

Coast Live Oak Resistance to *Phytophthora ramorum*

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Abstract

The oomycete *Phytophthora ramorum* is a plant pathogen with an unusually broad host range. Recognized in 2000 as a previously unknown and likely introduced species, this pathogen has become established in central and northern coastal California, southwestern Oregon, and Western Europe. Tree species that may be killed by stem cankers include true oaks (*Quercus agrifolia* Née, *Q. kelloggii* Newb., *Q. parvula* var. *shrevei* (C.H. Muller) Nixon, and *Q. chrysolepis* Liebm.), and tanoaks (*Notholithocarpus densiflorus* Hook. and Arn.), in North America; and Japanese larch (*Larix kaempferi* (Lam.) Carrière) in the United Kingdom. The disease, referred to as sudden oak death (SOD), is changing the composition of forests in California and potentially threatens forests worldwide. Coast live oak has been heavily-impacted by the epidemic, with infection and mortality rates in infested areas averaging 5 percent and 3 percent, per year, respectively, in forests of Marin County, California. Since this species is one of the dominant mast-producing trees in much of coastal California, the species composition and ecological integrity of many of these forests are threatened. Median survival of naturally infected coast live oaks in long-term disease progression plots established in 2000 was estimated as 9.7 years, using Weibull survival models. Beetle attacks in cankers reduced survival times by 65 to 80 percent. While coast live oak mortality has steadily increased since 2000, the infection rate in these sites has been declining. In heavily-affected areas, asymptomatic coast live oaks persist that have never exhibited the bleeding symptom of infection or that are in apparent remission from previously recorded bleeding.

Resistance to canker pathogens in trees can be assessed by measuring canker sizes induced by inoculation of the pathogen into mechanical wounds, which in resistant trees are not significantly different from wounds alone or are below a critical threshold. We inoculated a total of 80 asymptomatic mature coast live oaks with *P. ramorum* and mock-inoculated (controls; wounded without inoculation) 40 trees in two natural populations in Marin County in July 2002 and followed disease development to July 2009. By April 2003, 70 percent of the inoculated trees, and none of the controls, exhibited bleeding. We estimated the probability of survival to 2009 using a Logit model to regress on maximum external canker length measured 9 months after inoculation. Trees with external cankers < 21.2 cm (50 percent of the trees) had \geq 80 percent probability of survival, while cankers < 6.6 cm (35 percent of the trees) predicted \geq 90 percent probability of survival. The trees that died by 2009 (20 percent of the total inoculated with the pathogen) all had external cankers \geq 40 cm in 2003. Because the study started in 2002, after the most susceptible individuals in the stands likely had already been infected or killed by *P. ramorum* infection, our data may overestimate the proportion of resistant trees in the pre-epidemic stands. Even so, our study shows that coast live oaks in northern California exhibit substantial resistance to *P. ramorum*. The distribution of canker lengths is consistent with quantitative multi-gene resistance to the pathogen.

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