CALIFORNIA OAK MORTALITY TASK FORCE REPORT
NOVEMBER 2017

NEW HOSTS

In 2017 *Phytophthora ramorum* was recovered for the first time from several *Arctostaphylos* species with symptoms ranging from foliar spotting, stem lesions, and shoot tip blight to entire branches and growing tips dying. Most of the samples tested were collected from field restoration plantings or native stands; some were collected from nurseries. In total, seven new *Arctostaphylos* species were identified as potential new hosts of *P. ramorum*. These are in addition to *A. virgata* and *A. glandulosa* which were identified in 2015. In order for a new plant species to be federally listed as a *P. ramorum* host, Koch's postulates must be completed. The live cultures from which *P. ramorum* was detected must also be sent to USDA scientists for confirmation. California Department of Food and Agriculture (CDFA) scientists are currently conducting Koch's postulates on two *Arctostaphylos* species and plan to test the other seven potential host species once plant material is obtained. Many of the new potential hosts are considered endangered or threatened, making material difficult to acquire. Prior to these detections, four *Arctostaphylos* species were federally regulated for *P. ramorum*. These recent findings suggest that *Arctostaphylos* susceptibility and infection levels may be greater than previously thought.

P. ramorum foliar symptoms on *A. rainbowensis*.
Photo: M. Uhler, East Bay Regional Parks District

P. ramorum foliar blight and leaf spot symptoms on Brisbane box street trees, Marin Co., CA.
Photo: S. Rooney-Latham, CDFA

P. ramorum was also recovered from Brisbane box (*Lophostemon confertus*, syn. = *Tristania conferta*) for the first time from street trees in Sausalito (Marin Co.). Symptoms were identified in early spring and included foliar spotting and necrosis, stem cankers, and overall canopy blight. The pathogen was recovered from all of the symptomatic tissue sampled from multiple trees. Another infected tree was also confirmed a few miles away from the Sausalito infestation. The trees are located in an area known to have *P. ramorum*-infected California bay laurel. Koch's postulates testing for this potential new host is underway. It is possible that higher than average precipitation levels in 2017 contributed to the severe symptoms. Brisbane box is an Australia native that is frost tolerant to 25 ℉ and is cultivated throughout the U.S. It is regarded as a useful street tree due to its tolerance for drought, smog, and poorly drained soils as well as its overall pest resistance.

MONITORING

California's 2017 citizen scientist-based SOD Blitz surveys documented a three-fold increase in overall infection rates in those areas sampled since the drought ended in 2015, with 13% of samples found positive (the highest to date since the blitzes began in 2008).

Urban areas of the San Francisco Peninsula (including the western part of Redwood City) and East Bay have significant increases in pathogen levels on California bay laurels from previous years, putting oaks at high risk for infection for the first time. The pathogen is also now established in the Carmel Valley, with multiple confirmations in valley floor urban areas and sporadic locations on the drier northern side of the valley. Sonoma County has an increase in urban and rural outbreaks, with the pathogen reemerging near Cloverdale and found to be at epidemic levels east of Healdsburg, near Santa Rosa and Glen Ellen. In southern Sonoma County, the pathogen has become established for the first time in the more rural areas west and east of Petaluma. Western San Mateo County also has increased pathogen levels.

Several popular public destinations have been found to have substantial infestations, including the Point Reyes National Park Visitor Center near Point Reyes Station, the San Francisco Presidio, the UC Berkeley Campus and Botanical Gardens, and the UC Santa Cruz (UCSC) Arboretum. In the Presidio, 10 positive sites were found in two distinct areas of the park - the southeastern corner and the northern boundary. At the UCSC Arboretum, four manzanita (*Arctostaphylos*) species, including two rare species, were severely affected by SOD and had extensive dieback.

Blitz findings also determined San Luis Obispo County is still uninfested, confirming that the 2016 positive detections in the county were false positives. The determination was made after laboratory analysis of 2017 survey samples revealed no infection after using two different DNA assay tests, DNA sequencing, and culturing for the pathogen.

The 2017 SOD Blitz was the largest to date in terms of area covered and was the first to include three tribal land surveys. An estimated 300 volunteers surveyed nearly 15,000 trees and submitted leaf samples from approximately 2,000 symptomatic trees to the Garbelotto lab for pathogen testing. Counties surveyed included Siskiyou, Trinity, Humboldt, Mendocino, Lake, Sonoma, Napa, Solano, Marin, San Francisco, Alameda, Contra Costa, San Mateo, Santa Clara, Santa Cruz, Monterey, and San Luis Obispo. The Blitzes were possible thanks to funding from the US Forest Service State and Private Forestry, the National Science Foundation, the Gordon and Betty Moore Foundation, and the PG&E Foundation. They were organized by the UC Berkeley Garbelotto lab in collaboration with government and non-government organizations, including the National Park Service, Presidio Trust, San Francisco Public Utilities Commission, Midpeninsula Regional Open Space District, Save Mount Diablo, Land Trust of Santa Cruz County, East Bay Regional Parks, Santa Lucia Conservancy, Sonoma State University, UC Santa Cruz Arboretum, Los Padres National Forest, City and County of San Francisco Department of Recreation and Parks, UC Berkeley Botanical Garden, and California Native Plant Society.

NURSERIES

The Kitsap County Botanical Garden, WA (first found positive in 2015) September *P. ramorum* survey was negative for the pathogen. The next survey will be conducted in November.

In October, Washington's only *P. ramorum*-regulated interstate shipping nursery fall certification survey was conducted. All samples were negative for the pathogen. If the nursery tests negative during the spring 2018 survey, it will be released from the DA-2014-2 regulations.

Washington hosted the 2018 *P. ramorum* Working Group meeting in Poulsbo, WA on September 19th and 20th. Representatives from the USDA, National Plant Board and various states met to discuss regulatory issues, research, and *P. ramorum*. The group meets annually. Next year's meeting will be in Pennsylvania.

One *P. ramorum* detection was made in Richmond, British Columbia (near the Vancouver airport) during the Canadian Food Inspection Agency (CFIA) 2016-2017 Survey for Horticultural Pests. For more information, see the 2016-2017 Plant Protection Survey Report: Executive Summary at http://inspection.gc.ca/plants/plant-pests-invasive-species/plant-pest-surveillance/2016-2017-plant-protection-survey-report/eng/1501889533057/1501889533572

The Systems Approach to Nursery Certification (SANC) continues its pilot program with four nurseries now SANC-certified, three finishing their certification agreements, and eight more initiating the first steps of the program. SANC emphasizes plant health and quality. Participating nurseries are located in 15 states: WI, PA, MO, OR, WA, OK, GA, NJ, NC, TX, NH, OH, KS, NY, and CA. As the program continues, some of the nurseries have expressed interest in acquiring plant material only from other SANC-certified nurseries.

A SANC governing board was established to provide program oversight, evaluation, and policy development. Board membership is comprised of nine representatives from participating states, industry, and USDA APHIS Plant Protection and Quarantine. Training sessions for the National Plant Board (NPB) Western Region were recently held in Southern California for the staff of county agricultural departments as well as TX and AZ nursery inspectors likely to engage in SANC program activities. They are also planned for PA in November for inspectors in the NPB Eastern Region and for FL in January for the NPB Southern Region.

RESEARCH

A special "Sudden Oak Death Management" issue of the journal Forest Phytophthoras (7(1)) has been published at http://journals.library.oregonstate.edu/ForestPhytophthora. It contains five peer-reviewed articles on SOD management in California and Oregon (USA) as well as a foreword by Susan J. Frankel, guest editor. It serves as part of the proceedings from the Sixth Sudden Oak Death Science Symposium, held June 21 - 23, 2016 at Fort Mason Center in San Francisco, CA, USA.

Abstract: This special issue of Forest Phytophthoras serves as part of the proceedings from the Sixth Sudden Oak Death Science Symposium held June 21 - 23, 2016 at Fort Mason Center in San Francisco, CA, USA. The symposium marked almost 16 years to the day that David Rizzo (UC Davis) and Matteo Garbelotto (UC Berkeley) identified the cause of sudden oak death to be a previously unknown *Phytophthora* species, later named *Phytophthora ramorum*. Many of the approximately 200 participants at the conference have dedicated the past 15 years, a large portion of their life's work, to protect U.S. forests from this new invasive pathogen.

Conrad, A.O.; McPherson, B.A.; Wood, D.L.; Madden, L.V.; and Bonello, P. 2017. Constitutive Phenolic Biomarkers Identify Naïve *Quercus agrifolia* Resistant to *Phytophthora ramorum*, the Causal Agent of Sudden Oak Death. Tree Physiology. https://doi.org/10.1093/treephys/tpx116.

Abstract: Sudden oak death, caused by the invasive pathogen *Phytophthora ramorum* Werres, de Cock & Man in't Veld, can be deadly for *Quercus agrifolia* Neé (coast live oak, CLO). However, resistant trees have been observed in natural populations. The objective of this study was to examine if pre-attack (constitutive) levels of phenolic compounds can be used as biomarkers to identify trees likely to be resistant. Naïve trees were selected from a natural population and phloem was sampled for analysis of constitutive phenolics. Following *P. ramorum* inoculation, trees were phenotyped to determine disease susceptibility and constitutive phenolic biomarkers of resistance were identified. Seasonal variation in phloem phenolics was also assessed in a subset of non-inoculated trees. Four biomarkers, including myricitrin and three incompletely characterized flavonoids, together correctly classified 80% of trees. Biomarker levels were then used to predict survival of inoculated CLO and the proportion of resistant trees within a subset of non-inoculated trees from the same population. Levels of five phenolics were significantly affected by season, but with no pronounced variation in average levels among seasons. These results suggest that pre-infection levels of specific phenolic compounds (i.e., biomarkers) can identify trees naturally resistant to this invasive forest pathogen. Knowledge of resistant trees within natural populations may be useful for conserving and breeding resistant trees and for disease management.

Hulbert, J.M.; Agne, M.C.; Burgess, T.I.; Roets, F.; and Wingfield, M.J. 2017. Urban Environments Provide Opportunities for Early Detections of *Phytophthora* Invasions. Biological Invasions. https://doi.org/10.1007/s10530-017-1585-z.

Abstract: Globalization has increased the frequency of inadvertent introductions of plant pathogens. Many catastrophic invasions of both natural and agricultural systems have been initiated through anthropogenic dissemination pathways. *Phytophthora* species are a group of invasive plant pathogens causing many of the most important plant disease epidemics. A review of *Phytophthor*a species descriptions published following the publication of the first DNA-based *Phytophthora* phylogeny was conducted to highlight patterns of recent introductions and to provide insights for early pathogen detection initiatives. Seventy-two publications from 2001 to 2016 describing 98 *Phytophthora* species were evaluated. Of the 91 species with data on geographic location isolation, 22% were described from type specimens isolated from urban environments, 33% from agricultural environments and 45% from natural environments. Within the urban environment, ornamental plant trading nurseries were the most important sources. Specifically, for *Phytophthora ramorum*, a species causing multiple epidemics globally, the largest proportion of first report publications were from urban environments, including nurseries. We therefore suggest that detection programs for invasive plant pathogens within the urban environment would be valuable. In this regard, specialized monitoring and citizen science projects that target urban areas where live plant-trading industries are concentrated would be particularly effective to both promote early detection and to facilitate a rapid response to new species invasions.

LeBoldus, J.M.; Sondreli, K.; Sutton, W.; Reeser, P.W.; Kanaskie, A.; Navarro, S.; and Grünwald, N.J. *In press*. First Report of *Phytophthora ramorum* lineage EU1 Infected Douglas-fir and Grand Fir in Oregon. Plant Disease. https://doi.org/10.1094/PDIS-05-17-0681-PDN.

Abstract: Sudden oak death (SOD) is caused by the introduced oomycete pathogen *Phytophthora ramorum* S. Werres, A. W. A. M. de Cock & W. A. Man in't Veld. This fungus-like organism has four clonal lineages: NA1, NA2, EU1, and EU2 (Grünwald et al. 2016; Prospero et al. 2007). Until recently, the NA1 lineage was the only clonal lineage of *P. ramorum* reported in wildland forests in the western United States. In contrast, EU1, NA1, and NA2 have all been found in U.S. nurseries (Grünwald et al. 2012). In the winter of 2015, a symptomatic *Notholithocarpus densiflorus* Manos, Cannon & S.H.Oh (tanoak) was identified during a SOD helicopter survey in Curry County, OR. *Phytophthora ramorum* was isolated from symptomatic bark tissue. Subsequently, the isolate was determined to be of the EU1 lineage based on 14 microsatellite loci (Grünwald et al. 2016). Continued monitoring of the area in 2016 and 2017 has identified symptomatic *Abies grandis* (Douglas ex D. Don) Lindl. (grand fir; n = 3) and *Pseudotsuga menziesii* (Mirb.) Franco (Douglas-fir; n = 2) saplings growing near infected tanoak trees in the mixed conifer forest of Curry County, OR. Symptoms with shoot blight for these species were similar to those described in the literature, including wilting and dieback of new shoots, brown discoloration of needles, and needle loss on young shoots (Fig. 1). Isolations were made by surface sterilizing and plating tip dieback tissue from *A. grandis* and *P. menziesii* on a selective CARP medium. Based on the presence of chlamydospores, characteristic hyphae, and sporangial morphology, the isolates were identified as *P. ramorum*. DNA was extracted from hyphae and a portion of the cellulose binding elicitor lectin (CBEL) gene was amplified and sequenced using the CBEL5U and CBEL6L primers (Gagnon et al. 2014). The sequences of the unknown lineage were aligned to sequences of CBEL for NA1, NA2, EU1, and EU2 using the Staden package in GAP v4.11.2. The lineage of the isolates from *A. grandis* and *P. menziesii* (GenBank Accession Nos. MF918374 and MF918375, respectively) had 100% identity to the EU1 reference sequences (GenBank Accession Nos. EU688952 and EF117945). In order to satisfy Koch's postulates, three branches of *A. grandis* and *P. menziessii* were inoculated with the original EU1 isolates of *P. ramorum* from those hosts. Ten days after inoculation, the same pathogen was re-isolated from symptomatic stem tissue of both tree species. The EU1 lineage is considered more aggressive than the NA1 lineage and is of opposite mating type to NA1; thus, potentially resulting in establishment of sexual populations.

O'Hanlon, R.; Choiseul, J.; Brennan, J.M.; and Grogan, H. 2017. Assessment of the Eradication Measures Applied to *Phytophthora ramorum* in Irish *Larix kaempferi* Forests. Forest Pathology. DOI: 10.1111/efp.12389.

Abstract: *Phytophthora ramorum* is the causal agent of the sudden larch death epidemic in Ireland and the UK. Within the EU, it is a quarantine pathogen and eradication measures are required if it is detected in horticultural or forest environments. Eradication measures in forests include the clearance of susceptible tree hosts from the infected stand along with all host known to support pathogen sporulation within a 250-m buffer zone of the infected stand. Between 2010 and 2016, these measures have affected over 18,000 ha of *Larix kaempferi* forests in Ireland and the UK, but the epidemic continues to spread. An assessment of the efficacy of the eradication measures has not been published to date. Here, we provide details of the detection frequency of

P. ramorum from aerial (rainwater) and terrestrial (soil, watercourses, plant material) sources in three forest locations in Ireland that had significant areas of *L. kaempferi* affected by *P. ramorum* before their removal. Monitoring of six plots with differing infection and eradication management histories was carried out from September 2013 to 2015. Presence of *P. ramorum* was confirmed by plating plant material onto selective media, followed by morphological identification. *Phytophthora ramorum* was detected in 65 of 1283 samples, in all sample types and in 17 of the 20 months sampled. Only three of the 295 soil samples were positive for *P. ramorum*, with all of these coming from an area under perennial standing water. The most positive samples came from a plot where symptomatic *Larix* trees had not been removed and the findings occurred consistently over the 2-year study. Plots where infected *Larix* had been removed were rarely positive for *P. ramorum* across all the sample types indicating a level of success from the eradication measures in reducing pathogen levels on the sites.

Tubby, K.V.; Willoughby, I.H.; and Forster, J. 2017. The Efficacy of Chemical Thinning Treatments on *Pinus sylvestris* and *Larix kaempferi* and Subsequent Incidence and Potential Impact of *Heterobasidion annosum* Infection in Standing Trees. Forestry: An International Journal of Forest Research. 90(5): 728–736. https://doi.org/10.1093/forestry/cpx038.

Abstract: Chemical thinning can be used where conventional felling and extraction of trees is impractical or uneconomic. An experiment was established to examine the efficacy of a range of thinning treatments and to investigate subsequent *H. annosum* infection on Scots pine and Japanese larch. Ring barking, traditional applications of liquid glyphosate and glyphosate encapsulated as Ecoplug Max® were compared. Ecoplugs were more effective and faster acting on larch compared with conventional glyphosate treatments, killing 100 percent of trees within 17 months, whilst both glyphosate treatments killed 88 percent of pines. Most treatments allowed ingress of *Heterobasidion annosum*, although this did not directly relate to treatment wound size. Persistence of the pathogen within the trees, and the possibility of using prophylactic fungicidal products alongside thinning treatments requires further study. Ultimately, the speed of kill achieved is probably too slow for defoliating trees infected with *Phytophthora ramorum* in Britain, where sanitation felling remains the recommended option. Where thinning treatments are used, the impacts of *H. annosum* infection are unlikely to be significantly greater than those represented by conventional harvesting operations but this possibility requires further study.

Villari, C.; Sniezko, R.A.; Rodriguez-Saona, L.E.; Bonello, P. 2017. Accelerating dynamic genetic conservation efforts: Use of FT-IR spectroscopy for the rapid identification of trees resistant to destructive pathogens. In: Sniezko, Richard A.; Man, Gary; Hipkins, Valerie; Woeste, Keith; Gwaze, David; Kliejunas, John T.; McTeague, Brianna A., tech. cords. 2017. Gene conservation of tree species—banking on the future. Proceedings of a workshop. Gen. Tech. Rep. PNW-GTR-963. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. p. 69.

Abstract: A strong focus on tree germplasm that can resist threats such as non-native insects and pathogens, or a changing climate, is fundamental for successful genetic conservation efforts. However, the unavailability of tools for rapid screening of tree germplasm for resistance to critical pathogens and insect pests is becoming an increasingly serious bottleneck. Here we present the development of a new technique that can potentially revolutionize genetic

conservation efforts. Fourier-transform infrared (FT-IR) spectroscopy is a chemical fingerprinting technique that has been recently shown to be suitable for the rapid identification of oaks resistant to *Phytophthora ramorum* (cause of sudden oak death) prior to infection (Conrad, A.O.; Rodriguez-Saona, L.E; McPherson, B.A.; Wood, D.L.; Bonello, P. 2014. Identification of *Quercus agrifolia* (coast live oak) resistant to the invasive pathogen *P. ramorum* in native stands using Fourier-transform infrared (FT-IR) spectroscopy. Frontiers in Plant Science. 5: 521.). The aim of this study was to determine if FT-IR spectroscopy can be used for the rapid identification of resistant trees in other pathosystems as well, such as Port-Orford-cedar (*Chamaecyparis lawsoniana*)/root disease (caused by *P. lateralis*), and whitebark pine (*Pinus albicaulis*)/white pine blister rust (*Cronartium ribicola*). For both pathosystems, we collected and analyzed plant material that had been previously characterized in terms of resistance/susceptibility to its specific pathogen. Soft independent modeling of class analogy was used to discriminate between resistant and susceptible trees, while partial least squares regression was used to predict mortality rates or severity of symptoms in the progenies. Preliminary results strongly indicate that FT-IR can discriminate between different phenotypes, and predict resistance-associated traits in the progenies of sampled trees in these pathosystems. Our results also suggest that this technique can be expanded to the rapid phenotyping of hosts in many other pathosystems, including tree crops, e.g., cacao, coffee, or eucalypts. This technique could also be developed for rapid identification and separation of morphologically similar tree taxa, further contributing to genetic conservation efforts worldwide.

RELATED RESEARCH

Kane, J.M.; Varner, J.M.; Metz, M.R.; and van Mantgem, P.J. 2017. Characterizing Interactions between Fire and Other Disturbances and Their Impacts on Tree Mortality in Western U.S. Forests. Forest Ecology and Management. 405: 188-199.

Paap, T.; Burgess, T.I.; and Wingfield, M.J. 2017. Urban Trees: Bridge-Heads for Forest Pest Invasions and Sentinels for Early Detection. Biological Invasions. https://doi.org/10.1007/s10530-017-1595-x

CALENDAR OF EVENTS

11/8 – Sudden Oak Death SOD Blitz Fall Workshop; 251 C Hilgard Hall, UC Berkeley Campus, Berkeley; 1:00 – 3:00 p.m.; To register, email Katie Harrell with your name, phone number, and your affiliation (homeowner, professional, other).

11/15 – 11/16 – 66th Annual Meeting of the California Forest Pest Council, "Responding to Large-Scale Tree Mortality in Urban and Rural Communities;" UC Davis Campus Student Community Center Multipurpose Room, Davis; For more information, or to register, go to http://caforestpestcouncil.org/2017/04/save-the-date-cfpc-annual-meeting-nov-15-16-2017/.

11/17 – Sudden Oak Death SOD Blitz Fall Workshop; UC Cooperative Extension Office; 133 Aviation Blvd., Santa Rosa; 7:00 – 9:00 p.m.

2/1 – 2/3/18 – 2018 California Native Plant Society Conservation Conference; Los Angeles Airport Marriott; 5855 West Century Boulevard, Los Angeles; For more information, go to https://conference.cnps.org/.