Elucidate the mechanisms that regulate the function of photosynthesis

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Plants take in water and nutrients from the soil through their underground roots. At the same time, they use their leaves to catch the solar energy and then carry out photosynthesis reaction in the unique organelle named chloroplasts in the leaves, which uses the carbon dioxide in the atmosphere and water supplied from the roots to synthesize carbohydrates. In photosynthesis reaction, plants release the molecular oxygen, and the synthesized sugar molecules are stored as starch in the plant body or used for individual plant growth. Plants cannot easily change their living environment by themselves. This point is very different from animals. Even if a larger plant grows next to them in the summer and shades them, those plants cannot move once they settle in that place. Even if the sunny days continue and the soil is dried up completely, the plants cannot move to the nearest river to take water. To cope with the various environmental changes, plants have many mechanisms to regulate their functions.

Among the various regulatory functions of plants, the most critical mechanism for photosynthesis is a regulatory mechanism called redox regulation. Oxidation and reduction are the initial phenomena that occur when water is broken down in a photosynthesis reaction. In chemical terms, the reducing equivalents produced by this process finally reduce carbon dioxide to form sugar molecules. At the same time, a part of this reducing equivalents is used to regulate the activity of the various enzymes in the chloroplasts by reducing the disulfide bond on the enzyme molecule to change their molecular structure. Furthermore, plants use these reducing equivalents to protect themselves from light-induced damage. In our laboratory, we are conducting research to elucidate the redox regulation system at the molecular level, so to speak, the switch equipped to the enzyme.

The small redox-responsive protein, thioredoxin, regulates various enzymes involved in photosynthesis reactions. Thioredoxin is an abundant protein present in most living organisms, from bacteria to humans and plants. Thioredoxin also plays a critical role in the defense system of a living organism against reactive oxygen species. When plants are exposed to light, they immediately initiate various reactions in their body in addition to photosynthesis. For these decades, thioredoxin was recognized as a critical player in switching on multiple enzymes. In addition, it is also known the enzymes are switched off when exposed to light. As a result, these enzymes have to work at night.

Our former research results, in which we could incorporate a switch that regulates plant enzymes into a bacterial enzyme, have been included in the American biochemistry textbook entitled "Biochemistry (edited by L. Stryer et al.." including the research results. In addition, our new method of thoroughly examining various plant enzymes containing redox regulation switches

(Proc Natl Acad Sci USA. 2001, Proceedings of the National Academy of Sciences of the United States of America) is also described in "Lehninger Principles of Biochemistry."

Based on the proper understanding of the regulatory mechanism in plants, we can develop new ideas that will be useful for our future. For example, we may be able to think about how to make plants stronger when the environment changes or improve the metabolic system of plants to produce plants that can work better in the current global climate.

Plant with normal Photosynthetic regulator (Arabidopsis thaliana)

Plant with broken photosynthetic regulation (Arabidopsis mutant)

■Related Research Results

Motohashi K, Kondoh A, Stumpp MT, Hisabori T.
Comprehensive survey of proteins targeted by chloroplast thioredoxin.
Proc Natl Acad Sci USA. 2001 Sep 25;98(20):11224-11229.

Yoshida K, Hara S, Hisabori T.
Thioredoxin Selectivity for Thiol-based Redox Regulation of Target Proteins in Chloroplasts.
J Biol Chem. 2015 Jun 5;290(23):14278-14288.

Yoshida K, Hisabori T.
Two distinct redox cascades cooperatively regulate chloroplast functions and sustain plant viability.
Proc Natl Acad Sci USA. 2016 Jul 5;113(27):E3967-3976.