Toward a Dynamic Photosynthesis Model to Guide the Yield Improvement for C4 Energy Crop

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

Project Goals:

To meet the increasing societal need of 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.

A dynamic metabolic model from cell to canopy could help us identify potential targets for increasing photosynthesis, water, and nitrogen use efficiency, and improve 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 data of bioenergy crops, such as sugarcane and sorghum, and predict potential targets for increasing photosynthesis.**
3. **Develop leaf model of C4 bioenergy crop, including 3D leaf anatomy and dynamic metabolic model.**
4. **Develop a canopy model for C4 bioenergy crop, and identify targets for increasing canopy photosynthesis.**

Sorghum and sugarcane, the focal crops of CABBI, belong to the monophyletic grass tribe Andropogonae. The tribe includes the most productive crops and wild species known, which is associated with their use of C4 photosynthesis. All members, as would be expected with their common evolutionary ancestry use Malic enzyme as their primary decarboxylase; this type of C4 being known as C4-ME. Despite high productivities, in sorghum and sugarcane these fall well short of the theoretical maximum crop C4-ME solar conversion efficiency of 6% (Zhu et al., 2008). Understanding the basis of these inefficiencies is key to achieving bioengineering and breeding strategies to increase sustainable productivity and approach the high theoretical efficiencies of C4-ME crops.

Achieving the high potential efficiency of C4-ME photosynthesis requires coordination of a great many metabolic and anatomical features. To quantify the impact of each feature and identify limiting factors, we are developing a generic dynamic systems model of C4 photosynthesis. Previously, we built a C4-ME metabolic model for maize, a close relative of sorghum and sugarcane, simulating the fluxes of C4 metabolic pathways and their flexibility (Wang et al., 2014ab). In the CABBI version of the model, we are extending the model to include all individual steps in carbon metabolism, and their inter-cellular and inter-organelle trafficking factors affecting dynamic photosynthetic rate, which include posttranslational regulation and temperature response of enzyme activities, dynamic stomata conductance, and detailed light reaction. The model is also being re-parameterized with data from the sorghum and sugarcane materials being used in CABBI. The model outputs are tested in vivo against measured rates of CO2 uptake, water vapor flux and electron flow measured by infra-red gas analysis and modulated chlorophyll fluorescence. Once satisfactory validation is achieved, optimization routines will be used to identify the most promising points for genetic/bioengineering intervention to achieve increased photosynthetic efficiency at the leaf and canopy level following procedures we have already successfully field validated in C3 crops (Zhu et al. 2007; Srinivasan et al., 2017).

References

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This work was funded by the DOE Center for Advanced Bioenergy and Bioproducts Innovation (U.S. Department of Energy, Office of Science, Office of Biological and Environmental Research under Award Number DE-SC0018420). Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the U.S. Department of Energy.