# 3
# A Brief Overview of the Pine Wood Nematode and Pine Wilt Disease in Canada and the United States

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## 3.1 Introduction

The purpose here is not to review all the relevant literature on pine wilt disease, the pathogen, that is, the pine wood nematode (PWN), *Bursaphelenchus xylophilus*, host pines, or the nematode's insect vector, species of *Monochamus*, in North America. Instead, it is to briefly summarize for North America what has already been cited in several review articles that have been published on these topics, especially on the pathogen, and disease, and where relevant, the possible and known vectors in the USA (Dwinell and Nickle 1989) and Canada (Bowers et al. 1992). Then follows a narrative on the conditions that limit the importance of pine wilt in Canada and the USA. Additional information on pine wilt, the pathogen, vectors, effects of climatic conditions on the two, hosts and so on can be found in the review articles by Mamiya (1983) and Dwinell (1997) and the book entitled "Pathogenicity of the Pine Wood Nematode" (Wingfield 1987a). Although the PWN has been reported in Mexico (Dwinell 1985a), essentially nothing else is known about it or the disease there; consequently, the discussion here is confined to Canada and the USA.

## 3.2 Historical Aspects

The history of pine wilt disease follows a long series of research findings beginning with the publication of Steiner and Buhrer (1934) who described *Aphelenchoides xylophilus*, n. sp., which they had isolated 5 years earlier from blue-stained, longleaf pine, *Pinus palustris*, logs at a sawmill in Louisiana, USA. Dwinell and Nickle

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(1989) give point by point landmarks in the history of PWN research which started some 35 years after Steiner and Buhrer's work when Tokushige and Kiyohara (1969) reported the occurrence of a *Bursaphelenchus* sp. in the wood of dead pine trees in Japan. The next year, Nickle (1970) transferred *A. xylophilus* to the genus *Bursaphelenchus*. Kiyohara and Tokushige (1971) in Japan demonstrated the pathogenicity of a *Bursaphelenchus* sp. by inoculating 25-year-old Japanese red pine, *P. densiflora*. Later in Japan, Mamiya and Kiyohara (1972) described the PWN as *B. lignicolus* while that same year, Mamiya and Enda (1972) reported transmission of this nematode during maturation feeding by *Monochamus alternatus*. Seven years later, pine wilt disease was reported in Missouri, USA (Dropkin and Foudin 1979), and Nickle et al. (1981) placed *B. lignicolus* as a synonym of *B. xylophilus*. Wingfield (1983) showed transmission of *B. xylophilus* during oviposition of *Monochamus* vectors. Transmission during maturation feeding is commonly referred to as primary transmission while transmission during oviposition is secondary transmission. In 1983, *B. xylophilus* was found associated with dwarf mistletoe-infested Jack pine, *P. banksiana*, trees in Manitoba, Canada (Knowles et al. 1983). In 1984, Rautapaa (1986) reported that pine, *Pinus* spp., wood chips imported into Finland from the USA and Canada contained the nematode. Subsequently, in 1986, as outlined by Bowers et al. (1992) and references therein, the European Plant Protection Organization (EPPO) concluded that the PWN met all the criteria of a class "A-1" pest, that is, potentially important (Anonymous 1986). In 1985 Finland restricted the importation of conifer chips and timber from countries where the PWN is present because wood chips shipped from the USA and Canada were infested by the nematode (Rautapaa 1986). Other Nordic countries acted similarly and the EPPO recommended that Europe ban softwood products, except kiln-dried lumber, from countries with the PWN. Up until then, the nematode and the disease, which had only affected a few, mostly exotic, trees in the southern USA (Dwinell and Nickle 1989) had not caused serious economic consequences. Prior to that, the serious losses that had occurred in Japan (Mamiya 1983), while of interest to North Americans, were viewed mainly as a serious problem that occurred in Japan and nearby countries; however, these EPPO recommendations which also affected North American products resulted in an accelerated interest in the pathogen and the disease in both Canada and the USA. Since then, both the PWN and pine wilt disease have been found in Portugal (Mota et al. 1999).

## 3.3 Overview of the PWN in Canada

In Canada, work on the PWN began shortly after the EPPO restrictions were imposed and included surveys to determine the geographic and host distribution of the nematode in Canada and possible insect vectors. As well, research was done in British Columbia at the Pacific Forestry Centre, Forestry Canada, in Victoria, and at Simon Fraser University in Burnaby.

## 3.4 Nationwide Survey of the Nematode, Hosts and Potential Insect Vectors

Initially, in the early 1980s, several province- or area-specific surveys were made to determine the presence and status of the nematode; however, in 1985, the Forest Insect and Disease Survey of Forestry Canada initiated a nationwide survey to determine the distribution of the nematode and its potential insect vectors. The detailed protocols used in this survey and the survey results are given by Bowers et al. (1992). Briefly, the survey methods prioritized and emphasized the sampling of both host tree and vector species most likely to harbor the PWN. Consequently, the results represented the worst-case scenarios. Some 3,706 trees were sampled during the 5-year-long survey, of which 2,773 were dead or dying, and 1,294 *Monochamus* beetles, which were considered as having the greatest potential of containing the PWN, were assayed to establish the frequency of the nematode within potential host trees and insect vectors. Another 4,325, forest-inhabiting insects were assayed for the nematode.

The results showed that the PWN was present in: (1) all provinces except Prince Edward Island, (2) isolated groups of one or two trees, (3) both the mucronated (m), the most common and widespread, and round-tailed (r) forms were present, (4) low, for example Ontario, to rare, for example British Columbia, frequencies, and (5) in low numbers in six species of pines, that is, Scots, *P. sylvestris*, jack, *P. banksiana*, lodgepole, *P. contorta*, red, *P. resinosa*, Ponderosa, *P. ponderosa* and eastern white, *P. strobus*. As well, (6) the “r” form was only found in pines while the “m” form was more prevalent in *Abies* and *Picea* spp. (7) the “r” form occurs in New Brunswick, Nova Scotia, Quebec, Ontario, Manitoba and Alberta, plus (8) the PWN was present in low numbers in balsam fir, *Abies balsamea*, white spruce, *Picea glauca*, black spruce, *P. mariana*, red spruce, *P. rubens*, tamarack, *Larix laricina* and Douglas fir, *Pseudotsuga menziesii*. Almost all trees in which the nematode was found were weakened by other factors. Regarding the insect assays, of the 1,519 insects assayed for the PWN, including 1,294 *Monochamus* spp., only 1 specimen of *Monochamus clamator* yielded the nematode, while no other vectors contained PWNs, including possible vectors from logs which had been inoculated with massive numbers of the nematode.

Based on the survey results, it was concluded that the risk of importing the PWN with Canadian lumber and logs, or indirectly through vectors, is considered to be very low, especially with continued programs to eliminate bark and grub holes.

## 3.5 Research on the PWN in Canada

Canadian research on the nematode and the disease was done at the Pacific Forestry Centre, Canadian Forest Service, in Victoria, and at Simon Fraser University in Burnaby, both in British Columbia. The Victoria work was headed up by

J. Sutherland and J. Webster was the lead researcher at Simon Fraser. In Victoria, several researchers such as T. Forge, T.S. Panesar, K. Futai, B. Yang, F.G. Peet, and T.S. Sahota carried out studies to determine PWN host range, mainly by inoculating conifer seedlings with Canadian PWN isolates, the pathogenicity of "m" and "r" form nematodes, host attractiveness, movement of the nematode through wood bark and PWN survival in wood chips. At Simon Fraser, research was done on topics such as on PWN pathogenicity by E. Riga and J.M. Webster, and T.A. Rutherford and J.M. Webster on the effect of temperature on pine wilt disease occurrence.

## 3.6 Overview of the PWN in the United States

Although numerous papers have been written about the PWN and pine wilt disease in the USA, the most recent overview is that of Dwinell and Nickle (1989). Much of the historical information given in the introduction of this chapter comes from that publication. Not only have they reviewed their own work, but they have also summarized the work of others in the USA and elsewhere, for example, related to pathogenicity, hosts, and insect vector relationships of the pathogen.

Three prerequisites are needed for disease development, that is, presence of (1) a pathogen (and for pine wilt disease also a vector), (2) a susceptible host, and (3) of environmental conditions favorable for disease development. Dwinell and Nickle (1989) reviewed the PWN and pine wilt disease situation in the USA, especially the first two points, and made the best case as to why pine wilt disease is only of minor importance in the USA and Canada.

## 3.7 Relationship of *Bursaphelenchus* with *Monochamus*, that is, Presence of the Pathogen and Vectors

In the USA, PWN dauerlarvae have been found associated with five *Monochamus* species (pine sawyers), that is, *M. carolinensis*, *M. scutellatus oregonensis*, *M. titillator*, *M. mutator* and *M. notatus*. In Canada, 14 species of potential PWN vectors are known. The biologies of Asian, North American, and Euro-Siberian *Monochamus* are similar; however, species differ in their geographic distributions, hosts, oviposition site preference, and so forth, including the length of the life cycle. Adult pine sawyers are attracted to newly dead or dying trees and freshly killed timber (including logs) for breeding. The cause of tree death is not crucial, for example, it can vary from inclement weather, death or injury from other insects or diseases or fire damage. In more northern parts, 2 years are required to complete the life cycle. In the presence of the callow adult of the vector, the third larval dispersal stage of PWN moults to the fourth larval stage, that is, the transmission stage or dauerlarva. These are transmitted to the host tree during maturation feeding by the beetles (primary transmission) or during oviposition in weakened trees (secondary transmission). Thus, both in Canada (see above) and the USA, the pathogen and one or more suitable vectors are present; however, even under these conditions pine wilt disease is rare.

## 3.8 Pathogenicity of the PWN to North American Pines: Presence of a Susceptible Host

Dwinell and Nickle (1989) state that "Much of the information about pathogenicity of the PWN in North America is based on seedling pathogenicity tests". They then point out that this information may have contributed to the impression that pine wilt is epidemic in North America. In fact, field pathogenicity tests in which the inoculation protocols were similar to the natural infection process, and fulfilled Koch's postulates, have only been done with Scots, *P. sylvestris*, slash, *P. taeda* and Japanese red, *P. densiflora* and Japanese black, *P. thunbergii*, pines (see references cited by Dwinell and Nickle 1989). Of these, only slash pine is native to North America and in the field, pine wilt occurrence on this species is extremely rare. Based on these scientific reports, Dwinell and Nickle (1989) conclude that native, North American conifers are either immune or highly resistant to pine wilt disease. In North America, isolation of the PWN most likely results from the trees being weakened by other factors followed by secondary transmission of the nematode during oviposition.

Rutherford and Webster (1987) reviewed the relationship of temperature and pine wilt disease. They concluded that in North America and Japan where the PWN and its vectors occur, pine wilt in susceptible pines only occurs where mean air temperatures are above 20°C for long periods. In these warm areas, susceptible pines grow disease free only at high elevations while pines resistant to pine wilt transcend the 20°C temperature threshold without becoming diseased. Finally, even in the presence of PWN and its vectors there are no reports of susceptible pines dying from the disease in those regions where mean summer temperatures are less than 20°C. Such high temperatures seldom occur in either Canada or the USA.

## 3.9 Conclusions

1. Surveys show that PWNs, and often-suitable vectors, occur throughout much of Canada and the USA; however, pine wilt disease is of only minor importance in these countries.
2. The reasons for this are that most indigenous North American conifers are resistant to the disease and high summer temperatures are of too short a duration to favor the pathogen and pine wilt development.