The future of exotic plantation forestry in the tropics and southern Hemisphere: Lessons from pitch canker

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SYNOPSIS

Exotic plantation forestry, particularly with *Pinus* and *Eucalyptus* species in the tropics and southern Hemisphere, has expanded dramatically during the course of the last Century. Success of these intensively managed plantations is largely attributed to the fact that trees have been separated from their natural enemies. Due to increasing rates of introduction of pests and pathogens, this is a situation that is changing relatively rapidly. There is also growing evidence that unexpected native pests and pathogens are developing the capacity to infect exotic plantation trees. Clearly, highly productive, and intensively managed fibre farms are threatened and their future is likely to be more complicated than it has been in the past. The appearance of the pitch canker pathogen, *Fusarium circinatum* in South Africa, provides a contemporary example of new problems relating to a pathogen, previously absent from a country. This pathogen was first found in a single nursery and it has rapidly spread to all South African pine nurseries. It has significantly complicated pine propagation and is resulting in substantial losses in plantation establishment. Whether the fungus will manifest itself as a pathogen of adult trees as is the case elsewhere, is unknown. But this prospect is a matter of serious concern. Research aimed at a better understanding of the biology of *F. circinatum* in South Africa is essential. Furthermore, development of disease tolerant planting stock, in advance of a potentially deteriorating situation, would appear to be crucially important.

INTRODUCTION

The propagation of exotic tree species in intensively managed plantations of the tropics and Southern Hemisphere, contributes substantially to international paper and pulp production. The most extensively planted trees in these situations are species of *Pinus*, *Eucalyptus* and *Acacia*. The success of exotic plantation forestry is unquestionably linked to the fact that trees have been separated from the pests and diseases that damage them in their native environments (Wingfield *et al.* 2001 a, b). In this respect, they might be considered akin to weeds (Bright 1998).

In some countries that have extensive forestry industries, the focus is primarily on a single species. Typical examples are New Zealand and Chile that have huge forestry programmes based on *Pinus radiata*. Other countries rely on a suite of tree genera and species for their plantation programmes. In the latter group, the decision to develop, improve and propagate different species has not necessarily been based on a desire to minimise risk. It has rather emerged from the fact that the countries concerned have wide diversities of climatic zones and sites, which would not be suitable for the propagation of any single species.

Countries relying primarily on single exotic species for plantation forestry are well aware of risks due to pests and diseases (Gibson 1979; Chou, 1991; Wingfield *et al.* 2001 b). There are various views relating to risk abatement. It can thus easily be argued that propagation of single species enables companies to expend added research funding on improvement and risk abatement, through research. We do not contest this argument. Our warning is, however, against the danger of perceiving that such inputs are made, when they might not be sufficient to offset the risks of a serious disease epidemic.

In this paper, we consider various aspects of the risks posed to exotic plantations by pathogens. This is done using pitch canker caused by *Fusarium circinatum* (*Gibberella circinata*) as an example. Our choice of this example is based on a number of factors including:

- The relatively recent emergence of pitch canker causing an epidemic disease of native *Pinus radiata* in California (Correll *et al.* 1991; Gordon *et al.* 2001).

- The discovery of the pitch canker fungus in South Africa approximately one decade ago (Viljoen *et al.* 1994). This was more or less concurrent with its appearance in California and the fact that it is causing increasing damage.
- The recent discovery of *F. circinatum* in nurseries in Chile (Wingfield *et al.* 2002), where it is considered to be a high priority threat.
- The wide scale planting of the highly susceptible *P. radiata* in Australia and New Zealand and the threat that pitch canker poses to these countries (Devey *et al.* 1999).

ORIGIN OF THE PITCH CANKER PATHOGEN

Until relatively recently, pitch canker was known primarily as a disease particularly of *P. elliottii* in the South Eastern United States. The disease was first discovered in that area in 1946 (Hepting and Roth 1946) and it was hypothesised that it might have originated in Haiti. The impact of the disease was variable with occasional severe outbreaks, usually associated with physical damage to trees and with stress conditions (Dwinell and Phelps 1977; Dwinell *et al.* 1985).

Pitch canker was found in California for the first time in 1986 (McCain *et al.* 1987). The disease initially occurred on ornamental *P. radiata* trees, but it has subsequently spread to native stands where damage is severe (Correll *et al.* 1991; Devey *et al.* 1999; Gordon *et al.* 2001). The very high level of susceptibility of *P. radiata* to the pitch canker fungus has raised great concern in countries such as Australia, Chile and New Zealand, where this tree is extensively grown as an exotic in intensively managed plantations.

Fusarium circinatum first appeared in South Africa in 1991 (Viljoen *et al.* 1994; Viljoen *et al.* 1997 a). At this time, the fungus caused severe damage to *Pinus patula* seedlings in a major pine production nursery. This situation was confusing at the time because *P. elliottii*, the species best known as a host of *F. circinatum*, was not seriously damaged. There was no evidence of *P. patula* being affected by this pathogen elsewhere in the world and to some extent, this slowed the process of identifying the pathogen.

Recent studies have added substantially to our understanding of the origin of the pitch canker fungus. A series of studies based on DNA marker technology has shown that the fungus almost certainly originated in Mexico (Wingfield *et al.* 1999; Wikler and Gordon 2000; Britz *et al.* 2001). More specifically, it now appears that isolates of the fungus causing the pandemic in California originated in the eastern United Sates (Gordon *et al.* 2001). Those introduced into South Africa appear to have come directly from Central America, and they were probably introduced with seed of Central American pines.

Population genetic studies of *F. circinatum* associated with the first outbreak in South Africa, showed that the fungus was represented by a relatively uniform genetic base (Viljoen *et al.* 1997 b). At that time, there were 24 genotypes of the fungus recognised, but it was also shown that sexual reproduction was probably occurring in the fungus (Viljoen *et al.* 1997 c). This was the first clear evidence of sexual reproduction in the pitch canker fungus. Since its first appearance in a single nursery in South Africa, the pitch canker fungus has spread rapidly to other nurseries and it now occurs in all pine growing areas of South Africa. In a recent study where a contemporary population of the fungus was compared with the original population studied by Viljoen *et al.* (1997 b), it was shown that the genetic diversity of *F. circinatum* has increased markedly in South Africa (Britz 2002). The fungus is clearly well established in South Africa and there is anecdotal evidence that it has spread to plantations where it is causing problems in pine establishment.

THE CHANGING SITUATION

The pitch canker fungus has caused huge damage to pine propagation in South Africa. There is also good evidence to suggest that the situation is deteriorating. The involvement of the pathogen in failed pine establishment is worrying and its association with basal cankers on trees up to two years old, adds weight to this concern.

Whether *F. circinatum* will eventually cause cankers on mature trees is difficult to assess. One of the most obvious differences between the situation in South Africa and California, is the fact that many native pine infesting insects are associated with pitch canker in the latter case. We have previously suggested that the lack of these insects in South Africa might preclude the appearance of the more serious manifestation of this disease (Wingfield *et al.* 1999). However insects such as *Pissodes nemorensis* that are associated with pitch canker in the eastern United States, also occur in South Africa and could provide wounds for infection of trees in this country. Although one wishes to be optimistic, there is sufficient reason to be greatly concerned about the future of the pitch canker fungus in South Africa. Similar concerns might also be felt in countries such as Chile, where the fungus is now present (Wingfield *et al.* 2002), a highly susceptible tree species is planted and where various insects such as the pine tip moth (*Rhyacionia buoliana*) could provide infection courts for the fungus.

SUSCEPTIBILITY OF PLANTING STOCK

One of the reasons that the pitch canker fungus has caused such severe damage in pine nurseries, is linked to the high level of susceptibility in *P. patula* (Viljoen *et al.* 1994, Viljoen *et al.* 1997 a). Although not the only species propagated, *P. patula* is the most extensively planted pine species in South Africa. It is for this reason that the threat of pitch canker needs to be taken seriously. In evaluating risk, a key question that arises is whether *P. patula* harbours any resistance to *F. circinatum*.

A number of studies have considered the susceptibility of a range of pine species to the pitch canker fungus. In one of these, Hodge (1999) inoculated seedlings of a large number of *Pinus* spp. and showed that *P. radiata* and *P. patula* had virtually no resistance to the pitch canker fungus. This experiment used a very drastic inoculation procedure and possibly did not accurately reflect levels of susceptibility within species. What is important to recognise is that ecologically, pitch canker on *P. radiata* in California would be markedly different to the disease on *P. patula* in a country such as South Africa. In California, *P. radiata* is native and the pitch canker fungus is clearly an exotic invader. This disease situation might thus be compared with other tree diseases such as Dutch elm disease and Chestnut blight that are devastating diseases caused by exotic pathogens on native hosts (Boyce 1961; Sinclair *et al.* 1987; Manion 1991). We have good evidence to show that the pitch canker fungus is present on *P. patula* in native stands in Mexico (Britz *et al.* 2001). One should thus expect that *P. patula* has evolved with the pathogen and that this species should harbour some level of resistance to the disease.

Selection of *P. patula* families for resistance to the pitch canker pathogen must be one of South Africa's primary lines of defence against this and other fungal pathogens. Various trials are currently in progress to assess opportunities in this domain. However, there is also a clear need to seek alternative planting stock, or genes linked to resistance, that might be useful in breeding programmes.

Exotic *Eucalyptus* plantation forestry has been greatly successful in many parts of the world, including South Africa. This industry has, however, been seriously affected by diseases. One of the strategies developed to deal with serious diseases such as Cryphonectria canker caused by *Cryphonectria cubensis*, has been to promote vegetative propagation of disease resistant hybrids (Wingfield *et al.* 2001 b). The same strategy has been used to deal with incursions of diseases such as Coniothyrium canker caused by *Coniothyrium zuluense* (Wingfield *et al.* 1997). Our view is that South Africa, and other countries such as New Zealand, Australia and Chile, might best deal with disease threats such as those linked to pitch canker through intensive promotion of hybrid pine forestry. Evidence from early trials in South Africa has shown encouraging signs of resistance of pine hybrids in trials. Although complex and slow to progress, we strongly recommend enhanced efforts to develop outstanding pine hybrids, with resistance to the pitch canker fungus.

SUPER PATHOGENS

While we strongly recommend breeding and particularly the development of pine hybrids to reduce the risks associated with pitch canker, we also warn against dangers linked to changes in the pathogen. As already mentioned earlier in this paper, there is good evidence that the pitch canker fungus is undergoing sexual recombination in South Africa. It is thus likely that the pathogen would become adapted to newly developed planting stock, with time. Thus, ongoing breeding and development programmes will be necessary to maintain a longer-term base of security.

While hybrid pines might provide an outstanding opportunity to offset the risks of pitch canker, the fact that pathogens also have the capacity to hybridise needs consideration. Hybridisation in fungal pathogens is not a subject that has been particularly well studied. But examples are emerging where pathogens of related hosts have evidently hybridised, and developed the capacity to infect new hosts. One recent example from forestry is that of rust on hybrid poplars (Newcombe *et al.* 2001). Here, a rust hybrid *Melampsora x columbiana* was formed when *M. medusae* hybridised with *M. occidentalis*. This hybrid is now causing losses to poplar hybrids that were previously resistant to infection by *M. medusae*. Similar hybridisation events might be expected with the pitch canker fungus in the future.

GENETICALLY MODIFIED TREES

In the future, it seems likely that genetic modification of trees will provide opportunities to deal with new and damaging diseases. This trend is already reasonably well established for agronomic crops and there is little reason to think that the situation will be different in forestry. There are, however, many hurdles that must be overcome and these mainly relate to environmental issues and safety. Certainly, the ability to manage genetically modified tree crops and to prevent contamination of the environment, by for example genetically modified pollen and seed will be required. In addition, the capacity to multiply and test desirable traits in genetically modified trees, sufficiently quickly for them to be used in extensive planting programmes, will need to be established.

FUTURE PROSPECTS

The pitch canker pathogen has been known in South Africa for little more than a decade. In this short time, it has apparently adapted to the pine-growing environment and has become the major source of loss in pine nurseries and establishment. Much has been learnt about the pathogen in South Africa and the local industry has access to a very significant body of knowledge relating to the *F. circinatum* and its biology. However, many questions still remain. Some of these are as follows:

- Will full-blown pitch canker as it is known in the United States, appear in South Africa and what are the factors likely to be linked to the emergence of this disease?

- Are losses at establishment always directly linked to nursery infections or can non-infected seedlings become infected in the field?
- What is the role of insects in *F. circinatum* infections in South Africa, both in nurseries and in the field?
- What levels of resistance to pitch canker are present in *P. patula* and will it be possible to capitalise on such resistance in selection and breeding programmes?
- What opportunities exist to establish hybrid pines with desirable forestry traits and resistance to the pitch canker pathogen?

Answers to these questions are likely to impact strongly on the future of the forestry industry in South Africa. Most are already being addressed but they are also complex and require a long term view and investment in the future of forestry. It is reasonable to expect that many other new and damaging pests and diseases will affect exotic plantation forestry in the future. Dealing with the pitch canker pathogen invasion in South Africa, and also in other countries reliant on exotic plantation forestry, will clearly also provide a strengthened foundation on which to base risk abatement and disease management programmes.

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