Algae superpowers could provide major boost to food security

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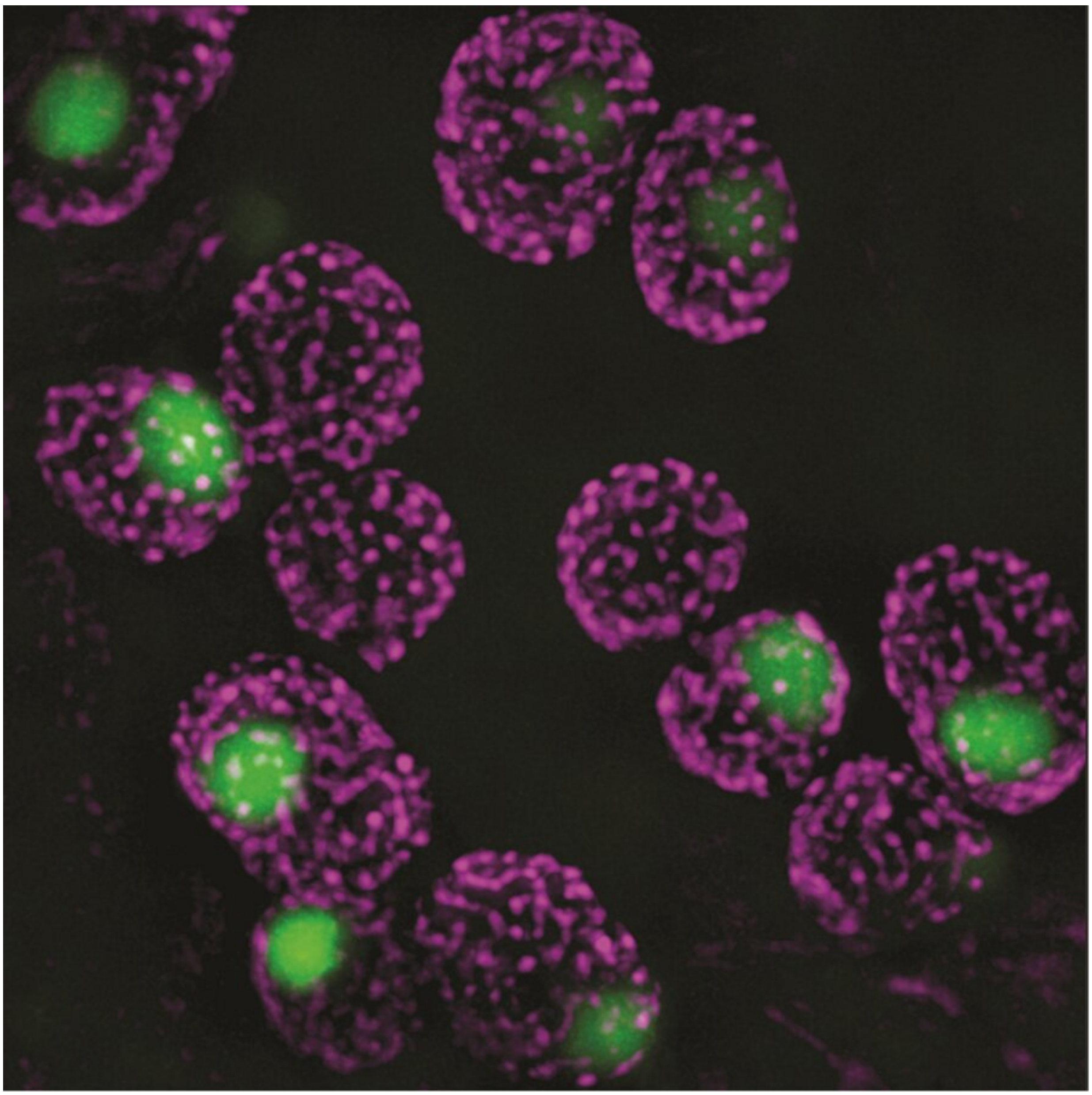

SIM microscopy image of the proto-pyrenoid inside a plant (Arabidopsis) chloroplast Credit: Alistair McCormick

The yields of vital food crops such as rice, wheat and soybean could be improved by equipping plants with proteins from algae to enhance their growth.

The approach could boost crop yields by up to 60% and make them more resilient to the impacts of climate change.

This will aid efforts to feed the planet's growing population by allowing the production of more food from the same amount of land, and helping crops to thrive in poor conditions, including drought.

The technique enhances photosynthesis, the complex process that plants use to convert sunlight and carbon dioxide (CO_2) into energy to fuel their growth.

Researchers at the University of Edinburgh sought to improve plant growth by using a genetic manipulation approach to improve the efficiency of photosynthesis.

In plants the key enzyme involved in photosynthesis, known as Rubisco, is inefficient.

Previous research has shown that Rubisco typically operates at only half its potential to capture and convert CO_2 that fuels plant growth.

To tackle this the team took their inspiration from algae—tiny single-celled photosynthetic powerhouses living in oceans and other bodies of water where CO_2 is scarce.

Algae improve their photosynthesis efficiency by using a specialized CO_2-concentrating mechanism associated with their chloroplasts—the photosynthesis centers found inside all plant and algal cells.

Algae have evolved a special liquid-like photosynthetic structure, known as the pyrenoid, which floods Rubisco enzymes in the chloroplast with a concentrated supply of CO_2.

The team recreated this pyrenoid-like structure inside plant chloroplasts by subtly modifying the Rubisco enzyme in plants so that it would behave more like an algal Rubisco.

They then added a protein, known as EPYC1, which is a vital part of algae's CO_2-concentrating mechanism and acts as a molecular glue binding multiple Rubisco enzymes together in the pyrenoid.

The advance marks a major step forward in improving the efficiency of photosynthesis, using a strategy that is predicted to significantly boost plant growth.

Similar efforts to boost photosynthesis in the past have required substantial changes to Rubisco, which is a difficult and complex enzyme to engineer in plants.

Results in the model plant species Arabidopsis revealed that pyrenoid-like structures could be successfully integrated inside chloroplasts without hindering the plant's growth.

The approach could also make crops more tolerant to climate change and reduce the use of fertilizers as it reduces leaf water loss and allows plants to use fertilizer more efficiently.

The next step will be to introduce a CO_2-pumping mechanism to feed the Rubisco-containing pyrenoid with a concentrated supply of CO_2.

The study published in *Nature Communications*, was funded by UK Research and Innovation Biotechnology and Biological Sciences Research Council and Leverhulme Trust.

The research was carried out in collaboration with the University of Illinois at Urbana-Champaign.

"The pyrenoid is a fascinating liquid-like compartment that helps make photosynthesis in algae very efficient. This year has brought several exciting breakthroughs in our understanding of how pyrenoids assemble and our capacity to build them in plants, which could lead to significant boosts in CO_2 capture and growth in crops."

Dr. Alistair McCormick, Reader in Plant Molecular Physiology and Synthetic Biology, University of Edinburgh.

More information: Nicky Atkinson et al. Condensation of Rubisco into a proto-pyrenoid in higher plant chloroplasts, *Nature Communications* (2020). DOI: 10.1038/s41467-020-20132-0

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