Demystifying the role of plant x- and y-type thioredoxins

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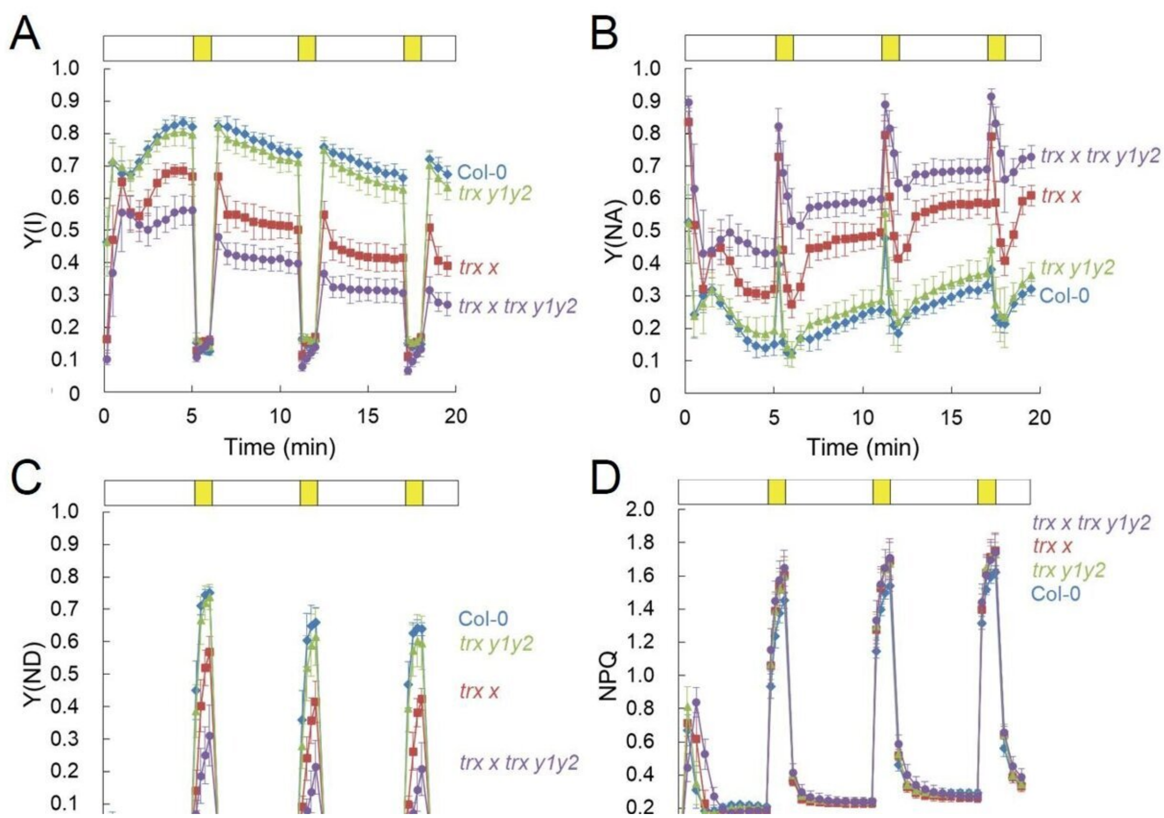

The photoprotective role of *x*- and *y*-type thioredoxins (Trxs) remains a mystery. Researchers in Japan have shown that *Arabidopsis thalianatrx x* and *trx y* mutants exhibit reduced photosynthetic efficiency in photosystem I [Y(I)] and acceptor-side limitation of photosystem I [Y(NA)] . This causes photoinhibition of photosystem I under fluctuating light conditions. Credit: Yuki Okegawa from Okayama University, Japan

The potential for exposure to fluctuating light has necessitated that plants evolve protective mechanisms for when the light intensity exceeds photosynthetic capacity. Under these conditions, reactive oxygen species cause photoinhibition, which hinders photosynthetic efficiency. To counter this loss in photosynthetic efficiency, chloroplasts evolved thioredoxin (Trx) proteins that regulate redox balance within the photosynthetic apparatus and provide a photoprotective function.

These proteins allow plants to modulate photosynthesis in response to variations in light intensity. Among chloroplast Trx proteins, x- and y-type Trxs are known to be functionally related, but little is known about their function under fluctuating light conditions.

During the light reactions of photosynthesis, electrons generated from splitting of water at photosystem II are transported across the electron transport chain (ETC) to photosystem I (PSI) via the cytochrome b6f complex in the chloroplast. Researchers from Okayama University and Kyoto Sangyo University in Japan, who use Arabidopsis thaliana (Arabidopsis) to study Trx regulation during photosynthesis, have recently discovered that x- and y-type Trxs prevent redox imbalance on the electron-accepting side of PSI.

This is a significant finding as a mechanism involving lesser-known Trxs that prevents PSI from suffering photoinhibition under fluctuating light conditions has been identified.

Assistant Professor Yuki Okegawa from the Institute of Plant Science and Resources at Okayama University spearheaded the research team and authored the study, which was published in Plant Physiology. Dr. Wataru Sakamoto, also from the Institute of Plant Science and Resources, was one of the co-authors of this study.

Speaking about the group's motivation to pursue the research, Dr.

Okegawa remarks, "Arabidopsis contains five types of Trxs, four Trx m, two Trx f, two Trx y, Trx x, and Trx z. Of the five types, Trx f and Trx m account for more than 90% of chloroplast Trx proteins, but Trx x and Trx y are minorities that make up less than 10% of Trx proteins. Why is this the case? Little is known about x- and y-type Trxs, so we decided to explore their role in photosynthesis and light stress."

The group generated trx x single, trx y1 trx y2 double, and trx x trx y1 trx y2 triple mutants in Arabidopsis and explored the changes in PSI during photosynthesis. They found that under low light conditions, the electron acceptor side of PSI was inhibited in trx x and trx x trx y1 trx y2 mutants compared to wild-type plants.

Similarly, the team observed that these two mutants exhibited a more pronounced inhibition on the PSI electron acceptor side during low- and high-light phases of fluctuating light.

"Relative to the wild-type plants, this PSI electron acceptor side inhibition under fluctuating light translated into severe PSI photoinhibition in the trx x and trx x trx y1 trx y2 mutants. When we measured plant growth under these fluctuating light conditions, the trx x and trx x trx y1 trx y2 mutants displayed impaired growth and even contained lower levels of PSI," explains Dr. Okegawa as she discusses the significant insights from the work.

These findings signify that Trx x and Trx y counter any redox imbalance on the PSI electron acceptor side, allowing photosynthesis to continue and preventing photoinhibition. These Trxs facilitate the transport of electrons through the ETC under fluctuating light conditions.

The group believes that Trx x and Trx y act as electron sinks during low- to high-light transitions and maintain the oxidized state on the PSI electron acceptor side. But what are the implications of this finding?

"Well, this function isn't critical when light conditions are constant. However, from an adaptive standpoint, preserving the redox balance on the PSI electron acceptor side acts as a safety net and helps prepare for sudden changes in light intensity," says Dr. Okegawa.

Further research on plant photoprotective mechanisms can one day help develop light stress-tolerant crops. Dr. Okegawa and his team believes these advances will be a game-changer for tackling food shortages that stem from inadequate crop production.

More information: Yuki Okegawa et al, x- and y-type thioredoxins maintain redox homeostasis on photosystem I acceptor side under fluctuating light, *Plant Physiology* (2023). DOI: 10.1093/plphys/kiad466

Provided by Okayama University

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