data to sorghum breeding. The low-cost robots and novel approaches being developed in this project could allow researchers to obtain statistically reliable and biologically meaningful candidate links between genotypes and phenotypes. These new tools could enable more efficient use of diverse genetic resources for crop improvement, including increased resilience and productivity. Ultimately, these phenotyping technologies could lead to new varieties of bioenergy that require less agronomic inputs and are more productive, sustainable, and resilient.

INTELLECTUAL PROPERTY AND PUBLICATIONS

As of November 2017, the project has generated five invention disclosures to ARPA-E. The team has also published the scientific underpinnings of this technology twice in open literature.