branchlines

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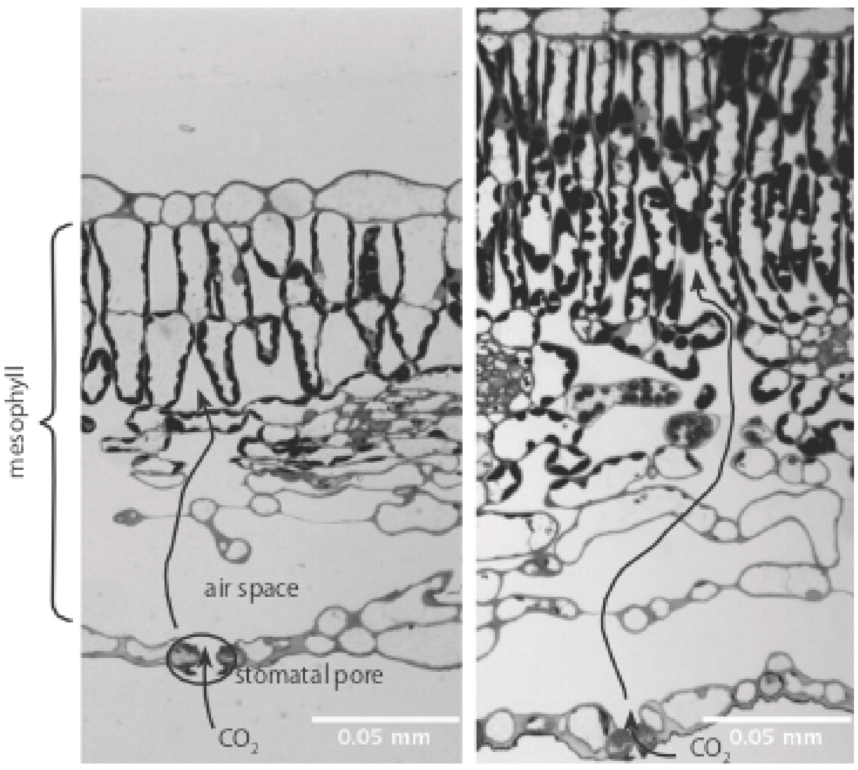
How form constrains function in balsam poplar



Cross-sections of leaves from 2 different balsam poplar clones, one with thin, loosely packed leaves (left) and the other with thick, densely packed leaves (right). Carbon dioxide moves into the leaf through stomatal pores on the lower leaf surface. From there it travels through intercellular air space towards the various layers of the mesophyll. Most of the chloroplasts (dark, rounded bodies in these figures) are in the cylindrical cells of the palisade layers.

For most plants, and certainly all trees, the carbon dioxide (CO_2) needed for photosynthesis must travel from the atmosphere into leaves, through the mesophyll and into the chloroplasts (see photo). To enter the leaves, CO_2 diffuses through microscopic pores called stomata. These pores open and close in a tightly regulated fashion to control the loss of water from the leaf, while at the same time permitting CO_2 to enter. Consequently, the stomatal conductance (ie, how open or closed the stomata are) is a major limitation on photosynthesis and on plant growth, and so has been a focus of crop and tree production research for many decades. The conductance of the rest of the CO_2 diffusion pathway, through the air spaces, cell walls and cytoplasm, was largely ignored because it was assumed to be non-limiting. Recent work, however, shows that the mesophyll conductance is often just as important as the stomatal conductance. Hence there is now a flurry of activity to better understand this part of the diffusion pathway, and how it varies, in order to breed for rapid growth and improved resource-use efficiencies.

Leaf thickness and anatomical traits such as cell packing, wall thickness and chloroplast distribution are likely to be some of the most important determinants of mesophyll conductance. Unfortunately, like the mesophyll conductance itself, none of these are easy to measure on a routine basis. A much more convenient measure, requiring only a balance and a paper punch, is the leaf mass per unit area (LMA). Variation in LMA could reflect differences in either leaf density and/or leaf thickness. LMA has been associated both positively and negatively with mesophyll conductance in a variety of species. For example, Raju Soolanayakahally, a previous graduate student in UBC's Faculty of Forestry, found that balsam poplars from northern Canada have higher LMA and higher mesophyll conductance (and higher photosynthesis), than balsam poplars from southern Canada. A positive correlation between LMA and mesophyll conductance seems counterintuitive because an increase in leaf thickness should increase the diffusion path length (see photo). On the other hand, a higher tissue density might increase the cell wall area available for absorbing CO_2, thereby improving the conductance. To sort these possibilities out, recent masters graduate Estefania Milla-Moreno, working with Dr Rob Guy in the Department of Forest and Conservation Sciences, investigated the microscopic basis of variation in LMA in 17 balsam poplar clones resulting from a cross between a female tree from northern Quebec and 3 male trees in southern Saskatchewan.

Using light and electron microscopy, Estefania measured leaf thickness, air space volume, cell wall surface area, cell wall thickness and several other traits. Many of these measurements had no relationship to LMA, but both leaf thickness and cell packing did, and with nearly equal effect. Most importantly, both of these dimensional parameters contributed to an increase in cell wall area. Estefania was able to show that leaves with high LMA provide chloroplasts with more cell wall area for the uptake of CO_2 from the intercellular air spaces. This may be what underlies high mesophyll conductance in northern trees, helping to explain their superior photosynthetic rates.

Readers may wonder why northern trees, despite higher photosynthetic rates, do not grow as much as trees from lower latitudes. The answer is simply that they stop growing, each year, well before their southern relatives. Our hope is that crosses produced between geographically disparate parent trees will combine the high photosynthetic rates of the north with the long growing seasons of the south, resulting in productive clones for commercial purposes.

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