**Innovative technologies for high-resolution and high-throughput plant and algal phenotyping**

**Dynamic Environmental Phenotyping Imagers (DEPI)**. To obtain sufficient sensitivity for high-resolution genetic mapping, the measurements must be highly reproducible, yet made at appropriate times and frequencies and performed under relevant environmental conditions. We address this using novel high-throughput plant phenotyping technology developed at MSU, including the Dynamic Environmental Phenotype Imager (DEPI) platform [1-3] that captures “videos” of plant photosynthetic and growth responses to highly reproducible, yet dynamic simulated environmental conditions. Work of the past two years has demonstrated that DEPI resolves previously unseen photosynthesis and plant growth phenotypes and greatly accelerates high-resolution measurements of photosynthetic phenomena, allowing for example QTL mapping for traits involved in efficient and robust photosynthesis.

**Environmental Photobioreactor (ePBR) Array [4, 5](cited in over 35 publications).** Algae in natural or production setting experience fluctuating environmental conditions including changes in light, temperature, CO2 and nutrient availability, oxygen and mixing. In response, algae respond to environmental changes dynamically, adjusting light energy capture strategies, physiological processes and cell cycle control. It is thus the combination of environmental conditions and biological responses that determines the performance of the algae. In contrast, much algal research is performed under artificially static laboratory environments, where different constraints determine performance. Consequently, algal strains selected for mass production in the laboratory may fail to perform well or outcompete local algal strains under outdoor production conditions. To address these issues, we have developed a novel environmental photobioreactor (ePBR), designed to mimic lighting from natural pond environments while controlling key environmental parameters including temperature, pH and CO2 levels, mixing, and culture density.

**PhotosynQ.org and MultispeQ.** CAAPP has developed the PhotosynQ platform (www.photosynq.org) with the aim to address several challenges that currently limit the wide-scale application of techniques for phenotype-driven plant screening, selection and breeding. The PhotosynQ platform is an open-source platform to create a community of researchers that can make sophisticated geo-referenced measurements in the field, and share results and analyses to answer important scientific and agricultural questions at both local and global scales. It is currently being used by over 600 users in over 18 countries. Participants can design experiments and engage in the experiments of others, analyze data, and discuss results via the website and mobile apps. One component of the PhotosynQ platform is a hand-held sensor called “MultispeQ,” an inexpensive (~$200) yet sophisticated field-deployable instrument capable of measuring several key plant properties and related environmental conditions. MultispeQ is well suited for the project because it measures very specific mechanistic phenotypes related to photosynthesis including photosynthetic efficiency and rates, plant and soil respiration, photoprotection and photoinhibition, plant pigment analysis and plant architecture, as well as important environmental parameters such as location, temperature, light quality and intensity, humidity, and CO2 levels. Data from MultiSpeQ are wirelessly connected to the PhotosynQ platform so that results can be immediately shared and compared with data from complementary approaches, potentially giving us mechanistic insights into variations in bioenergy efficiency. We have also developed a set of on-line analytical tools that allow sophisticated PhotosynQ data analyses.

**Publically Available Software Packages and Computational Approaches:**

* DEPItrol [6] (control software for the DEPI instrument)
* Visual Phenomics (dynamic environment phenotype visualization package) [7]
* PhenoMath (integrative analyses of photosynthetic phenotypes) [8]
* OLIVER (multi-dimensional visualization of photosynthetic phenotypes) [9]
* CAAPP-LIMS. The high throughput data afforded by DEPI requires careful experimental planning and record keeping. We have thus developed a Laboratory Information Management System (LIMS) to record the complete history of each plant, from its genomic information, to its planting and growth conditions, to its ultimate phenotypic behaviors. This tool is available on-line to the community of MSU researchers to plan experiments and track the results.
* PhotosynQ-App Android App for control of PhotosynQ MultispeQ instrument in the field (www.photosynq.org)
* PhotosynQ-Chrome, Chrome App for control of PhotosynQ MultispeQ instrument in the lab (www.photosynq.org)
* PhotosynQ Analysis platform (open-source analytical tools for PhotosynQ)
* PhenoCurve platform for characterizing complex multi-parameter photosynthetic phenotypes [10]
* DynamicFilter, a phenotype data cleaning package [11]
* A platform for characterizing and quantifying high-dimensional phenotype data [12]
* Method, hardware and software for visualization and quantification of chloroplast movements [13]
* Methods for tracking and characterizing individual plant leaves [14, 15]

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