Economic Impact of Yield and Composition Variation in Bioenergy Crops: *Populus trichocarpa*

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Project Goals: The Center for Bioenergy Innovation (CBI) vision is *to accelerate domestication of bioenergy-relevant, non-model plants and microbes to enable high-impact innovations at multiple points in the bioenergy supply chain.* CBI addresses strategic barriers to the current bioeconomy in the areas of 1) high-yielding, robust feedstocks, 2) lower capital and processing costs via consolidated bioprocessing (CBP) to specialty biofuels, and 3) methods to create valuable byproducts from the lignin. CBI will identify and utilize key plant genes for growth, composition and sustainability phenotypes as a means of achieving lower feedstock costs, focusing on poplar and switchgrass. We will convert these feedstocks to specialty biofuels (C4 alcohols, C6 esters and hydrocarbons) using CBP at high rates, titers and yield in combination with cotreatment, pretreatment or catalytic upgrading. CBI will maximize product value by *in planta* modifications and biological funneling of lignin to value-added chemicals.

To achieve a bio-based economy, it is necessary to consider variability within a feedstock population. We must understand the range of key phenotypic characteristics in order to select economically advantageous genotypes for domestication in an optimized supply chain. In this analysis, we measured cell wall composition traits in a large natural variant population of *Populus trichocarpa*. The compositional analysis results were combined with agronomic growth data from the matching genotype to conduct a series of techno-economic analyses utilizing Aspen Plus [1] based on Humbird [2] of a lignocellulisic biomass refinery. These analyses evaluated the impacts of physical and compositional variability and determining the ultimate phenotypic drivers for yield and economic metrics. Here we show that while ethanol yield per land area per year and minimum fuel selling price (MFSP) were most strongly impacted by tree size, when considering the largest 25% of trees, size and carbohydrate content were nearly identical influencers on MFSP, highlighting the need to focus on both size and carbohydrate content in selecting economically optimal feedstocks.

Feedstock cost is one of the greatest operational expenses in a biorefinery, so understanding which feedstocks are advantageous relative to one another in terms of both cost and quality should be an important consideration for any biorefinery [2,3]. No formally accepted standard of lignocellulosic biomass quality has been previously defined, but several metrics may be used. Process yield, defined as amount of fuel produced per unit of feed, is one metric that evaluates the impact of a feedstock on total production. However, growers are typically concerned with achieving the highest biomass yields for a given land area with little consideration given to process yield or quality. To reconcile the gap between grower and biorefinery, both biomass yield and process yield can be combined and normalized to define the metric of fuel yield per land area per year [5]. This can be an important consideration when evaluating the land footprint required to reach a production target, but in conjunction to process yield may also serve as a negotiating point between the biorefinery and grower, or grower and plant breeders, in determining price. With respect to economics, minimum fuel selling price (MFSP) needed to achieve a net present value of zero for a plant is often used to summarize the entire biorefinery in terms of economic drivers such as capital expense, operating expense, and revenue, where feedstocks that lead to the lowest MFSP can be regarded as the best performers. While not a direct measure of feedstock quality, MFSP can serve as a bottom-line economic indicator of the value of quality and quantity and through multiple analyses, determine which feedstock characteristics are most impactful.

As interest in poplar as a lignocellulosic feedstock grows, so too will the need to understand its variability across a population. There is a need to comprehend this variation not only as the range of physical and compositional phenotypes, but also how these phenotypes impact overall feedstock quality and biorefinery economics. Determination of advantageous processing phenotypes can provide insight guiding plant breeders into focusing on attributes which are the most influential to improving yields, while simultaneously reducing production costs. In this paper, we present the larger economic impact a broad range of natural variation in plant growth and cell wall composition for *Populus trichocarpa* has on the bioenergy landscape as MFSP, process ethanol yield, and field ethanol yield.

References

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