Pitch canker: Risk of establishment in New Zealand based on a global perspective

Rebecca Ganley[1]

Abstract

Fusarium circinatum is the casual agent of the disease known as pitch canker and has been considered one of New Zealand's most undesirable and unwanted exotic forest pests. Pitch canker is present in a variety of locations worldwide. However, the behaviour of this disease varies considerably between countries, depending on the host tree species, climate, wound agents, host resistance and silvicultural practices. The risk of establishment and potential control of pitch canker in New Zealand is discussed, based on observations of this disease overseas and current literature. In the absence of intricate insect-host systems, insects currently in New Zealand are unlikely to play a significant role in disease establishment. Temperature and humidity levels would be sufficient in many areas for the establishment of pitch canker and the disease would be expected to be more severe in areas with more tropical weather conditions than regions that are colder or dryer. The effect of nutrient levels in plantations on disease establishment or severity is unclear but fertilisation would not be recommended. If detected early, *F. circinatum* could be eradicated.

Introduction

Pitch canker was first described in North Carolina, USA (Hepting and Roth 1946) and the pathogen is throughout the southeastern (SE) USA occurring from Florida to as far north as Virginia, and westward to Texas (Ridley and Dick 2000). The disease was first observed in California in 1986 and appears constrained to near coastal regions (Gordon *et al*. 2001), although *Fusarium circinatum* has been found inland in *Pseudotsuga menziesii* (Douglas-fir) in the Sierra Nevada (Vogler *et al*. 2004). Despite early expectations to the contrary, pitch canker has not spread northward beyond California. In addition to the USA, other countries known to have *F. circinatum* include: Haiti (Berry and Hepting 1959), Chile (Wingfield *et al*. 2002b), Japan (Kobayashi and Muramoto 1989), Mexico (Britz *et al*. 2001), South Africa (Viljoen *et al*. 1994), and Spain (Landeras *et al*. 2005). Mexico and the SE USA are both likely to be centres of origins of this pathogen due to the genetic diversity and disease levels in these regions.

In Spain, pitch canker has been found in *Pinus radiata* plantations and in nurseries on *P. radiata* and *P. pinaster* (Landeras *et al*. 2005). Other susceptible species present in the nurseries, *P. nigra*, *P. sylvestris*, and Douglas-fir, did not show disease symptoms (Landeras *et al*. 2005). The distribution of this pathogen in Spain is unknown. However, based on its presence in plantations and methods of dissemination, it is possible that *F. circinatum* could be across this country, if not further into Europe. It is unknown how *F. circinatum* was introduced to Spain. In South Africa, *F. circinatum* was first identified in the early 1990s in several nurseries. Despite high levels of inoculum, pitch canker had not become established in plantations until its recent discovery throughout several *P. radiata* stands in the Western Cape Province, over 15 years since it was first introduced (Coutinho *et al*. 2007). In Chile, *F. circinatum* is also known to be present in nurseries but is not spreading between plantations. The pathogen is present in only a few nurseries in the drier, northern *P. radiata* growing regions and not in the south of Chile. Infected but symptomless seedlings from nurseries have been outplanted and later developed disease symptoms, however, pitch canker has not become established in the field. *Fusarium circinatum* is believed to have been introduced to both Chile and South Africa from contaminated seed stock (Wingfield *et al*. 2002a).

Fusarium circinatum is present in a variety of locations worldwide and the disease, pitch canker, is also problematic in many of these countries. Factors such as host tree species, climate, wound agents, host resistance and silvicultural practices can influence the establishment, frequency and severity of this disease. This report reviews the epidemiology and current situation of pitch canker worldwide, based on both a review of the current literature and personal observations of the pathogen/disease in a variety of different countries. The risk and potential of establishment of pitch canker in New Zealand is discussed, along with the possible impact and preventative methods that have or could be employed.

Wounding agents, vectors and climate

Fusarium circinatum can be disseminated through infected seed or by spores, which can be vectored by a variety of agents such as wind, rain, animals, insects or soil. In California, over 80% of seed is infested with *F. circinatum* mainly due to spread by cone-feeding insects (Storer *et al*. 1998). Seed-borne infections are also common in the SE USA, although, the frequency varies between tree species (Dwinell *et al*. 1985) and is probably related to specific insect relationships with the host. In contrast, there is little indication of seedborne infections in exotic planted pines in other countries with pitch canker; this is likely due to the lack of host specific cone-feeding insects in these regions.

Spore vectored infections are only successful when

[1] *Ensis, Private Bag 3020, Rotorua*

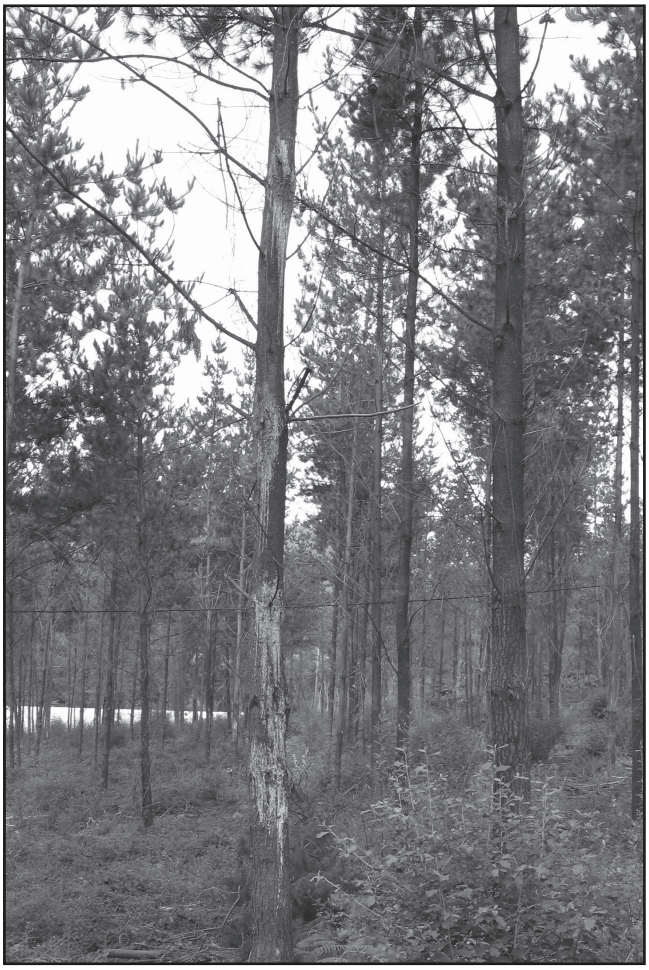

Figure 1. Severe resinous lesions in Pinus radiata *from multiple infections along the bole of the tree.*

Figure 2. Pinus radiata *plantation heavily infected with pitch canker.*

dissemination of the spores is coupled with wounds or openings on the trees. In general, wounds may be caused by insects, weather or mechanical damage, however, the relative importance of these agents can vary between locations. A marked difference has been apparent between the SE USA, where the disease can occur from insect transmitted fungal spores or from infection of weather or mechanical injuries (Dwinell *et al.* 1985), and California, where pitch canker infections are almost solely associated with insects. Although infections of wounds caused from weather or mechanical injuries can occur in California, the frequency is so low that this form of infection is considered unimportant. Little is known about the effect or frequency of infection of wounds caused from weather or mechanical injury versus insect vectors on the spread of pitch canker in Spain or South Africa.

Although wounding is critical for infection, it is apparent that not all types of wounds result in pitch canker. The type of wound created and wound/climate conditions are important for successful infection to occur. For instance, it has been suggested that wounds that result in high resin exudation may effectively seal the wound, preventing infection and that wounds that are exposed to moisture, such as from plant moisture (deeper wounds) or atmospheric conditions, are more likely to result in successful infection (Sakamoto and Gordon 2006). These factors could help explain differences in infections from different feeding insects and also the variation in infection of weather/mechanical wounds in the SE USA versus California. For example, high humidity and temperature in the SE USA may be more conducive for infection of weather or mechanical wounds. Although coastal California is frequently subjected to a belt of fog, it is possible that the lower temperature in these regions when the fog is present suppresses pathogen growth, as temperatures of 9°C in the laboratory have been found to prevent growth (McDonald 1994). When the temperature rises to a more optimal level, the fog belt may effectively get "burned off" thus, reducing the relative humidity to levels not conducive for infection of weather or mechanical wounds. For insects, infections may only occur from 1) the creation of wounds deep enough to provide adequate moisture, 2) wounds created by insects that also vector the pathogen (i.e. spores present at wounds before wound can dry out), or 3) wounds that do not result in substantial resin production. This makes native host-insect associations extremely important. For instance, infection levels in exotic pines planted in California have been substantially lower than those in native pines and this variation has been attributed to a lack of visitation by the native, host-specific insect populations present (Clark and Gordon 1999). Likewise, the low frequency of suitable insect wounding agents and climate conditions potentially not conducive to infection in South Africa and Chile, is thought to have lowered the likelihood of infection in these regions.

Silvicultural practices

Silvicultural practices such as fertilisation, stand density and irrigation have been found to influence the incidence and severity of pitch canker. Fertilisation or high levels of nitrogen (N) in pine stands can result in intensification of the disease (Blakeslee *et al.* 1999). Recent outbreaks of pitch canker across the SE United States have been attributed to air pollution from chicken houses, which have been found to increase foliar N levels, thus increasing disease susceptibility (Lopez-Zamora *et al.* 2007). Likewise water stress from overstocking or drought can also exacerbate

Figure 3. Pine plantation in Florida devastated by pitch canker. Increased foliar nitrogen levels from emissions from an adjacent chicken house (see white roofs in background) are responsible for the outbreak of pitch canker in this plantation. A hurricane subsequently toppled many of the dying or dead trees.

pitch canker outbreaks. Thinning or irrigation can reduce the effects of pitch canker (Blakeslee *et al*. 1999). Thinning combined with fertilisation resulted in high disease levels, equivalent to those found with fertilisation alone, indicating the importance of nutrient levels for this disease. In California, water stress from overstocking of stands and drought has been attributed to disease intensification during the 1980's, when the worst levels of disease were recorded. In other countries, severe levels of pitch canker in overstocked plantations at about the time of crown closure indicates that water stress is an important factor in the progression of this disease.

Genetic resistance

Genetic resistance to pitch canker has been demonstrated in all pine species tested. *P. radiata* is considered one of the most susceptible species and greenhouse trials have predicted that only 0.3-2.1% of New Zealand's stock is resistant to the disease (Hodge and Dvorak 2000). However, there appears to be an age related factor, as resistance does not appear to be operative in young *P. radiata* seedlings, suggesting that the low level of resistance from greenhouse trials may not be applicable for more mature plants (Aegerter and Gordon 2006). Douglas-fir is considered moderately resistant to the disease, although little is known about the epidemiology or the effects of pitch canker on this tree species. In addition to genetic resistance, induced resistance responses from repeated pathogen attack have also been demonstrated in the native populations of *P. radiata* in California (Bonello *et al*. 2001). The long-term effects and mechanisms behind this form of resistance are currently being investigated and it is unknown whether such mechanisms would also occur in New Zealand. Initially, it was predicted that California could lose at least 85% of its *P. radiata* population, based on an estimated 15% field resistance (Storer *et al*. 1997). More recently, the level of mortality and severity of infections has reduced and pitch canker appears to be becoming a balanced

Figure 4. Pitch canker in Pinus radiata *in California. Many of the mature trees that were predicted to die have not and are showing signs of disease remission.*

part of the *P. radiata* ecosystem, potentially replacing fire as an agent to open and regenerate stands.

Control

A variety of control methods has been investigated for preventing and/or reducing the effects of pitch canker. Once the disease is established, the most common form of control has been to prune branch infections when first detected and to remove heavily infected or dying trees (Gordon *et al*. 2001). Insecticides, fungicides and bacterial-biological control methods have also been investigated. Although all have been shown to reduce the number of infections, the reductions in infections were generally not significant nor were they feasible for large-scale prevention (Tjosvold and McCain 1988; Barrows-Broaddus and Dwinell 1985; Runion *et al*. 1993). Several chemicals have been found to reduce external contamination of infected seed, but no methods have been effective at eliminating *F. circinatum* from internally-borne infections (Storer *et al*. 1998). In view of this, the current restrictions on the importation of pine seed to New Zealand should be retained. In South Africa and Chile, where pitch canker is problematic in the nurseries, sanitation procedures of soil, containers and infected material are used to help control the disease. If more stringent procedures had been enforced it is believed that this disease could have been eradicated.

Risk of establishment

It is possible that pitch canker could be introduced to New Zealand through infested seed, soil, timber or on insects. Restrictions have been placed on seed imported from countries known to have pitch canker and seed must also be screened for the presence of *F. circinatum*. Timber and wood products also pose a risk for the introduction of *F. circinatum* and wood from areas not considered to be free of *F. circinatum* must be heated treated before it can be imported (Biosecurity New Zealand, 2007). Despite these procedures, it is still possible that countries listed as being *F. circinatum* free may not be, due to proximity to infected regions, and contaminated seed could escape detection and potentially become established in nursery stock. Similarly, the fungus could inadvertently be introduced on crates or pallets made from contaminated material in other countries thought to be free from *F. circinatum*. Also, the origin of wood used to make crates and pallets is usually not known. No nursery stock of *Pinus* species or Douglas-fir can be imported into New Zealand (Biosecurity New Zealand, 2007).

If *F. circinatum* were introduced into New Zealand, predicting how it would function is difficult as disease establishment and severity requires a combination of many environmental factors and the fungus behaves differently in different regions, as described. Insects closely associated with pitch canker in the USA, such as *Ips* spp., *Ernobius punctulatus*, and *Pissodes nemorensis* are not present in New Zealand. It is possible that many of the insects that are present here could vector *F. circinatum* but as the majority would not feed or create suitable wounds, the likelihood of disease establishment would be low unless favourable wound conditions were encountered. The effect that damage caused by possums could have on the spread of pitch canker is unknown. New Zealand's climate is thought to be conducive to pitch canker based on its similarity to California. However, pitch canker is an insect-associated disease in California and infections of other types of wounds are so low that these are not considered important. It is likely that a combination of both high humidity and temperature is important for infection of weather or mechanical wounds. Drier climate in Chile and South Africa is thought to have helped prevent the spread of this disease from the nurseries to the plantations, despite the abundance of spores present. Areas of northern Spain and the Western Cape Province, South Africa where pitch canker has been found in plantations are coastal and this is likely to have contributed to disease establishment. The climatic conditions in New Zealand would be considered sufficient for the establishment of pitch canker but low temperatures in some areas could hinder pathogen growth, thus, minimising the likelihood of infections occurring in these region. Pitch canker would be expected to be more severe in some coastal regions or in areas with more tropical weather patterns that mimic those in the SE USA. Colder or dryer regions would be expected to have a low incidence and severity of disease.

Perhaps of more importance than climate conditions are the silvicultural influences on pitch canker. Stand density is unlikely to be influential in the establishment of pitch canker in New Zealand as *P. radiata* plantations are generally well spaced. However, the majority of plantations are subjected to fertilisation treatments or are planted in areas with high nutrient levels, which is of concern. The low nutrient levels in regions of Chile and South Africa, where there is *F. circinatum* inoculum but pitch canker is not present in the plantations, are likely to have contributed to the lack of disease establishment. The exact effect that New Zealand's nutrient levels in plantations could have on the incidence of pitch canker is unknown. Management of pitch canker, if *F. circinatum* were to become established, would be difficult in the absence of effective control treatments. Genetic resistance could be utilised but the degree to which it could contribute is unclear. Eradication of the pathogen could be possible if detected early and especially so, if it were limited to nurseries.

Conclusion

Pitch canker is a varied and complex disease of *Pinus* species. Despite the establishment of this disease in many countries worldwide on a variety of hosts, it is difficult to predict how *Fusarium circinatum* would behave if it were to be introduced to New Zealand. Eradication of this fungus is possible if measures are swift and stringent. If pitch canker were to be established in New Zealand, there are positive reports from some countries of success in maintaining or lowering the level of disease incidence and severity. For instance, the apparent remission of pitch canker in California, the management of pine plantations in the southeast USA, and the prevention of spread both between nurseries and to plantations in Chile and, for a significant period of time, in South Africa. Regardless, continued vigilance and monitoring for this disease is essential for prevention or early detection of this pathogen in the forestry sector.

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