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Newly identified enzymes help plants sense elevated CO2 and could lead to water-wise crops

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Biologists have identified plant enzymes that may help to engineer plants that take advantage of elevated carbon dioxide to use water more efficiently. The finding could help to engineer crops that take advantage of rising greenhouse gases.

Plants take in the carbon dioxide they need for photosynthesis through microscopic breathing pores in the surface of leaves. But for each molecule of the gas gained, they lose hundreds of water molecules through these same openings. The pores can tighten to save water when CO_2 is abundant, but scientists didn't know how that worked until now.

A team led by Julian Schroeder, professor of biology at the University of California, San Diego, has identified the protein sensors that control the response. Enzymes that react with CO_2 cause cells surrounding the opening of the pores to close down they report in the journal *Nature Cell Biology* online December 13.

The discovery could help to boost the response in plants that do not take full advantage of elevated levels of the gas, Schroeder says. "A lot of plants have a very weak response to CO_2. So even though atmospheric CO_2 is much higher than it was before the industrial age and is continuing to increase, there are plants that are not capitalizing on that. They're not narrowing their pores, which would allow them to take in CO_2, while losing less water," he said. "It could be that with these enzymes, you can improve how efficiently plants use water, while taking in CO_2 for photosynthesis. Our data in the lab suggest that the CO_2 response can be cranked up."

Plants lose 95 percent of the water they take in to evaporation through these pores, also called stoma. Modifying crops to be more responsive to CO_2 could help farmers meet demand for food as competition for water increases. In California, for example, 79 percent of water diverted from streams and rivers or pumped from the ground is used for agriculture according to the California Department of Water Resources.

Schroeder's team identified a pair of proteins that are required for the CO_2 response in *Arabidopsis*, a plant commonly used for genetic analysis. The proteins, enzymes called carbonic anhydrases, split CO_2 into bicarbonate and protons. Plants with disabled genes for the enzymes fail to respond to increased CO_2 concentrations in the air, losing out on the opportunity to conserve water.

Several types of cells in plant leaves contain carbonic anhydrases, including those responsible for photosynthesis, but Schroeder's team showed that the enzymes work directly within a pair of cells, called guard cells, that control the opening of each breathing pore. By adding normal carbonic anhydrase genes designed to work only in guard cells they were able to restore the CO_2-triggered pore-tightening response in mutant plants.

Adding extra copies of the genes to the guard cells actually improved water efficiency, the researchers found. "The guard cells respond to CO_2 more vigorously," said Honghong Hu, a post doctoral researcher in Schroeder's lab and co-first author of the report. "For every molecule of CO_2 they take in, they lose 44 percent less water."

The action of carbonic anhydrases is specific to changes in CO_2, the researchers found. Mutant plants still open their pores in response to blue light, a sign that photosynthesis can begin. And their pores also shut when water is scarce, a response mediated by a plant drought-stress hormone.

Photosynthesis continued normally in the mutants as well, suggesting that altering CO_2 sensitivity wouldn't stunt growth - good news if the goal is to engineer drought-resistant crops with robust yields.

But saving water and surviving heat involves a tradeoff for plants: Evaporation of water through the pores also cools the plant, just like sweat cools human beings. If future growing conditions are hotter and drier, as they are predicted to be in some parts of the world, then modifications to the CO_2 response will need to be carefully calibrated.

Source: University of California - San Diego (news : web)

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