Detection of disease in forest nurseries

by

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THE JOINT FORCES OF CSIRO & SCION

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Client Report No. 40490

Detection of disease in forest nurseries

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Contract No:

CSIRO SCION

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EXECUTIVE SUMMARY

Objectives

1. To determine the optimal method of pest detection survey and sampling in forest nurseries and to recommend best practice for nursery survey methods in the future.

2. To review the world literature relating to incursions to forest nurseries, to demonstrate the quarantine risk associated with forest nurseries and to determine the extent of the risk that New Zealand forest nurseries may act as a pathway for incursions.

Surveys in New Zealand forest nurseries

- An incursion such as *Fusarium circinatum* (the cause of pitch canker disease) is likely to be manifest early in the growing season. Therefore targeting a pre-lift survey for detection of new introductions may be too late to prevent serious losses and possible spread beyond the nursery.

- Altering the timing or the frequency of nursery inspections would not provide additional knowledge of existing disorders that might affect selection for planting out.

- When reporting on known pests and diseases some early season disorders may be missed by a pre-lift survey but this is unimportant. Disorders such as Phytophthora root rot and Dothistroma needle blight are relevant to the forest company purchasing plants and the focus of reports should be on these.

- In all four nurseries surveyed disorders were more frequently of abiotic than of biotic origin.

- Surveyors need to place considerable reliance on nursery staff to provide the history of climatic and chemical effects on plant health. Without this input it may be impossible to separate symptoms caused by micro-organisms or insects and those caused by abiotic agents

- There is a high level of awareness amongst members of the New Zealand Forest Nursery Growers Association of the symptoms of pitch canker and of other nursery problems. It is expected that nursery staff will recognise un-characteristic symptoms and send them to the Diagnostic Laboratory for diagnosis.

Disease incursions in forest nurseries

- Nurseries are strongly implicated in the spread of disease, both to other nurseries and out to the wider environment; within a country and across borders. Seed, scions, whole plants and their growing medium have all been the source of documented incursions.

- In North America and Europe there are examples of micro-organisms entering a new country through the nursery pathway that have been devastating to the forest ecosystems they have entered.

- The only record from New Zealand was the identification of pitch canker in asymptomatic Douglas fir scion material. That it was discovered before the release of the plants from quarantine is an example of effective biosecurity.

- With global trade on the increase the potential for further incursions is ever present.

- The systems currently in place in New Zealand to restrict or monitor plant material for forest nurseries appears to be working well. However there is clearly a need to maintain stringent control.

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Information for Ensis abstracting:

Contract number	
Products investigated	Nursery stock
Wood species worked on	*Pinus radiata*
Other materials used	
Location	Forest nurseries in Auckland, Rotorua and Nelson

INTRODUCTION

Surveys of forest nurseries have in recent years had a two-fold purpose; a pre-lifting report on plant health and condition and also an incursion detection function.. Because of concern in the forest industry over the potential seriousness of pitch canker disease and the knowledge that the fungus responsible was introduced into several countries through nurseries, early detection of a pitch canker incursion was considered a priority. The potential for detection of incursions of other new diseases and insect pests has also been a part of this rationale. To date no new-to New Zealand records of pests or diseases of radiata pine have been made as a consequence of these surveys. As there is high awareness in the forest industry of the nursery/pitch canker link and because there are stringent regulations covering the importation of *Pinus radiata* seed the risk of an incursion of *Fusarium circinatum* through this pathway is negligible. Secondly, forest owners wanted reassurance that the stock they were planting was healthy. Documenting the extent and the cause of disease and pest problems resulting from established micro-organisms and insects helped provide this reassurance. In the early 1960s the newly introduced fungus *Dothistroma pini* was spread through many parts of New Zealand on nursery stock. Because of the lack of incursion detections over the years this second function has become the primary objective for many forest companies.

It has been customary to undertake forest nursery surveys only once during the growing season, in the period leading up to lifting and dispatch of plants for field establishment. As many nursery diseases are symptomatic for only brief periods of time, are related to environmental conditions, and as soil-inhabiting pathogens may only be retrievable under certain soil conditions, one survey may not give an accurate picture of the range of pathogens that inhabit any particular site. It is also common practice for nursery staff to remove small pockets of diseased plants in order to prevent the build-up of inoculum and disease spread (e.g. terminal crook disease). Most nursery managers also practice a regular regime of insecticide and fungicide applications, or will monitor plant health regularly and implement chemical treatments at early signs of infection. These practices may effectively suppress and/or disguise underlying disease, especially to an outside surveyor who visits the site only once and briefly. Hence a single targeted nursery survey may not be an effective method for detecting an incursion, or indeed of providing a valid record of plant health over the growing season.

From the diagnostic laboratory point-of-view nursery samples sent in for diagnosis often require many hours of work. One disorder can often require several samples of different kinds, for example needle dieback may require needle, stem, root and soil samples. Each different kind of sample requires a separate procedure which may have many different stages. For example the procedure for soil samples sent in with suspected *Phytophthora* sp. consists of four stages:

1. The soil must be set up with baits (e.g. rhododendron leaves) and left for several days.
2. Rhododendron leaves are then surface sterilized and plated onto two different media.
3. Within 14 days the mycelium is microscopically examined for confirmation of presence of a *Phytophthora* sp.
4. For species identification further tests are needed.

Therefore the cost for laboratory analysis is considerable and must be balanced by the desire by forestry companies to keep the cost of nursery surveys low.

In this study the results from the currently suggested one-off survey in April-May were compared with what was found during the rest of the growing period, and with historical data by interrogating the Forest Health Database (Section 1 of this report).

In addition a literature review of incursions in forest nurseries overseas was undertaken in order to determine the likelihood of pests or pathogens entering New Zealand via the forest nursery pathway (Section 2 of this report).

1. SURVEYS IN NEW ZEALAND FOREST NURSERIES

MATERIALS AND METHODS

Four nurseries (Table 1) in different locations and varying size were surveyed each month from October 2005 until June 2006. Only *Pinus radiata* stock (seedlings, cuttings and stool plants) was examined. Production at Forenza nursery was from containerised stock only and production at the other three was from bare rooted stock. Different locations provided a range of weather conditions. Information on monthly weather conditions was obtained from both the nursery managers and the NIWA Science monthly 'Climate Summary' (http://www.niwascience.co.nz/ncc/cs).

Table 1: Forest nursery details

Nursery	Owner	Location	No. of seedlings	Expected no. of cuttings	Stools (km)
Forenza Ltd, Waiuku	PF Olsen & Co. Ltd	Waiuku	1,500,000	700 000	nil
Ngongotaha Nursery, Oturoa Rd, Rotorua	Bob Mackay	Rotorua	972,000	175 000	29
Te Ngae Nursery, Rotorua	Kaingaroa Timberlands	Rotorua	1,200,000	3,300,000	12
Appletons Tree Nursery, Wakefield	Robert Appleton	Nelson	1,500,000	120 000	110

For Forenza, Ngongotaha and Appletons Nurseries the entire nursery was surveyed. Due to the size of Te Ngae nursery only one third of the total beds were surveyed and the same third was surveyed each month. In all nurseries except Forenza *P. radiata* seedlings, cuttings and stool bed plants were surveyed. Only *P. radiata* seedlings and cuttings were surveyed at Forenza.

The Rotorua nurseries were surveyed by an Ensis pathologist and the remaining two were surveyed by two different trained forest health observers.

Survey

The procedure followed the basic guidelines outlined in the "Forest Nursery and Greenhouse Health Inspection Protocol" with the major difference that the surveyors observed four beds at a time rather than the eight or ten beds in the Protocol. Surveyors recorded the incidence, severity and area affected for root, stem, needle and top disorders. A sample of the record sheet is shown in Table 2. Surveyors were asked to complete one nursery survey in four hours.

Table 2: Sample of assessment sheet for a section at Ngongotaha Nursery

Te Ngae Nursery date inspected

				Root			Stem			Needle			Top		
seedlings	date	bay	bed (m)	Sev[1]	Inc[2]	Area	Sev	Inc	Area	Sev	Inc	Area	Sev	Inc	Area
Block 4	25-10-05	1/1	770												
	25-10-05	1/2	770												
	25-10-05	1/3	770												
	25-10-05	2/1	770												
	25-10-05	2/2	770												
	25-10-05	2/3	770												

[1] Sev – severity, [2] Inc - incidence

The inspector assessed the overall health in each nursery and scored it according to the categories in Table 3.

Table 3: Categories for overall health score

Health description	Score
Totally healthy	1
Trace	2
Minor damage	3
Scattered or occasional patch	4
Significant damage	5

Information about local weather, treatment schedules, and other factors that may have influenced plant health was obtained from the nursery managers.

Sampling procedure

Samples were collected when disease symptoms were observed. The number of samples was limited to a maximum of two representative samples per disorder per plant type, i.e. seedling, cutting or stool plant. When the disorder was a root disease a soil sample was included along with the root sample.

Photo points

Photos were taken each month from designated photo points.

Diagnosis of disorders

Samples were sent to the Forest Health Diagnostic Laboratory, Ensis, Rotorua for examination and assessment by both entomology and pathology staff. In the laboratory the guidelines in the Forest Health Diagnostic Protocols Manual were followed. Results were collated into a monthly report for each nursery.

Forest Health Database Search

The Forest Health Database (FH database) was interrogated for entries from the four nurseries in April and May during surveys between 1998 and 2005. Relevant information was collated and used for a comparison with the 2005-2006 month-by-month survey.

RESULTS

Surveys

Some surveys took longer than the allocated four hours to complete. Recording the incidence, severity and area affected for each bed proved to be very time consuming and as a result a subjective comment about symptoms and levels of disease was often recorded instead of completing the form as designed. The process was reviewed after the first two surveys and it was concluded that an adequate picture of plant health was being gathered. Appendices I to IV summarise the information obtained from each nursery. Figures 1-3 illustrate the changes in overall health score for the three types of *P. radiata* stock throughout the period of the surveys.

Diagnostic results

No fungi or insects that have not previously been recorded in New Zealand were detected during this project.

No bacterial disease was detected. Root diseases were caused by *Phytophthora cinnamomi, Phytophthora* sp., *Cylindrocladium scoparium* and *Fusarium oxysporum.* Stem and foliar disease was caused by *Colletotrichum acutatum* f. sp. *pinea* (terminal crook)*, Sphaeropsis sapinea*, and *Botrytis cinerea. Dothistroma pini* infection was restricted to stool plants and cuttings. Terminal crook was recorded at Appletons nursery in March, the first record for this nursery although the disease has been found in other Nelson nurseries in the past.

Damage attributed to insects was restricted to Appletons nursery and only two different insects were recorded. White-fringed weevil (*Naupactus leucoloma*), recorded in January, is a common cause of seedling mortality in newly established nurseries but is infrequently found in nursery sites after two growing seasons. Onion thrips (*Thrips tabaci)* were recorded in January, February and March. Insecticide, which had not been applied since October, was reapplied in January, February and March and the number of onion thrips diminished during this time. Onion thrips are difficult to control and although affected plants are not killed they may suffer significant reduction in quality and thereby do not meet planting requirements.

Overall health assessments

Abiotic factors were the main contributing factors to poor scores for overall health assessments (Figs. 1-3, see details in Appendices I-IV). The seedlings at Ngongotaha Nursery scored ‘significant damage’ in January 2006. This score was related to wet conditions. No pathogens or insects were seen in January that were not also seen in other months. The high scores at Forenza for cuttings from December to April was solely related to abiotic disorders rather than pests or diseases. In other nurseries the poorer scores were also attributable to abiotic influences (see Tables 4- 7). The highest scores for stool plants related to an unthrifty appearance following topping.

Generally, plant health was poorest in the November to February period but symptoms did not persist. By May or June overall health score was either trace damage or totally healthy (Figs. 1-3). Recovery was a result of a number of factors such as nurserymen applying chemical or cultural control, the biology of the pest, and growth and vigour of the plants.

Figure 1: Health score for seedlings at four nurseries

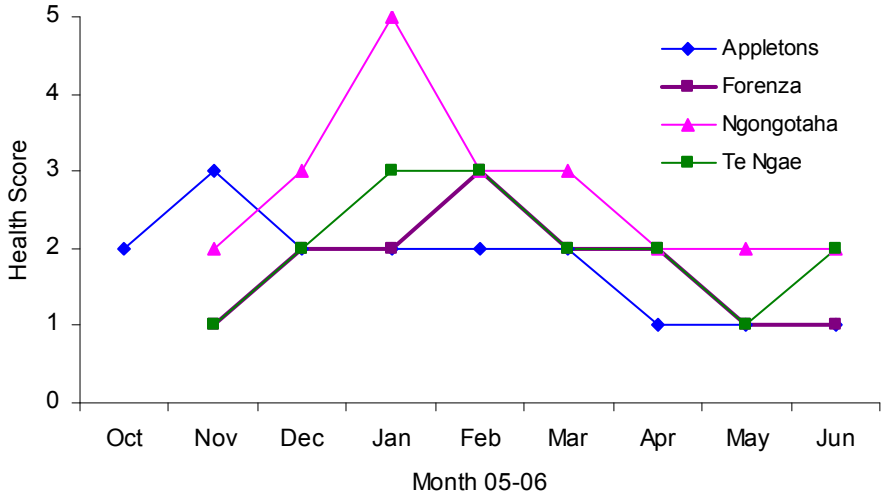

Figure 2: Health score for cuttings at four nurseries

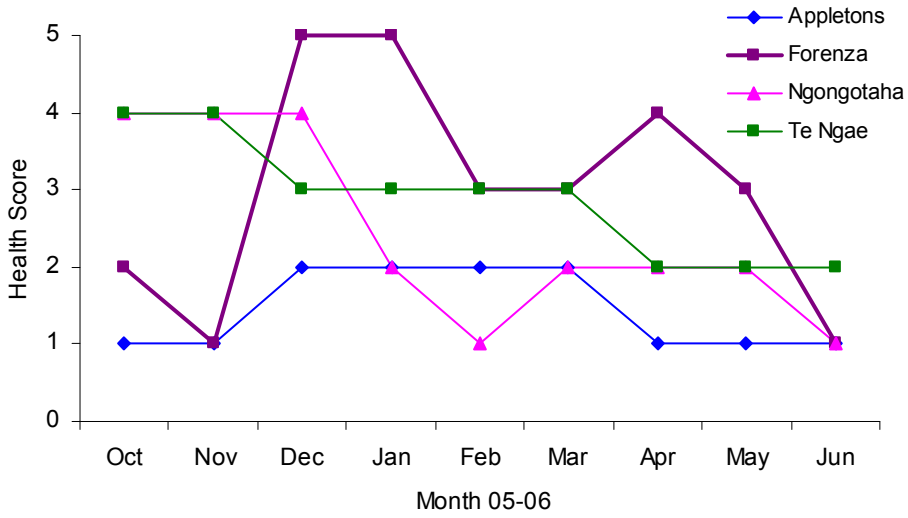

Figure 3: Health score for stool beds at three nurseries

Photographs

Photographs were taken each month from photo points and in a number of instances closer shots of particular disorders were taken. The photos did not contribute to diagnostic capability during this period. Nurseries are illustrated in Appendix V.

Forest Health Database

Results of the interrogation of the Forest Health database are given in Table 4. These data are limited to formal identifications made at the diagnostic laboratory from samples submitted by forest health inspectors. No entries for Ngongotaha Nursery were present. Only one instance of an abiotic factor causing ill-health was recorded, this being a nutrient deficiency at Appletons nursery in May 2000. No samples containing insects were received during the 1998 to 2005 period.

Table 4: Comparison of fungi found on 'one-off' survey compared to throughout the year

Pathogenic Fungi found in April and May during 'one-off' survey in 1998-2005	Fungi found October 2005 to June 2006
Botrytis cinerea *Botrytis* sp. *Cyclaneusma minus* *Cylindrocladium scoparium* *Fusarium oxysporum* *Fusarium solani* *Fusarium* sp. *Phomopsis* sp. *Phytophthora citricola* *Phytophthora cinnamomi* *Phytophthora* sp. *Sphaeropsis sapinea*	*Botrytis cinerea* *Colletotrichum acutatum* f. sp. *pineum* *Cylindrocladium scoparium* *Dothistroma pini* *Fusarium oxysporum* *Fusarium* sp. *Phomopsis* sp. *Phytophthora cinnamomi* *Phytophthora* sp. *Sphaeropsis sapinea*

Colletotrichum acutatum f. sp. *pineum* and *Dothistroma pini* were the only two fungi found during the 2005-2006 survey that were not found on the one-off surveys in April and May and between 1998-2005. Three fungi - *Botrytis* sp., *Fusarium solani* and *Phytophthora citricola* were found during one-off surveys but not during the 2005-2006 survey.

DISCUSSION

Assessment method and conduct of surveys

Accurate assessment was difficult when the extent of the damage was less than, or equal to, 1% of the area. But as any outbreak in a nursery is likely to start in one spot these little areas are just as important as larger patches. This, and other problems, could have been resolved by allowing more time to complete the surveys and by modifying data collection and recording protocols. However, the objective of this study was to determine the efficacy of nursery surveys and therefore the intensity and duration of the study surveys had to be comparable with operational surveys. Surveyors found that they tended to run over the allocated number of hours even with the standard method. However assessment problems were recognised early in the project and were overcome by combining the overall health assessment with comments from both the observer and the nursery manager. This enabled patches of ill health to be recorded without the need to quantify it and this method was used in subsequent assessments.

Two nursery managers commented that surveyors missed symptoms that they had observed. One was the relatively subtle change in foliage colour that signals severe root rot (*P. radiata* seedlings can sustain a healthy-appearing top even when root systems are completely dead provided there is sufficient moisture available). This was demonstrated by the nursery manager who was able to identify affected plants, which when pulled up had dead root systems. Visitors were unable to detect the difference in foliage colour between these and healthy plants. Symptoms of terminal crook disease were also missed on one occasion. These were plants that had been lightly infected and had grown with kinked stems but without the severe stunting that is characteristic of this disease. Nursery managers will typically 'walk through' the beds on a regular basis (sometimes weekly) and will probably be more familiar with symptoms of ill health than observers who are usually not specialists in nursery plants. Monthly visits during the nine months of this project did help track symptoms but lack of familiarity with nursery symptoms on the part of surveyors was not entirely compensated by the monthly visits.

Some surveyors stated that they would not have been able to adequately examine the nursery if required to cover 8 beds at one time (4 on each side of the alleyway being traversed) as is required in the current nursery survey specifications. Although major disorders were always

apparent, those with more subtle symptoms could be easily missed, particularly if the surveyors were trying to keep to a tight time schedule.

Comparison of results for a single survey and multiple visits through a growing season

During this study damage attributed to insects was only observed at one nursery. From January to March *Thrips tabaci* damage was noted but insecticide application reduced populations to undetectable levels by April. *Naupactus leucoloma* damage was recorded in March only. When the database was interrogated for the April-May surveys between 1998 and 2005 no records of insect related damage were present. In an established nursery insect damage on *P. radiata* is rare. A single survey in April or May would not have picked up the two occurrences of insect damage recorded in this study.

Two fungi, *Colletotrichum acutatum* f. sp. *pineum* and *Dothistroma pini*, were recorded early in the growing season but not during the standard pre-lift inspection period of April-May. *Colletotrichum acutatum* f. sp. *pineum* was recorded at Te Ngae in February and at Appletons in March. These fungi did not appear in the database records for the previous six years (during 'one-off' surveys) although we knew from conversation with nursery staff that there had been incidences (also early in the season) on some occasions. Fungal infection by *C. acutatum* f. sp. *pineum* occurs during warm, moist weather and it is uncommon for new infections to develop later in the season. Typically infected plants will be removed by nursery staff as a sanitation measure to reduce inoculum loading. *Dothistroma pini* can be readily controlled in the production beds through fungicide application and is seldom an issue. It is more difficult to manage in stool plants. Thus, it is likely that confining surveys to one inspection late in the season will lead to some organisms being missed. Quality specifications stipulate minumum plant sizes and generally plants affected by terminal crook or onion thrips will be removed before packing, or culled during the lifting and packing process so from a quality perspective missing some early season disorders is of no consequence. In contrast infections by root fungi such as *Phytophthora cinnamomi* may not be readily visible at lifting but infective propagules transported into the field in soil adhering to the roots can cause post-establishment infection especially if plants are under stress.

Incursion detection

The potential for pitch canker disease (caused by *Fusarium circinatum*) to seriously damage the pine plantations in New Zealand has been a major concern to the forest industry. Pathway analysis identified contaminated seed as the most likely method by which *F. circinatum* might enter the country. The fungus would therefore be expected to first appear in a forest nursery and early detection of pitch canker has been the primary justification for nursery surveys in recent years. However based on the pest risk analysis MAF closed this pathway and placed restrictions on the importation of conifer seed. Under these regulations no seed is imported from known pitch canker areas. Furthermore if *F. circinatum* were introduced on contaminated seed we expect that pitch canker disease would become apparent early in the growing season and that losses would be substantial within a short period of time. The concept of undertaking nursery surveys pre-lifting with the primary aim of incursion detection is therefore flawed with relation to pitch canker.

Nursery managers have endeavoured to ensure that all members of the Forest Nursery Growers Association (FNGA) are fully informed and aware of the symptoms of pitch canker and of other nursery problems. Such issues are discussed at the annual conference, through the Association newsletter and the FNGA has commissioned a series of illustrated information sheets on pests and diseases in forest nurseries. These highlight symptoms and indicate appropriate action. The first in the series is pitch canker (Appendix VI). With this level of knowledge within the industry it is difficult to imagine that a pitch canker incursion would go undetected or unreported.

CONCLUSIONS

- Results from this project did not indicate that altering the timing or the frequency of nursery inspections would provide additional knowledge of disorders that might affect selection for planting out. Some early season disorders may be missed but this is unimportant. The specifications for plant size ensure that plants that have been affected by disorders such as terminal crook and onion thrips will be culled.

- There is considerable reliance on the nursery staff to provide the history of climatic and chemical effects on plant health (without this input it may be impossible to separate symptoms caused by micro-organisms or insects and those caused by abiotic agents). Nursery managers generally have a very good understanding of the health of the plants in their nursery and the causal agents. Often this knowledge is vastly greater than that of the non-specialised nursery surveyor.

- Because it is in the nursery manager's best interest to observe and report and send in samples of unusual or worrying symptoms it seems unlikely that the surveyors will be any more likely to notice suspect symptoms that signify an incursion than nursery staff. For these reasons a pre-lift survey targeted solely at detection of pitch canker is not valid.

- Other disorders (e.g. *Phytophthora* root rot) are relevant and the focus of reports should be on these.

- There is no justification for carrying out nursery surveys if new pest detection is the primary aim.

RECOMMENDATIONS

If a forest company requires an independent evaluation of plant health prior to lifting then a single survey undertaken during April –May is appropriate.

- Discussion with the nursery staff about plant condition should be an important component of the evaluation.

- A review of survey specifications should be made in consultation with experienced surveyors and nursery staff.

- A single survey pre-lifting is not suitable for incursion detection in radiata pine. Considerable reliance can be placed on nursery staff to detect and seek advice at any time on unusual symptoms.

2. DISEASE INCURSIONS IN FOREST NURSERIES

A review of the global literature

BACKGROUND

There are numerous examples of the spread of diseases within a country when infected plants are dispersed from a nursery. Here in New Zealand *Dothistroma pini* was spread into some plantation forests on infected *Pinus radiata* nursery stock. A recent high-profile example in North America is the spread of *Phytophthora ramorum*, the cause of Sudden Oak Death, from California to many other parts of the USA on infected *Rhododendron* plants (the fungus causes minor disease of rhododendrons but these provide the source of inoculum for infection and subsequent mortality of a range of tree species).

The trade in nursery stock is also considered a high risk pathway for the spread of plant pests and pathogens internationally and is the recognised source of some incursions. In the Northern Hemisphere beech bark disease arrived in eastern Canada in the 1800's and has contributed to extensive mortality of native beech. Chestnut blight all but wiped out the North American chestnut. White pine blister rust and *Phytophthora* root disease of lawsons cypress are other examples of invasive pests imported on nursery stock (Britton and Lewis 2006).

Traditionally, phytosanitary certification of nursery stock has been based on visual inspection of plants prior to shipping. This has considerable limitations as pathogens may be carried as hitch-hikers on non-susceptible plants, or disease symptoms may be suppressed because of the chemical applications that are a routine part of nursery production. The medium in which plants are growing is also a potential source of new introductions. Recent research in Western Australia has clearly demonstrated that potting mix is a source of plant pathogens, including exotic species (Davison 2006).

This potential for plants and their growing medium to carry pests and diseases has been recognised in New Zealand forestry biosecurity circles and such pathways have been rigorously controlled. The potential for inadvertent importation of fungal pathogens was recently clearly illustrated in New Zealand when Douglas fir scion material was collected from a seed orchard in Sierra Nevada, 160 km from the nearest known pitch canker infected site. It was imported into quarantine in Christchurch, grafted onto rootstock and 8 months later two plants tested positive for *Fusarium circinatum* the cause of pitch canker disease (Ormsby 2004). The find did however demonstrate that the mechanism in place to prevent incursions via this route was robust. All plant material from the consignment was destroyed.

Seed is perceived to present a much lower biosecurity risk than plants. Numerous species of fungi are known to be carried either on the surface or within the embryonic tissues of seed. Most of these are probably saprophytes or endophytes that neither affect seed quality, nor have the ability to cause disease of seedlings. Micro-organisms carried on the surface of seed can be readily destroyed by surface sterilisation techniques or by the application of fungicides and should not therefore represent a biosecurity risk. However seed is also capable of carrying fungal pathogens internally in a latent state and this represents a greater challenge, both in being able to identify that such infection exists and in treatment. Two groups of seed-borne fungi in particular are implicated in the development of disease problems in forest nurseries. These groups include various *Fusarium* spp., such as the pitch canker fungus, and *Diplodia*-like fungi.

A number of strategies are available to ensure that seed is as clean as possible but seed is still often implicated as the source of a new infection in a nursery.

As part of this project a brief review of incursions via nurseries was undertaken, with focus on micro-organisms. The review covered trees with the exception of fruit trees. Information gathered will assist in evaluating the quarantine risk associated with forest nurseries.

Lasiodiplodia theobromae The world literature was searched using web-based search engines and papers on new diseases in forest nurseries gathered. The National Forestry Library at Scion was a valuable source of material and further papers have been obtained through interloan services. We sought unequivocal reports of disease-causing organisms that were first records for a country and were the result of the importation of infected seed, plants, or the medium in which plants were growing. Several hundred reports of 'new' diseases in forest nurseries were studied. The majority of these were quickly eliminated as they were either just new host records for a nursery, or the first report of a fungal disease that was already established in the country but had not been previously reported from that nursery. A few records could not be readily interpreted – i.e. whether it was an incursion or rather whether it fell into the category of 'new to the nursery'.

RESULTS

Records that were clearly an incursion through a nursery have been tabulated with annotations (Table 5). *Fusarium circinatum*, the cause of pitch canker is the subject of four of these reports. Both seed and potted plants have been identified as an incursion source.

DISCUSSION

Nurseries are strongly implicated in the spread of disease, both to other nurseries and out to the wider environment; within a country and across borders. Seed, scions, whole plants and their growing medium have all been the source of documented incursions.

Some of the micro-organisms that have found their way to a new country through the nursery pathway have caused destructive forest diseases that have been devastating to the ecosystems they have entered. Prime examples are chestnut blight caused by *Cryphonectria parasitica,* the disease that virtually wiped out the American chestnut *Castanea dentata*, and *Phytophthora lateralis* which has become a serious disease of *Chamaecyparis lawsoniana* in the USA (Britton & Lewis 2006). In recent years there have been a number of examples from the genus *Phytophthora*. *Phytophthora ramorum* (cause of sudden oak death) is thought to have entered California on plants imported from Europe or Asia. The further spread of *P. ramorum* into many parts of the USA has been traced to the transport of asymptomatic nursery plants (Venette and Cohen 2006).

Likewise the spread of numerous *Phytophthora* species throughout member countries of the European Community is associated with the importation of new plant species and cultivars into nurseries since the freeing up of trade (Orlikowski 2006). Both *P. ramorum* and *P. kernoviae* are thought to have entered Great Britain on infected plants imported by a nursery (Brasier pers. comm.). A campaign to eradicate these two fungi is currently being waged in Great Britain.

Although the 'unequivocal' records obtained in this search of the literature were few in number the consequences of these incursions have been extremely serious. The one record pertaining to New Zealand was the identification of pitch canker in asymptomatic Douglas fir scion material. That it was discovered before the release of the plants from quarantine is an example of biosecurity in action. The systems currently in place in New Zealand to restrict or monitor plant material for forest nurseries appears to be working well. However there is clearly a need to maintain stringent control.

Table 5: Nursery survey literature review

Country	Comments	Host	Fungus	References
Spain	Assumed that it was seed-borne. Caused extensive mortality of *Pinus radiata* seedlings in bare-root nurseries occurred.	*Pinus radiata*	*Fusarium circinatum* (as *F. subglutinans* f. sp. *pini*)	Dwinell (1999)
South Africa	Assumed that it was seed-borne. Caused extensive mortality of *Pinus patula* seedlings in a container forest nursery.	*Pinus patula*	*Fusarium circinatum* (as *F. subglutinans* f. sp. *pini*)	Britz *et al*. (2001) Viljoen *et al.* (1994)
Philippines	Believed to have arrived in the un-sterilised potting mix. Caused yellowing, stunting and death.	*Pinus caribaea* seedlings	*Fusarium solani*	Quiniones (1985)
Switzerland	Assumed to have arrived on potted plants.	*Viburnum bodnantense*	*Phytophthora ramorum*	Heiniger and Theile (2004)
Italy	Incursion via an infected pot plant from Belgium.	*Rhododendron yakushimanum*	*Phytophthora ramorum*	Gullino *et al.* (2003)
Italy	Causes dieback and mortality.	*Cornus florida* *Cornus nuttallii*	*Discula destructiva*	Holdenrider and Sieber (2006)
Canada	Causes stem cankers, dieback and mortality.	*Fagus* spp.	*Nectria* spp.	Sinclair *et al.* (1987)
USA	First noticed in nursery stock. Causes root rot leading to mortality	*Chamaecyparis lawsoniana*	*Phytophthora lateralis*	Sinclair *et al.* (1987)
USA and Canada	White pine blister rust causes dieback and mortality of many 5-needle pines	*Pinus* spp.	*Cronartium ribicola*	Sinclair *et al*. (1987)
Chile	Believed to be from Mexican pine seeds. Nursery plants die rapidly with resin exudation from root collar	*Pinus radiata*	*Fusarium circinatum*	Wingfield *et al.* (2002a) Wingfield *et al*. (2002b)
New Zealand	Asymptomatic infection of Douglas fir scions from the USA was detected and the plants destroyed.	*Pseudotsuga menziesii*	*Fusarium circinatum*	Ormsby (2004)
USA	First noticed in nursery stock. Causes root rot leading to mortality	*Chamaecyparis lawsoniana*	*Phytophthora lateralis*	Sinclair *et al.* (1987)

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Appendix I – Summary of information from Appletons Nursery

Seedlings

Month	Health score	Abiotic factors, pests and comments	Samples taken[1]	Laboratory identification
Oct	2	Seedlings being planted	N	-
Nov	3	Dry and windy. Small patch of desiccated seedlings.	N	-
Dec	2	Birds and wind.	Y	No pathogens found
Jan	2	Fertiliser burn, rabbit and *Thrips tabaci* (onion thrip) damage	Y	No onion thrip observed on samples sent to laboratory.
Feb	2	As for January.	N	-
Mar	2	Rabbit, *Naupactus leucoloma* (white fringed weevil) damage and reduced onion thrip damage.	Y	*Colletotrichum acutatum* f. sp. *pinea* (terminal crook)
Apr	1	Terminal crook no longer apparent.	N	-
May	1	-	N	-
Jun	1	-	N	-

Cuttings

Month	Health score	Abiotic factors, pests and comments	Samples taken[1]	Laboratory identification
Oct	1	Frost cloth still on	N	-
Nov	1	Frost cloth still on	N	-
Dec	2	-	Y	No pathogens found
Jan	2	-	Y	*Fusarium oxysporum, Phomopsis* sp.
Feb	2	-	N	-
Mar	2	-	N	-
Apr	1	-	N	-
May	1	-	N	-
Jun	1	-	N	-

Stools

Month	Health score	Abiotic factors, pests and comments	Samples taken[1]	Laboratory identification
Oct	2	Topped last week	N	-
Nov	2	Most sprayed with Glyphosate	N	-
Dec	1	-	N	-
Jan	2	-	N	-
Feb	2	-	N	-
Mar	2	-	N	-
Apr	2	-	N	-
May	1	-	N	-
Jun	1	-	N	-

[1] Y – samples collected, N – no samples collected

Appendix II *Summary of information from Forenza Nursery*

Seedlings

Month	Health score	Abiotic factors, pests and comments	Samples taken[1]	Laboratory identification
Oct	na	Seed recently planted.	-	-
Nov	1	Just emerging	N	-
Dec	2	Discolouration	Y	*Fusarium oxysporum*
Jan	2	Strong winds possible cause for twisted stems	Y	No pathogens found
Feb	2	Low incidence of dieback	Y	*F. oxysporum*
Mar	2	Dieback due to lack moisture	Y	No pathogens found
Apr	2	Some minor damage due to weather.	N	-
May	1	Seedlings have been topped to strengthen the stems.	N	-
June	1	-	N	-

Cuttings

Month	Health score	Abiotic factors, pests and comments	Samples taken[1]	Laboratory identification
Oct	2	Yellowing and some dieback due to lack of moisture	Y	No pathogens found
Nov	1	-	N	-
Dec	5	Burning on tips due to overdose of chemicals	N	-
Jan	5	Cutting not forming roots	N	-
Feb	3	Dieback: suspect combination of lack water and spray	Y	*F. oxysporum*
Mar	3	No change in last month	N	-
Apr	4	Damage may be due to spray drift	Y	No pathogens found
May	3	'Possible' spray drift damage reduced due to topping	N	-
June	1	Black fruiting bodies	Y	*Dothistroma pini*

[1] Y – samples collected, N – no samples collected

Appendix III *Summary of information from Ngongotaha Nursery*

Seedlings

Month	Health score	Abiotic factors, pests and comments	Samples taken[1]	Laboratory identification
Oct	Na	Just emerging	-	-
Nov	2	Needle collapse, scalding at time needles shedding their seed coat.	N	-
Dec	3	Seedlings with needle collapse last months have healthy centres. Some dieback due to spot spraying for dock	N	-
Jan	5	Dieback and mortality, wet weather and additional watering to overcome sand blasting	Y	*Fusarium oxysporum, Cylindrocladium scoparium*
Feb	3	-	Y	*C. scoparium, F. oxysporum*
Mar	3	Dieback, fertiliser burn	Y	No pathogens found
Apr	2	Wilting & mortality	Y	*C. scoparium*
May	2	Wilting and mortality	Y	*Fusarium* sp., *C. scoparium*
Jun	2	Needle dieback	Y	No pathogens found

Cuttings

Month	Health score	Abiotic factors, pests and comments	Samples taken[1]	Laboratory identification
Oct	4	Scattered top death, probably physiological.	Y	*Botrytis cinerea*, *Sphaeropsis sapinea*
Nov	4	Top dieback, slight improvement on last survey.	Y	*B. cinerea*
Dec	4	Most recovering from dieback	N	-
Jan	2	Some old top death apparent, yellowing	N	-
Feb	1	-	N	-
Mar	2	Dieback	Y	No pathogens found
Apr	2	Occasional brown top	Y	*B. cinerea*
May	2	Occasional brown top	N	-
Jun	1	-	N	-

Stool beds

Month	Health score	Abiotic factors, pests and comments	Samples taken[1]	Laboratory identification
Oct	1	-	Y	No pathogens found
Nov	3	Needle dieback, possibly due to topping	Y	No pathogens found
Dec	2	Yellowing, needle dieback as in November	Y	No pathogens found
Jan	2	Some yellowing, probably nutrient.	N	-
Feb	3	Yellowing, probably nutrient.	N	-
Mar	3	Yellowing, probably nutrient.	N	-
Apr	2	Browning on edge, mechanical damage.	Y	No pathogens found
May	2	Browning on edge, mechanical damage.	Y	No pathogens found
Jun	Na	All lifted.	-	-

[1] Y – samples collected, N – samples not collected

Appendix IV - *Summary of information from Te Ngae Nursery*

Seedlings

Month	Health score	Abiotic factors, pests and comments	Samples taken[1]	Laboratory identification
Oct	Na	Just emerging	N	-
Nov	1	-	N	-
Dec	2	-	N	-
Jan	3	Wet conditions	Y	*Cylindrocladium scoparium* and *Fusarium oxysporum*
Feb	3	-	Y	*P. cinnamomi*, *F. oxysporum*, *Colletotrichum acutatum* f.sp. *pinea*
Mar	2	Walk through removing terminal crook seedlings had been done the day before.	N	-
Apr	2	-	Y	*Phytophthora* (not *P. cinnamomi*) and *C. scoparium*
May	1	-	N	-
Jun	2	Wilting of occasional seedling	Y	*P. cinnamomi*

Cuttings

Plant source	Health score	Description/Comment	Samples taken[1]	Laboratory identification
Oct	4	Top death dependent on seed lot and soft tissue at time of collection.	Y	*Sphaeropsis sapinea*, *Botrytis cinerea*, *Fusarium oxysporum*
Nov	4	Reduced top death and seed lot dependent.	Y	*S. sapinea, B. cinerea*
Dec	3	As previous month, no root development in dead plants.	N	-
Jan	3	Recent mortality.	Y	No pathogens found
Feb	3	Needle burning, dieback due to root rot.	Y	*S. sapinea, P. cinnamomi*, *Colletotrichum acutatum* f.sp. *pinea*
Mar	3	-	Y	No pathogens found
Apr	2	-	Y	*S. sapinea*, *Phytophthora* sp.
May	2	-	Y	*S. sapinea*, *P. cinnamomi*, *Botrytis cinerea*,
Jun	2	Occasional wilting.	Y	*P. cinnamomi*

Stool beds

Plant source	Health score	Description/Comment	Samples taken[1]	Laboratory identification
Oct	4	Unthrifty, topped.	Y	*Dothistroma pini*
Nov	4	Growing through Dothistroma needle blight	N	*D. pini*
Dec	3	Dothistroma needle blight still apparent, new foliage healthy	N	*D. pini*
Jan	2	Root rot, Dothistroma needle blight no longer apparent.	Y	No pathogens found
Feb	1	-	N	
Mar	2	Isolated plants with dieback	Y	*Sphaeropsis sapinea*
Apr	1	-	N	-
May	1	-	N	-
Jun	1	-	N	-

[1] Y – samples collected, N – samples not collected

Appendix V - Figures

Figure 4: Seedlings, Ngongotaha, May 2006

Figure 5: A surveyor scoring plant health

Figure 6: Stool Bed, Te Ngae Nursery, February 2006

Figure 7: Unhealthy containerised cuttings, Forenza

Figure 8: Containerised Cuttings, Forenza, October 2005

Figure 9: Cuttings, Te Ngae Nursery, February 2006

Appendix VI – Pitch canker information sheet

Pests and Diseases in Forest Nurseries

No. 1 – Pine Pitch Canker

[1] Cotyledon infection from contaminated seed

Pine pitch canker – a threat to New Zealand's plantation forests

The threat

Pine pitch canker - caused by the fungus *Fusarium circinatum* - is a serious disease of pines and a threat to the forest industry in New Zealand. *Fusarium circinatum* can infect vegetative and reproductive tissues of susceptible hosts at all ages, from seedlings through to mature trees. Contaminated seed is a likely pathway for introduction of the fungus and nurseries growing pines are therefore the most likely place for an introduction to occur.

Symptoms: What to watch for

Pre- and post-emergence damping-off: Damping-off is the generalised collapse of very young seedlings and causal agents cannot be separated on the basis of symptoms alone.

Root rot: It may also act as a typical root-infecting pathogen. Again the symptoms cannot be separated from those caused by other root-infecting fungi.

Terminal wilt and stem discolouration

Stem infection: The fungus can survive in soil and may infect seedlings or cutting stools at, or just above, the soil-line. The plant will wilt and there will be ample resin production. Infected tissues typically become resin-soaked and develop a characteristic shiny honey colour.

[2] Resin-impregnated stem

Pink spore masses: Salmon-pink masses of spores, very similar in appearance to those formed on plants with terminal crook, may develop on some tissues.

Basal resinosis

Fungal growth on the soil surface: In container nurseries in South Africa, once the potting/soil mix is infected the fungus will grow across the surface of the containers, visible as a whitish mould.

What to do

As there are so many symptoms of this disease that are characteristic of other disorders and diseases that are already present in New Zealand it may be impossible to distinguish without laboratory tests. In any instance of untoward seedling death collect seedling and/or soil samples for examination in an authorised laboratory. Pack samples in a heavy plastic bag, securely and place it in another heavy gauge plastic bag. Seal this securely and pack in a crush-resistant carton. Wrap and seal the carton to make sure that the contents do not spill out. Parcels containing samples should be clearly marked "PINE PITCH CANKER?" and sent by courier. If an outbreak of the disease is confirmed incursion management comes under MAF control.

[3] Damping-off with fungal growth on soil surface in tray on right.

New Zealand Forest Owners Association

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