Risk Analysis of *Passalora sequoiae* Invasion to China with Imported Coniferous Wood

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Abstract According to international standard plant quarantine measures and principle risk analysis (ISPM No. 11), a risk assessment was carried out for *Passalora sequoiae* through geographical distribution, possibility of colonization, probability of diffusion, economic importance and difficulty in risk management. Results show that *P. sequoiae* has a greater risk of introduction and diffusion, and it has distributed in parts of China. It is suggested that *P. sequoiae* should be added to the list of forest dangerous pests in China. Besides, porting departments should focus on the pathogen on imported host seedlings like *Cryptomeria*.

Key words *Passalora sequoiae*; Pest; Risk analysis

1 Introduction

Passalora sequoiae Ellis & Everhart, belonging to *Passalora*, Mycosphaerellaceae, Capnodiales, Dothideomycetes, Pezizomycotina, Ascomycota, Fungi, is the teleomorph of *Cercospora sequoia*, causing widespread damage to coniferous plants. In 1887, it was first found on *Sequoiadendron giganteum* in Pennsylvania (USA)[1]. In the early 20th century, *P. sequoiae* occurred in a large area on *Cryptomeria japonica*. Later, the phenomenon of needle blight was found on *Taxodium mucronatum* in the Philippines. Ito K *et al.* studied the pathogen, *C. crytomeriae*, on *C. japonica* and *C. sequoiae* in the United States, and found that it was impossible to distinguish the two pathogens clearly. In subsequent studies, scholars named the disease after needle blight symptom caused by the pathogen[2-5], so it is called *P. sequoiae* in this paper. According to the EPPO, the pathogen had been successively included in A_1 List of warning organisms by Egypt in 2018 and Chile in 2019.

2 Risk assessment of *P. sequoiae* invasion

2.1 Geographical distribution *P. sequoiae* is distributed widely in the southeastern United States (including Texas and Oklahoma) and central United States (from Pennsylvania to Nebraska)[6-7], and locally in Tokyo, Akita, Gunma, and Kochi prefectures in Japan[3,8].

It has been found in 7 provinces of China, namely Hubei (Wuhan)[9], Henan (Zhumadian)[10], Taiwan[11], Jiangsu, Zhejiang and Sichuan[12].

2.2 Possibility of invasion In late summer and autumn, the hosts infected with *P. sequoiae* begin to show blight symptoms near the main stem, with needles initially turning from bronze to dark red, and finally falling off in October - November. Usually all the needles on the shoots are infected, and then the leaves begin to fall from the bottom to the top of the tree, and from the inside of the branches, with a duration of several years. In severely affected hosts, the branches will become loose, and the twigs will be elongated by fallen leaves, looking like they have been scorched by fire. *P. sequoiae* may infect the hosts throughout the summer. The conidia usually germinate on 0 - 1 year old leaves, enter the leaves through stomata or directly through the cuticle, and develop symptoms 2 - 3 weeks later. The pathogen survives the winter in the diseased leaves of living trees. The spores can make short distance transmission by water or wind.

As cultured at 25 ℃ for 1 month, the colony of *P. sequoiae* is dark green to blackish green, with a diameter up to 20 - 30 mm, and the aerial mycelia are white to gray, covering the entire colony. When 1 - 2 year old *Cryptomeria* seedlings were inoculated with spore suspensions and then placed in a humid environment at 20 - 30 ℃ for 48 h, needle blight symptoms appeared at 30 d post inoculation, and the inoculated seedlings developed more severe symptoms in the field at 2 months post inoculation[2,13-14]. It came to the same result when inoculating *Cryptomeria* seedlings with spore suspensions or mycelia[15]. The histological reaction results of *Cryptomeria* seedlings inoculated with *P. sequoiae* demonstrated that peridermal lesions were formed at the inoculation site at 4 d post inoculation, and lignin, suberin and a kind of phenolic substance appeared in the cork layer cells; at 32 d post inoculation, the mycelia of *P. sequoiae* could be observed in the peridermal wound and cork cambium, but no mycelia was observed in the tissue and around the wound[16].

In summary, there is a risk of *P. sequoiae* invasion to China along with infected seedlings or branches.

2.3 Possibility of colonization Coniferous trees, especially *C. japonica*, *S. giganteum*, *T. distichum*, *T. mucronatum*, *Cedrus* sp., *Juniperus* sp., *Cupressus arizonica*, *Platycladus orientalis*[17], and *Metasequoia glyotostroboides*[9], are easily colonized by *P. sequoiae*.

Most of the above species, such as *Cryptomeria* sp., *M. glyo-*

Received: September 20, 2023 Accepted: January 7, 2024
Supported by Projects of General Administration of Customs (2020HK159); Nanjing Customs Research Projects (2023KJ20).
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tostroboides, *T. distichum*, *Cedrus* sp., are widely planted in China, and the warm and humid climates in South China and East China are suitable for the colonization of *P. sequoiae*.

2.4 Possibility of diffusion *P. sequoiae* can be easily transmitted through seedlings, but is relatively hard to make long-distance transmission through wood. Warm and humid weather is conducive to the development of *P. sequoiae*. Water is the necessary medium for the spread, germination and infection of pathogenic spores, so rainfall can increase the infection efficiency of *P. sequoiae*. Spores are spread by rain and rarely travel long distances with wind, most settling within a few feet of the initial infection site. When the precipitation is higher than average, the woodland will be more severely infected, and the hosts usually begin to show symptoms 2 – 3 weeks after being infected.

Seedlings and furred branches are the main approaches of long-distance transmission of *P. sequoiae*. *P. sequoiae* is a pathogen on *C. japonica* that causes severe needle blight in *C. japonica* seedlings, and the disease was not recorded before the 20th century, though *C. japonica* seedlings were cultivated from seeds in Japan as early as the 16th century. At first, the pathogen on *C. japonica* was thought to be *Cercospora* sp. native to Japan and was named *C. cryptomeriae* Shirai. Later, through morphological and etiological studies, it was proved that *C. crytomeriae* in Japan belonged to the same species as *P. sequoiae* in the United States. *P. sequoiae* was introduced to Japan in the early 20th century along with susceptible coniferous woods in the United States and quickly spread in *C. japonica*[4,18].

Overall, once *P. sequoiae* colonizes in China, it will spread rapidly under suitable host and climatic conditions.

2.5 Economic importance *P. sequoiae* can cause devastating damage to coniferous seedlings, such as *Cryptomeria* sp., *S. giganteum*, *etc.*, and it is difficult to control the pathogen due to rapid development and diffusion. Small pale brown spots first appear on the needles, and then become larger and brownish throughout the needles, eventually leading to curliness and defoliation of needles. When the host is infected again, the needles with diseased spots gradually fall off and many powdery clumps are produced on the infected leaf, ranging in color from greenish brown to tan. The pathogen can infect not only the needles but also the new buds. In severely damaged conifers, almost all the needles are lost, and only a few green needles remain in the top branches[19].

From 1868 to 1926, needle blight of *Cryptomeria* sp. caused by *P. sequoiae* spread throughout Japan, while *C. japonica* accounted for about half of Japan's planted forests. The pathogen caused serious losses, leading to a crisis in seedling production. Although effective control methods have been established, it is still serious in the nursery land of conifer[8].

In 1977, needle blight was found on potted seedlings of *T. mucronatum*, which had been introduced from the United States to the Padar Forest of the Philippines. In the artificial windbreaks of the Rocky Mountains in the United States, the harm caused by *P. sequoiae* was more serious than that caused by *Phomopsis*[6].

Cryptomeria sp., a major host of *P. sequoiae*, is a unique species in China, distributed in the south of the Yangtze River basin to Guangdong, Guangxi, Yunnan, Guizhou, Sichuan and other places. *Cryptomeria* sp. prefers a warm, humid mountain climate. *Cryptomeria* sp. is an important timber tree because of tall crown and straight trunk. *M. glyotostroboides*, the other host, is known as the "living fossil" in the plant kingdom. It is native to Sichuan Province and now has been widely planted in China. Once *P. sequoiae* is introduced and spread, it will pose a threat to forest ecology and resources.

2.6 Difficulty in risk management In the forest with close planting spacing, it is difficult to control *P. sequoiae* once occurred. Proper spacing between forests, rapid air flow between forests and rapid drying of leaves can effectively inhibit the occurrence of *P. sequoiae*.

In the humid summer months, it is necessary to apply chemical control measures. Although the symptoms appear in late summer to autumn, *P. sequoiae* infects in summer. Therefore, fungicides (copper-based products and other fungicide types) must be applied at least twice in early June and again in early July. Sometimes, the application of fungicides may not be effective, so it is necessary to apply fungicides for the third time in middle and late July. When spraying, the leaves must be completely covered by the agents, especially the lower two-thirds of the crown. Once the disease is under control, it may be not necessary to apply fungicides annually. However, trees should be carefully inspected every year to monitor for recurrence[11].

3 Conclusions

P. sequoiae has been distributed in 6 provinces of China, and is more restricted to the United States and Japan internationally. Currently, China has not imported *Cryptomeria* seedlings from the above two countries. Considering the degree of damage, distribution and management difficulty, it is suggested that *P. sequoiae* should be added to the list of dangerous forest pests in China for the time being. In the future, when there are imported *Cryptomeria* sp., *Taxodium* sp. and other seedlings, porting departments should focus on checking the existence of *P. sequoiae*.

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ping. It is necessary to implement effective control methods suitable for the characteristics of Lu'an City, which must coordinate with each other and use less or no chemical agents. Starting from seedling cultivation, the control work of nursery and plant inspection must be strictly checked, so as to make scientific and systematic control of landscape plant diseases. Through this survey, the occurrence of plant diseases in urban parks, residential areas, roads and other green space in the main urban area of Lu'an City has been generally understood, and the species and causes of the diseases have been mastered. Meantime, targeted prevention and control countermeasures are also put forward, in order to provide a reference for the prevention and control of landscape plant diseases in the urban area of Lu'an City.

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