

# California Bay Laurel Susceptibility to *Phytophthora ramorum* Depends Upon Season, Leaf Age, and Fungal Load<sup>1</sup>

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## Abstract

*Phytophthora ramorum* can produce spores on dozens of native California plant species, but the most important vector for infection of oak (*Quercus*) is California bay laurel (*Umbellularia californica*). Presence of bay laurel is associated with increased infection of oaks and it is the most common tree species that co-occurs with coast live oak (*Quercus agrifolia*) in northern California woodlands. Understanding the interaction between *P. ramorum* and bay laurel is critical to predicting dynamics of disease establishment in mixed oak woodlands. Previous studies showed that *P. ramorum* lesion growth and expression of *P. ramorum* symptoms depends on environmental factors and on bay laurel genotype. However, these studies did not measure susceptibility to infection by *P. ramorum* spores on the leaf surface. In addition, they did not work with pathogen isolates that had been cleared of all microbial associates.

We addressed five questions using detached leaf assays employing *P. ramorum* isolates and bay laurel trees: 1) How does leaf age affect susceptibility to infection? 2) Do *P. ramorum* isolates vary in infectivity of bay laurel (pathogen isolate by host tree interaction)? 3) What traits of individual bay laurel relate to susceptibility? 4) How does susceptibility vary over the year? and 5) At what temperatures are trees most susceptible to infection? For this study, we used 20 *P. ramorum* isolates from across the contiguous range in California and 51 bay laurel trees from eastern Sonoma County, California, where infection of bay laurel and canker host species is widespread.

Young leaves of bay laurel from the current growing season are less susceptible to infection than leaves that grew in prior years (Figure 1). This effect was observed for six different host trees. Lesion scores were twice as high on leaves from previous growing seasons than on current year leaves. We also found that individual bay laurel trees vary significantly in susceptibility, and *P. ramorum* isolates vary in infectivity of bay laurel. However, there was also a significant host tree by pathogen isolate interaction. Trees that were not susceptible to most *P. ramorum* isolates were very susceptible to a few, and some *P. ramorum* isolates that were usually unable to infect a bay laurel tree frequently infected a few host trees.

To identify which bay laurel traits affect susceptibility, we quantified susceptibility on 24 trees from three Sonoma county localities exposed to four *P. ramorum* isolates. We assessed four leaf characteristics, including leaf size and protein content; eight characteristics of trees growing in the field, including leaf retention, number of lateral shoots, and insect herbivory; features of the field site where the trees naturally grow, including topographic position, temperature-moisture index, and microclimate conditions recorded by a data logger; and the

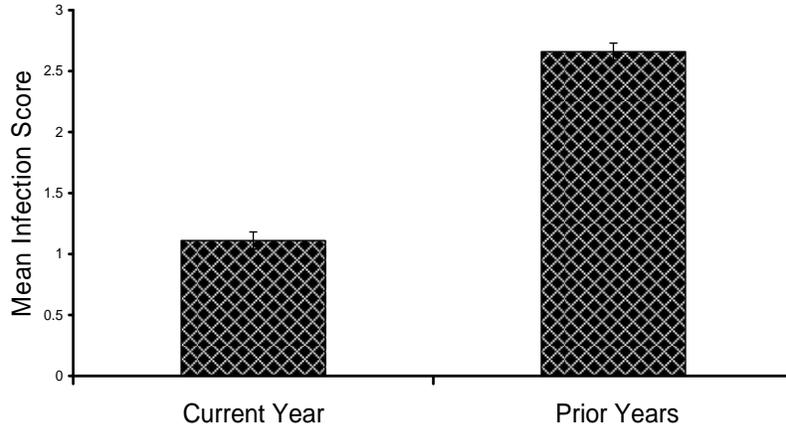
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Leaf Age  $p$  , 0.037, Leaf Age\*Isolate  $p < 0.0001$

Figure 1. Current year bay laurel leaves are less susceptible to *P. ramorum* Infection than older leaves.

natural microbial community growing on bay leaves, including the diversity and total number of fungal and bacterial colony forming units (CFU). To relate these characteristics to susceptibility, we conducted a path analysis based on *a priori* hypotheses about direct and indirect relationships among predictor variables. Results indicated that leaf area and the number of lateral shoots were positively related to susceptibility, while fungal CFU was negatively related to it. Temperature moisture index and maximum relative humidity were positively related to fungal load.

Previous studies have shown that *P. ramorum* sporulates at relatively low temperatures, which are common during winter rain in California, but that bay laurel infection occurs later in spring when conditions are warmer. We examined susceptibility at the same temperature range and found that susceptibility was highest between 5° C to 15 °C. These results support the finding that the pathogen is capable of growth and sporulation at the lower temperatures that prevail during winter, but they do not explain why bay laurel infection levels remain low until late spring.

Other studies suggest that bay laurel is less susceptible during the summer months, and our susceptibility assay findings agreed with this conclusion. We found that susceptibility declines during summer and early fall and increases slightly during fall and winter. Shortly before bud break, susceptibility increases rapidly and it peaks in May or June.

We propose a new conceptual model for *P. ramorum* epidemiology in oak woodlands (Figure 2). Once winter rains begin, *P. ramorum* begins to produce spores, but the bay laurel trees are not yet susceptible enough to support multiple cycles of spore production. In years when late spring rains overlap with increased susceptibility of bay laurel trees, cascading spore production facilitates bay laurel infection. Our results highlight the importance of bay laurel phenology in disease establishment.

## Conceptual model of *P. ramorum* epidemiology in oak/ bay woodlands

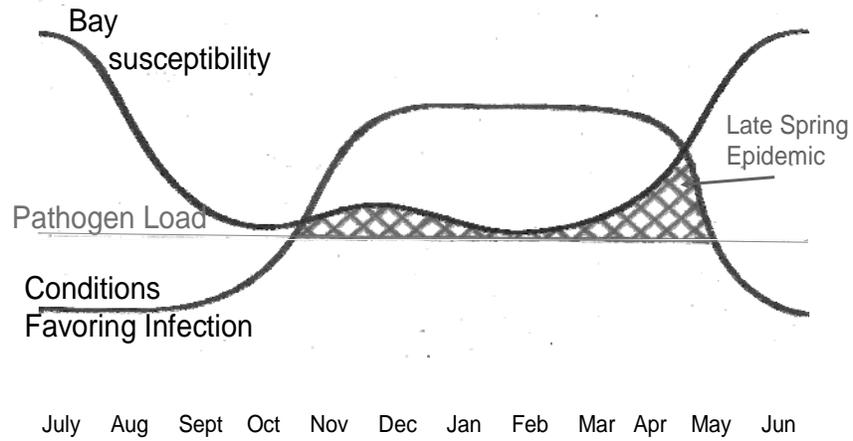


Figure 2. Model for *P. ramorum* epidemiology in oak woodlands.