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Introduction

1.1 Discovery of the Pine Wilt Disease Pathogen

Prior to the pine wood nematode (PWN) being shown to be the causal agent of pine wilt disease, the widespread death of pines in Japan had been attributed to bark and wood boring insects, especially coleopteran insects in the families Cerambycidae, Curculionidae, and Scolytidae. However, during a national project (1968–1971) to find a control for the problem it was shown that such insects, which supposedly had been responsible for killing the trees, could not lay their eggs in healthy pine trees, and also that the trees were wilting prior to insect attack. Consequently, the goals of the project had to be changed from focusing just on insects as causing the mortality to looking at other possible causes such as microorganisms, edaphic, tree physiological, and climatic factors.

In early autumn, 1968, Dr. Y. Tokushige, a tree pathologist member of the National Project at the Kyushu Branch of the Forestry and Forest Products Research Institute (FFPRI), while looking at possible causes of the problem happened to notice something in a Petri dish that caught his eye. The pile of Petri dishes on his table contained microorganisms that had originated from the wood of dead pines. The Petri dish that caught his eye contained not only immobile microorganisms but also squirming nematodes. Consequently, Dr. Tokushige asked his colleague, Dr. Kiyohara, a nematologist working in Tokushige's laboratory, to identify the nematode. After careful examination, Dr. Kiyohara identified the nematode as a species of *Bursaphelenchus* (Tokushige and Kiyohara 1969). In subsequent studies the two scientists collected many wood samples from dead pine trees in various districts on Kyushu Island, and confirmed the ubiquitous presence of the nematode in the dead trees, that is, they fulfilled Koch's first postulate by demonstrating that the organism was consistently associated with diseased plants. Most species of the genus *Bursaphelenchus* are mycophagous and can be propagated on fungi. Next, to fulfill Koch's second postulate they reared the nematodes on some fungi isolated from dead pine trees. They then identified the potential pathogens and inoculated them into pine seedlings to determine their pathogenicity. Although they were

skeptical about the ability of the nematode to kill trees, they also inoc ulated *Bursaphelenchus* nematodes into eight, pine trees growing outdoors at the Institute. Surprisingly, most of the trees receiving the nematodes showed acute and well-defined wilting symptoms, that is, the researchers had fulfilled Koch's postulate No. 3. Thus, they had fulfilled Koch's postulates for the newly found *Bursaphelenchus* nematode. After the unexpected results of their initial work, they made a well-planned, series of inoculation trials consisting of eight experiments. In 1970 they made many inoculation tests and clearly confirmed the pathogenicity of the *Bursaphelenchus* nematode (Kiyohara and Tokushige 1971).

1.2 New Control Tactics and Discouraging Results

About 40 species of *Bursaphelenchus* nematodes had been described before PWN was found with of them having a phoretic relationship with insects, that is, they are vectored by insects. Using this knowledge an intensive search for vector insects of the PWN was conducted with emphasis on the insects related to wilting and dead pine trees. Ultimately, a species of sawyer beetle, *Monochamus alternatus*, was found to be the sole vector of the PWN (Mamiya and Enda 1972; Morimoto and Iwasaki 1972), and after exhaustive research the disease cycle was determined (Mamiya 1975). Based on this new information, spraying pine trees with an insecticide such as fenitrothion was implemented to prevent maturation feeding of *Monochamus* beetles. This new control tactic received government support in 1978. Such spraying seemed to be effective and reasonable, but its use over vast areas of pine forests raised environmental concerns which have always restricted its use. Such restrictions have led to poor overall results. Thus, as the result of pine wilt disease Japanese pine forests have suffered losses of over 46 million cubic meters of trees in the last 50 years.

1.3 Spread of Pine Wilt Disease to Other Countries

Pine wilt disease spread from Japan to neighboring East Asian countries such as China and Korea in 1982 and 1988, respectively. Both countries have made enormous efforts to eradicate the disease by employing similar control methods as used in Japan, but there too the results have never been successful (see Chaps. 4 and 5). After the discovery of PWN in wood chips imported from Canada and the USA, Nordic governments placed a strict ban on the importation of wood products from these and other countries where PWN occurs. The European and Mediterranean Plant Protection Organization (EPPO) listed both the PWN and the vector *Monochamus* beetles as quarantine pest A1, and implemented strict inspection of imported wood products. In 1999 pine wilt disease was found in Portugal (see Chap. 6), thus this epidemic disease has become a widespread threat to forests.

1.4 The Purpose of This Textbook

Because of the serious damage that pine wilts causes many scientists have tried numerous techniques for its control. So far, more than 3,000 papers on pine wilt disease have been published in Japan, and as well many papers have been published in China and Korea. Since most of these papers have been written in the local language it is difficult for foreigners to access them. To solve this problem, Dr. Y. Kishi made an extensive review of the Japanese literature, which he published in English (Kishi 1995). Since then, however, research on pine wilt disease has progressed at a rapid rate and innumerable papers have been published. Consequently, in 2006 Dr. B.G. Zhao and Dr. K. Futai agreed to prepare this new textbook, which includes both basic information about pine wilt and updates recent findings on the disease.