Differential metabolic and regulatory responses to exogenous glucose uptake across plant species revealed by isotopic metabolomics

Description

Isotopic metabolomics reveals that plant species exhibit highly divergent carbon allocation and metabolic rewiring strategies when taking up exogenous glucose. Studies using stable isotope tracking ^{13}C â?? labeled glucose) demonstrate that plants do not process external sugars through a uniform, fixed pathway. Instead, species shift carbon allocation differently between **primary glycolysis, the oxidative pentose phosphate pathway (OPPP), cell wall synthesis, and secondary metabolism** based on their evolutionary adaptations, ecological niches, and endogenous metabolic pool sizes. Isotopic flux analysis exposes how distinct plant groups branch external carbon at critical metabolic junctions. The primary metabolic fates of glucose, including glycolysis and the Krebs cycle, are rewired dynamically depending on the plant species.

When plants absorb exogenous glucose, the carbon is distributed across four primary pathways with highly variable flux rates:

Glycolysis vs. OPPP: Some species funnel the majority of absorbed glucose directly into glycolysis to rapidly generate ATP and pyruvate. Conversely, others direct it toward the **Oxidative Pentose Phosphate Pathway (OPPP)** to generate NADPH, which fuels antioxidant systems and biosynthesis.

TCA Cycle and Respiration: The incorporation rate of \(^{13}\text{C}\) into tricarboxylic acid (TCA) intermediates (like citrate, succinate, and malate) differs significantly. Fast-growing species rapidly turn over the TCA cycle, while stress-adapted species store the carbon as organic acids.

Cell Wall & Biomass Structural Investment: A major fraction of exogenous glucose is often diverted to UDP-glucose and subsequent cell wall polymers (cellulose, hemicellulose).

Secondary Metabolite Shunting: Variations in downstream labeling appear in pathways like the shikimate pathway, driving the synthesis of species-specific defensive or structural phenolics.

These metabolic variations reflect distinct survival strategies shaped by natural selection. Species adapted to nutrient-rich environments or those engaged in symbiotic relationships (e.g., mycorrhizal networks) possess highly responsive systems designed to immediately incorporate external carbon surges into active biomass. Stress-adapted or slow-growing plants show minimal shift in their core metabolic pipelines upon glucose uptake. They favor storing the resource safely as starch or vacuolar solutes to maintain osmotic balance rather than accelerating growth.

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