Regulating Photosynthesis

This project has improved our understanding of photosynthesis, thus providing new strategies for boosting plant productivity and resistance to stressful conditions.

Who cares and why?

During photosynthesis, plants use light energy to synthesize food (carbohydrates) for growth from carbon dioxide and water. As the key process in plant productivity, photosynthesis plays a vital role in every aspect of agricultural production. However, researchers and farmers do not fully understand how photosynthesis is affected by environmental, molecular, and genetic constraints. Alleviating some or all of these constraints could lead to substantial increases in plant productivity. Understanding photosynthetic processes could also help researchers develop new crop varieties with improved grain or oil yield or better resistance to water, heat, and salt stress. In these ways, exploiting the photosynthetic processes underlying plant productivity could help agriculture meet increasing demands for food, fiber, and biofuels. Because photosynthesis captures carbon dioxide from the atmosphere, a better understanding of photosynthesis could also illuminate new opportunities for reducing atmospheric carbon dioxide levels—a major factor in global warming.

What has the project done so far?

The NC-1168 project has brought together outstanding researchers from across the U.S. to investigate critically important areas of photosynthesis research. Over the past five years of the project, researchers have examined how photosynthetic processes are regulated, especially the genetic and environmental factors that influence photosynthetic productivity. These studies have found enzymes that could be engineered to increase plant production of starch and biomass as well as ways to alter photosynthesis so that plants are more efficient at converting sunlight into grain. Researchers have also gained better understanding of the genetic mechanisms that regulate which photosynthates—sugars like starch and sucrose—are produced by photosynthesis and where they end up in the plant (e.g. leaf cells, tissues, fruits, seeds). For example, one study revealed that day length affects the proportion of photosynthates stored in leaves as either starch or sucrose. This line of research gives scientists the potential to alter photosynthesis so that the substances produced are stored in the optimum chemical form and cellular location depending on the desired end use of the plant. Indeed, one NC-1168 study demonstrated a 10% to 20% increase in rice yields through these kinds of alterations. Additionally, NC-1168 has advanced research on the conversion of photosynthetic sugars into vegetable oils—work that is essential for engineering novel biofuel crops. NC-1168 studies on the expression of genes involved in photosynthesis have advanced the potential to breed plants that perform better under stressful conditions. For example, researchers have engineered more heat tolerant enzymes involved in photosynthesis. Other studies which measured photosynthesis in

By studying the genetic mechanisms that regulate which sugars are produced by photosynthesis and where they end up in the plant, NC-1168 researchers have been able to engineer plants that convert sunlight into grain more efficiently. Top photo by Kay Ledbetter/Texas A&M AgriLife Research, Flickr. NC-1168 researchers have also found ways to alter photosynthesis so that plants are more resilient to stress from heat and frost, which can damage plant leaves and impair photosynthetic processes and plant productivity. Middle photo by International Maize and Wheat Improvement Center, Flickr. Bottom photo by Alameda County Community Food Bank, Flickr.

cotton plants have revealed useful details about the onset of heat and drought stress. Researchers have also discovered a new mechanism for plants to cope with freezing stress and have genetically engineered improved salt tolerance in small flowering plants related to cabbage. Other studies have shed light on regulatory patterns that could help researchers develop water-saving plants. Another focus of NC-1168 research has been determining and modifying the biochemical and regulatory factors that impact the capture and release of carbon dioxide by plants.

Impact Statements

Addressed rising demand for food and fiber for increasing populations with decreasing arable land by designing strategies for manipulating photosynthetic processes so that plants produce more usable biomass.

Opened doors to new starch types for industrial, medical, and food-processing applications by providing new knowledge about starch formation.

Identified genetic mechanisms that increase resistance to salt, heat and water stress, reducing crop loss and costs and advancing strategies to maintain plant yields under climate change.

Discovered ways to regulate gene expression during photosynthesis, enabling scientists to modify crop genetics without introducing foreign genes, thus relieving many consumer concerns about genetically engineered plants.

Determined proper timing for applying agrochemicals without disrupting photosynthesis, reducing farmers' costs.

Found ways to manipulate photosynthesis so that plants produce more oil, helping satisfy increased demand for renewable biomass fuels.

Advanced opportunities to regulate global warming by modifying the capture and release of carbon dioxide during photosynthesis.

During photosynthesis, algae produce significant amounts of oil, which can be extracted and processed into biofuels. NC-1168 researchers are exploring how to manipulate photosynthesis in algae to produce more oil without impacting algae growth. Top photo by Andrea Pokrzywinsk, Flickr. Bottom photo by Texas A&M AgriLife, Flickr.

What research is needed?

Future research must focus on improving the response of photosynthesis to developmental and environmental factors that limit productivity so that sufficient food and fuels can be produced in a rapidly changing climate. Researchers must also continue to improve the capture and release of carbon during photosynthesis with emphasis on reducing greenhouse gas production. A more detailed understanding of the chloroplast—the part of plant cells that harbors the photosynthetic apparatus—is also needed.

Want to know more?

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This project was supported, in part, through USDA's National Institute of Food and Agriculture by the Multistate Research Fund (MRF) established in 1998 by the Agricultural Research, Extension, and Education Reform Act (an amendment to the Hatch Act of 1888) to encourage and enhance multistate, multidisciplinary research on critical issues that have a national or regional priority. Additional funds were provided by contracts and grants to participating scientists. For more information, visit *http://ncra.info/*.

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