Field experiment reveals tree hydraulic acclimation partially mitigates effects of warming and drought

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A new study at Los Alamos National Laboratory disentangles the relative impacts of drought and warming on plant function and reveals how trees adapt to drought and heat in semi-arid regions. This was the first tree manipulation study that factored the role of acclimation to both precipitation and temperature and separated their effects.

“Separating both drought and temperature effects is very difficult because increased temperatures induce atmospheric drought, therefore plants can respond to both differently. This work, supported by our team’s previous studies, allows separation of these two responses so models can incorporate more accurate data about responses,” said Charlotte Grossiord, Los Alamos scientist and lead author. “I think this new way of thinking will impact the whole field studying vegetation responses to changing climate.”

The paper summarizes a vast amount of tree-water dynamics’ observations and builds a framework to unravel stress response in juniper and pinon. Their paper was recently published in the journal *Plant, Cell and Environment*.

Los Alamos researchers subjected pinon and juniper to five years of artificial drought and heat at the world’s first tree-drought/heat experiment site, Los Alamos’ Survival Mortality experiment (SUMO). Located in the high desert of New Mexico, the SUMO site contains 80 trees with 64 randomly selected trees secluded in acrylic chambers with manipulated water and temperature (separate and combined) to test how the pinon and juniper react to environmental changes.

How Drought Affects Tree Health

Trees obtain their nutrition via atmospheric carbon dioxide, absorbed through microscopic pores called stomata. They open and close these stomata to absorb water vapor or sweat (transpiration). A tree transports vital nutrients, including carbohydrates photosynthesized from the carbon and water captured by its stomata or roots, through tubal systems called phloem and xylem. These carbohydrates are used for growth and also to create protective resin to defend against insects and pathogens.

When the air is hot and dry, a pressure change known as a Vapor Pressure Deficit (VPD) affects gases; water vapor is sucked out of the plant if the stomata are not closed. During times of prolonged drought, trees close stomata—a response is triggered as the plant goes into emergency mode to conserve water and prevent evaporation.

Pressure changes from closed stomata and dry soil create tension in the xylem, impeding the flow of water and potentially collapsing the hydraulic system—the primary focus of this study. The very mechanism that helps protect the thirsty tree also halts photosynthesis. The tree starves and can also no longer create protective resin.

Juniper and Pinon Stress Responses

Previous findings suggested warming superimposed on drought would exacerbate drought stress and increase mortality. However, during this study's five-year period of warmer and much drier conditions, no mortality was observed. The tree stomata adjusted to heat and drought even when other functions were drastically impaired by drought—stomata acclimation prevented tree death from the additive effects of warming and drying.

Also, previous work had revealed that juniper trees can be highly resistant to drought, keeping their stomata open, while pinon shut down all functions that kept them alive. However, in this study, juniper was unable to significantly acclimate and showed strong reductions in function. Pinon, which suffered when exposed to drought, actually acclimated when warming was the only stressor, and it retained hydrological functions including sap production to repel invaders.

What it took to crash the trees' systems, a one-two punch

However, the trees' physiological functions (primarily water and food use, not the hydraulic system) collapsed when they encountered subsequent droughts and heat waves—they shut down water and carbohydrate use, weakening themselves and becoming defenseless against potential invaders such as bark beetles (not present during this study). The stomata were also unable to acclimate to the effects of dry soil, which is different from atmospheric drought.

Some trees grew deeper roots, which improved access to soil water, but the researchers said deeper roots would not protect against the predicted megadrought, a decades-long period of minimal precipitation that hasn't occurred in North America in 700 years. The researchers acknowledge that acclimation is a long-term process. Longer-duration studies are needed to provide evidence of a full-range of responses.

The paper: "Tree water dynamics in a drying and warming world," Plant, Cell & Environment, DOI 10.1111/pce.12991. Charlotte Grossiord, Sanna Sevanto, Isaac Borrego, Allison M. Chan, Adam D.Collins, Lee T. Dickman, Patrick J. Hudson, Natalie McBranch, SeanT.Michaletz, William T. Pockman, Max Ryan, AlbertoVilagrosa & Nate G. McDowell.

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