Researchers successfully simulate photosynthesis and design a better leaf

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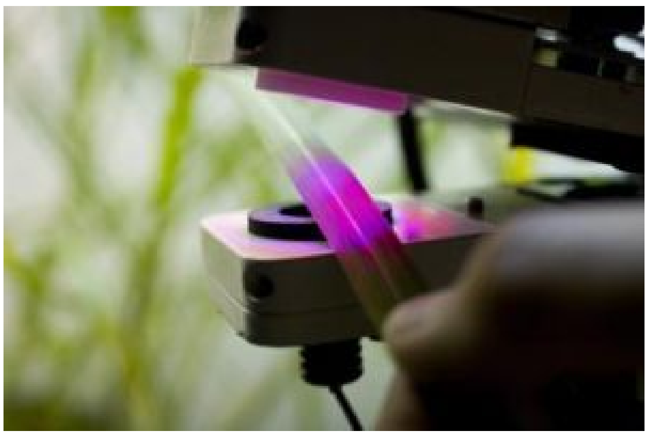

In a computer model, researchers at Illinois were able to simulate the photosynthetic behavior of actual leaves. Here, a gas exchange system measures the rate of carbon dioxide and electron transport in intact leaves. Credit: Don Hamerman

University of Illinois researchers have built a better plant, one that produces more leaves and fruit without needing extra fertilizer. The researchers accomplished the feat using a computer model that mimics the process of evolution. Theirs is the first model to simulate every step of the photosynthetic process.

The research findings appear in the October issue of *Plant Physiology*, and will be presented today at the BIO-Asia 2007 Conference in Bangkok, Thailand.

Photosynthesis converts light energy into chemical energy in plants, algae, phytoplankton and some species of bacteria and archaea. Photosynthesis in plants involves an elaborate array of chemical reactions requiring dozens of protein enzymes and other chemical components. Most photosynthesis occurs in a plant's leaves.

"The question we wanted to ask, was, 'Can we do better than the plant, in terms of productivity?' " said principal investigator Steve Long, a professor of plant biology and crop sciences at the University of Illinois.

It wasn't feasible to tackle this question with experiments on actual plants, Long said. With more than 100 proteins involved in photosynthesis, testing one protein at a time would require an enormous investment of time and money.

"But now that we have the photosynthetic process 'in silico,' we can test all possible permutations on the supercomputer," he said.

The researchers first had to build a reliable model of photosynthesis, one that would accurately mimic the photosynthetic response to changes in the environment. This formidable task relied on the computational resources available at the National Center for Supercomputing Applications.

Xin-Guang Zhu, a research scientist at the center and in plant biology, worked with Long and Eric de Sturler, formerly a specialist in computational mathematics in computer sciences at Illinois, to realize this model.

After determining the relative abundance of each of the proteins involved in photosynthesis, the researchers created a series of linked differential equations, each mimicking a single photosynthetic step. The team tested and adjusted the model until it successfully predicted the outcome of experiments conducted on real leaves, including their dynamic response to environmental variation.

The researchers then programmed the model to randomly alter levels of individual enzymes in the photosynthetic process.

Before a crop plant, like wheat, produces grain, most of the nitrogen it takes in goes into the photosynthetic proteins of its leaves. Knowing that it was undesirable to add more nitrogen to the plants, Long said, the researchers asked a simple question: “Can we do a better job than the plant in the way this fixed amount of nitrogen is invested in the different photosynthetic proteins?”

Using “evolutionary algorithms,” which mimic evolution by selecting for desirable traits, the model hunted for enzymes that – if increased – would enhance plant productivity. If higher concentrations of an enzyme relative to others improved photosynthetic efficiency, the model used the results of that experiment as a parent for the next generation of tests.

This process identified several proteins that could, if present in higher concentrations relative to others, greatly enhance the productivity of the plant. The new findings are consistent with results from other researchers, who found that increases in one of these proteins in transgenic plants increased productivity.

“By rearranging the investment of nitrogen, we could almost double efficiency,” Long said.

An obvious question that stems from the research is why plant productivity can be increased so much, Long said. Why haven’t plants already evolved to be as efficient as possible?

“The answer may lie in the fact that evolution selects for survival and fecundity, while we were selecting for increased productivity," he said. The changes suggested in the model might undermine the survival of a plant living in the wild, he said, "but our analyses suggest they will be viable in the farmer's field."

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Source: University of Illinois at Urbana-Champaign

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