PROJECT TITLE

Plasticity of carbon distribution in sugar beet (Beta vulgaris) taproots using combined MRI and PET-approach

CONSORTIUM

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SUMMARY OF THE REPORT

Understanding how carbon is distributed within sugar beet taproots is central to improving both yield and stress resilience in this crop. Sugar beet accumulates large amounts of sucrose in its taproot, a process dependent on high photosynthetic activity in the leaves, efficient long-distance transport via the phloem, and active sucrose uptake into root storage cells. Earlier work using ^{11}CO? labeling and PET imaging revealed that carbon is allocated in radial taproot sectors, but whether this sectoral pattern can adapt to disturbances in carbon flow has remained unclear. The project addressed this knowledge gap by investigating how localized shading of individual leaves, mimicking phloem blockage, affects carbon allocation and metabolic responses in the corresponding taproot sectors.

Using a combination of MRI and PET, the experiment tracked the movement of fixed carbon in real time. Initial full-plant labeling confirmed uniform carbohydrate distribution throughout the root. Labeling a single source leaf allowed identification of its associated sector in the taproot. Subsequent shading of this leaf during full-plant labeling simulated a blockage in phloem transport. Overlaying MRI and PET data enabled precise tissue sampling of shaded vs. non-shaded sectors for sugar analysis and gene expression profiling.

The PET results confirmed a strict sectoral pattern of carbon unloading in the taproot. Photoassimilates moved within 40 minutes from leaves to root sectors, but disruption of this flow resulted in localized deficits with no visible compensation from neighboring sectors. Sugar levels and gene expression were then analyzed in sampled shaded and non-shaded leaves and connected taproot sectors. Non-shaded leaves showed a slight increase in sugars, also reflected in higher expression of sugar-responsive genes in comparison to shaded leaf tissue. Associated root sectors, by contrast, did not show strong metabolic shifts or clear transcriptional responses. Notably, expression of key transporters like *TST2;1* and *SUC4* remained unaltered in taproot sectors in response to single-leaf shading, and no statistically significant changes were observed in taproot sugar contents.

The findings reinforce the notion of a rigid, phloem-defined architecture in sugar beet roots, where carbon unloading is highly localized and not rapidly compensated across sectors. While the findings largely confirm existing assumptions rather than uncovering new mechanistic insights, the study demonstrates the feasibility and power of combining MRI, PET, and image-guided molecular analysis to investigate carbon allocation dynamics. Although significant changes in sugar content or gene expression were not observed within the short treatment window, the experimental setup provides a robust and scalable platform for future studies.