Strategies to Increase Photosynthetic Efficiency, CO_2 Fixation and Resource Allocation in Crops.

Heike Sederoff[1], Nathan Wilson[1], Brianne Edwards[1] and Danny Schnell[2]

[1]North Carolina State University, Dept. Plant and Microbial Biology
[2]Michigan State University, Department of Plant Biology

https://groecamelina.natsci.msu.edu

Project Goals:

One of the major limitations in photosynthetic carbon fixation occurs when O_2 competes with CO_2 at the active site of ribulose-1,5-bisphosphate carboxylase/oxygenase (Rubisco), resulting in the oxygenation of ribulose-1,5-bisphosphate (RuBP). This reduces CO_2 fixation and leads to the non-productive photorespiratory pathway at a significant energy cost and net loss of fixed carbon. Photorespiration accounts for a 30-40% decrease in the efficiency of carbon fixation in C3 photosynthesis, the pathway of carbon fixation used by the majority of crops, including Camelina, and about 85% of all terrestrial plant species. Our team is developing several distinct, but complementary approaches to address the limitations of CO_2 fixation in source tissues and increase seed yields in the model oilseed crop, Camelina sativa.

Abstract:

To increase the efficiency of biofuel crops to produce oil from photosynthetic CO_2 fixation, we designed and implemented several metabolic pathway modifications into our model oil seed crop Camelina sativa. One of the major limitations of photosynthetic CO_2 fixation is due to low activity and specificity of the CO_2-fixing enzyme Ribulose bisphosphate Carboxylase/Oxygenase (RuBisCO) and the CO_2 conductivity of the membrane systems surrounding RuBisCO. Other bottlenecks are due to the export control of assimilated carbon in form of sucrose from the photosynthetic leaf to the seeds and other sink tissues and the allocation of sucrose in seeds to increase the oil content. We used genetic engineering to a) increase the CO_2 conductivity of the leaf tissue by expression of a CO_2 transporter; b) expression of a synthetic CO_2 fixation cycle based on bacterial enzymes; c) expression of a photorespiratory bypass to reduce CO_2 loss; and d) reduction of a cell wall invertase inhibitor to reduce the limitation of sucrose phloem loading and unloading. While each modification (a-d) was successful in generating overall yield increases, integration of those traits show yield increases that are more dependent on environmental conditions like photoperiod and light intensity. This research will enable us to understand mechanisms underlying the integration of genotype and environment to optimize the use of genetic engineered traits in different bioenergy crops and growth regions.

This work was funded by ARPAe, BETO and BER #DE-SC0018269.