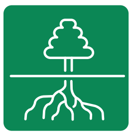
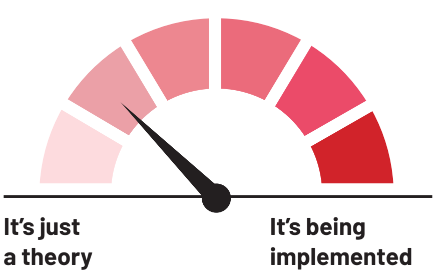
Enhanced Photosynthesis

POINT OF INTERVENTION



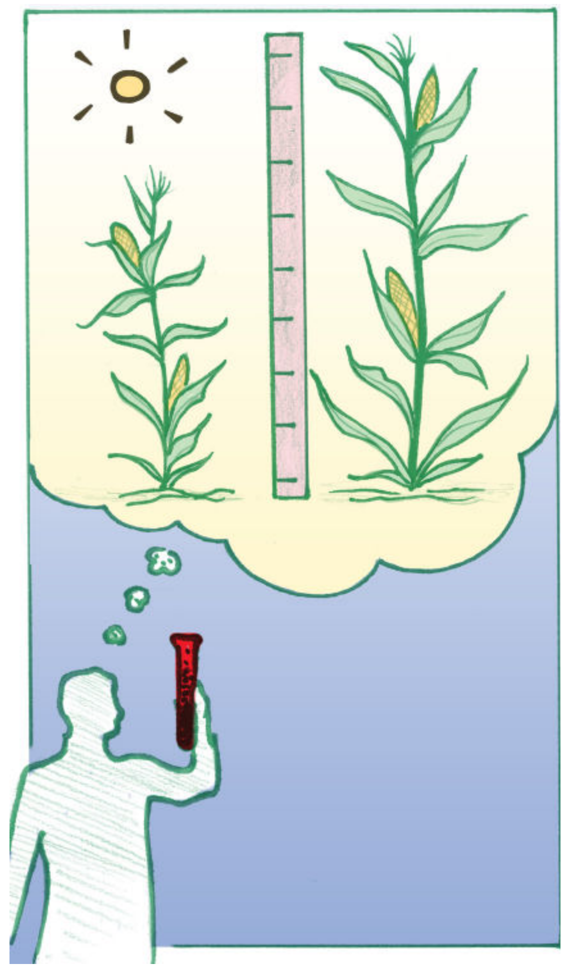
Photosynthesis enhancement proposals aim to genetically engineer plants and algae to exhibit "more efficient" photosynthetic traits, in part so those organisms can metabolize more CO2. Research into altering the photosynthesis of plants is primarily justified through food security arguments: that world population is growing, crop yields have reached a plateau and, given growing demands for food and fuel in the face of climate change, we must find a way to increase crop yields. For photosynthesis engineers, "the key remaining route to increase the genetic yield potential of our major crops"[i] is enhancing photosynthesis. However, since this modification is designed to absorb more carbon from the atmosphere, carbon dioxide removal technology is also used to justify this research. For carbon dioxide removal (CDR) to be accomplished, it is assumed that the additional carbon that would be absorbed by the genetically modified plants would permanently remain in the soils or buried beneath the sea.

REALITY CHECK



ACTORS INVOLVED

The C4 Rice Project was kick-started in 2008 with an initial US$ 11.1 million grant from the Bill and Melinda Gates Foundation and involves a consortium of scientists from Europe, North America and Asia. Rice is categorized a "C3" plant based on the way it converts CO2 to carbohydrates. But, if rice can be transformed into a "C4" plant, it is expected to fix carbon faster, resulting theoretically in more efficient water and nitrogen use, improved adaptation to hotter and drier climates and eventually sequestering more carbon from the atmosphere. Critics question the wisdom of using rice as the target crop for such extreme



genetic engineering in a time of water stress, and they worry that there is a high risk of failure.[ii] Some researchers consider rice "an ideal crop" to practice C4 engineering using synthetic biology because it was the first crop species to have its genome sequenced and has large amounts of physiological, genetic and genomic data available. Rice could pave the way to engineered

C4 wheat, C4 cotton and C4 trees.[iii] In time, switching major crops to enhanced photosynthesis on a large scale would theoretically draw down large amounts of CO2.

The European Union is funding its own "3to4" project (€6.8 million), a consortium of private and public-sector researchers to engineer C4 photosynthesis into C3 crops; many of them are also partners in the C4 Rice Project. While the researchers are focusing initially on rice as a model crop, they "envisage rapid transfer of technological advances into mainstream EU crops, such as wheat and rape."[iv] Private sector consortium members include Bayer Crop Science and Chemtex Italia (now Biochemtex).

Other research is currently underway to show how plants' absorption of CO2 could be increased synthetically. Synthetic biologists have built entirely novel biochemical processes into engineered organisms to speed up the carbon fixation process and make plants better at turning carbon dioxide into energy. In 2016, a US-German team of synthetic biologists stitched together 17 different enzymes from nine different organisms across the three kingdoms of life to achieve a proof of principle CO2-fixation pathway in an engineered organism that exceeds what can be found in nature. They included a new synthetic CO2-fixing enzyme that is nearly 20 times faster than the most prevalent enzyme in

The use of monocultures of crops genetically modified to reflect more light could exacerbate land grabs and forced displacement.

nature responsible for capturing CO_2. Future applications are envisaged for higher biofuel and food production.[v]

In another study, researchers enhanced crop productivity by reducing the time it takes plants to "recover" from detecting too much light.[vi] By adding proteins to certain tobacco plants, the engineered plants grew up to 20% bigger, and the focus is now achieving the same with crops like rice, sorghum, and cassava. The research is also funded by the Bill and Melinda Gates Foundation.

The U.S. Department of Energy has developed the PETRO program, which stands for "plants engineered to replace oil, which also has some research on enhanced carbon concentration in plants.[vii]

IMPACTS

The ability to manipulate photosynthesis implies control over just about everything that determines how and if a plant survives and thrives: how efficiently it uses water and nutrients to grow and produce the biomass that we use for food, fiber and fuel, as well as how efficiently it fixes CO_2 and releases oxygen. The serious concerns that accompany all genetic engineering of plant life, involving unexpected side effects, risks of contamination in natural systems, poorly-understood long-term impacts on humans and ecosystems and corporate control, are therefore also relevant to efforts to enhance photosynthesis.

According to critics of the approach, enhancing photosynthesis by converting C3 plants into C4 plants is a high-tech, high-risk project. Jill E. Gready, Research Professor at the Australian National University, argues: "Pursuit and public promotion of some very high-tech solutions for photosynthesis improvement with high risk of failure…present a high-level risk to food security as they provide false confidence that the problem is being addressed, and, by diverting funds, lead to lost opportunity for R&D with greater likelihood of success and impact."[viii]

Cornell University's Norman Uphoff, another critic, has spearheaded an agroecologically-based method of

Billions of people depend on rice harvests – what if genetically engineered rice had unintended consequences on traditional varieties (SarahTz) cultivating rice known as the System of Rice Intensification. He recently published data demonstrating that a change in farm management practices – such as wider spacing of plants and increased soil aeration – can dramatically increase rice yields beyond what has been thought possible, and without increased dependence on chemical inputs or genetic engineering.[ix]

REALITY CHECK

Research into photosynthesis enhancement is well underway and the techniques are being commercialized currently. However, their effectiveness as a Carbon Dioxide Removal technology is mostly theoretical, particularly because there are many uncertainties related to the permanence of the absorbed carbon in soils or sea.

FURTHER READING

ETC Group and Heinrich Böll Foundation, "Outsmarting Nature? Synthetic Biology and Climate Smart Agriculture": http://www.etcgroup.org/content/outsmarting-nature/report

This video summarizes what the researchers are trying to achieve through photosynthesis enhancement but doesn't discuss the potential impacts: https://www.youtube.com/watch?v=AvOdTk9KzIY

ETC Group and Heinrich Böll Foundation, "Geoengineering Map." map.geoengineeringmonitor.org

The Big Bad Fix: The Case Against Climate Geoengineering, http://etcgroup.org/content/big-bad-fix

SOURCES

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ii. ETC Group and Heinrich Böll Foundation, "Outsmarting Nature? Synthetic Biology and Climate Smart Agriculture," Communiqué. Issue 114, 2015, pp. 6-8, http://www.etcgroup.org/content/outsmarting-nature/report.

iii. Xin-Guang Zhu et al., "C4 Rice – an Ideal Arena for Systems Biology Research", *Journal of Integrative Plant Biology*, Vol. 52, 2010, pp. 762–770

iv. CORDIS, "3to4: Converting C3 to C4 photosynthesis for sustainable agriculture", 2016, http://cordis.europa.eu/project/rcn/101753_en.html

v. Thomas Schwander et al., "A synthetic pathway for the fixation of carbon dioxide in vitro", *Science*, Vol. 354, 2016, pp. 900-904

vi. Johannes Kromdijk et al., "Improving photosynthesis and crop productivity by accelerating recovery from photoprotection", *Science*, Vol. 354, 2016, pp. 857-861

vii. https://arpa-e.energy.gov/?q=arpa-e-programs/petro

viii. Jill Gready, "Best-fit options of crop staples for food security: productivity, nutrition and sustainability." Handbook on Food: Demand, Supply, Sustainability and Security, 2015, pp. 406

ix. Norman Uphoff, "Rethinking the concept of 'yield ceiling' for rice: implications of the System of Rice Intensification (SRI) for agricultural science and practice", *Journal of Crop and Weed*, Vol. 9, 2013, pp. 1-19