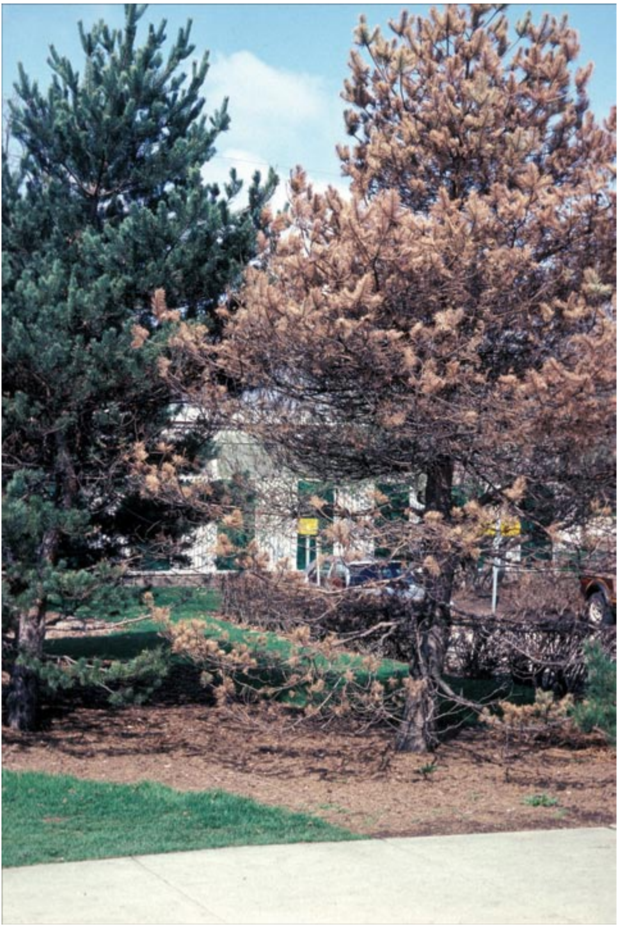
HOW to

How to Identify and Manage Pine Wilt Disease and Treat Wood Products Infested by the Pinewood Nematode



USDA United States Department Agriculture

Prepared by Forest Service

Northeastern Area State & Private Forestry

NA-FR-01-04

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Acknowledgments

The authors thank Dr. Tom Nicholls, Dr. L. David Dwinell, Dr. Joseph O'Brien and Dr. Marc Linit for their reviews of the manuscript and to Lucy Burde for editing the manuscript.

Cover photo:

Scotch pine that has died from pine wilt disease.

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Figures 2, 5, 6 and 7. Dr. Jim Appleby, University of Illinois.

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Introduction

Pine wilt is a disease of pine (*Pinus* spp.) caused by the pinewood nematode, *Bursaphelenchus xylophilus*. The pinewood nematode is native to North America and is not considered a primary pathogen of native pines, but is the cause of pine wilt in some non-native pines. In countries where the pinewood nematode has been introduced, such as Japan and China, pine wilt is an important non-native disease.

The pinewood nematode (Fig. 1) is transmitted (vectored) to conifers by pine sawyer beetles *(Monochamus* spp.) (Fig. 2) either when the sawyer beetles feed on the bark and phloem of twigs of susceptible live trees (primary transmission) or when the female beetles lay eggs (oviposition) in freshly cut timber or dying trees (secondary transmission). Nematodes introduced during primary transmission can reproduce rapidly in the sapwood and a susceptible host can wilt and die within weeks of being infested if conditions are favorable to disease development.

Figure 1. Pinewood nematode adult male with spicule (see arrow) at posterior end.

Figure 2. Adult *Monochamus* beetle.

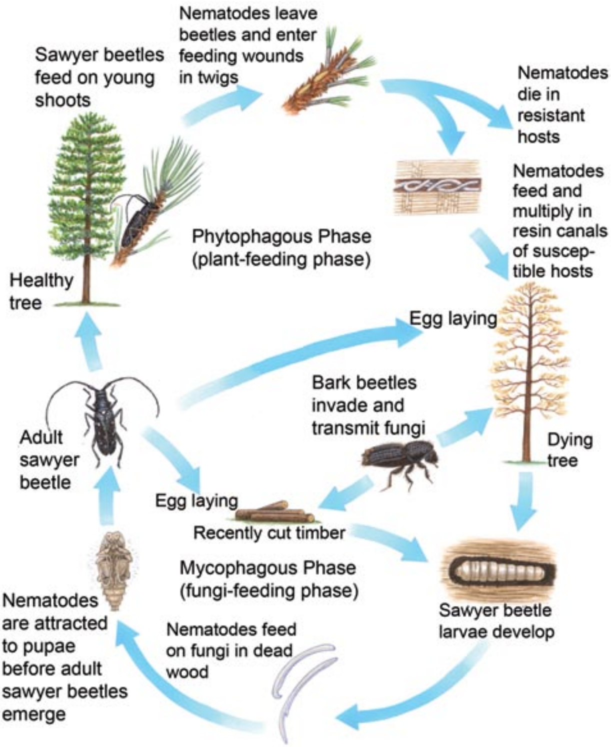

Figure 3. Interactions of the pinewood nematode with sawyer beetles and bark beetles to cause pine wilt disease. Redrawn with permission of T. Nicholls from Wingfield et al. 1984.

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Pinewood nematodes introduced to fresh logs or dying trees during egg laying of sawyer beetles feed on fungi introduced by the sawyer and other bark beetles (Fig. 3).

The common presence of the pinewood nematode from such secondary transmission can confound the diagnosis of pine wilt disease. For example, if a dead or dying pine tree with pinewood nematode also has oviposition pits from sawyer beetles at the time of sampling, then pine wilt disease may not be the cause of mortality. The common presence of the pinewood nematode in forest products due to secondary transmission has resulted in restrictions on wood exports from North America.

History

Pine wilt disease was first described in 1905 in Japan, but the pinewood nematode was not identified as the causal agent of this disease until 1971. Since the pinewood nematode was introduced into Japan, it has extensively damaged Japanese red pines *(P. densiflora)* and black pines *(P. thunbergii)*. Analysis of DNA from several studies indicates that the pinewood nematode was introduced to Japan from the United States.

In the United States, the pinewood nematode was first reported in 1934 associated with fungi in timber, but it was not until 1979 that the nematode was reported to induce pine wilt disease of non-native pines in Missouri. Subsequent surveys and studies have established that the pinewood nematode is native to North America and not a threat to native forests. The pinewood nematode has been reported from the United States, Canada, and Mexico.

The pinewood nematode is a common secondary colonizer of freshly cut timber and dying conifers. In North America, pine wilt disease occurs predominately in non-native pines that include Austrian *(P. nigra),* Scotch *(P. sylvestris),* and Japanese red and black pines. Most documented cases of pine wilt by the pinewood nematode have occurred in the Midwestern United States.

Asian countries other than Japan began to report presence of the pinewood nematode in the mid- to late-1980s. Taiwan reported the pinewood nematode in Japanese black pine and luchu pine *(P. luchuensis)* in 1985. By 1989, China and Korea had also reported pinewood nematode in Japanese red and black pine. In 1999, Portugal reported the pinewood nematode present in declining maritime pine *(P. pinaster)* in the Iberian Peninsula.

Interceptions of the pinewood nematode from imported pine chips by the Finnish Plant Quarantine Service in 1984 resulted in a ban of untreated conifer chips and timber into Finland from countries where the pinewood nematode occurs. A year later the European Plant Protection Organization (EPPO) listed the pinewood nematode as a quarantine pest and recommended that Europe ban conifer products from countries that have the

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nematode unless the products have been kiln-dried. Several other countries soon adopted import restrictions on untreated softwood products.

Life Cycle and Biology

Pinewood nematode — The life cycle of the pinewood nematode involves a propagative cycle and a dispersal cycle (Fig. 4). The propagative cycle occurs in the sapwood and involves six life stages: the egg, four larval stages and the adult. The sequence of egg to adult takes only 4 to 5 days under favorable conditions of adequate wood moisture, temperature and nutrient availability. The first stage occurs within the egg followed by hatching to the second stage, which soon molts into the third stage. There are two forms of the third stage: 1) larvae that change into fourth stage larvae, which eventually change into adults that remain in infested trees; and 2) a nonfeeding dispersal stage. The development of the nematode switches to this dispersal mode in the late stages of tree infection after tree death and occurs only in the presence of *Monochamus* pupae within the wood. These third-stage larvae aggregate on the wall of the pupal chamber of the sawyer beetle *(Monochamus* spp.) in the xylem, and then molt to a dauerlarvae. The dauerlarvae is a nonfeeding larval stage that is specialized for survival during the transport phase of the life cycle. These fourth-stage larvae enter the respiratory system of the young adult beetle and are vectored by the beetle to new hosts. The dauerlarvae can molt into adults within 48 hours after transmission to a conifer host.

The plant-feeding phase (phytophagous phase) occurs when pinewood nematodes are introduced into the branches of a susceptible pine by adult sawyer beetles feeding on the young bark. Once the nematodes are introduced, they feed on the epithelial cells and resin ducts in susceptible host trees and can become distributed throughout the sapwood of the branches, trunk, and roots. Vascular dysfunction can occur rapidly under dry conditions or with mean summer temperatures above 20°C resulting in pine wilt and death of a susceptible pine host.

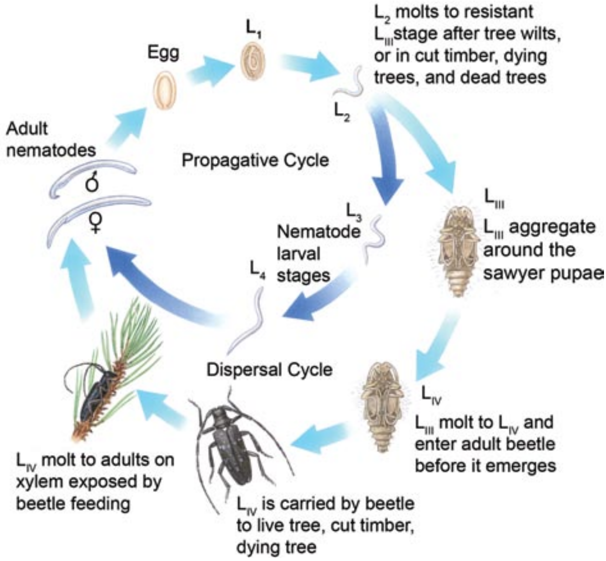

Figure 4. Life cycles of the pinewood nematode. Redrawn with permission of T. Nicholls from Wingfield et al. 1984.

The fungi-feeding phase (mycophagous phase) of the pinewood nematode life cycle occurs in freshly cut softwood and in dead and dying conifers. In North America, this is the most common phase and is usually the result of secondary transmission during egg-laying by sawyer beetles infested with the pinewood nematode. The pinewood nematodes feed on blue-stain fungi *(Ceratocystis* spp.) and other fungi that typically invade cut timber and dead and dying softwood.

Sawyer beetles — Pine sawyer beetles *(Monochamus* spp.), also referred to as long-horned beetles, serve as vectors of the pinewood nematode. Primary transmission occurs when sawyer beetles feed on the bark of young branches (Fig. 5) Pine sawyers

Figure 5. Sawyer beetle feeding.

Figure 6. Larva of sawyer beetle.

infested with the pinewood nematode can transmit the nematode by the way of feeding wounds to a susceptible host, and pine wilt can develop under favorable conditions for the disease.

Pine sawyer beetles are attracted to weakened trees, or recently cut logs, where they mate and lay eggs. The beetles will deposit eggs only on trees or logs with the bark attached. The beetle larvae hatch within a week and feed on the phloem. The larvae tunnel into the xylem (wood) to form an oval entrance hole and U-shaped galleries (Fig.6). The sawyer beetles overwinter as larvae and then pupate within an enlarged portion of the gallery (Fig. 7). The pinewood nematode larvae, introduced by infested beetles along with their eggs, invade the thoracic spiracles and tracheae of the beetle pupa in numbers as high as 289,000. The adult beetle emerges from the tree, leaving a round, ¼- inch-diameter exit hole. Because beetle development is temperature dependent, the number of generations is lower in northern climates and higher in southern climates. In

Figure 7. Pupa of sawyer beetle.

the central Midwest there is generally more than one generation per year.

Presence in wood products — The pinewood nematode has been found in shipments of conifer wood chips, in unseasoned lumber, and in packing case wood. The *Monochamus* spp. vectors of the nematode have been found in wood pallets, crates, and dunnage. Because of the close relationship between the nematode and its vector, shipments from areas where the nematode occurs can be assumed to be at risk of also carrying the nematode and/or its vector.

Taxonomy

Pinewood nematodes found associated with fungi in logs in the United States were first reported in 1934 as *Aphelenchoides xylophilus,* later renamed *Bursaphelenchus xylophilus*. In 1979, the pinewood nematode was recovered from Austrian and Scotch pine in Missouri and was referred to as *B. lignicolus.* By 1981, *B. lignicolus* was synonymized with *B. xylophilus* and was determined to be native to North America.

The genetics and taxonomy of the pinewood nematode and closely related species are not clearly defined. Over 50 known species of *Bursaphelenchus* inhabit trees; at least 2 found in the United States are closely related. *Bursaphelenchus xylophilus* and *B. mucronatus* share several morphological characteristics and are sometimes referred to as members of the pinewood nematode species complex (PWNSC).

In North America, *Bursaphelenchus xylophilus* has a pathogenic form "r" and a non-pathogenic form "m." The "r" form has a round tail and the "m" (or mucro) form has a pointed tail. The "r" form usually occurs in pine, and the "m" form occurs most often on fir and spruce but occasionally may be found on pine and other conifers. Under natural conditions, most pine wilt disease has been attributed to *B. xylophilus* with the "r" form.

Economic and Ecological Impact

In the United States, losses from pine wilt disease can occur in some non-native pine plantations and landscape trees. The greatest economic effect from the pinewood nematode in North America, however, has resulted from the embargoes on untreated wood chips and timber. From 1972 to 1989, before the bans on softwood, Canada and the United States shipped almost 5 million tons of conifer chips to Scandinavia from 1972 to 1989. The exact losses to the American forest industry are difficult to determine because of a variety of factors affecting international trade; however, one possible estimate of loss is $100 million annually in green lumber exports to Europe during the 1990s.

Management

Pine wilt disease — Management of pine wilt disease is primarily limited to prevention. There are no cures for pine wilt disease once a susceptible tree becomes infested with the pinewood nematode. The most effective prevention strategy is to avoid planting non-native pines, such as Scotch and Austrian pine, where the mean summer temperature is greater than 20°C. Where these non-native pines already exist, landowners can reduce susceptibility of high-value landscape trees by watering to avoid drought stress. If they discover infestations, landowners can consider removing and chipping infested trees to limit the spread to nearby susceptible trees.

Pinewood nematode — The pinewood nematode can be prevented from infesting softwoods by removing the bark at the time of felling and by avoiding harvesting when the *Monochamus* beetles lay their eggs (typically July-September). Although most regulations require treatments for all softwoods, some conifer species are rarely colonized by the pinewood nematode. These species include Douglas-fir *(Pseudotsuga menziesii),* redwood *(Sequoia sempervirens),* white fir *(Abies concolor),* western redcedar *(Thuja plicata),* eastern hemlock *(Tsuga canadensis),* and western hemlock *(T. heterophylla).*

Many methods have been investigated for treating wood products to eliminate the pinewood nematode. Heat treatments and fumigation currently have some practical use. The pinewood nematode has been eliminated in wood when kiln-dried, or heated to a core temperature of 56°C or greater for 30 minutes. Fumigation with aluminum phosphine has been effective in eliminating the nematode from wood chips. Over time, other treatments may be discovered or become more practical.

The standards for international regulation of softwoods are continually fluctuating. The most current regulation requirements for softwood export can be obtained from the U.S. Department of Agriculture, Animal Plant Health Inspection Service (APHIS) serving state. The web site for APHIS is: www.aphis.usda.gov.

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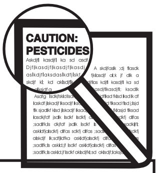

Pesticide Precautionary Statement:
Pesticides used improperly can be injurious to humans, animals, and plants. Follow label directions and heed all precautions on the labels. Store all pesticides in original containers, out of reach of children and foodstuffs. Apply pesticide selectively and carefully. Do not apply a pesticide when there is danger of drift to other areas. After handling a pesticide, do not eat, drink, or smoke until you have washed. Dispose of empty pesticide containers properly. It is difficult to remove all traces of a herbicide (weed killer) from equipment. Therefore, to prevent injury to desirable plants do not use the same equipment for insecticides that you use for herbicides.

NOTE: Some States have restrictions on the use of certain pesticides. Check you State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agent or State extension specialist to be sure that intended use is still registered.

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For further information, contact:

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