CALIFORNIA OAK MORTALITY TASK FORCE REPORT
AUGUST 2019

NURSERIES

In mid-July, USDA Animal and Plant Health Inspection Service (APHIS) released an official notice, 'Detection of *Phytophthora ramorum*-Infected Plants in Commerce' confirming that more than 50 rhododendron plants found in Indiana nurseries have tested positive for *P. ramorum*. The infected rhododendron plants were part of a larger shipment that originated from nurseries in Washington State and Canada. APHIS reported they are working with state officials to trace the distribution of plants from these shipments, which were sent to 18 states, including Alabama, Arkansas, Iowa, Illinois, Indiana, Kansas, Kentucky, Michigan, Missouri, Nebraska, North Carolina, Ohio, Oklahoma, Pennsylvania, Tennessee, Texas, Virginia, and West Virginia.

Figure 1. Symptoms of *P. ramorum* infection on rhododendron plants. Photo: Indiana DNR.

APHIS confirmed that *P. ramorum* positive nursery stock has been detected in nurseries in eight states (Iowa, Illinois, Indiana, Kansas, Missouri, Nebraska, Oklahoma, and Washington). Plants that test positive for *P. ramorum* are being destroyed along with all plants that are within a 2 meter radius of an infected plant. Host plants outside the 2 meter radius are being sampled intensively. Several major retailers have agreed to voluntarily recall plants from their stores. APHIS is continuing trace-back and trace-forward investigations in cooperation with state agriculture departments to ensure risk mitigation measures are in place for all positive plants.

Numerous state agriculture departments issued news releases warning about potential or confirmed *P. ramorum* infected nursery plant shipments to their states in spring 2019 and sale of the plants to consumers. Most of the infected plants are rhododendrons, kalmias or lilacs. Further investigations resulted in 28 states receiving notices of shipment of potentially infected plants to their state. These trace-back and trace forward investigations are on-going, an update will be provided in our October issue.

California Department of Agriculture (CDFA) *P. ramorum* program update - Five shipping nurseries positive for *P. ramorum* in 2019 are now under compliance in California. Five California nurseries that had foliar positives for *P. ramorum* in 2019 and that ship *P. ramorum* host material out of the infested area have completed or are undergoing the Confirmed Nursery Protocol per 7 CFR 301.92 the Federal Domestic Quarantine for *Phytophthora ramorum*.

One of the positive nurseries also had a positive soil sample and coordinated with the National Ornamentals Research Site at Dominican University of California (NORS-DUC) to mitigate the pathogen by steaming the positive soil (Figure 2). Soil samples collected after steaming tested negative for *P. ramorum* at the CDFA Plant Pest Diagnostics Center.

Figure 2. Steam treatment to eradicate *P. ramorum* at a nursery in California.
Photo courtesy of CDFA.

Related to the recent "detection of *P. ramorum*-infected plants in commerce" investigations, CDFA received trace-forward information from APHIS for six nurseries in California triggering inspections by county agriculture departments in all six facilities. Samples were taken at one retail nursery in Alameda County, one inter/intrastate shipper in San Joaquin County, and one inter/intrastate shipper with a compliance agreement in Humboldt County. Samples were collected from rhododendron, kalmia and viburnum, lab results are pending. For more information, contact Carolyn Lambert, Carolyn.Lambert@cdfa.ca.gov.

Oregon Department of Agriculture *P. ramorum* program update: Oregon Department of Agriculture (ODA) 2019 compliance inspections began in late March and were completed in May. No *Phytophthora ramorum* was detected at ten of the 11 nurseries surveyed. ODA tested 1,344 foliar samples, two water, and two soil samples during this time. One nursery in Marion County was confirmed positive and has since completed the Confirmed Nursery Protocol and signed a new compliance agreement.

Oregon was one of many states that received material from the nurseries determined to have been the source of the *P. ramorum*-infested material that triggered trace investigations (described above). In mid-June, Oregon was notified that 34 licensed nurseries received material from the Washington nursery mentioned in the USDA APHIS July 10 announcement. Only one of the 34 nurseries is currently in the *P. ramorum* program. Upon notification, ODA assembled an action plan to inspect these nurseries with the assistance of the Portland-based APHIS Plant Protection and Quarantine (PPQ) staff. As of late July, 25 of the identified nurseries have been inspected

and 159 suspect samples submitted for testing. Of those samples, 80 tested by ELISA indicated 14 *Phytophthora* positives. The positives are pending PCR analysis for species identification. Any sample that is found to be *P. ramorum* positive will be classified as a Potential Actionable Suspect Sample (PASS) and sent to the USDA APHIS laboratory for final confirmation. (This applies to all cases, except the one nursery already in the *P. ramorum* program.)

It should be noted that samples were not taken at each of the 34 locations. Inspectors were targeting the genera and varieties identified by USDA APHIS to have been previously confirmed positive by other states. In addition, many locations no longer had the material on their properties since it was shipped out by the Washington nursery in early spring. Many of the listed nurseries were retail nurseries, which move material quickly. For more information, contact Chris Benemann, sbenemann@oda.state.or.us.

Washington State Department of Agriculture (WSDA) *P. ramorum* program update. In late May, WSDA conducted a trace-back investigation at an interstate shipping nursery in Washington. A sample collected from a 3-gallon rhododendron was determined to be positive for *P. ramorum*. The Confirmed Nursery Protocol was enacted and extensive delimitation surveys were conducted in June and July. During the surveys, 852 samples were collected and 15 additional positive plants were discovered. The last delimitation survey, conducted on July 10 was negative for *P. ramorum*. All positive plants have been destroyed by steam treatment and the nursery has voluntarily destroyed many of the nursery blocks where the positives were detected. To date, well over 12,000 plants have been destroyed, the majority voluntarily. Trace-back and trace-forward lists have been provided to the USDA Animal and Plant Health Inspection Service (APHIS). The nursery will eventually be brought into the DA-2014-2 compliance program. Prior to these recent detections of *P. ramorum*, the nursery had tested negative for the pathogen from 2004-2014 as a certified host shipper that was sampled annually.

A rhododendron was also found to be positive at a small retail nursery in Washington as part of the trace-forward investigation from the situation mentioned above. The nursery was put under the Confirmed Nursery Protocol for retailers. Five additional positive plants were detected during the delimitation. The samples are pending confirmation at the USDA APHIS laboratory. For more information, contact Scott Brooks, SBrooks@agr.wa.gov.

RESEARCH

The 2019 American Phytopathogical Society (APS) conference held August 3-7 in Cleveland, Ohio included several *P. ramorum*-related presentations or posters. Abstracts for submissions on epidemiology, genetics and genomics are available here.

Grünwald, N.; Leboldus, J.; Hamelin, R. 2019. (Review in Advance.) Ecology and evolution of the sudden oak death pathogen, *Phytophthora ramorum*. Annual Review of Phytopathology. 57. https://doi.org/10.1146/annurev-phyto-082718-100117.

The sudden oak and sudden larch death pathogen, *Phytophthora ramorum*, emerged simultaneously in the United States on oak and in Europe on Rhododendron in the 1990s. This pathogen has had a devastating impact on larch plantations in the United Kingdom as well as mixed conifer and oak forests in the Western United States. Since the discovery of this pathogen, a large body of research has provided novel insights into the emergence, epidemiology, and

genetics of this pandemic. Genetic and genomic resources developed for *P. ramorum* have been instrumental in improving our understanding of the epidemiology, evolution, and ecology of this disease. The recent reemergence of EU1 in the United States, EU2 in Europe, and the discovery of *P. ramorum* in Asia provide renewed impetus for research on the sudden oak death pathogen.

Hansen, E.; Reeser, P.; Sutton, W.; Kanaskie, A.; Navarro, S. and Goheen, E.M. 2019. Early view. Efficacy of local eradication treatments against the sudden oak death epidemic in Oregon tanoak forests. Forest Pathology. doi.org/10.1111/efp.12530.

Phytophthora ramorum, cause of sudden oak death, has been distributed widely across the United States in horticultural situations, but is not established in forests outside of California and Oregon. Here, it has triggered widespread concern and, especially in Oregon, an intensive disease management program. Now, we provide the first systematic evaluation of the efficacy of that effort.

This paper evaluates four measures of the efficacy of Sudden Oak Death (SOD) local eradication treatments: inoculum availability; inoculum from tree species other than tanoak; disease spread from treated areas; and cumulative infested area with and without treatment. We conclude that local treatments demonstrably reduce local inoculum levels. Eradication of SOD from infested sites is difficult but not impossible. The disease usually does not persist after cutting infected trees but spread on the landscape continues because the pathogen may be present on undetected new infections for a year or two before whole tree symptoms are visible. This limits early detection and coupled with delays in completing eradication treatments, prolongs the chances for long-distance aerial dispersal.

He, Y.; Chen, G.; Potter, C. and Meentemeyer, R.K. 2019. Integrating multi-sensor remote sensing and species distribution modeling to map the spread of emerging forest disease and tree mortality. Remote Sensing of Environment. 231: DOI: 10.1016/j.rse.2019.111238 (June 2019).

Forest ecosystems have been increasingly affected by a variety of disturbances, including emerging infectious diseases (EIDs), causing extensive tree mortality in the Western United States. Especially over the past decade, EID outbreaks occurred more frequently and severely in forest landscapes, which have killed large numbers of trees. While tree mortality is observable from remote sensing, its symptom may be associated with both disease and non-disease disturbances (e.g., wildfire and drought). Species distribution modeling is widely used to understand species spatial preferences for certain habitat conditions, which may constrain uncertain remote sensing approaches due to limited spatial and spectral resolution. In this study, we integrated multi-sensor remote sensing and species distribution modeling to map disease-caused tree mortality in a forested area of 80,000 ha from 2005 to 2016. We selected sudden oak death (caused by pathogen *P. ramorum*) as a case study of a rapidly spreading emerging infectious disease, which has killed millions of oak (*Quercus* spp.) and tanoak (*Lithocarpus densiflorus*) in California over the past decades. To balance the needs for fine-scale monitoring of disease distribution patterns and satisfactory coverage at broad scales, our method applied spectral unmixing to extract sub-pixel disease presence using yearly Landsat time series. The results were improved by employing the probability of disease infection generated from a species distribution model. We calibrated and validated the method with image samples from high-spatial resolution NAIP (National Agriculture Imagery Program), and hyperspectral AVIRIS (Airborne Visible/Infrared Imaging Spectrometer) sensors, Google Earth® imagery, and field

observations. The findings reveal an annual sudden oak death infection rate of 7% from 2005 to 2016, with overall mapping accuracies ranging from 76% to 83%. The integration of multi-sensor remote sensing and species distribution modeling considerably reduced the overestimation of disease effects as compared to the use of remote sensing alone, leading to an average of 26% decrease in detecting disease-affected trees. Such integration strategy proved the effectiveness of mapping long-term, disease-caused tree mortality in forest landscapes that have experienced multiple disturbances.

Keriö, S.; Daniels, H.A.; Gomez-Gollego, M.; Tabima, J.F.; Lenz, R.R.; Søndreli, K.L.; Grünwald, N.J.; Williams, N.; Mcdougal, R. and Leboldus, J.M. 2019. From genomes to forest management – tackling invasive *Phytophthora* species in the era of genomics, Canadian Journal of Plant Pathology. DOI: 10.1080/07060661.2019.1626910

Species of *Phytophthora* pose one of the most serious biosecurity threats to forest ecosystems worldwide. Despite management efforts and increased awareness of forest pathogens, there is continued introduction and spread of *Phytophthora* species. Uncertainty about the center of origin for many of the invasive species hampers disease control efforts. Additionally, the management efforts are often made impossible either by the vast host range or the extreme susceptibility of naïve hosts. In this review, we discuss how genomics has shed light on the extent of spread and destruction caused by invasive *Phytophthora* species, and how approaches leveraged by genomics can be applied to enhance the management of these invasive forest pathogens. Four case studies, *Phytophthora ramorum, Phytophthora lateralis, Phytophthora cinnamomi*, and *Phytophthora pluvialis* are used to illustrate how genomics can be applied to forest management. We urge researchers, governmental research institutes, private companies, and citizens to collaborate in order to stop the spread of invasive *Phytophthora* species. To accomplish this, we see the following themes as critical parts of resolving the forest health crisis: i) integration of DNA-based pathogen detection into forest inventory programs; ii) development of practical and affordable DNA-based diagnostic methods; iii) re-sequence hosts as models for resistance gene identification; iv) prediction of pathogen impact based on genomic data; and v) increase collaborative projects and outreach to raise awareness of forest diseases.

Migliorini, D.; Ghelardini, L.; Luchi, N. and others. Temporal patterns of airborne *Phytophthora* spp. in a woody plant nursery area detected using real-time PCR. 2019. Aerobiologia. 35: 201. https://doi.org/10.1007/s10453-018-09551-1.

In this study, spore trap monitoring was applied to provide a proof of concept for the use of qPCR to detect *Phytophthora* in aerial samples and provide valuable information for epidemiological studies in nurseries. Two qPCR TaqMan assays were developed to detect pathogen DNA: the first used a generic probe to detect *Phytophthora* spp., and the second was based on a specific probe for detecting *P. ramorum* and *P. lateralis*. All samples tested positive for the genus *Phytophthora*, although *P. ramorum* and *P. lateralis* were not detected. In late spring and in autumn, two main peaks of *Phytophthora* sporulation were observed. Peaks were preceded by rainfall, high relative humidity, and mild temperature. From mid-May to the end of August, *Phytophthora* DNA detected in the air increased with relative humidity, while it decreased with increasing mean temperature. There was also a positive correlation between *Phytophthora* DNA detected and rainfall in the same period. No significant correlations between *Phytophthora* DNA and temperature or rainfall were found from the end of August to December.

Our results are in agreement with those obtained with classical diagnostic methods based on microscopy, but the approach used here enabled rapid detection and relative quantification of the target organisms, thus assisting in the implementation of disease management strategies.

Sondreli, K.L.; Kanaskie, A.; Kerio, S. and LeBoldus, J.M. 2019 (First Look). Variation in susceptibility of tanoak to the NA1 and EU1 lineages of *Phytophthora ramorum*, the cause of sudden oak death. Plant Disease. https://doi.org/10.1094/PDIS-04-19-0831-RE

Phytophthora ramorum, the cause of Sudden Oak Death (SOD), kills tanoak (*Notholithocarpus densiflorus*) trees in southwestern Oregon and California. Two lineages of *P. ramorum* are now found in wildland forests of Oregon (NA1 and EU1). In addition to the management of SOD in forest ecosystems, disease resistance could be used as a way to mitigate the impact of *P. ramorum*. The objectives of this study were to: (i) characterize the variability in resistance of *N. densiflorus* among families using lesion length; (ii) determine whether lineage, isolate, family, or their interactions significantly affect variation in lesion length; and (iii) determine if there are differences among isolates and among families in terms of lesion length. The parameters isolate nested within lineage [isolate (lineage)] and family by isolate (lineage) explained the majority of the variation in lesion length. There was no significant difference between the NA1 and EU1 lineages in terms of mean lesion length; however, there were differences among the six isolates. Lesions on seedlings collected from surviving trees at infested sites were smaller on average than lesions of seedlings collected from trees at non-infested sites (P = 0.0064). The results indicate that there is potential to establish a breeding program for tanoak resistance to SOD and that several isolates of *P. ramorum* should be used in an artificial inoculation assay.

RELATED RESEARCH

Redekar, N.R.; Eberhart, J.L. and Parke, J.L. 2019. Diversity of *Phytophthora*, *Pythium*, and *Phytopythium* species in recycled irrigation water in a container nursery. Phytobiomes. 3(1). e-ISSN: 2471-2906. doi.org/10.1094/PBIOMES-10-18-0043-R.

Riddell, C.E.; Frederickson-Matika, D.; Armstrong, A.C.; Elliot, M. and others. 2019. Metabarcoding reveals a high diversity of woody host-associated *Phytophthora* spp. in soils at public gardens and amenity woodlands in Britain. PeerJ. 7: e6931.

RESOURCES

Testing the waters by Jennifer Parke, Oregon State University and **How to test your irrigation system for the presence of *Phythophthora*** by Neelam R. Redekar and Jennifer L. Parke have been added to the Growing Knowledge series in Digger magazine, published by the Oregon Association of Nurseries and Oregon State University (June 2019, pg. 33-37). The article displays baiting techniques and discusses water disinfestation.

MEETINGS

Presentations from the Seventh Sudden Oak Death Science and Management Symposium, "Healthy Plants in a World with *Phytophthora*" (SOD7) held June 25- 27, 2019 in the Presidio, San Francisco have been posted at https://www.youtube.com/playlist?list=PLyHJjt9y0tE3btI2YtQAjWxbyI0beZTkI. Special thanks for the video recording to Stephen Rosenthal, California Native Plant Society. Some of the

SOD7 posters may now be viewed, along with abstracts, in the list of poster abstracts. Thanks again to the approximately 200 people that participated in the indoor sessions, Presidio Nursery tour and field trip to Mt. Tamalpais. A field trip group photo has been posted at the conference website, https://ucanr.edu/sites/sod7/; the proceedings are in production.

On July 18, 2019, southern Humboldt County community members, the Telegraph Ridge Volunteer Fire Department, and the Mattole Restoration Council organized an educational event that brought together 45 people in the upper portion of the Mattole Watershed to discuss the western expansion of sudden oak death in southern Humboldt County and recent tanoak mortality in their communities. The event included a presentation by Yana Valachovic of UC Cooperative Extension who provided information about the disease, expected impacts, tanoak fuels management, and the opportunity for community members to work together to address some of the tanoak mortality issues. The Mattole Restoration Council and the Natural Resource Conservation Service expressed their interest in helping organized community members address fuels issues and other forest health challenges.

CALENDAR OF EVENTS

November 13 -14, 2019. California Forest Pest Council 2019 Annual Meeting, UC Davis.
Save the date. Further information will be available shortly.