Biologist solves mystery of tropical grasses' origin

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Around 30 to 40 million years ago, grasses on Earth underwent an epic evolutionary upheaval. An assemblage capitalized on falling levels of atmospheric carbon dioxide by engineering an internal mechanism to concentrate the dwindling CO_2 supply that, like a fuel-injection system in a car, could more efficiently convert sunlight and nutrients into energy.

The rise of C4 grasses is not disputed. They dominate in hot, tropical climes and now make up to 20 percent of our planet's vegetational covering. Scientists have pinned the rise of C4 plants primarily to dwindling concentrations of CO_2. But C4 grasses have been closely linked with warmer temperatures. Indeed, on a map, C4 grasses are found along tropical gradients, while C3 grasses occupy the northern, or colder, end of the temperature gradient. Considering knowledge of their past and their current distribution, what was left to question?

Everything, apparently, according to Erika Edwards, an evolutionary biologist at Brown University. In a paper published online in the Proceedings of the National Academy of Sciences, Edwards and Stephen Smith, a postdoctoral researcher at the National Evolutionary Synthesis Center in North Carolina, have found that rainfall — not temperature — was the primary trigger for C4 grasses' evolutionary beginnings. Moreover, the pair say C4 grasses were already in tropical forests before moving out of the shade of the taller trees and into drier, sunnier environments.

"We've kind of changed the story a bit," said Edwards, assistant professor of biology.

The paper is important, Smith said, because it "demonstrates the importance of precipitation in the evolution of grasses and particularly in the evolution of C4 grasses — specifically, their movement into drier, not necessarily warmer climates."

To arrive at their findings, the biologists compiled a database of roughly 1.1 million specimens of grasses collected by botanists worldwide. They mapped the locations for these species and then added global precipitation and temperature charts.

"By combining all these data," Edwards said, "we could get individual climate profiles for each grass species."

The pair then went a step further. They whittled the list to approximately 1,230 species for which the plants' genes had been sequenced and from there built a phylogenetic profile for the collection, the most comprehensive evolutionary tree to date for grasses. The reason for building the phylogeny, Edwards said, was to tease out the junctures at which C3 and C4 grasses diverged over time. The scientists zeroed in on 21 such "transition nodes" and examined the climatic conditions during those branching periods.

They found that in 18 of the 21 instances, precipitation, rather than temperature, had changed. "That was the clincher," Edwards said.

Looking more closely at the differences in rainfall, Edwards and Smith noticed the shifts in the amount of rainfall between C3 and C4 grasses in the tropics dictated in sharp relief how the different lineages evolved. Generally speaking, C3 grasses flourished in areas that received, on average, 1,800 millimeters (71 inches) of rain annually; C4 grasses took root in areas that received, on average, 1,200 millimeters (47 inches) of rain annually.

"Twelve-hundred millimeters isn't a desert," Edwards noted. "It's still a fairly mesic place. And so when you start looking at climate profiles, these closely related C3 and C4 lineages are straddling this transition zone between tropical forests and tropical woodlands and savanna."

So, did C4 grasses evolve in the tropical forest and then move out from the canopy or did they move out first and then adopt a different photosynthetic pathway? Edwards isn't sure, but she thinks the pathway may have begun to form with C3 grasses on the forest margins, where those plants would have been subjected to greater fluctuations in precipitation, sunlight, temperature and other environmental stresses, spurring the photosynthetic innovation.

What that all means for the future of C4 grasses and climate change is an open question. While the grasses would presumably benefit from projections of lower mean rainfall in some areas of the tropics, they may be less competitive with rising levels of atmospheric CO_2. Also, the effects of changes in land through deforestation and other practices would need to be considered, Edwards said.

In a related finding, the scientists attempt to explain the dominance of a lineage of C3 grasses, called Pooideae, in northern, cold areas of the globe, such as the Mongolian steppes. "The global latitudinal gradients of C3 and C4 always has been explained by the physiological advantages that C4 grasses have under high temperatures," Edwards explained. "No one has considered that the evolution of cold tolerance might have been equally important in setting up that latitudinal gradient. Climatically speaking, the cool-climate Pooideae are really the grasses that are doing something very different."

"It highlights the apparently important role that cold tolerance has played for the evolution of non-C4 grasses and especially the group Pooideae, which includes rye, barley, and wheat and many of the other grasses in the temperate and boreal habitats," Smith said.

Provided by Brown University