Transmission of Pine Wood Nematode to Cut Timber and Girdled Trees

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ABSTRACT

Wingfield, M. J. 1983. Transmission of pine wood nematode to cut timber and girdled trees. Plant Disease 67:35-37.

The pine wood nematode, *Bursaphelenchus xylophilus*, was recovered from Austrian pine (*Pinus nigra*), jack pine (*P. banksiana*), and red pine (*P. resinosa*) logs 4 mo after they had been cut from healthy trees that did not contain nematodes. *B. xylophilus* was found only in logs in which cerambycid beetles had oviposited. Similarly, only previously girdled jack pine that had been colonized by cerambycid beetles contained *B. xylophilus*. The results of this study show that *B. xylophilus* can be transmitted to cut timber and dying trees and suggest that the nematode may be transmitted to dead and dying trees without necessarily being the primary cause of their death.

The pine wood nematode, *Bursaphelenchus xylophilus* (Steiner and Buhrer) Nickle (formerly *B. lignicolus* Mamiya and Kiyohara), causes a severe wilt disease of Japanese black pine (*Pinus thunberghii* Parl.) and Japanese red pine (*P. densiflora* Sieb. et Zucc.) in Japan (13,14,18). *B. xylophilus* was first found in the United States in 1934 and named *Aphelenchoides xylophilus* Steiner and Buhrer (17). In 1979, *B. xylophilus* was found on Austrian pine (*P. nigra* Arnold) in Columbia, MO, and was pathogenic on greenhouse seedlings (6). Since this first report of pathogenicity, *B. xylophilus* has been found to be widely distributed on many species of conifers in the United States (7,8,18). The biology and pathogenicity of *B. xylophilus* have been described in review articles (14,15) in Japan and the United States (7,8,18).

During a recent pine wood nematode investigation in Minnesota, Iowa, and Wisconsin, *B. xylophilus* was found only in Austrian pine, jack pine (*P. banksiana* Lamb.), red pine (*P. resinosa* Ait.), Scots pine (*P. sylvestris* L.), and white pine (*P. strobus* L.) stressed by various forest insects and fungal diseases and colonized by cerambycid beetles (19). Typical wilt symptoms associated with *B. xylophilus* infestation in Japan were not observed, and trees appeared to have died gradually. In addition, *B. xylophilus* was found commonly in dead tops or dead branches of trees that had died from white pine blister rust (*Cronartium ribicola* Fischer ex Rabh.) infection, *Diplodia pinea* Kickx infection, or Zimmerman pine moth (*Dioryctria zimmermanii* (Grote) infestation (19). These were different from the partial deaths observed on Scots pine in Illinois (12) and reported occurring in northern Japan (8), where only *B. xylophilus* was associated with the symptoms. Trees not attacked by the various fungal pathogens or insects were not symptomatic, suggesting that *B. xylophilus* was not the primary cause of mortality of trees or tree parts (19). This paper presents evidence that *B. xylophilus* may be transmitted to dead and dying trees or tree parts.

Paper 12,018, Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul 55108.

This research was funded in part by the USDA Forest Service, North Central Forest Experiment Station, St. Paul, MN, contract RWU-NC 2205.

Accepted for publication 10 May 1982.

0191-2917/83/01003503/$03.00/0

MATERIALS AND METHODS

During April 1981, healthy Austrian pine trees were selected in Zimmerman (Sherburne County), MN, and felled to provide 20 bolts 1.5 m long and between 10 and 25 cm in diameter. After a 2-cm-thick disk of wood had been removed from the end of each bolt, 10 bolts were placed in nylon screen bags (1 × 2 mm mesh), and 10 were left unscreened. The screened and unscreened bolts were placed in four stacks of five bolts in a shaded area within 5 m of each other (Fig. 1). Replicates of this study were established using jack pine in Black River Falls (Jackson County), WI, and red pine in Spring Green (Sauk County), WI.

Samples of wood (70 g) removed from each disk at the beginning of the experiment were placed in Baermann funnels (5) to determine whether nematodes were present in the healthy wood. Wood stacks were inspected after 4 mo, and the presence or absence of bark beetles and cerambycid larvae was noted. Disks of wood 2 cm thick were removed from the ends of each bolt and chopped into 70-g subsamples. Nematodes were extracted from wood samples using Baermann funnels, and the presence or absence of *B. xylophilus* was noted.

In Black River Falls, 20 healthy, 15-yr-old jack pine trees were selected, and 10 were girdled at breast height. Trees were inspected after 4 mo for insect attack. Four increment borings measuring 5 × 10 mm were removed from each tree at breast height and placed in Baermann funnels to extract nematodes.

RESULTS

No nematodes were detected in pine bolts at the time of cutting. After 4 mo, wood samples from both screened and unscreened bolts contained *B. xylophilus* (Table 1). However, the nematode was detected only in bolts on which adult cerambycid beetles (Fig. 2) had oviposited (Fig. 3) and larvae had developed (Fig. 4). In Zimmerman and Black River Falls, screens covering bolts had been damaged, apparently by grasshoppers and rodents. Only bolts in the damaged screen bags contained cerambycid larvae. Bark beetles (*Ips* spp.) had penetrated the screen and were present in all bolts. *B. xylophilus* was found only in bolts with cerambycid larvae. No *B. xylophilus* were recovered from bolts with bark beetles and no cerambycid beetles. Screens covering bolts in Spring Green had not been damaged, and no cerambycid larvae or *B. xylophilus* were found in screened logs, although bark beetles were present. Only three of the unscreened logs had signs of cerambycid beetle activity (oviposition sites and the presence of larvae in the wood), and only these three contained *B. xylophilus*. The logs in Spring Green were in a more shaded area than those in Black River Falls and Zimmerman and were consequently wetter and covered with saprophytic fungi.

Four of the 10 girdled jack pine in Black River Falls had been infested by bark beetles and cerambycid beetles. Only trees with cerambycid larvae and bark beetles contained *B. xylophilus*. The remaining six girdled trees and 10 untreated trees were free of insects and yielded no nematodes.

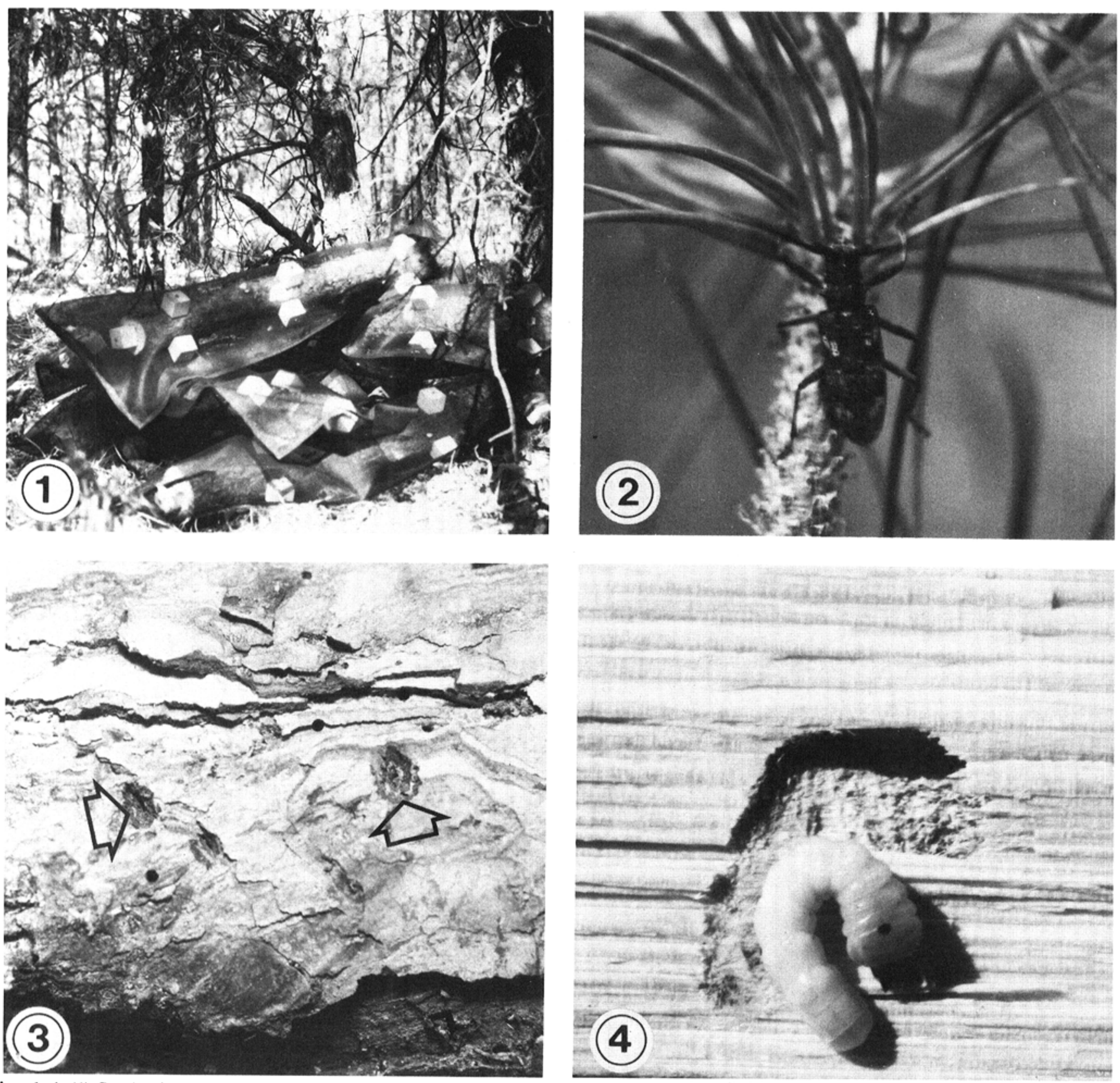
DISCUSSION

In Japan, *B. xylophilus* is transmitted by cerambycid beetles during maturation feeding on young shoots of healthy trees (15,16). Results of this study show that *B. xylophilus* is also transmitted to cut timber and artificially stressed trees. These results help to explain the presence of *B. xylophilus* in stressed trees or tree parts primarily colonized by other forest pathogens and insects (19).

Table 1. Number of pine bolts containing *Bursaphelenchus xylophilus*, bark beetles, and cerambycid beetles after 4 mo

Condition of bolts	No. of bolts	Cerambycid larvae (Coleoptera:Cerambycidae)	Bark beetles (Coleoptera:Scolytidae)	*B. xylophilus*
		Zimmerman, MN		
Screen				
Damaged	7	7	7	7
Undamaged	3	0	3	0
No screen	10	10	10	10
		Black River Falls, WI		
Screen				
Damaged	8	8	8	8
Undamaged	2	0	2	0
No screen	10	10	10	10
		Spring Green, WI		
Screen				
Undamaged	10	0	10	0
No screen	10	3	10	3

Cerambycid beetles oviposit in dead and dying trees as well as downed timber after maturation feeding (2). These beetles also carry *B. xylophilus* in Japan (15,16) and in the United States (7,8,18). The association between cerambycid beetles and *B. xylophilus* in cut timber and girdled trees in this investigation suggests that nematodes may be transmitted during cerambycid beetle oviposition. An alternative explanation is that the beetles undergo maturation feeding on the bark of cut timber and transmit *B. xylophilus* at this stage. Maturation feeding on the bark of cut timber in this study would be unlikely because beetles would have fed on the bark of downed logs in preference to succulent shoots of healthy trees under which the logs were placed.



Figs. 1–4. (1) Stack of bolts covered with nylon screen to prevent cerambycids from infesting wood. **(2)** *Monochamus carolinensis* adult during maturation feeding on pine seedling. **(3)** Cerambycid beetle oviposition niches (arrows) in pine bark. **(4)** Cerambycid beetle larva and gallery in dead pine wood.

Large numbers of *B. xylophilus* have been extracted from *Monochamus scutellatus* (Say.) and *M. carolinensis* (Olivier) trapped in the study areas in this investigation (*unpublished*), and these cerambycids seem to be the most likely candidates for transmission of *B. xylophilus* to cut logs and dying trees. It has been suggested (15) that most of the nematodes leave the beetle vectors during the early stages of maturation feeding. Gosling (9) reported that *M. scutellatus* does not necessarily undergo maturation feeding and may oviposit shortly after emergence if a suitable substrate is present. The *Monochamus* spp. most common in the study areas may therefore carry large numbers of *B. xylophilus* when they oviposit.

Although bark beetles (*Ips* spp.) were present in all logs and in some girdled trees, there was no association between the presence of these insects and *B. xylophilus*. Stain fungi in logs are, however, associated with these insects (3); they probably serve as food for the nematodes, which are known to feed on fungi (4,10,11,13). Transmission of *B. xylophilus* to cut timber or dying trees provides an ecologically efficient means for perpetuation of the nematode when trees susceptible to it as a primary pathogen are not present.

This investigation supports the hypothesis (19) that *B. xylophilus* does not by itself cause tree mortality in areas examined in Minnesota, Iowa, and Wisconsin. However, the nematode may be a significant problem in other parts of the United States on extremely susceptible exotic species, such as Japanese black pine and Scots pine. This view would explain reports that *B. xylophilus* is the primary factor associated with the mortality of Scots pine in Missouri (7,8) and Illinois (12) and of Japanese black pine in Delaware (1). Surveys for the pine wood nematode are under way in the United States and other countries. In light of present findings, it is important that all possible causes of tree death be considered carefully before attributing tree mortality solely to the presence of *B. xylophilus*. The means of nematode transmission to cut timber and the potential of *B. xylophilus* to kill mature trees in the United States require investigation.

ACKNOWLEDGMENTS

I thank R. A. Blanchette, V. H. Dropkin, D. C. L. Gosling, M. Linit, T. H. Nicholls, and K. Robbins for advice and help with the manuscript. The technical assistance of R. W. Conklin, D. L. Hall, J. A. Hess, F. S. Morse, and K. J. Zuzek is sincerely appreciated.

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