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PII: S0168-9452(17)31031-2
DOI: https://doi.org/10.1016/j.plantsci.2017.12.007
Reference: PSL 9718

To appear in: *Plant Science*

Received date: 1-11-2017
Revised date: 16-12-2017
Accepted date: 16-12-2017

Daring metabolic designs for enhanced plant carbon fixation

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Highlights

- Rubisco's catalytic steps could be distributed across several novel enzymes.
- Carboxylation via 6-phosphogluconate dehydrogenase could replace Rubisco.
- Synthetic carbon fixation pathways could enhance carbon fixation rate and yield.
- Carboxylation reactions could be replaced with CO_2 reduction.
- Photorespiration bypass routes that do not release CO_2 can boost carbon fixation.

Abstract

Increasing agricultural productivity is one of the major challenges our society faces. While multiple strategies to enhance plant carbon fixation have been suggested, and partially implemented, most of them are restricted to relatively simple modifications of endogenous metabolism, i.e., "low hanging fruit". Here, I portray the next generation of metabolic solutions to increase carbon fixation rate and yield. These strategies involve major rewiring of central metabolism, including dividing Rubisco's catalysis between several enzymes, replacing Rubisco with a different carboxylation reaction, substituting the Calvin Cycle with alternative carbon fixation pathways, and engineering photorespiration bypass routes that do not release carbon. While the barriers for implementing these elaborated metabolic architectures are quite significant, if we truly want to revolutionize carbon fixation, only daring engineering efforts will lead the way.

Keywords: Rubisco, Calvin Cycle; Metabolic Engineering, Synthetic Biology, Photorespiration, Carboxylation, Formate Assimilation.

Introduction

Global crop production needs to double by 2050 to meet the demands of a growing population. To achieve this goal, agricultural yield needs to increase by 2.4% per year, almost double the average annual yield increase in the past 40 years [1]. As the efficiency with which plants intercept light and the partitioning of biomass into harvested parts are close to their theoretical maxima, major improvements in plant productivity