OSMOTICALLY DRIVEN FLOWS IN PLANTS

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Summary Plants have highly effective vascular systems, which can transport fluid over large distances. The phloem system carries sugar solutions from sources (leaves) to sinks (roots, fruits etc.) and thus provides the necessary material for growth. In the 1920'ies, Ernst Münch proposed that sugar transport in the phloem is driven by passive osmotic pressure gradients generated by loading and unloading sugar into the phloem tubes, a proposal that has remained controversial. We present new theoretical and experimental results on sugar translocation in plants, in particular illuminating the question of optimality in the design of the phloem vascular system.

The verification of the Münch Mechanism for sugar transport in the phloem vascular tissue of plants has been hampered by the difficulty of accessing the phloem to measure concentrations and pressures accurately [1, 2]. Recently, it has been argued that [3] that the phloem vascular system seems to have been optimised with respect to passive osmotic transport, and that this holds quite universally for both small herbaceous plants and large trees. It is argued there that the radii a of the phloem tubes (seive elements) should scale in a particular way with the length l_{source} of the sugar loading source region (the leaf) and the length l_{trans} of the translocation pathway (the stem). Thus

$$a^3 \sim G\, l_{source}\, l_{trans} \tag{1}$$

In [4] it is shown that also gymnosperms seem to be optimised in this way despite their considerably slower transport velocities and Figure1 shows the data presented there, indeed presenting a strong case for the relation (1).

In the lecture we shall in particular discuss various ways of defining optimality as well as detailed studies of the phloem transport pathway.

References

[1] N. M. Holbrook & M. A. Zwieniecki, *Vascular Transport in Plants*. Elsevier Academic Press (2007).
[2] M. Knoblauch, W. S. Peters, *Münch, morphology, microfluidics Ð our structural problem with the phloem*. Plant, Cell & Environment 33, 1439-1452 (2010).
[3] K. H. Jensen, J. Lee, T. Bohr, H. Bruus, N. M. Holbrook & M. A. Zwieniecki M.A., *Optimality of the M§nch mechanism for translocation of sugars in plants*. Journal of the Royal Society Interface Journal of Royal Society Interface 8, 1155-1165 (2011)
[4] K. H. Jensen, J. Liesche, T. Bohr & A. Schulz, *Universality of Phloem Transport in Seed Plants*. Plant, Cell and Environment to appear 2012.

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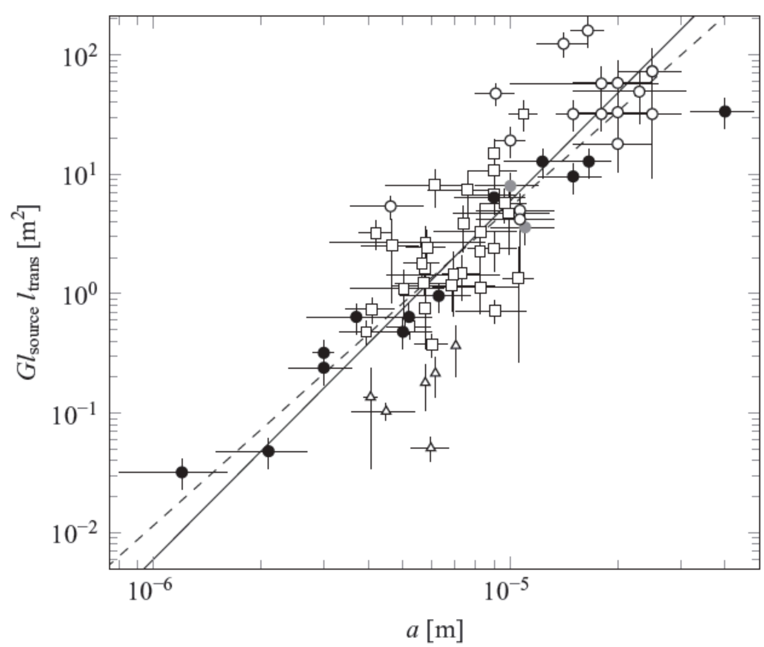

Figure 1: Logarithmic plot of $G\, l_{source}\, l_{trans}$ as a function of the effective osmotic radius a. G is a geometric factor depending only on the shape of the cell (with the value 16 for cylindrical cells and 3 for cuboidal cells (typical of gymnosperms)).The plants are hydraulically optimized for rapid translocation in the phloem if the points fall on the solid black line (slope 3). The dashed line is a linear fit made by least square regression analysis. Symbols: angiosperm trees (open circle), angiosperm herbs (black dot), angiosperm shrubs (grey dot), gymnosperm trees (open square), gymnosperm trees with scales (open triangle). From [4]