Spectroscopic Diagnosis of Plant Phosphorus Availability and Relationship to Tissue Chemistry and Productivity of a Bioenergy Feedstock

Zhao Hao[1], Yuan Wang[2], Na Ding[2], **Wolf Scheible**[2], **Kelly Craven**[2], **Michael Udvardi**[2], **Mary Firestone**[3], **Eoin Brodie**[1,3*]

[1]Lawrence Berkeley National Laboratory, Berkeley, California; [2]Noble Research Institute, Ardmore, Oklahoma; [3]University of California, Berkeley, California

Project Goals: Switchgrass (*Panicum virgatum* L.) is a perennial C_4 grass native to the tallgrass prairies and a promising feedstock for U.S. bioenergy production. Capable of abundant biomass yield with minimal fertilizer or water, switchgrass can survive on marginal soils, and even thrive once established. We hypothesize that successful establishment and sustainable cultivation of switchgrass in marginal soils is in part enabled by beneficial plant-microbial interactions. We are investigating the succession of rhizosphere microbial communities, and ecosystem-scale effects of high- and low-performing switchgrass plants grown in nutrient-limited soils in southern Oklahoma. The outcome of this research will provide a better genomic basis for switchgrass cultivation in marginal soils, expand our knowledge of the interactions between soil microbiomes, plants and ecosystems, and ultimately guide efforts for translation into agronomic row crops.

Economic bioenergy/bioproduct feedstock production will likely require the utilization of marginal soils. Although crops such as switchgrass (*Panicum virgatum L.*) may obtain a fraction of their nitrogen requirement through associate N-fixation, phosphorus (P) is exclusively derived from soil or added fertilizer. Soil P availability is chemically complex and varies significantly based on pH, mineralogy, hydrology and the chemistry of inputs - resulting in heterogeneous P availability across soils of production systems. Plants and microbes have evolved mechanisms to liberate mineral, and organic associated P – these mechanisms frequently require allocation of resources in the form of carbon cost. Better understanding of these mechanisms calls for high-throughput, non-invasive yet accurate prediction tools we have developed, and will lead to improved biomass yield and feedstock quality for bioenergy feedstock development program.

In this work, we used infrared spectroscopy to monitor plant P dynamics and tissue chemistry during switchgrass growth, establishing a linkage between P availability and spectral signatures using plants grown in a controlled laboratory environment. We used these data as a benchmark, assisted by machine learning algorithms, to evaluate P availability in the switchgrass plants cultivated in two marginal soils in Oklahoma. This represents a relatively noninvasive approach to quantifying inorganic and organic phosphorus content and other chemical constituents of leaf tissue during plant growth. We used these data to observe relationships between P availability, P uptake and re-allocation dynamics and biomass productivity in subsequent growing years.

We report three important findings: (1) In response to P stress (but not N stress), switchgrass cell wall composition had increased lignin concentration, leading to lower cellulose:lignin ratios—an important index of biofuel feedstock quality. P-limitation also appeared to lead to lipid accumulation and a relative decrease in amide (protein) content. (2) In our field plots of mixed genotypes, plants growth in soils with higher P availability accumulated more organic P and re-allocated more P during pre-harvest senescence. Within each site, we observed significant variability in P pools, reflecting either heterogeneity in switchgrass cultivar genetics, subsurface chemical properties or variability in soil-plant-microbial interactions that mobilize P. (3) Greater re-allocation of organic P during senescence was associated with increased biomass productivity of individual plants during the subsequent growing season.

Overall this work demonstrates the potential of high-throughput spectroscopic approaches to diagnose plant nutrient availability, its consequences for feedstock compositional quality and productivity, and the relationships with chemical and biological heterogeneity in soils of production systems.

This work was funded by the US Department of Energy Office of Science, Office of Biological and Environmental Research Genomic Science program under Award Number DE-SC0014079 to the UC Berkeley, Noble Research Institute, the University of Oklahoma, the Lawrence Livermore National Laboratory and the Lawrence Berkeley National Laboratory. Work performed at Lawrence Berkeley National Lab was under contract DE-AC02-05CH11231.