Improving Photosynthetic Efficiency of C4 Energy Crops: A Dynamic Modeling Analysis

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https://cabbi.bio/research/feedstocks-theme/

Project Goals:
To meet the increasing societal need for energy, one of the missions of the Center for Advanced Bioenergy and Bioproducts Innovation (CABBI) is developing efficient ways to increase the biomass productivity of bioenergy crops and improve the efficiency of conversion from biomass into valuable chemicals.

The goal of our work is to engineer, or identify, more photosynthetically efficient sorghum and sugarcane germplasm. A dynamic model from leaf metabolism to crop canopy could help us identify potential targets for improving energy, water, and nitrogen use efficiency, and increase the biomass productivity of bioenergy crops in various environmental conditions.

1. **Develop a dynamic metabolic model for general C4 plants.**
2. **Parameterize the model using measured gas exchange data of bioenergy crops, such as sugarcane and sorghum, and predict targets for increasing photosynthesis under non-steady state conditions.**
3. **Develop a canopy model for C4 bioenergy crops and identify targets for increasing canopy photosynthesis and biomass accumulation.**

Photosynthesis is the ultimate source of bioenergy and bioproducts, and its efficiency is closely related to the productivity of crops. Increasing crop photosynthetic efficiency is one means to meet the pressure of increasing food, biofuels, and bioproducts without the need to bring more land into agriculture. The most productive C4 biofuel crops, such as corn, sugarcane, and sorghum, utilize NADP-ME-type C4 photosynthesis. Despite high productivities, these crops still fall well short of the theoretical maximum energy conversion efficiency. Understanding the basis of these inefficiencies is key to improving the productivity of these C4 crops.

Attempts to improve photosynthesis have focused on efficiency under constant high light, steady-state conditions. However, in the field, leaves are rarely in steady state and are affected by frequent light fluctuations. This has led to a growing awareness of the need to address photosynthetic efficiency in fluctuating light.

We measured the rates of CO_2 uptake and stomatal conductance of sorghum and sugarcane under fluctuating light regimes. The measured gas exchange data was combined with a new dynamic C4 photosynthesis model to infer the limiting factors for each crop species under non-steady

state conditions. Our modeling identified Rubisco activase, the PPDK regulatory protein, and rate of stomatal opening as key limitations under non-steady state conditions, although this may vary between species. Our work identified feasible targets for improving photosynthetic efficiency of bioenergy crops, which are now being bioengineered.

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