CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

California Pest Rating Proposal for

Bursaphelenchus xylophilus (Steiner & Buhrer, 1934) Nickle, 1970

Pine wilt disease
Pinewood nematode

Current Pest Rating: C

Proposed Pest Rating: C

Domain: Eukaryota, Kingdom: Metazoa
Phylum: Nematoda, Family: Parasitaphelenchidae

Comment Period: 09/03/2021 through 10/18/2021

Initiating Event:

This nematode has not been through the pest rating process. The risk to California from *Bursaphelenchus xylophilus* is described herein and a permanent pest rating is proposed.

History & Status:

Background:

Bursaphelenchus spp. are part of the nematode family Aphelenchoididae and approx. 70 species have been described for the genus. Most nematodes within this clade, including most of the *Bursaphelenchus* species, are fungal feeders. They are usually found in dead or dying trees, feeding on fungi colonizing the wood. The pinewood nematode, *Bursaphelenchus xylophilus*, is exceptional in that it can be a primary pathogen of trees and is the causal agent of pine wilt disease. It is thought to be native to North America and was described in 1934 from Louisiana, as *Aphelenchoides xylophilus* (Steiner and Buhrer, 1934). These nematodes are vectored by cerambycid longhorn beetles, also known as sawyers, in the genus *Monochamus*. The nematodes are transmitted to young adult beetles shortly after they emerge from their pupal chambers. The beetles fly to feed on young pine shoots and the nematodes enter the shoots through their feeding wounds.

Conifers that are native to North America are mostly resistant or tolerant to *B. xylophilus*, and it causes little damage here, other than on exotic species (Mamiya, 1983). (Kiyohara and Tokushige, 1971). The

vector, the nematode, or both may be found in pine chips, unseasoned lumber, and logs. Consequently, it is easily transported in wood products, such as logs, lumber, pallets, crates, wood chips, and furniture. Unfortunately, *B. xylophilus* was introduced into Japan in 1905, and then in 1971 was confirmed as the cause of pine wilt disease there. Today it has spread to other countries in Asia including China, Korea, and Taiwan, and causes disease on important forestry tree species, including pine, spruce, fir, and larch (CABI-CPC, 2021). Many native tree species in Japan, such as *Pinus thunbergii* (Japanese black pine) and *P. densiflora* (Japanese red pine), are highly susceptible to *B. xylophilus* which causes extensive damage with infected trees killed quickly. Damage is estimated at $10 million per year in this region.

The first California state record of pinewood nematode (with the older name *Bursaphelenchus lignicolus*) was made by CDFA Nematologists Adam Weiner and Robert Hackney from Yreka, Siskiyou County in 1980. Samples were collected on a Ponderosa pine (*Pinus ponderosa*) estimated to be eight years old and was growing in a residential yard. The yard was one mile from forest trees. A second detection was made weeks later in Pacific Grove, Monterey County. Monterey Pine (*Pinus radiata*) wind fall limbs that were sent for analysis for pinewood nematode also yielded a beetle larva, which was damaged and killed by the removal process. It was identified as an *Enoclerus* sp. (Coleoptera: Cleridae) and numerous pinewood nematode adults and juveniles were recovered from the beetle larva specimen This find was a first record of this nematode species associated with a beetle larva in North America. *Enoclerus* spp. are predaceous beetles. There was a second detection in Yreka, from a lodgepole pine (*Pinus contorta* var. *murrayana*) that was in the process of dying and submitted to the CDFA lab. This second sample was also from a residence and about two miles from the first find site. In the fall of 1980, juvenile pinewood nematodes were recovered from *Monochamus obtusus* Gasey (the obtuse sawyer) captured in Siskiyou County, one mile west of McCloud, in a pine tree plantation. There have been no official records in the forty years since.

In 1999, *B. xylophilus* was reported for the first time in Europe in Portugal. It was found in very high numbers inside declining pine trees that were also infested with *Monochamus galloprovincialis* (pine sawyer beetles) (Mota et al., 1999). A first report from Spain, close to the Portuguese border, was made from *Pinus radiata* in 2015 by Zamora et al. *Pinus radiata* is the Monterey pine, native to North America, which is not seriously affected in California, but is very susceptible when planted outside of its native range.

Bursaphelenchus xylophilus develops from egg to adult through a series of molts that include four juvenile stages. As food becomes limited or nematode density increases, a specialized third juvenile stage (J3) called the pre-dauer juvenile forms. This occurs just as late instar larvae or pupae of Cerambycid beetles are formed. *Monochamus* spp. beetles occupy the same area of the tree as the nematodes. *Monochamus alternatus* and *M. galloprovincalis* are the most important vector species in Asia (Mamiya and Enda, 1972; Sousa et al., 2001). The pre-dauer J3s aggregate around the pupal chambers of the beetles and molt to the dauer stage larva, a stage that is adapted for long-term survival in the absence of food. This molt to the dauer stage requires the presence of the beetle (Maehara et al., 1996). The dauer larvae are picked up by the adult beetles as they emerge, and they settle beneath the elytra and inside the trachea of the beetles. The nematodes can then be transmitted

to new trees during oviposition or adult feeding, and this is the route that leads to disease (Li et al., 2007; Shibata and Okuda, 1989).

Hosts: *Abies* (fir), *A. balsamea* (balsam fir), *Cedrus* (cedar), *C. atlantica* (Atlantic cedar), *C. deodara* (Himalayan cedar), *Larix* (larch), *L. decidua* (European larch), *L. laricina* (American larch), *Picea abies* (Norway spruce), *P. pungens* (Colorado blue spruce), *Pinus* (pine), *P. armandii* (Armand pine), *P. banksiana* (jack pine), *P. bungeana* (Bunge's pine), *P. cembra* (arolla pine), *P. clausa* (sand pine), *P. contorta* var. *murrayana* (Sierra lodgepole pine), *P. densiflora* (Japanese pine), *P. echinata* (shortleaf pine), *P. elliottii* (slash pine), *P. koraiensis* (Korean pine), *P. lambertiana* (sugar pine), *P. luchuensis* (luchu pine), *P. massoniana* (Masson pine), *P. mugo* (dwarf mountain pine), *P. nigra* (black pine), *P. palustris* (longleaf pine), *P. pinaster* (maritime pine), *P. pinaster* subsp. *escarena*, *P. ponderosa* (ponderosa pine), *P. radiata* (Monterey pine), *P. resinosa* (American red pine), *P. strobus* (eastern white pine), *P. sylvestris* (Scotch pine), *P. tabuliformis* (Chinese pine), *P. taeda* (loblolly pine), *P. thunbergii* (Japanese black pine), *P. virginiana* (Virginia pine), *P. yunnanensis* (Yunnan pine), *Pseudotsuga*, *P. menziesii* (Douglas fir), *Tsuga* (hemlock), *T. canadensis* (Canadian hemlock) (CABI-CPC, 2021).

Symptoms: Nematode infection of trees occurs mainly via wounds made by beetles feeding on twigs. Nematodes are found in the vascular tissue of twigs, stems, and trunks. They migrate, feed, and reproduce within the resin canals and the cambium cells. In the young *Pinus* shoots, *B. xylophilus* multiplies in the resin canals and attacks the epithelial cells. Approximately 3 weeks after infection, the tree shows early symptoms of 'drying out', in the form of reduced oleoresin exudation. The vascular system may become blocked by secondary resin originating from radial parenchyma cells damaged because of nematode infection. In addition, cavitation, possibly caused because of increased production of volatile defense compounds, may disrupt water transport. Tissues can be destroyed mechanically as the nematode migrates through the host (Mamiya, 1980).

Once the defenses of the trees are overcome, the nematodes can move freely throughout the dying tree which becomes attractive to adult beetles. The beetles gather on the trunks to mate. At this stage, intensified wilting and yellowing of the needles is seen. The tree can be completely dead 30-40 days after infection and may then contain millions of nematodes throughout the trunk, branches, and roots. The remainder of the phytophagous life cycle is like the mycophagous life cycle, as the nematodes locate the pupa of *Monochamus* spp. just before emergence (Mamiya, 1980).

The severity of the symptoms and of the incidence of pine wilt are related to both host species and to temperature. Inoculation of trees in summer when temperatures are high results in their rapid death (Kiyohara and Tokushige, 1971). Branch dieback is the most common symptom in trees infested with pinewood nematodes in California. Pinewood nematodes may also be a secondary invader, infecting unhealthy trees in which have typically been damaged by other causes, such as root disease or improper care (UC IPM, 2021).

Transmission: Pinewood nematodes are spread locally by flying beetle vectors. Many adult *Monochamus* spp. can travel up to 1000 m in one flight, both in the maturation feeding and the oviposition stages (Zhang, et al., 2007). Long-range spread of *B. xylophilus* can occur with movement of

timber or wood packing materials. Nematodes and their vectors may be transported separately as immature stages inside wood.

Damage Potential: On its natural hosts in North America, *B. xylophilus* lives a mostly a mycophagous life on trees weakened or damaged by other causes. When introduced into new areas, or to new host species of *Pinus*, some of which are exceptionally susceptible, the nematode adapts to a phytophagous life. Transmitted by local *Monochamus* spp., it invades and destroys pine forests, feeding incidentally on other conifer species too. Pine wilt disease caused by B. *xylophilus* in susceptible Asian pine species results in serious economic and environmental damage in forests and to specimen trees. North American pine species were thought to have resistance to this nematode, however, plantings of Monterey pine in Portugal and Spain have suffered losses, suggesting that changing the climate can cause a life cycle shift in this nematode, becoming a more dangerous pathogen (Sousa et al., 2001).

Worldwide Distribution: America: *Canada, Mexico, United States* (Alabama, Arizona, Arkansas, California, Colorado, Connecticut, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Jersey, New York, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, Tennessee, Texas, Vermont, Virginia, West Virginia, Wisconsin). Asia: *China, Japan, Korea, Taiwan.* Europe: *Portugal, Spain*

Official Control: Pinewood nematode is on the USDA harmful organism list Albania, Argentina, Azerbaijan, Brazil, Chile, China, Colombia, Costa Rica, Cuba, Ecuador, Eurasian Customs Union, European Union, Georgia, Holy See (Vatican City State), Honduras, India, Israel, Jordan, Korea, Mexico, Moldova, Republic of, Monaco, Morocco, Namibia, Nicaragua, Norway, Oman, Panama, Paraguay, Peru, Qatar, San Marino, Serbia, South Africa, Taiwan, Tajikistan, Thailand, Tunisia, Turkey, Turkmenistan, Ukraine, United Arab Emirates, United Kingdom, Uruguay, Uzbekistan, and Viet Nam (USDA PCIT, 2021). It is on the EPPO's A1 List for Argentina, Azerbaijan, Bahrain, Brazil, Chile, COSAVE (Comite Regional de Sanidad Vegetal del Cono Sur), EAEU (Eurasian Economic Union), Georgia, Jordan, Kazakhstan, Moldova, Paraguay, Russia, Turkey, Ukraine, Uruguay; on the A2 List for APPPC (Asia-Pacific Plant Protection Commission), China, EPPO (European and Mediterranean Plant Protection Organization; it is an A2 Quarantine pest (Annex II B) for the EU (European Union); and a Quarantine Pest in Israel, Morocco, Norway, Tunisia (EPPO, 2021).

California Distribution: The first detections of this nematode were made in 1980, found in dead and dying pine trees in Siskiyou and Monterey Counties, and from an obtuse pine sawyer, *Monochamus obtusus* collected in Siskiyou County.

California Interceptions: In 1999, there were two interceptions in Humboldt County on wood imported from British Columbia, Canada.

The risk *Bursaphelenchus xylophilus* would pose to California is evaluated below.

Consequences of Introduction:

1) **Climate/Host Interaction:**

This pest is not serious or aggressive in areas where it has been found in Northern California or on the Central Coast on native hosts (Chitambar et al., 2018).

Evaluate if the pest would have suitable hosts and climate to establish in California.

Score: **2**

- Low (1) Not likely to establish in California; or likely to establish in very limited areas.
- **Medium (2) may be able to establish in a larger but limited part of California.**
- High (3) likely to establish a widespread distribution in California.

2) **Known Pest Host Range:**

The host range includes many important conifer forestry trees. Pines (*Pinus* spp.) are favored hosts but other genera of conifers including *Abies, Picea, Larix, Cedrus* and *Pseudotsuga* are also attacked.

Evaluate the host range of the pest.

Score: 2

- Low (1) has a very limited host range.
- **Medium (2) has a moderate host range.**
- High (3) has a wide host range.

3) **Pest Reproductive Potential:**

This nematode can reproduce rapidly, especially at high temperatures in summer. One tree can produce millions. It relies on its insect vector to find new hosts, and the vectors can fly.

Evaluate the natural and artificial dispersal potential of the pest.

Score: 3

- Low (1) does not have high reproductive or dispersal potential.
- Medium (2) has either high reproductive or dispersal potential.
- **High (3) has both high reproduction and dispersal potential.**

4) **Economic Impact:**

So far, pine wilt disease is not common or economically damaging in California on native tree species. If a new susceptible host were to be planted, or if native hosts are grown in different climates (i.e. Monterey Pine in Portugal), more losses could occur. It is an important quarantine pest in Europe and uninfested parts of Asia.

Evaluate the economic impact of the pest to California using the criteria below.

Economic Impact: A, C, E

A. The pest could lower crop yield.

B. The pest could lower crop value (includes increasing crop production costs).

C. The pest could trigger the loss of markets (includes quarantines).

D. The pest could negatively change normal cultural practices.
E. The pest can vector, or is vectored, by another pestiferous organism.
F. The organism is injurious or poisonous to agriculturally important animals.
G. The organism can interfere with the delivery or supply of water for agricultural uses.

Economic Impact Score: **3**
- Low (1) causes 0 or 1 of these impacts.
- Medium (2) causes 2 of these impacts.
- High (3) causes 3 or more of these impacts.

5) **Environmental Impact:**
Environmental impacts have not been reported in California.

Evaluate the environmental impact of the pest to California using the criteria below

Environmental Impact:
A. The pest could have a significant environmental impact such as lowering biodiversity, disrupting natural communities, or changing ecosystem processes.
B. The pest could directly affect threatened or endangered species.
C. The pest could impact threatened or endangered species by disrupting critical habitats.
D. The pest could trigger additional official or private treatment programs.
E. The pest significantly impacts cultural practices, home/urban gardening or ornamental plantings.

Environmental Impact Score: 1
- Low (1) causes none of the above to occur.
- Medium (2) causes one of the above to occur.
- High (3) causes two or more of the above to occur.

Consequences of Introduction to California for *Bursaphelenchus xylophilus*: Medium

Add up the total score and include it here. **11**
-Low = 5-8 points
-Medium = 9-12 points
-High = 13-15 points

6) **Post Entry Distribution and Survey Information**: Evaluate the known distribution in California. Only official records identified by a taxonomic expert and supported by voucher specimens deposited in natural history collections should be considered. Pest incursions that have been eradicated, are under eradication, or have been delimited with no further detections should not be included.

Evaluation is 'Medium'.

Score: -2
-Not established (0) Pest never detected in California or known only from incursions.
-Low (-1) Pest has a localized distribution in California or is established in one suitable climate/host area (region).
-Medium (-2) Pest is widespread in California but not fully established in the endangered area, or pest established in two contiguous suitable climate/host areas.
-High (-3) Pest has fully established in the endangered area, or pest is reported in more than two contiguous or non-contiguous suitable climate/host areas.

7) **The final score is** the consequences of introduction score minus the post entry distribution and survey information score: (Score)

Final Score: *Score of Consequences of Introduction – Score of Post Entry Distribution and Survey Information* ***= 9***

Uncertainty:

Monterey Pine growing in warmer climates such as are found in plantations in Portugal are badly damaged by pinewood nematodes. As the climate of California changes, pine wilt could become a larger problem for forestry and landscape trees.

Conclusion and Rating Justification:

Based on the evidence provided above the proposed rating for *Bursaphelenchus xylophilus* is C.

References:

CABI Crop Production Compendium 2021. *Bursaphelenchus xylophilus* (pine wilt nematode) https://www.cabi.org/cpc/datasheet/10448

Chitambar, J. J., Westerdahl, B. B., and Subbotin, S. A. 2018. Plant Parasitic Nematodes in California Agriculture. In Subbotin, S., Chitambar J., (eds) Plant Parasitic Nematodes in Sustainable Agriculture of North America. Sustainability in Plant and Crop Protection. Springer, Cham.

EPPO Global Database. 2021. https://gd.eppo.int/taxon/BURSXY. Accessed 7/30/2021

Kiyohara, T. and Tokushige, Y., 1971. Inoculation experiments of a nematode, *Bursaphelenchus* sp., onto pine trees. Journal of the Japanese Forestry Society, 53(7), pp.210-218.

Maehara, N. and Futai, K., 1996. Factors affecting both the numbers of the pinewood nematode, *Bursaphelenchus xylophilus* (Nematoda: Aphelenchoididae), carried by the Japanese pine sawyer, *Monochamus alternatus* (Coleoptera: Cerambycidae), and the nematode's life history. Applied Entomology and Zoology, 31(3), pp.443-452.

Mamiya, Y., 1972. Reproduction of pine lethal wilting disease by the inoculation of young trees with *Bursaphelenchus lignicolus*. Japanese Journal of Nematology, 2, pp.40-44.

Mamiya, Y. and Enda, N. 1972. Transmission of *Bursaphelenchus lignicolus* (Nematoda: Aphelenchoididae) by *Monochamus alternatus* (Coleoptera:Cerambycidae). Nematologica, 18, 159–166

Mamiya, Y. 1983. Pathology of the pine wilt disease caused by *Bursaphelenchus xylophilus*. Annu. Rev. Phytopathol. 21, 201–220

Mota, M.M., Braasch, H., Bravo, M.A., Penas, A.C., Burgermeister, W., Metge, K. and Sousa, E., 1999. First report of *Bursaphelenchus xylophilus* in Portugal and in Europe. Nematology, 1(7), pp.727-734.

Nemaplex UC Davis Nemabase 2010. *Bursaphelenchus xylophilus*. Accessed 8/2/21

Shibata, E. and Okuda, K., 1989. Transmission of the pine wood nematode, *Bursaphelenchus xylophilus* (Steiner et Buhrer) Nickle (Nematoda: Aphelenchoididae), by the Japanese pine sawyer, *Monochamus alternatus* Hope (Coleoptera: Cerambycidae), to pine twigs under laboratory conditions. Japanese Journal of Nematology, 18, pp.6-14.

Soliman, T., Mourits, M.C., Van Der Werf, W., Hengeveld, G.M., Robinet, C. and Lansink, A.G.O., 2012. Framework for modelling economic impacts of invasive species, applied to pine wood nematode in Europe.

Sousa, E., Bravo, M.A., Pires, J., Naves, P., Penas, A.C., Bonifacio, L.and Mota, M.M. 2001. *Bursaphelenchus xylophilus* (Nematoda:Aphelenchoididae) associates with *Monochamus galloproincialis* (Coleoptera: Cerambycidae) in Portugal. Nematology, 3, 89–91

Steiner, G. and Buhrer, E.M., 1934. *Aphelenchoides xylophilus* n. sp., a nematode associated with blue-stain and other fungi in timber. Journal of agricultural research, 48(10), pp.949-951.

UC Pests in the Garden and Landscape. Pinewood nematode—*Bursaphelenchus xylophilus* http://ipm.ucanr.edu/PMG/GARDEN/PLANTS/INVERT/pinewdnem.html Accessed 8/2/2021

USDA Phytosanitary Certificate Issuance and Tracking System, Phytosanitary Export Database (PExD) Harmful Organisms Database Report. *Bursaphelenchus xylophilus* Accessed 2/26/2021

Zamora, P., Rodríguez, V., Renedo, F., Sanz, A.V., Domínguez, J.C., Pérez-Escolar, G., Miranda, J., Álvarez, B., González-Casas, A., Mayor, E. and Dueñas, M., 2015. First report of *Bursaphelenchus xylophilus* causing pine wilt disease on *Pinus radiata* in Spain. Plant Disease, 99(10), pp.1449-1449.

Zhang, J., Zhang, R., Chen, J., 2007. Species and their dispersal ability of *Monochamus* as vectors to transmit *Bursaphelenchus xylophilus*. Journal of Zhejiang Forestry College, 24(3):350-356. http://zjlx.chinajournal.net.cn

Responsible Party:

Heather J. Scheck, Primary Plant Pathologist/Nematologist, CDFA/PHPPS ECOPERS, 1220 N St Rm 221,

Sacramento, CA 95814 Phone: (916) 654-1017, permits[@]cdfa.ca.gov.

***Comment Period: 09/03/2021 through 10/18/2021**

***NOTE:**

You must be registered and logged in to post a comment. If you have registered and have not received the registration confirmation, please contact us at permits[@]cdfa.ca.gov.

Comment Format:

- Comments should refer to the appropriate California Pest Rating Proposal Form subsection(s) being commented on, as shown below.

  Example Comment:

  Consequences of Introduction: 1. Climate/Host Interaction: [Your comment that relates to "Climate/Host Interaction" here.]

- Posted comments will not be able to be viewed immediately.
- Comments may not be posted if they:

  Contain inappropriate language which is not germane to the pest rating proposal;

  Contains defamatory, false, inaccurate, abusive, obscene, pornographic, sexually oriented, threatening, racially offensive, discriminatory or illegal material;

  Violates agency regulations prohibiting sexual harassment or other forms of discrimination;

  Violates agency regulations prohibiting workplace violence, including threats.

- Comments may be edited prior to posting to ensure they are entirely germane.
- Posted comments shall be those which have been approved in content and posted to the website to be viewed, not just submitted.

Proposed Pest Rating: C
