Seeing the forest through the trees and seeing the trees through the leaves

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Since the time of the earliest humans, people have attempted to understand the natural environment. We have observed our surroundings and searched for explanations for natural phenomena. Yet despite our persistence over thousands of years, many basic questions remain to be answered. Although we understand core processes such as photosynthesis, we do not have a full understanding of issues such as how plants maximize their photosynthetic capacity.

Specific leaf area, or SLA, plays a prominent role in ecological theories that attempt to provide explanations for plant and ecosystem function. SLA, a measurement of the total leaf area to dry mass, has been found to correlate with the potential for light-resource use, the relative growth rate of a plant, and differences in essential nutrient demand and habitat preference.

Scientists also have observed that the SLA of individual leaves varies within a single plant, and this measurement often correlates with leaf maturation and position within the canopy. More recently, scientists have discovered that, as a tree increases in size, its total canopy SLA decreases—that is to say, its total leaf surface area fails to keep pace with increases in total leaf mass.

What causes this decrease in SLA as tree size increases has remained a mystery, but recent research by Cornell University scientists Karl Niklas and Edward Cobb published in the January issue of the American Journal of Botany provides an explanation for this decrease in SLA with an increase in tree size.

"The traditional explanation for the size-dependent decrease in SLA was never very satisfying," Niklas said. "We wanted to look at this phenomena in greater details with more care, and we found a totally different answer to a classic ecological question."

The commonly accepted hypothesis has been that decreasing SLA in trees of increasing size is a result of leaf-by-leaf acclimation to the local environment. Physical factors such as differences in light intensity are affected by differences in leaf position within the canopy, providing different local environments. Niklas and Cobb hypothesized that changes in SLA may be a result of changes in the relative numbers of different shoot types that produce leaves differing in SLAs—a developmental shift that occurs as a tree increases in size.

Niklas and Cobb examined 15 red maple trees that differed in trunk size and found that the changes in SLA can be attributed to shoot type rather than to the location of the leaves within the canopy. As the trunk diameter increased, the number of short-shoots increased rapidly relative to the number of long-shoots. Detailed analyses of the largest tree demonstrated that short shoots, on average, produce leaves with smaller specific leaf areas than those produced by long shoots. Consequently, developmental shifts occurring at the shoot and whole plant level account for size-dependent decreases in total canopy SLA, rather than leaf-by-leaf acclimation to the local environment.

Mathematical models for the distribution of light within the canopy predict that the photosynthetic rate of the entire canopy is maximized when the specific leaf area is lowest for leaves at the top of the canopy. This research provides new insight into the mechanism by which trees have evolved to obtain light and photosynthesize at the greatest rate.

"Our research shows that plants are highly integrated organisms that respond to their environments in ways that are every bit as complex as even the most sophisticated animals," Niklas said. "This research also shows that we still have plenty to learn about phenomena that we thought we understood very well."

More information: http://www.amjbot.org/cgi/content/full/97/1/27

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