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An investigation into the causes of recent widespread *Acacia* spp. mortality in the San Francisco Bay Area

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In October 2020, observations of dying Acacia were reported, primarily *Acacia melanoxylon* (blackwood acacia), in numerous San Francisco Bay Area locations. The Acacia die-off was described as highly unusual: groups or even entire stands of trees that appeared to die-off rather rapidly, showing bright, burnt-orange crowns (Figure 1). Upon examination, Acacia of all conditions could be found in the vicinity of the dying trees, some green, others yellowing, some with dead branches. What appeared to be older dead Acacia were also present.

Figure 1. Die-off of *Acacia melanoxylon* in Leona Heights, Oakland (Alameda County) in October 2020. Photo: USFS, PSW.

In order to enable management of this new tree disease concern, in early December 2020, we set out to determine its cause by answering the following questions:

1. Are there known pathogens that are consistently isolated from Acacias at all sites displaying dieback?
2. What is the effect of environmental conditions on disease development?
3. Are the fungi involved in the observed tree mortality native or introduced?
4. Are secondary fungi involved in the die-off?
5. Can preliminary management recommendations be made based on the biology and the ecology of the fungi involved in the dieback?

This project was conducted between December 2020 and February 2021 in San Mateo, Alameda and Contra Costa Counties, with lab analysis done at the UC Berkeley Laboratory of Forest Pathology and Mycology. A total of five sites in four distinct locations (Leona Heights/Montclair, Dimond Canyon, Carquinez Strait and Burlingame - San Francisco Public Utility Commission) were sampled. Eight trees were sampled in all locations except for Dimond Canyon, where six trees were sampled. Samples were collected from blackwood acacia and occasionally from silver wattle (*Acacia dealbata*) that were at various stages of decline but still alive. Many of the trees showed stem cankers at the soil line or higher up on the bole. Stems, twigs and roots were evaluated for the presence of pathogens by directly plating out symptomatic tissue onto several types of media and on washed carrot disks. Tissues containing both necrotic and healthy portions were sampled. Besides direct plating of symptomatic tissue, each declining tree was also tested for the presence of *Phytophthora* by baiting from soil samples collected near its base. Molecular and microscopic evaluations of recovered fungi were made to identify the species and assess its risk to trees and shrubs. Molecular identification was based on ITS sequence and, for groups of fungi of interest, the EF-alpha and the Histone 3 loci were additionally sequenced to obtain a more accurate species identification.

A total of 200 cultures was obtained from 81 soil or tree samples. Only two fungi, were identified at all sites, *Diaporthe foeniculina* and *Dothiorella viticola*. The symptoms observed, pie-shaped wood discoloration and stem or branch cankers, are consistent with disease caused by these two fungi (figure 2). All trees examined fit in one of the following four categories: 1) negative (no fungi isolated); 2) *Diaporthe*/*Dothiorella* positive; 3) *Umbelopisis* positive; 4) only contaminants or fungi of uncertain effect isolated. A closer look revealed important patterns: trees were infected either by *Diaporthe* or by *Dothiorella* (only one tree had both). *Fusarium* spp. and *Mortierella* spp. were isolated only from trees infected by *Diaporthe*. There were several trees infected by *Diaporthe* and *Dothiorella* that were not infected by *Fusarium, Mortierella* or *Umbelopsis* (the latter two are endophytic zygomycetes).

Figure 2. Internal discoloration typical on declining *Acacia melanoxylon.* Photo: USFS, PSW.

The analysis summarized above, combined with the fact that all other fungi - except for the widespread *D. foeniculina* and *D. viticola*—were site-specific, supports the primary role played by *Diaporthe* and *Dothiorella* in causing this Acacia dieback. However, it should be noted that these fungi have complex biology. They both start as endophytes, living inside trees without

any obvious effect on tree health, then often become pathogens - some relatively aggressive - in conjunction with the onset of predisposing stress factors (drought, heat stress, fewer foggy days, competition due to high stand density) and then survive as saprobes on the wood of the dead trees.

Some aspects of the biology of these fungi warrant attention: 1. Infection is positively correlated with abundant rainfall. We expect that the record-breaking rainfall of 2017 resulted in widespread infection. 2. The endophytic phase can last from 1 to 30+ years, meaning that disease development is almost never immediate. Even in the presence of stress, we expect a minimum of a 2-year lag between infection and disease expression, so the timing of disease development is consistent with a 2017 infection wave. 3. Disease is density dependent, so we expect to see more mortality where plants are in thick clusters and monospecific stands, rather than in isolated trees. 4. Sporulation is positively correlated with the amount of dead and decaying wood. Many of these patterns have implications for management.

D. foeniculina and *D. viticola* have been previously reported on multiple hosts, but not on Acacias, in California and elsewhere in the world. This suggests that Acacia infection in Northern California may be the result of a host jump of native or long-naturalized fungi that occurred in the past decades. Infection was possibly accelerated by increasing densities of self-propagating Acacias which statistically would increase the chance of new host-pathogen encounters. The problem was also exacerbated by the alternation of very rainy years known to facilitate fungal infection, with very dry years known to trigger the shift from endophytic to pathogenic life-style. However, *Dothiorella moneti*, an Australian relative of *D. viticola* was found in a single location. This fungus is reported only on Acacias and close relatives from Australia, hence it is likely to be introduced. How it got to California and its virulence need to be further investigated. Another possible explanation is: this fungus has been present in Bay Area Acacia for some time but never isolated since the trees are typically unmanaged. While less likely, that hypothesis is also possible.

Many *Dothiorella* and *Diaporthe* species become pathogenic, capable of causing harmful or lethal damage, when hosts experience a predisposing physiological stress. These fungi are already present in their hosts as endophytes, so are positioned to take advantage of their hosts when conditions allow. Hence, with the onset of stress, these fungi can rapidly cause disease, generating large scale outbreaks in a short period of time. Note that host predisposition may be unlinked to infection by other primary pathogens and caused by different factors. Drought may be a major predisposing factor, but water availability depends on multiple factors including aspect, frequency and abundance of coastal fog, soil, and plant density and size/age. Finally, the effects of chemical changes in soil and leaves caused by smoke exposure are largely unknown.

Both Acacias studied are exotic and invasive. They are not native to the Bay Area but naturally reproduce to rapidly increase their populations. Furthermore, it appears that these Acacias thrive in mesic environments in their native Australia, therefore, the Mediterranean climate of the San Francisco Bay Area is not perfectly suited to their growth.

Management recommendations (preliminary)

Based on the ecology and biology of the hosts and pathogens involved, and on experience with these pathogens in agricultural settings, the following preliminary management recommendations are proposed:

1. If some Acacia are desired, manage the proliferation of Acacias from individual trees as it forms dense thickets. Thin out some trees since a high host density increases the cumulative demand for resources and facilitates infectious disease contagion among dense stands or clumps.
2. If some Acacia are desired, prioritize their preservation on more mesic sites, while eliminating them from drier sites.
3. For individual high value ornamental specimens, prune any portion of the canopy showing symptoms, in order to eliminate fungal inoculum and reduce water and resource demands from the canopy.
4. Inoculum is produced with great abundance on dead wood. As the host range of these fungi is broad, inoculum can infect not only Acacias, but also other hosts including native plants. Ideally, remove all apparently dead trees and woody debris under declining trees. Dispose of chipped or unchipped debris by burning, composting or by burying in a landfill.
5. Sanitize all tools and equipment employed in affected Acacia stands by cleaning the tools till no soil or debris is visible and then apply a disinfectant.

These preliminary recommendations are based on knowledge and application from agricultural systems, such as orchards. Although these pathogens' biology justifies such recommendations, their applicability in non-agricultural systems needs to be carefully evaluated through a case-by-case, cost-benefit analysis. Most of these prescriptions are not to be intended as "all or nothing"-- even partial implementation could be beneficial.

We do not know whether affected stands will regenerate through resprouting, which may compound the severity of this issue and require different prescriptions. Further research is currently ongoing to confirm the role played by Diaporthes and Dothiorellas in conjunction with unfavorable climatic conditions in the widespread dieback of Acacias occurring in the greater San Francisco Bay Area.

Note. These investigations are preliminary, so recommendations may change as more becomes known. This is a summary report. A comprehensive report with supporting data is pending publication. Cite this report as: Garbelotto, M. 2021. An investigation into the causes of recent widespread *Acacia* spp. mortality in the San Francisco Bay Area. (April.) https://www.suddenoakdeath.org/wp-content/uploads/2021/03/Garbelotto.summary.AcaciaStudy.03.30.21.pdf.

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