Engineering central metabolism – a grand challenge for plant biologists

The goal of increasing crop productivity and nutrient-use efficiency is being addressed by a number of ambitious research projects seeking to re-engineer photosynthetic biochemistry. Many of these projects will require the engineering of substantial changes in fluxes of central metabolism. However, as has been amply demonstrated in simpler systems such as microbes, central metabolism is extremely difficult to rationally engineer. This is because of multiple layers of regulation that operate to maintain metabolic steady state and because of the highly connected nature of central metabolism. In this review we discuss new approaches for metabolic engineering that have the potential to address these problems and dramatically improve the success with which we can rationally engineer central metabolism in plants. In particular, we advocate the adoption of an iterative ‘design-build-test-learn’ cycle using fast-to-transform model plants as test beds. This approach can be realised by coupling new molecular tools to incorporate multiple transgenes in nuclear and plastid genomes with computational modelling to design the engineering strategy and to understand the metabolic phenotype of the engineered organism. We also envisage that mutagenesis could be used to fine-tune the balance between the endogenous metabolic network and the introduced enzymes. Finally, we emphasise the importance of considering the plant as a whole system and not isolated organs: the greatest increase in crop productivity will be achieved if both source and sink metabolism are engineered.

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