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# As Rainy Winter Spreads Sudden Oak Death Pathogen, a Scientist Races to Build Resistance

by Alison Hawkes on March 28, 2017


A tanoak seedling from an acorn collected in San Mateo County will be planted in a new orchard at a UC Berkeley research facility. That preserves this humble native's disease-resistant genetic stock. (Photo by Andrea Laue, sparebeauty.com



Often lost, or at least overlooked, in Northern California's inspiring redwood forests is the unassuming tanoak, a scruffy tree compared to its towering neighbors. But it's almost always present, filling out the forest understory and adding to the complex architecture of redwood and Douglas fir stands. And, truth be told, it has its own admirable features: a full canopy; crackled bark that tends to become shaggy with moss like a scene in an elf forest; and a prolific acorn crop. All of which make the tanoak (not actually an oak, but both belong to the beech family) a dependable source of food and habitat for dozens of animal and plant species, an important host for essential soil fungi, and a significant traditional cultural resource for California Indians across its range from southwestern Oregon to Ventura County.

Probably what now most comes to mind with tanoaks, though, is Sudden Oak Death, a disease caused by *Phytophthora ramorum*, a pernicious water mold that slunk from nursery plants into Northern and Central California wildlands two decades ago. Transmitted largely through infected plant material, the pathogen can also be carried in water and even hitch a ride in the soil on hiking boots and car tires. *P. ramorum* is known to kill three oak species and cause branch dieback in well over 100 other species of plants, but tanoaks are the most susceptible and *P. ramorum* has felled millions of them.

Since its arrival, land managers have been deploying a variety of imperfect techniques to stop its spread—from culling bay laurels, whose leaves can serve as a reservoir of the pathogen, to inoculating valuable oaks with a chemical prophylactic agent. Every spring, hundreds of citizen scientists fan out across public and private lands to record signs of the advancing disease in "SOD Blitzes." In 2016, the rains unleashed the largest expansion of *P. ramorum* in a decade, causing it to pop up for the first time as far east as Mount Diablo, while new outbreaks were found from Mendocino to San Luis Obispo counties. Even the San Francisco Botanical Garden now has it. This year, it could be even worse.

Matteo Garbelotto, a plant pathologist at UC Berkeley, has devoted much of his professional life to dealing with the problem of *P. ramorum*. While working to deploy these measures, including leading the SOD Blitzes, Garbelotto has also been steadily advancing another approach to saving tanoaks. He's been studying the tree's genetic lineages in search of natural reserves of resistance to the disease. Tanoaks, like other reproducing species, have familial lines in which genes are passed along.

"At the very beginning we asked, 'Are there any differences in tanoaks or are all the families equally susceptible?'" he says.

Fifteen years later—and with the help of dozens of landowners and collaborators—Garbelotto has not only found significant differences in the abilities of tanoak families to withstand *P. ramorum*, but believes he's closer to identifying a set of genetic markers that confer some degree of tolerance to the disease and could become a powerful tool in managing tanoak stands.

He began in 2005 with a "common garden" experiment in which his team fanned out across California to collect acorns from tanoak families throughout the species' range. Assembling the specimens in the same place and subjecting them to the same conditions allowed the researchers to scientifically compare the outcomes. His team ultimately grew 25,000 plants in a small, gated nursery just off UC Berkeley's main campus, later inoculating them with *P. ramorum* in a quarantined laboratory to see how they performed.

Disease resistance has been found before in trees and even harnessed through breeding programs. Notable examples include elms and American chestnuts, both of which suffer from fungal pathogens. That gave Garbelotto some hope that tanoaks, too, might harbor such genetic reserves of resistance within populations. Furthermore, anecdotal evidence has suggested that individual tanoaks, sometimes within the same area, behaved differently toward this nemesis. "You'd be walking along a trail with so much devastation," recalls Cindy Roessler, a senior resource management specialist at Midpeninsula Regional Open Space District, one of the study's participants and funders. "You'd turn a corner and there would be a beautiful, large tanoak with a full canopy and no signs of leaf loss or bleeding, and heavy with acorns, and you'd go, 'Why this one?'"

During the tests, not only did about 18 family lines, about 5 percent of the samples, show some level of tolerance to *P. ramorum*, but these traits were found well-represented across the state—including about 20 percent of the 35 trees sampled on MROSD lands, according to Roessler.

But a laboratory setting is different than a natural one, and so to confirm his results, Garbelotto took a thousand of his tanoaks that had not been inoculated, including the most promising families, and planted them in a *P. ramorum*-infested setting in the wilds of the Santa Lucia Mountains. "We left them alone and five years later we measured survivorship," he says. "We were happy because the ones we called 'more resistant' were the ones that survived, and there were other survivors from ecologically fit families. So, that was very promising."

With his identification of resistant family groupings confirmed, Garbelotto then used a mathematical model to calculate a theoretical picture of disease resistance in these tanoaks' genome. He estimated that between six and eight genes helped the tree tolerate the disease, suggesting that the tree might still get sick but its chances of survival would be higher. "In our case, it was clear we didn't have real resistance," Garbelotto says. That's actually not a bad scenario, he points out, because single-gene resistance could easily turn into an Achilles' heel for a plant facing a mutating pathogen, while multiple-gene resistance in tanoaks potentially makes them more durable.

Just why these genes are present in tanoaks remains unclear—after all, *P. ramorum* is an exotic species that has not been around long enough for tanoaks to have evolved to combat it. Garbelotto suspects these genes weathered the natural selection process as the tanoaks combated a similar pathogen, perhaps another species of *Phytophthora*, and fortuitously the genes work against *P. ramorum*.

He next tried to identify the *P. ramorum* resistance genes by monitoring the tree's molecular response, specifically to ascertain which proteins battle an onslaught of *P. ramorum*. First he had to differentiate the tree's proteins from the proteins produced by all the other organisms present in a tiny specimen of tree tissue—including bacteria, fungi, and insects, and of course *P. ramorum* itself. "It was a big mess," Garbelotto recalls. Then from the proteins produced by the trees, he determined which genes were expressed in the *P. ramorum*-resistant tanoaks but not in the susceptible ones. And the work paid off. He found that the tanoaks tolerant to *P. ramorum* strongly expressed, or activated, genes involved in identifying microbes, signaling action within the cell, and producing antimicrobial compounds. That part makes a lot of sense in the context of an infection—but there's a twist. These trees were expressing the microbe-bashing genes prior to the infection, meaning something other than *P. ramorum* was causing the genes to activate.

Garbelotto hypothesizes that the "something" is perhaps another organism, possibly even a symbiont, like a beneficial fungus, or a pathogen of no consequence. The tanoaks may depend on such "priming" of these genes by other organisms to effectively resist *P. ramorum*. "Maybe it makes sense that the only way plants can resist a pathogen is by using their own experience with their own garden-variety pathogens."
Though the prospect is theoretical, Garbelotto also hopes that exposing uninfected tanoaks to the priming organisms might jump-start resistance in individual trees, sort of like a vaccine. "That exposure is going to cause gene expression that might make it more tolerant."

Garbelotto is finishing the analysis and developing a set of biomarkers to test for the presence of the resistant genes. Ultimately he wants to be able to go into the field, clip a tanoak leaf, pass it through a test and—presto!—he'll know that particular tanoak's genetics. "It's going to tell me this tanoak is tolerant to Sudden Oak Death, and then I'm going to use this [same] one in a reforestation project."

Already, Roessler has identified a spot on MROSD lands that could be reforested with SOD-resistant strains of tanoaks. A portion of Bear Creek Redwoods Open Space Preserve in Los Gatos was once a vineyard, but today invasive French broom (and *P. ramorum*) overruns it. She says, "We could go into those areas, and kick out the broom and restore it with resistant tanoak trees. Wouldn't that be amazing?"

This spring, Garbelotto is planting trees from close to 30 of his best-performing tanoak families at UC Berkeley's Global Campus at Richmond Bay. There they will live as a repository, their precious genes preserved as a resource for when the time comes to bring back the tanoaks. "Remember, I have families that are resistant and it took me 15 years to find out," he says. "So, those are really valuable to me."

*Interested in joining a SOD Blitz this spring? Visit SODblitz.org.*



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