GAIN4CROPS - Rewiring photorespiration using natural and synthetic pathways to sustainably increase crop yield

Photorespiration – recycling Rubisco's oxygenation production, 2-phosphoglycolate (2PG), back to the Calvin Cycle – is an ineluctable process in today's plants, which dissipates energy and releases CO2. Photorespiration reduces CO2 assimilation efficiency, and thus biomass yield, by ~30% and represents a prime target for improving agricultural productivity, as was demonstrated in several recent studies. Yet, the engineering of alternative photorespiration routes to date is restricted to pathways that release CO2, leaving space of considerable further improvement. Another opportunity to reduce the inefficiencies of photorespiration is to minimize it by engineering C4 metabolism, which serves as a carbon-pump that increases the CO2 concentrations near Rubisco. GAIN4CROPS aims to boost plant productivity using novel strategies to minimize the inefficiencies of photorespiration. GAIN4CROPS will follow a stepwise approach, starting by engineering naturally occurring carbon pumps and culminating with the introduction of highly efficient synthetic metabolic pathways that can dramatically boost carbon fixation. First, we will engineer a C3 crop to operate the naturally-occurring C3-C4 carbon-pump, boosting carbon fixation while requiring less complex anatomical modifications than C4 metabolism and using solely genome editing and wide crosses. This step serves as a conceptually novel, 'natural' approach towards engineering C4 metabolism. Second, GAIN4CROPS will develop more efficient synthetic C3-C4 carbon pump variants that are based on the effective intercellular transport of aspartate or malate while conserving cellular resources. Finally, based on C3-C4 metabolism, GAIN4CROPS will explore two innovative photorespiration bypass routes which, rather than releasing CO2, fix inorganic carbon, thus directly assisting carbon fixation. GAIN4CROPS will serve as a research and innovation roadmap to attain similarly higher photosynthetic performance in a broad range of C3 crops.

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