Old growth giants limited by water-pulling ability

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The Douglas-fir, state tree of Oregon, towering king of old-growth forests and one of the tallest tree species on Earth, finally stops growing taller because it just can't pull water any higher, a new study concludes.

This limit on height is somewhere above 350 feet, or taller than a 35-story building, and is a physiological tradeoff between two factors in the tree's wood - a balance between efficiency and safety in transporting water to the uppermost leaves.

The findings are being published this week in *Proceedings of the National Academy of Sciences,* by a team of scientists from Oregon State University and the U.S.D.A. Forest Service. The research was funded by grants from the U.S. Department of Agriculture and the Forest Service.

"People have always been fascinated by how some trees, such as Douglas-fir or redwoods, can grow so tall," said Barb Lachenbruch, a professor of wood science at Oregon State University. "This is not an easy thing to do. Think about trying to drink water through a narrow, 350-foot-long straw. It takes a lot of suction."

Douglas-fir wood consists mostly of dead cells called "tracheids" that function in water transport and physical support, the researchers said. These tracheids have pits on their sides that function as valves, allowing water to go from one tracheid to the next, and the pits have a membrane with an impermeable middle. Normally, water flows through the porous edges of the membrane, but if there's an air bubble in one tracheid, the membrane moves to the side and blocks off the pit so air bubbles can't spread.

Although it's important to allow water to pass efficiently from one wood cell to the next, air bubbles would block water movement altogether. Because water is pulled through a tree by the forces of evaporation from the leaf surfaces, the water is in "tension," like a pulled rubber band. If an air bubble gets in, it's like the rubber band breaking and water can no longer be transported. With a 350-foot-long water column, there's a lot of tension on the water in the cells at the top of the tree, and a lot of force trying to get errant air bubbles to enter.

"Higher and higher in the tree, the valves are able to withstand more pulling force from the long heavy column of water before air bubbles can be sucked through," Lachenbruch said. "But the problem is that the valves become less efficient at letting water pass. The height at which no water would pass at all, according to our models, coincides the tallest records for Douglas-fir, about 350 to 400 feet."

Trees of that height were discovered in Washington and British Columbia in the late 19th and early 20th centuries. The tallest Douglas-fir today is a 326-foot-tall tree in Coos County, Oregon.

"As you go higher and higher in a Douglas-fir tree, it's almost like experiencing a drought," said Rick Meinzer, a Forest Service scientist at the Pacific Northwest Research Station. "And that's what we see at the tops of very tall trees. The foliage is struggling to get enough water and seems to be under drought stress. It's not unusual to see periodic die-back at the tops of very tall Douglas-fir trees that are near their height limits."

At a specific height determined by the physical structure of these pits and their membranes, the scientists discovered, the fierce resistance put up by the Douglas-fir to prevent any spread of air bubbles also prevents water from being pulled any higher. That is where it finally stops growing in height, no matter how favorable any other conditions might be, such as climate, soil or water availability.

The studies, Meinzer said, may improve our understanding of how trees grow in height and may be able to adapt to different environments, including their ability to deal with droughts or climate change.

Although height can be important in a competition for sunlight and photosynthesis, natural selection has not favored a wood structure in Douglas-fir that facilitates water transport at even greater tensions and allows for greater height, the scientists noted in their study.

Apparently 350 feet is tall enough.

Source: Oregon State University

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