Why juniper trees can live on less water

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Hardy junipers grow near cacti in New Mexico's Florida Mountains. Photo: Cynthia Willson

An ability to avoid the plant equivalent of vapor lock and a favorable evolutionary history may explain the unusual drought resistance of junipers, some varieties of which are now spreading rapidly in water-starved regions of the western United States, a Duke University study has found.

"The take-home message is that junipers are the most drought-resistant group that has ever been studied," said Robert Jackson, a professor of global environmental change and biology at Duke's Nicholas School of the Environment and Earth Sciences.

"We examined 14 species from the U.S. and Caribbean, and they're all

relatively drought-resistant -- even ones in the mountains of Jamaica that get hundreds of inches of rain a year," he said.

"They've been expanding for about 100 years in some places, and drought plays a role in that," added Jackson, who is corresponding author of the new report published Feb. 27 in the American Journal of Botany's online edition. "For example, recent droughts have decimated pinyon pine populations in pinyon-juniper woodlands of the Southwestern U.S. but left the junipers relatively unscathed."

Many juniper species -- including several popularly known as cedars -- "are invading drier habitats and increasing in abundance where they already exist by surviving droughts that other conifers cannot," the report said.

The work was funded by the National Science Foundation, Duke University and the Andrew W. Mellon Foundation.

To understand why junipers are so successful, Jackson's graduate student Cynthia Willson and Duke associate biology professor Paul Manos assessed structural and genetic features in the 14 species that can explain their special drought tolerance.

They found a key structural adaptation in junipers: resistance to what scientists call "cavitation" -- a tendency for bubbles to form in the water-conducting xylem tissues of plants.

Water is sucked through xylem tissues under a partial vacuum, "so it's almost like a rubber band being stretched out," explained Jackson. "The dryer the conditions, the greater the tension on that 'rubber band' and the more likely that it will snap. If it snaps, air bubbles can get into the xylem."

The scientists found that xylem tissues of juniper species tend to be reinforced with extra woody material to prevent rupture. Such rupturing can introduce bubble-forming air either through seepage from adjacent cavities or by coming out of solution from the water itself, Jackson said.

The scientists also determined that the more cavitation-resistant Juniper species have thicker but narrower leaves -- a trait known as low specific leaf area (SLA) -- and live primarily in the western United States.

"Plants in drier environments typically have lower SLA," said Willson, the study's first author, who having completed her Ph.D. at Duke is now a student at North Carolina State University's College of Veterinary Medicine. "We found that junipers from the driest environments were more drought resistant and also had the lowest SLA."

Their research found that the most cavitation-resistant species is the California juniper, which grows in California's Mojave Desert, while the least resistant is the eastern red cedar -- the most widespread conifer in the relatively-moist eastern U.S.

While less drought-tolerant than other junipers, eastern red cedars still handle dry spells well and are in fact invading into Midwestern states including Nebraska, Jackson noted. Juniper species growing in wet parts of the Caribbean also benefit from drought tolerance because they "tend to grow in shallow, rocky soils that don't hold a lot of water," Jackson said.

In parts of the Southwest undergoing an extended drying period, junipers are edging out another hardy, water-thrifty conifer -- the pinyon pine. "They're both very drought- resistant, but the pinyons aren't as resistant as the junipers are," Jackson said.

The scientists also investigated how and where these tree types evolved

their collective drought tolerance by analyzing each juniper species' DNA. That analysis found that junipers evolved into different species relatively recently, separating into eastern and western groups -- technically called "clades."

"The center of diversity for junipers is in arid regions of Mexico," said Willson. "The fact that many juniper species seem to be more drought-resistant than necessary for their current range suggests that a common ancestor of those two clades was also quite drought-resistant."

Source: Duke University