# CALIFORNIA OAK MORTALITY TASK FORCE REPORT
# AUGUST 2026

## THE STATE OF *PHYTOPHTHORA RAMORUM* RESEARCH

***Editor's note:*** *Over the coming year we hope to provide information about the state of research programs that have historically been active in investigating P. ramorum. This first in the series addresses the current status of the research program at the National Ornamentals Research Site at Dominican University (NORS-DUC).*

**Several new foliar host plants of *P. ramorum* were detected recently at NORS-DUC (the National Ornamentals Research Site at Dominican University).** Carob (*Ceratonia siliqua;* Fabaceae) is a woody plant native to the Palearctic and widely planted as an ornamental worldwide. Black necrotic lesions were detected along the leaf margins of mature carob trees in Marin County. *P. ramorum* was isolated from the symptomatic leaves, identified morphologically and using DNA sequencing of the internal transcribed spacer (ITS) and the beta tubulin gene. Inoculation of detached leaves and whole plants with *P. ramorum* resulted in development of foliar symptoms, and the pathogen was re-isolated from the plants, fulfilling Koch's postulates (Pham et al 2026). *P. ramorum* was also isolated from symptomatic oleander leaves (*Nerium oleander;* Apocynaceae) in Marin County and used for successful inoculation experiments, confirming that this very popular ornamental plant is a host (Pham et al., 2026 b). Previously, *P. ramorum* was detected on *N. oleander* in Ireland, but no inoculation studies were reported (O'Hanlon et al. 2016). Another new foliar host of *P. ramorum* is silverleaf cotoneaster (*C. pannosus*; Rosaceae), native to south-central China (Pastalka et al. 2024). Cotoneaster is naturalized in forests of the California Coast Range and could play a role in the spread of *P. ramorum* to native plants.

*P. elongata* was recently detected for the first time on rhododendron in California. *P. elongata* was first identified in Western Australia causing severe root and collar rot of *Eucalyptus marginata* (Rea et al. 2010). The pathogen has been isolated from rhododendron during a nursery survey in Maryland between 2010 and 2012; that study, however, did not perform inoculation experiments to confirm disease infection (Bienapfl and Balci 2013). The NORS-DUC team conducted inoculation experiments and fulfilled Koch's postulates for the *P. elongata*-rhododendron pathosystem (Pham et al 2026 c).

NORS-DUC also collaborates with Prof. Johanna Del Castillo Munera and Dr. Saskia Desiree Mesquida Pesci from UC Davis on an USDA APHIS funded project: "Development of rapid and sensitive diagnostic assays to detect Phytophthora spp. in nursery irrigation and surface water." The purpose of this project is to develop and validate the Recombinase Polymerase Amplification (RPA) Phytophthora genus and *P. ramorum* -specific diagnostic assays in water samples. Previously, Del Castillo Lab validated the RPA assay to detect Phytophthora from plant tissue. In this current project, specifically, the UC Davis team aims to 1) Determine the limit of detection, from water samples, of the Phytophthora genus-level RPA assay for several Phytophthora species recurrent in nursery production, 2) Test the efficacy of the Phytophthora genus and *P. ramorum* -specific RPA detection assays in a simulated nursery water system at

NORS-DUC and compare it with traditional baiting methods, and 3) evaluate the RPA detection assays to detect Phytophthora from leachate water of infected plant material. By developing and validating a rapid and robust diagnostics tool that can detect Phytophthora pathogens from water, a greater number of plant samples can be tested simultaneously, via run-off or leachate water, and results can be delivered on the same day of testing. These diagnostics tools will benefit nursery growers, regulatory agencies, diagnostics laboratories, and extension personnel by determining in a timely manner if nursery plant stock is infected with Phytophthora pathogens.

These experiments have been conducted against a background of constantly and rapidly shifting funding support. NORS-DUC began receiving funding from the federal government in 2009 and has depended on it since, as the host facility, Dominican University, can provide space but not a permanent operating budget. Within the past few years, it has become increasingly difficult for NORS-DUC to secure the needed financial support for its ongoing research projects and maintenance of the research infrastructure. In the future, it is likely that additional funding sources will have to be sought to support the research program at NORS-DUC, which features specific strengths not available at many other research institutions, including a collaborative environment with advanced facilities and research space not available anywhere else. Although NORS-DUC has developed an in-demand fee-for-service soil steaming program aimed at remediating *Phytophthora* infestations in soils, this service alone is not sufficient to support the personnel and maintenance needs that make this outstanding collaborative research program possible. For the foreseeable future, NORS-DUC will continue to diversify beyond *P. ramorum* research to include research into other plant pathogens that impact ornamentals, urban plantings, and nursery stock. For more information, contact Wolfgang Schweigkofler, NORS-DUC Lead Scientist, at wolfgang.schweigkofler@dominican.edu.

## RESOURCES

**Oak mortality issues connected on the COMTF website.** We have updated the COMTF home page to help direct people to other issues causing oak mortality. While our focus remains *Phytophthora ramorum*, we are acknowledging the "oak mortality" of our Task Force's name and providing references to those who may be looking for a fuller resource. We have included links to Goldspotted Oak Borer, Mediterranean Oak Borer, *Phytophthora* root rot, and human disturbance, as well as the California Oak Disease and Arthropod Database.

**New *Phytophthora* sanitation handouts posted.** For other *Phytophthoras* spread primarily through soil movement, two new resources have been added to assist in training and sanitation protocols for land managers, staff, and volunteers who are actively working in the field. See the CalPhytos.org site for details and links.

## NURSERIES AND MANAGED LANDSCAPES

**California Department of Agriculture *P. ramorum* Nursery Program report.** Eight California nurseries that were previously positive for *Phytophthora ramorum* (*P. ramorum*) underwent enhanced inspections in March, April, May, and June. Six of the enhanced inspection nurseries were found positive for *P. ramorum*. An additional nursery was found to be positive through a trace back inspection from a California nursery. Trace forward inspections from

positive nurseries found a positive plant at a residence in an infested county. Positive nurseries follow protocols in the USDA's *Phytophthora ramorum* Domestic Regulatory Program Manual.

Plants confirmed positive for *P. ramorum* in 2026: *Arctostaphylos* sp. 'Emerald Carpet'; *Camellia* sp. varieties 'Debutante', 'Blood of China', 'Bob Hope', 'Cleopatra', 'Hana Jiman', 'Kramer's Supreme', 'Nuccio's Gem', 'Pearl Maxwell', 'Setsugekka', 'Silver Waves', 'Spellbound', 'Swan Lake', and 'White Doves'; *Loropetalum chinense* var. Rubrum and Green; *Pieris* sp., *Pieris japonica* 'Bisbee Dwarf'; *Michelia* x *foggii*, *Michelia* sp. 'Warm Fuzzies'; *Rhododendron fragrantissimum* 'Coastal Spice'; and *Rhododendron* spp. 'Alice Eastwood', 'Golfer', 'Holden', 'True Blue', and 'Vibrant Violet'. For more information, please contact Carolyn Lambert at carolyn.lambert@cdfa.ca.gov.

**Oregon Department of Agriculture *P. ramorum* Nursery Program report.** As of April 2026, sixteen Oregon nurseries are participating in the *Phytophthora ramorum* Nursery Program. Eight nurseries are interstate shippers under federal compliance agreements. They are in Washington (4), Clackamas (2), Lane (1), and Polk (1) counties. Eight nurseries are intrastate shippers operating under state compliance agreements in Washington (1), Clackamas (2), Clatsop (1), Coos (2), Curry (1), and Lane (1) counties.

One interstate nursery was added to the program in February 2026 due to a traceback detection and is still under Potentially Actionable Suspect Sample (PASS) delimitation. The remaining seven interstate nurseries have completed their spring compliance surveys. To date, four nurseries tested positive for *Phytophthora ramorum* during their spring survey (Polk, Clackamas, Washington and Lane counties). Of these, one nursery was negative for their first delimitation, one nursery was positive for first delimitation and undergoing a second delimitation, and one nursery is awaiting results for their first delimitation.

One intrastate nursery was added to the program in summer of 2025 and is still under the PASS delimitation process. Additionally, four intrastate nurseries identified through trace-forward detections in February and March of 2026 completed their PASS surveys and delimitations and are eligible for fall compliance survey. The remaining three intrastate nurseries have completed their spring compliance surveys. Two of the nurseries tested positive (Clackamas and Curry counties). Of these, one nursery was negative for their first delimitation, and one nursery was positive for the first delimitation and negative for the second. One interstate nursery and one intrastate nursery are eligible to be released after two more negative surveys, and one interstate nursery is eligible after four more negative surveys.

As of July 2026, thirteen Oregon nurseries have had positive *P. ramorum* detections in 2026. Six interstate wholesale nurseries and seven intrastate retail nurseries were found to have positive plants. Eight nurseries had previous *P. ramorum* detections, while five nurseries were confirmed positive for the first time in 2026. Delimitation surveys were conducted at each nursery until negative survey results were achieved or the nursery elected to destroy the entire affected block. All positive nurseries have completed plant destruction, and many are proceeding with substrate solarization. Trace-forward and trace-back inspections were completed and did not result in any additional detections. Plants confirmed positive for *P. ramorum* in 2026 include *Rhododendron* spp., *Pieris* spp., *Camellia* spp., *Kalmia* spp., *Viburnum* spp., *Magnolia grandiflora*, *Arbutus*

*unedo*, *Polystichum munitum*, *Myrica californica*, and *Ilex* × *meserveae*. For additional information, contact Emily Perkins at emily.perkins@oda.oregon.gov.

**Washington State Department of Agriculture (WSDA) *P. ramorum* report.** WSDA received notice of multiple trace forwards in April and May 2026. One location yielded 2 positive rhododendron samples. Confirmed retail protocols were followed, and the location is waiting for steam treatment of soil.

Washington State University staff sampled a suspect rhododendron in a new roadside landscape (5 months in ground) at a municipal park with abundant native vegetation and old growth. The sample tested positive at WSU and was confirmed positive by WSDA and USDA. The cultivar of *Rhododendron* is unknown at this time; it could be *Rhododendron* 'Capistrano', *Rhododendron* 'Holden,' or *Rhododendron* 'Crete.' WSDA is in the process of responding with positive landscape protocols in conjunction with the USDA. A trace-back investigation has already been conducted and invoices shared with USDA.

For more information contact Haley Palec (hpalec@agr.wa.gov) the WSDA Plant Services Program Supervisor for Western Washington based in Tacoma.

## RESEARCH

**Chase S.M., Søndreli, K.L., Grünwald, N.J., LeBoldus, J.M. 2026.** Recurrent invasion of Oregon's coastal forests by the sudden oak death pathogen: the NA2 lineage's first escape into the wild. Phytopathology. 2026 Jul 23. doi: 10.1094/PHYTO-04-26-0106-R.

**Abstract:** *Phytophthora ramorum*, the sudden oak death (SOD) pathogen, has invaded U.S. nurseries and western forests repeatedly. Invasions by three distinct clonal lineages (NA1, NA2, and EU1) have affected U.S. wildland forests since 2001. Most recently, NA2 established an invasive population in coastal forests surrounding Port Orford in southwest Oregon. This is the first instance of NA2 encountered outside of a nursery. We assessed this new invasion's diversity and population structure using single-nucleotide polymorphisms from whole genome sequences of 195 isolates. Genomes were sampled from the nursery trade and from the forest invasion surrounding Port Orford. The NA2 forest invasion lacks genetic diversity and likely originated from a single introduction. A subset of NA2 isolates (10.8%) were genetically distant from all other isolates including each other. This distance was correlated with frequency of genomic runs of homozygosity. No evidence of hybridization was found, though NA2 and EU1 mating types are compatible and their ranges in wild forests overlap. Aggressiveness and sporulation of NA2 isolates were measured on three host tree species and compared with isolates of other lineages. NA2 and EU1 phenotypes were similar. NA2 caused larger lesions on Douglas-fir and tanoak seedlings than NA1, the lineage of the original introduction into Oregon forests. Results indicate that the NA2 population is not distinct from the older EU1 Oregon population in terms of population diversity, disease aggressiveness, or potential for spread. However, the introduction of NA2 has increased the SOD epidemic's range, risk of hybridization, overall genetic diversity, and adaptive potential.

**Fiaschetti, M., Benigno, A., Ginetti, B., Papini, V., & Moricca, S. 2026.** Susceptibility of leaves from commercially important ornamental shrubs to artificial inoculation with *Phytophthora ramorum*. *Life*, *16*(6), 996. https://doi.org/10.3390/life16060996.

**Abstract:** The quarantine pathogen *Phytophthora ramorum* has a high potential for dispersal due to its airborne inoculum, its wide range of hosts, and its ability to spread through the trade of nursery plants. For these reasons, it represents a serious threat to ornamental nursery production and, consequently, to urban, natural and semi-natural ecosystems. This oomycete pathogen (EU1 lineage, A1 mating type) has been detected on *Viburnum tinus* in a commercial nursery located in the Pistoia nursery district (PND) (Tuscany, central Italy), one of the main nursery areas for the production of ornamentals in Europe. Artificial inoculations were carried out in the laboratory under controlled conditions, following a standard detached-leaf assay protocol, on leaves of 16 ornamental shrub species commonly marketed by the PND. Disease severity was assessed, and susceptibility categories (high, moderate, low, and non-susceptible) were defined based on data collected at 7 and 14 days post-inoculation and validated through statistical analysis. Inoculated species exhibited variable levels of disease severity. The results confirmed the pathogen's high virulence on *Viburnum tinus* and *Rhododendron* hybrid 'Madame Masson'. The following species were also found to be highly susceptible: *Ilex aquifolium*, *Loropetalum chinense*, *Magnolia stellata*, *Osmanthus fragrans*, and *Trachelospermum jasminoides*. *Camellia japonica*, *Nerium oleander*, *Osmanthus heterophyllus*, *Prunus laurocerasus*, and *Rhododendron obtusum* showed moderate susceptibility. *Arbutus unedo*, *Laurus nobilis*, *Photinia fraseri* and *Syringa vulgaris* exhibited low susceptibility. At the end of the trial, no infected species fell into the non-susceptible categories. The oomycete proved particularly aggressive on *Ilex aquifolium*, the most susceptible host among those tested. This high susceptibility is a new finding that could have significant epidemiological implications. Our findings emphasize the need for rigorous phytosanitary surveillance in nursery systems, based on constant monitoring and the adoption of high-throughput diagnostic protocols, in order to implement effective and rapid control measures.

**Kurth, E.G., Sudermann, M.A., Daniels, H.A., Grunwald, N.J., Chang, J.H., and LeBoldus, J.M. 2026.** Impacts of Sudden Oak Death treatment and wildfire on the soil microbial communities of douglas-fir/tanoak forests. PhytoFrontiers; First Look 4 Aug 2026 https://doi.org/10.1094/PHYTOFR-04-26-0052-R.

**Abstract:** Biotic and abiotic forest disturbances can significantly alter soil microbial communities. *Phytophthora ramorum*, the causal agent of Sudden Oak Death (SOD), is a plant pathogen invading western United States forests that has been subject to eradication efforts in Oregon since 2001. In this study, a metabarcoding approach targeting bacteria (16S), fungi (ITS), and oomycete (*rps10*) markers were used to characterize soil microbial communities in *P. ramorum*-infested sites that underwent treatment and those that did not. SOD management was associated with an initial increase in bacterial alpha diversity and significant shifts in bacterial and fungal beta diversity. Oomycete communities showed no significant changes in richness or composition in response to SOD management. Across a 1-12 year chronosequence, bacterial communities exhibited early signs of recovery in diversity and composition by 10-12 years post SOD treatment, while fungal communities did not show evidence of recovery. Oomycete communities fluctuated in diversity and composition throughout the chronosequence without a

clear recovery trend. Conversely, subsequent wildfire disturbances, specifically the 2017 Chetco Bar Fire, had more pronounced effects on soil microbial communities. Wildfire-burned sites exhibited a slight reduction in richness for bacteria and distinct shifts in community composition for both bacteria and fungi. Oomycete communities declined in both richness and community composition only following wildfire. These findings highlight the differential impacts of invasive disease management and wildfire on soil microbial dynamics and underscore the importance of long-term monitoring to understand ecosystem recovery.

**Pham, D.H. 2026.** Host Range and Characterization of Phytophthora Species That Cause Plant Diseases in California. Biological Sciences Master's Theses, Natural Sciences and Mathematics. 76 pp. DOI: https://doi.org/10.33015/dominican.edu/2026.BIO.03.

**Pham, D.H., Pastalka, T., Liu, H., Schweigkofler, W. 2026.** First report of *Phytophthora ramorum* causing leaf blight on *Ceratonia siliqua* in the United States. Plant Disease. 22 July 2026 First Look. https://doi.org/10.1094/PDIS-04-26-0830-PDN.

**Abstract:** *Ceratonia siliqua* (Fabaceae; carob) is a woody plant native to the Palearctic and widely planted as an ornamental worldwide. In February 2024, large, irregularly shaped black necrotic lesions were detected along the leaf margins of a mature carob tree in Larkspur, Marin Co., CA (37.94779 ºN, 122.54812 ºW). Symptomatic leaves tested positive using a genus-specific lateral flow assay (LFA) for *Phytophthora* (Agdia Inc, Elkhart, IN, USA). Tissue segments were surface sterilized using 70% Ethanol, plated on selective PARPH media (Jeffers et al. 1986) and incubated at 20ºC. A single culture (NORS075) was isolated from the leaves, which produced morphological structures typical of *P. ramorum*, including coralloid mycelium with distinct hyphal swellings, chlamydospores, and semi-papillate sporangia (Werres, S., et al. 2001). The isolate was identified by sequencing the internal transcribed spacer (ITS) and beta tubulin regions using the primers ITS1/ITS4 (White et al. 1990; GenBank Accession No. PX564765.1) and TUBUF2/TUBUR1 (Kroon et al. 2004; GenBank Accession No. PX614639), respectively. A BLAST search revealed 99.50% identity for ITS (796/800 bp) and 99.77% for the beta tubulin (878/880 bp) with *P. ramorum* ex-type strain CBS 101553 (accession no. NR_147877.1 and LC595884.1, respectively). Detached leaves of *C. siliqua* were inoculated with strain NORS075 using two methods: i) mycelial plugs and ii) zoospore solution (1.13 x 105 zoospores/ml). Ten unwounded and ten wounded leaves were inoculated for each inoculation method. All four treatments resulted in necrotic leaf spots, and *P. ramorum* was successfully re-isolated. Sporulation was observed on the inoculated leaves. Pathogenicity tests were also performed on whole plants (N = 20; 12cm tall and 8cm wide) of *C. siliqua* using two methods: i) a zoospore solution (1.9 × 105 zoospores/mL) was sprayed on ten plants until runoff; ii) leaf tips of ten other plants were immersed in 0.75 mL of the zoospore solution in a 1.5 mL microcentrifuge tube attached to the leaves. For both experiments, five leaves per plant were wounded, while the remaining leaves were left unwounded. Control plants were treated as described above but with water. Leaves inoculated by any of the four different treatments developed symptoms 5 dpi consisting of small black necrotic spots and lesions around the inoculated area. Symptomatic leaves tested positive using the same *Phytophthora* LFA, and *P. ramorum* was re-isolated from them. The identity of the isolates was confirmed morphologically and by sequencing the ITS region. No symptoms were detected on the control plants. To our knowledge, this is the first report of *P. ramorum* occurring on *C. siliqua* globally and the first

confirmation of Koch's postulates for this host-pathogen combination. Previously *P. ramorum* has been isolated from other members of the Fabaceae, such as *Pickeringia montana* and *Cercis chinensis* (APHIS 2022). Later in 2024, symptoms associated with the presence of *P. ramorum* were detected on approximately 90% of all ornamental carob trees in Larkspur and the neighboring town of Mill Valley, but not in other areas within Marin Co. During 2025, symptoms were detected in the same areas, but at much lower rates. The exceptionally rainy winter of 2023–2024 in the area likely contributed to high inoculum pressure and favorable infection conditions not typically found in the open, drier areas characteristic of carob habitats. Nurseries growing carob trees should survey them regularly to avoid spreading the disease to new areas.

## RELATED RESEARCH

**Asiegbu, F.O., Meng, W., Ren, W., Yang, G., Azeez, A., Li, Y. , Gao, Z., Wen, Z., Wang, K., and Chano, V., 2026.** Forest tree–pathogen interactions under climate change. *Essays Biochem* 2026. doi: https://doi.org/10.1042/EBC20250054.

**Abstract:** Forest trees are ecologically and economically vital, contributing to carbon sequestration, biodiversity conservation, pollution mitigation, and renewable bioenergy. However, forests worldwide are increasingly threatened by interacting biotic and abiotic stressors, including pathogens, insect pests, drought, heat, and extreme weather events driven by climate change. Drought and heat stress trigger complex physiological and metabolic responses in trees that can reshape their resistance to pathogens. While moderate stress may activate protective mechanisms, severe stress can cause cellular damage, dehydration, and reactive oxygen species accumulation, weakening defense capacity. Emerging evidence highlights additional layers of regulation, including epigenetic mechanisms and the role of beneficial microbiomes in enhancing tree resilience under combined environmental and pathogen pressures. Breeding and genetic improvement are also essential for strengthening adaptation and resistance to emerging diseases. Although advances in forest genetics, long-term field studies, and tree genomics are improving our predictive capacity, major knowledge gaps remain. Addressing how forest trees respond to pathogens under climate change will require multidisciplinary approaches integrating molecular biology, multiomics, big data analytics, remote sensing, ecology, and climate modelling.

**Bregant, C., Carloni, F., Montecchio, L., Murolo, S., Bourret, T.B., and Linaldeddu, B.T. 2026.** *Neofusicoccum* and *Phytophthora* species: an emerging threat to fig trees (*Ficus carica*) in Italy, with the description of *Phytophthora messapica* sp. nov. *Plant Pathology* 75, no. 3: e70216. https://doi.org/10.1111/ppa.70216.

**Abstract:** Monitoring surveys, conducted in four Italian regions (Apulia, Marche, Sardinia and Veneto), revealed the widespread occurrence of young and mature fig trees (*Ficus carica*) showing sudden death, crown thinning, shoot blight, branch dieback, cankers and root rot symptoms. Given the widespread distribution and severity of these symptoms, a study was conducted to identify the main causal agents. To achieve this goal, 86 samples including fine roots with rhizosphere (11) and branches with bleeding and sunken cankers (75) were collected from 11 symptomatic fig trees. Isolations performed on universal and selective growth medium yielded colonies belonging to three families: *Botryosphaeriaceae*, *Diaporthaceae* (Ascomycetes)

and *Peronosporaceae* (Oomycetes). Based on morphobiometric data and DNA nucleotide sequences, seven species, namely *Botryosphaeria dothidea* (14 isolates), *Diaporthe cinerascens* (10), *Neofusicoccum australe* (9), *Neofusicoccum mediterraneum* (10), *Neofusicoccum parvum* (28), *Phytophthora citricola* (3) and *Phytophthora plurivora* (6) were identified. In addition, two isolates of a new putative *Phytophthora* species obtained from the rhizosphere including symptomatic fine roots of fig trees in Apulia region are described here as *Phytophthora messapica* sp. nov. For *Phytophthora* species, *N. australe* and *N. mediterraneaum* (reported here for the first time on fig trees worldwide), Koch's postulates were satisfied by inoculating 5-year-old fig trees under controlled conditions. Sixty days after inoculation, all inoculated plants showed the same symptoms as those observed in the field. Overall, the data obtained highlights the involvement of multiple *Botryosphaeriaceae* and *Phytophthora* species in the aetiology of the emerging diseases affecting fig trees in Italy.

**Forkuo, G.O. and Borz, S.A. 2026.** Emerging and re-emerging threats to global forest health: A systematic review of fungal, oomycete, nematode, and viral pathogens in the context of climate change and biosecurity. *Current Forestry Reports* **12** (24). https://doi.org/10.1007/s40725-026-00285-9.

**Abstract:** *Purpose of Review:* Forest ecosystems are increasingly threatened by a dynamic array of fungal, oomycete, nematode, and viral pathogens. Accelerating climate change, globalized trade, and the expansion of intensively managed plantations are simultaneously broadening pathogen ranges and exposing naïve host populations, yet a comprehensive cross-kingdom synthesis of these threats has been lacking. This systematic review synthesizes the state of knowledge on forest pathogen biology, epidemiology, diagnostics, and management for the 2018–2026 period, identifying research and policy priorities to safeguard global forest health.

*Recent Findings:* A systematic review conforming to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, synthesizing 142 peer-reviewed articles and assessing for methodological quality using the Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I) tool, reveals that while fungal pathogens ($n = 80$; ~56.3%) continue to dominate the research corpus, oomycetes ($n = 27$; ~19.0%) and nematodes ($n = 31$; ~21.8%) are also well-represented, reflecting their rising ecological and economic significance. Research is geographically biased toward Europe and East Asia, leaving tropical plantation pathosystems under-represented. Climate change is identified as a pervasive modifier of pathogen pressure, with drought-induced stress and temperature-driven range expansions documented across all four kingdoms. Concurrently, molecular diagnostics — specifically environmental DNA (eDNA) surveillance, Loop-Mediated Isothermal Amplification (LAMP) assays, and high-throughput sequencing (HTS) metagenomics — have transformed the field, enabling a transition from reactive symptom-based detection to prospective, landscape-scale early warning systems. We introduce the Pathogen Pressure Index (PPI) as a newly proposed conceptual framework to integrate driver-pathogen-outcome relationships for research prioritization.

*Summary:* This synthesis reveals that while diagnostic capabilities have undergone a step-change, an evidence-to-practice translation gap persists in integrated forest management. The ROBINS-I assessment confirmed broadly satisfactory methodological quality across the corpus,

with molecular pathogen identification consistently rated low risk; the principal outstanding weakness — serious confounding in plantation and climate-change studies — reflects structural constraints of field-based research and flags where experimental designs require strengthening. Priority areas for the next decade include addressing the near-absence of viral pathology research, fostering cross-kingdom comparative epidemiology, and increasing investment in tropical forest surveillance. By leveraging the Pathogen Pressure Index (PPI) framework, future management can better integrate molecular diagnostics, biological control, and climate-smart silviculture to mitigate the compounding risks of global environmental change.