CAPITALISE

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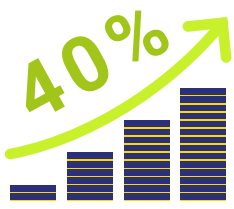
BREEDING FOR BETTER PHOTOSYNTHESIS

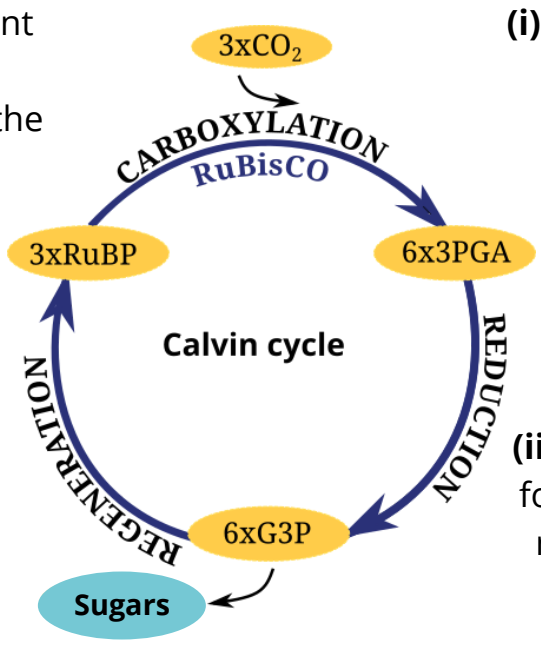
1. TUNING THE CALVIN-BENSON CYCLE



Transgenic manipulation of specific enzymes in the Calvin-Benson Cycle has already been utilised to improve photosynthesis, growth, and yield of crop plants by 40%.

THREE STAGES OF THE CYCLE

Plant growth and development depends on the supply of carbohydrates generated in the Calvin-Benson cycle. This process can be divided into three stages:



(i) Carboxylation (or Carbon fixation) carried out by Ribulose-1,5-bisphosphate carboxylase-oxygenase (RuBisCO)

(ii) Reduction of the C_3 acids formed by the carboxylation reaction (the stage of sugar formation)

(iii) Regeneration of ribulose-1,5-bisphosphate (RuBP), the CO_2 -acceptor molecule at RuBisCO

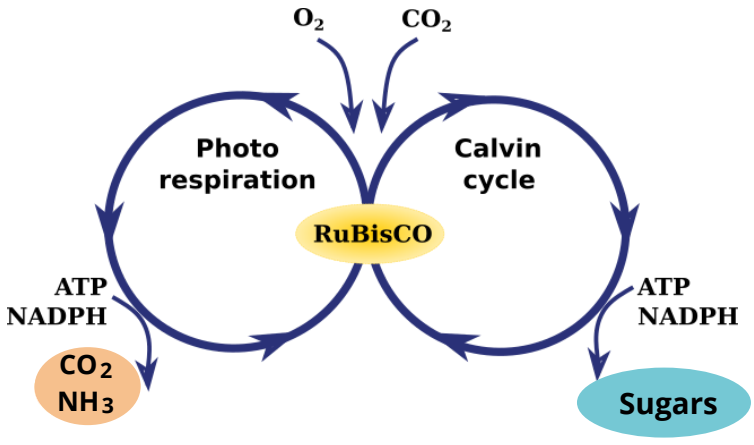
LIMITATIONS OF THE CYCLE

Both carboxylation and regeneration phases represent limiting factors for the photosynthetic efficiency of crop plants.

CARBOXYLATION

RuBisCO has a low carboxylation rate so plants require large amounts of this enzyme to support adequate levels of photosynthesis.

RuBisCO also acts as an oxygenase initiating a wasteful photorespiration cycle. This results in loss of previously fixed CO ₂ ammonia production and consumption of ATP.

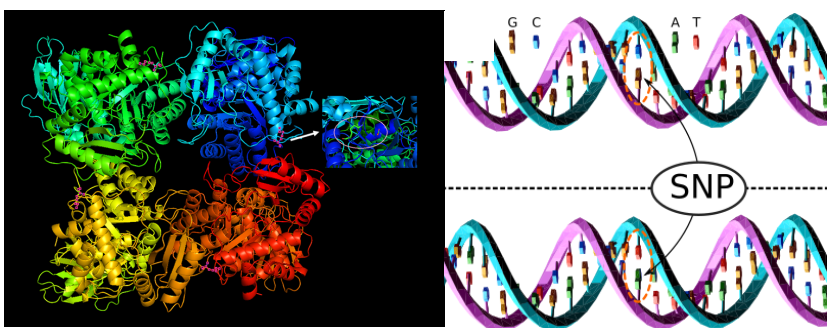


REGENERATION

The regeneration phase is limited by the activities of specific key enzymes in the pathway, particularly by the enzyme seduheptulose-1,7-bisphosphatase (SBPase) and, to a lesser extent, fructose-1,6-bisphosphate aldolase (FBPA).

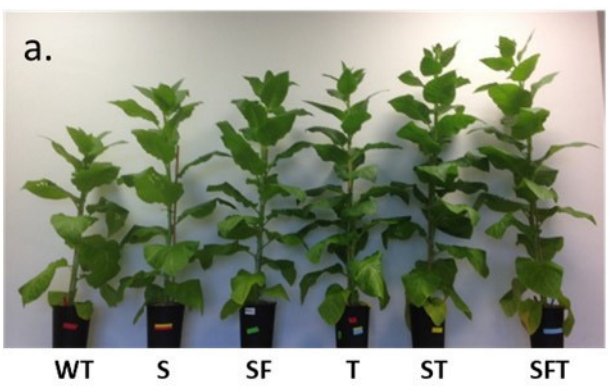
SOLUTIONS

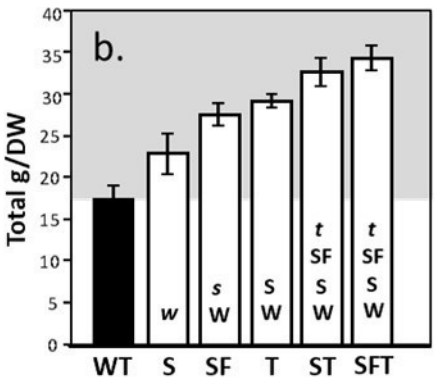
Replacement of crop RuBisCO by better-performing RuBisCO forms found in crop wild relatives should **improve photosynthetic efficiency** at ambient CO_2 and **decrease the amount of water and fertilisers required** for crop production.



Slight differences in DNA sequence across diverse germplasms can have different effects on efficiency of Rubisco.

A transgenic overexpression of specific enzymes in the regeneration phase of the Calvin-Benson cycle **improves photosynthesis and growth** in Arabidopsis, Tobacco and grain yield in wheat.





Transgenic tobacco plants over-expressing three specific enzymes in the Calvin cycle individually (S, T) or in combination (SF, ST, SFT) show **increased growth** (a.) **and total biomass** (b.) compared to the wild type (WT; modified from Simkin et al. 2015 [2]).

Multigene manipulation results in cumulative increase in biomass and **decrease of water required** for crop production.

References: [1] photo credit: Ericlin1337 - Own work, CC BY-SA 4.0; **[2]** photo credit: David Eccles (gringer), CC BY 4.0; **[3]** DOI: 10.1093/jxb/erv204

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