

Improving Photosynthesis in Grain Legumes with New Plant Phenotyping Technologies (S01.A2–MSU)

Lead U.S. and Host Country Principal Investigators, Institutions, and Countries

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Project Problem Statement and Justification (Brief)

Photosynthesis and the need for increased crop productivity. There is an urgent need to develop highly productive, environmentally robust and sustainable energy and food production under a rapidly changing environment. The increases in plant productivity seen in the green revolution, which focused on maximizing many of the easily modifiable plant parameters (e.g., crop architecture, plant growth cycle, harvest index) have flattened out in recent years. It is proposed that future increases in productivity will require environmental robustness and improvements in the efficiency of the energy storing reactions of photosynthesis. Photosynthesis provides the energy to generate all food on the planet. However, the realized efficiency of photosynthesis is far below its theoretical limit partly because it is inherently potentially dangerous to plants, particularly under fluctuating (rapidly changing) environmental conditions. Under many circumstances, photon capture can exceed the rate at which the energy can be used, resulting in production of ROS and cell damage. As a consequence, nearly every step in photosynthesis is highly regulated by processes that result in tradeoffs between efficient energy capture and the avoidance of photo damage.

Improving photosynthesis requires selection for multiple traits simultaneously that both increase yield and resilience to natural, fluctuating environmental conditions. Importantly, there are large natural genetic and breeding-induced variations in the responses of photosynthesis across species and germplasm, leading to large differences in productivity in specific environments. These variations may be exploited for plant improvement, provided that we can identify the genetic loci and processes controlling these traits. Recent advances in genomics, genetics, and breeding methodologies make possible the identification of quantitative genetic loci (QTL) responsible for desired traits as well as the introgression of desirable QTL into production lines via marker-assisted breeding to achieve improved performance, e.g., increased resistance to pests, drought tolerance, etc. However, these approaches *require* sensitive, reproducible, high throughput detection and analyses of relevant phenotypes *under appropriate conditions*. This

approach also requires “accuracy and communication between plant breeders, pathologists, quantitative geneticists, and support staff.” These requirements are more easily met for some qualities (e.g. germination, pest resistance) that have obvious (strong, easily measured) phenotypes, consistently expressed under the relevant conditions. More complex traits, especially yield or resilience to combinations of dynamic changes in environmental conditions, require more sophisticated approaches to phenotyping that make appropriate measurements under appropriate (local, dynamic) conditions and analyze the results to yield connections to the genome. Such tools must be high throughput (many genetic variations under many conditions), spatially resolved (e.g., to identify trends across soil types), noninvasive, highly sensitive, reproducible, and highly specific (to reveal important biochemical and biophysical traits). They also need to be highly integrated so that experimental conditions and results can be shared and analyzed.

Objectives

1. Develop and evaluate innovative new technologies (DEPI and PhotosynQ) for improvement of grain legumes both under controlled yet dynamic and field conditions.
2. Employ these technologies in proof-of-concept projects to identify QTLs in cowpea and common beans that modulate the efficiency of photosynthesis and its responses to changing environmental conditions in collaboration with Professor Tim Close (U.C. Riverside, Identification of photosynthesis- and heat-stress related QTLs in cowpea using the multiple advanced generation InterCross (MAGIC) approach), Professor Phil McClean (NDSU, photosynthesis-related genes in a genome wide association (GWAS) panel of common beans) and Professor Maren Friesen (MSU, Plant Biology, Assessing the ability of DEPI and PhotosynQ to probe differences in biological nitrogen fixation and plant-microbe interactions)
3. Establish and enable an African-USA community of networked scientists, extension agents, students and growers to address field-level research and production questions in collaboration with Kelvin Kamfwa (U. Zambia), Wayne Loescher (MSU), Phil McClean (NDSU), and Stanley Nkalubo (NaCRRI) in Uganda.
4. Establish and enable an Africa–USA community of networked scientists.

Target Outputs

Year 1 (2014–2015)

1. Construction and testing of initial MultispeQ units (Target date: March 2015)
2. Preparation of initial instruction module for use of PhotosynQ platform (Target date: April 2015)
3. Preparation of prototype field measurement protocols (Target date: April 2015)
4. First runs of selected cowpea and common bean genotypes in DEPI chambers (Target date: Oct 2015)
5. Train students from HCs in theory and use of PhotosynQ (Target date: May 2015)
6. Develop educational modules (Target date: May 2015)
7. Test educational modules with students from U. Zambia (Target date: June–Oct 2015)
8. Expand PhotosynQ platform to enable LIL group interactions for both US and HC (Target date: June 2015)participants

9. First field trials of PhotosynQ in NDSU and UC Riverside (Target date: March–Sept 2015)
10. Comparative DEPI studies of cowpea and common bean genotypes under simulated environmental conditions (Target date: May–Oct 2015)
11. Distribute devices to collaborators. (Target date: June 2015)
12. Students travel to NDSU and UC Riverside for training (Target date: June 2015)
13. Dissemination of results via the PhotosynQ web site and publications (Target date: Oct 2015)

Year 2 (2015–2016)

1. Detailed study of selected cowpea or bean lines for phenotypes under simulated environmental conditions (Target date: Jan. – Oct 2016)
2. Use DEPI results from outcome 12 to determine which sets of lines are most promising for QTL mapping (Target date: March–April 2015)
3. Training for field work in Zambia (Target date: March 2015);
4. First field trials at University of Zambia (Target date: Sept 2015–March 2016);
5. 18) Assessment of field performance of PhotosynQ platform in Zambia (Target date: March–Oct 2016).

Year 3 (2016–2017)

1. Based on assessment in outcome 16, revise MultispeQ device, protocols, etc. (Target date: Nov. 2016)
2. Training for field work in Uganda (Target date: Oct 2016)
3. Field trials in Uganda (Target date: Nov 2016–April 2017)
4. Continuation of field trials in Zambia (Target date: Nov 2016–April 2017)
5. Assessment of results from HC: Can PhotosynQ be used to map relevant QTLs? (Target date: April 2017–Oct. 2017)
6. Detailed DEPI studies of selected panels (Target date: Nov 2016–Aug. 2017)
7. Analysis of DEPI results and assess the capability of DEPI to identify QTLs (Target date: Aug. 2017–Oct 2017)