Limitation of sucrose biosynthesis shapes carbon partitioning during plant cold acclimation

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Abstract

Cold acclimation is a multigenic process by which many plant species of the temperate zone increase their freezing tolerance. Stabilization of photosynthesis and carbohydrate metabolism plays a crucial role in cold acclimation, and amounts of transient leaf starch, soluble carbohydrates and secondary metabolites, e.g., flavonoids, show significant cold-induced dynamics. To study regulation of primary and secondary metabolite accumulation during cold acclimation of *Arabidopsis thaliana*, metabolic mutants with deficiencies in either starch or flavonoid metabolism were exposed to 4°C over 14 days and sampled before as well as at early and late time points of cold acclimation. Photosynthetic activity was determined together with amounts of carbohydrates, anthocyanins, organic acids and maximum enzyme activities of the central carbohydrate metabolism. Starch deficiency was found to significantly delay soluble sugar accumulation during cold acclimation, while starch overaccumulation did not affect accumulation dynamics but resulted in lower total amounts of sucrose and glucose. Anthocyanin amounts were lowered in both starch deficient and overaccumulating mutants. *Vice versa*, however, flavonoid deficiency did not result in a changed starch amount which suggested a unidirectional signalling link between starch and flavonoid metabolism. Mathematical modelling of carbon metabolism indicated kinetics of sucrose metabolism and its export form source to sink tissue to be limiting for carbon partitioning in leaf tissue during cold exposure. Together with cold-induced dynamics of fumarate and malate amounts this provided evidence for a central role of sucrose phosphate synthase activity in carbon partitioning between biosynthetic and dissimilatory pathways which stabilizes photosynthesis and metabolism at low temperature.

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