Rice Genetically Engineered to Stand Heat Stress is also More Productive

Global warming imposes a serious threat to global crop production and may cripple the outcome of a successful breeding program. Because the photosystem II (PSII) complex, a protein supercomplex that acts to harvest sunlight energy for photosynthetic plants, is sensitive to thermal damage.

Luckily, plants have evolved a repair process to prevent the accumulation of damaged PSII via *de novo* synthesis of a group of proteins, particularly the D1 subunit protein encoded by the chloroplast gene *psbA*. There is, however, an undesired complication: the chloroplast also produces a variety of reactive oxygen species (ROS) during photosynthesis. ROS repress the repair process of PSII by inhibiting the synthesis of PSII proteins, primarily by targeting translation of the *psbA* mRNA that encodes for the D1 protein. As a result, ROS block the rapid turnover of the D1 protein, which is essential for the maintenance of active PSII.

Given that the D1 protein plays a central role in rescuing PSII, it is necessary to increase the rate of its synthesis in order to improve the repair efficiency of PSII and photosynthetic efficiency under heat stress.

Recently, a team of researchers led by Dr. GUO Fang-Qing at the CAS Center for Excellence in Molecular Plant Sciences (CEMPS), Shanghai Institute of Plant Physiology and Ecology (SIPPE), Chinese Academy of Sciences, reported that the nuclear expression of the *psbA* cDNA driven by a heat-responsive promoter in the nuclear genome sufficiently protects PSII from severe loss of D1 protein and dramatically enhances survival rates of three kinds of transgenic plants of Arabidopsis, tobacco and rice under heat stress.

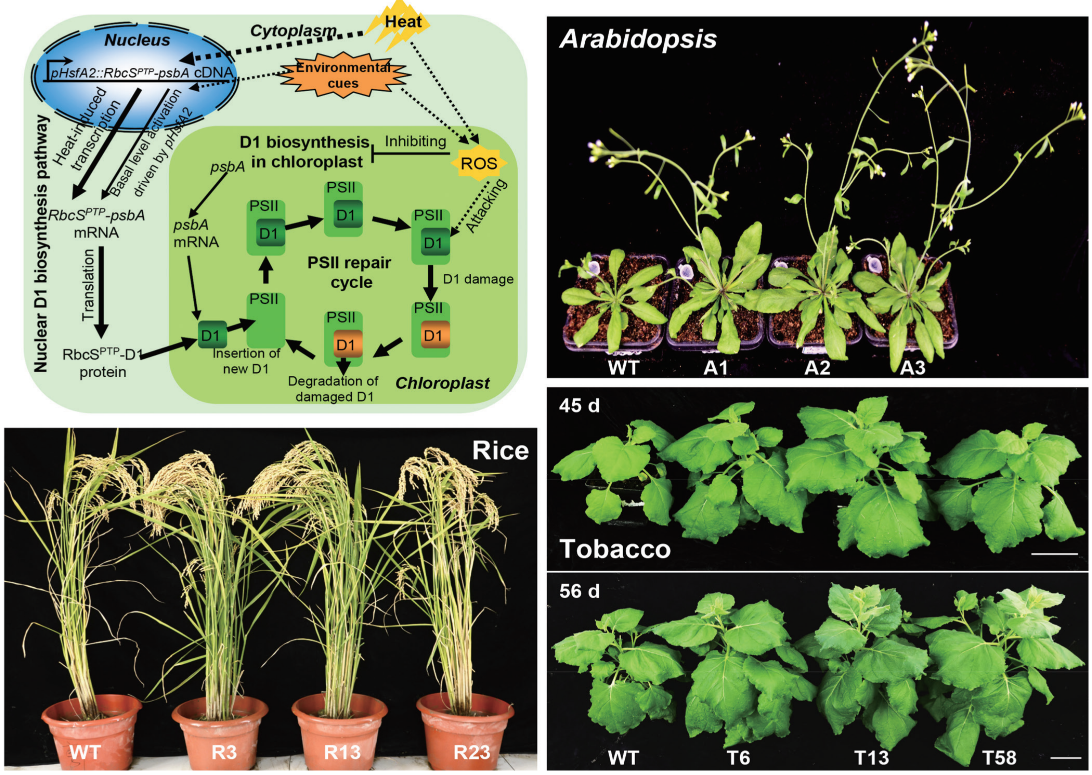
In other words, the nuclear expression of D1, as supplementation to the chloroplast-made D1 proteins, is able to help the plants to resist heat-induced damages.

Unexpectedly, they also found that the nuclear origin supplementation of the D1 protein significantly stimulates plant growth by enhancing net CO_2 assimilation rates with increases in biomass and grain yield. These findings represent an unprecedented breakthrough in bioengineering plants to achieve efficient photosynthesis and increase crop productivity under normal and heat stress conditions.

The study was published online on April 20, 2020 in *Nature Plants*. Their findings represent a conceptually novel principle to enhance survival rate of plants by sustaining PSII activity under heat stress via creating a nuclear origin supplementation pathway of the D1 protein. They have demonstrated the actual effectiveness and sufficiency of this bioengineering strategy in enhancing plant thermotolerance using three model systems of monocot and dicot plant species, including Arabidopsis, tobacco and rice, suggesting such enhancement could be extended to other plants.

In agreement with increasing photosynthesis, aboveground biomass at harvest was significantly greater in the transgenic lines of Arabidopsis, tobacco and rice, and the increase ranges were 43.7-80.2% for Arabidopsis, 15.1-22.3% for tobacco and 20.6-22.9% for rice, respectively. In addition to aboveground biomass, grain yield of the transgenic rice plants significantly increased at the range of 8.1-21.0% when grown under field conditions and harvested at Songjiang, Shanghai, China and at the rice cultivation region of Southern China at Lingshui, Sanya, Hainan Province, China.

Over the last 50 years, global crop yield tripled and estimates suggest that a 70% increase in crop production is needed for global food demand by 2050. In general, Guo and his colleagues (CHEN Juan-Hua and CHEN Si-Ting as major contributors) have shown here that a conceptually novel bioengineering strategy can directly achieve efficient photosynthesis and increase crop productivity under normal and heat stress conditions. Their findings have provided an immediate and feasible resolution to boost



Genetically modified plants with boosted production of a particular protein named D1 subunit can resist heat-induced damage and become more productive. Plants tagged with WT are the wild-types, otherwise are genetically engineered ones. (Image by Guo's lab)

plant biomass and crop productivity around the world, especially for helping crop plants survive more frequent and more severe heat waves under global warming situations, which has the great potential to contribute towards global food security in years to come.

This breakthrough was highlighted and commented as "The work bucked conventional wisdom among photosynthesis scientists" by *Science* on April 21 in a News report written by Erik Stokstad, a reporter at *Science* journal. In this report: Peter Nixon, a plant biochemist at Imperial College London, predicts the study will "attract considerable attention."; Veteran photosynthesis researcher Donald Ort of the University of Illinois, Urbana-Champagne, says the group presents credible evidence of plant benefits, but he's not yet convinced that the D1 made by nuclear genes could have repaired PSII in the chloroplast. "Anything this potentially important is going to be met with some skepticism. There are lots of experiments to do, to figure out why this works," he says.

"The elegant strategy by combining the *AtHsfA2* promoter and a nuclear-expressed *psbA* gene has led to a breakthrough in overcoming the vulnerability of PSII under stress," says Yoshitaka Nishiyama, a renowned scholar from the Saitama University in Japan who is not involved in this study, in a commentary from the same issue of *Nature Plant*.

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Reference

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