Forest Biosecurity Research Council

A Summary
of Research Findings
2004/2005

Members of the Forest Biosecurity Research Council

NZ Forest Owners' Association, Ensis, Bio-Protection, Biosecurity NZ, and Forest Health Research Collaborative

Members of the Forest Biosecurity Research Council

NEW ZEALAND FOREST OWNERS ASSOCIATION INC

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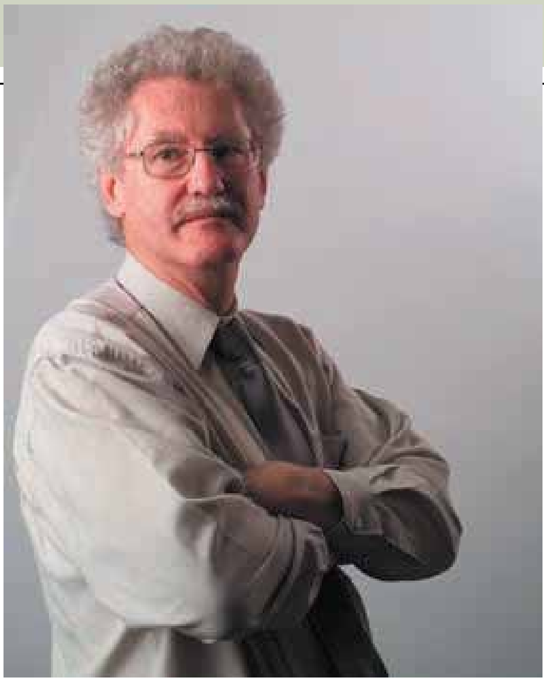
FBRC Annual Report – Foreword



The Forest Biosecurity Research Council (FBRC) has emerged as a constructive vehicle for helping to protect the forest resource in New Zealand from insect pests and diseases. An effective biosecurity system requires continual input of science knowledge to support risk assessments and key risk management decisions.

The FBRC is a partnership between forest owners, research providers and Biosecurity NZ (BNZ). This partnership aims to attract funding for forest biosecurity research, provide the governance to oversee expenditure of research funding raised by the Forest Owners' Association, and to drive strategic direction for biosecurity research programmes dedicated specifically to the interests of the industry.

This report summarises the FBRC research activities from 2004-05 year, with additional funding support from the Foundation for Research, Science and Technology (FRST). These projects represent the combined efforts of New Zealand's primary forest biosecurity specialists, working on applied problems for the benefit of forestry stakeholders.

Having now completed its second year of operation, the FBRC is enabling the delivery of solutions on high-impact biosecurity issues. In particular, significant resources have been committed to understanding the biology and management of *Nectria fuckeliana*, the fungus that is causing malformation of radiata pine stems in the South Island.

An important milestone for the FBRC over the past year was the completion of our collaboration agreement that defines how our partnership operates. Part of this process involved the formulation of an overall research strategy that ensures, for the first time, that funding is allocated to research priorities in a balanced way. The direct input of forest managers and other industry people has made sure that the work programme delivers information that can be used in managing biosecurity risks, not only at the border, but also within the forest estate.

Another highlight of the past year was the formation of FRST-funded "Better Border Biosecurity" (or B^3) Outcome Based Investment (OBI). This collaborative venture between major New Zealand research providers and other government agencies, aims to reduce the number of border incursions and establishments by pests that threaten our primary industries and natural ecosystems. The FBRC had significant input into the formation of this collaboration, and its subsequent funding by FRST. This example demonstrates the power of the FBRC to represent the interests of the industry on a range of fronts.

As we pause to reflect on the achievements of the FBRC, I wish to thank all of the people from within the industry who donate their time to supporting the partnership and to work closely with research providers. It is vital that we have these

knowledgeable people taking an active role in biosecurity matters on behalf of the whole industry.

I also acknowledge the contribution of Rob McLagan who retired this year from his position as CEO of the Forest Owners' Association. Rob was a key figure in the formation of the FBRC and his personal effort in marshalling the support of forest growers was a significant part of our early success.

While the FBRC is now well recognised as an effective body for biosecurity research, the future of the research programmes depends on continued government funding through FRST. This support is, in turn, dependent on adequate levels of co-funding supplied by the industry. I trust that this report will provide some insight into why this research is so vital to our future prosperity as one of New Zealand's largest and most promising industries.

Jeremy Fleming – Chair

"These projects represent the combined efforts of New Zealand's primary forest biosecurity specialists, working on applied problems for the benefit of forestry stakeholders".

Cost Benefit of Biosecurity Research

The forest industry is an important contributor to the New Zealand economy, accounting for 4.0% of gross domestic product. The industry employs over 25 000 people in forestry, logging and first stage processing, while forest product exports (excluding newsprint) account for 10% of all exports by value. This value is achieved through highly productive plantation forests, producing 18 to 24 m^3 /ha/yr.

The introduction of exotic pests is a significant threat to the productivity of New Zealand's plantation forests. There are about 1000 pests recorded on radiata pine that are not presently found in New Zealand, including western gall rust caused by *Endocronartium harknessii*, root disease fungi such as *Phellinus weirii* and *Heterobasidion annosum*, and bark beetles such as the North American *Ips grandicollis* and mountain pine beetle (*Dendroctonus ponderosae*).

The growth in global trade is creating increased opportunities for unintentional introductions. New Zealand import volumes have grown 10%/yr over the last two decades. Since the 1950s over 250 exotic tree pests have established in New Zealand. Given the value of the forest industry to New Zealand's economic well being, and the threat posed by exotic pests, an active biosecurity and forest health research programme is viewed as an important means of ensuring the continued contribution of the forest industry to the New Zealand economy.

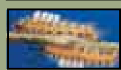
A cost-benefit analysis was funded over the past year by MAF and the FRBC to determine the economic benefit of continued biosecurity and forest health research for New Zealand. The analysis considered the likelihood of exotic pest arrival, detection, and successful eradication and control, and the effect of research on these. The net present benefit of the NZ$3.5 million annual cost of research was estimated to range from NZ$6,909 million to NZ$1,174 million for discount rates of 6% to 12%.

This study's estimate of the economic loss to New Zealand due to exotic pests is larger than previously thought. This reflects the inclusion of the costs of exotic pests in both urban and commercial forests, and the impact of successive pest arrivals out to 2040. These results show there is considerable benefit to the New Zealand economy from biosecurity research, and have been used to demonstrate the value of continued funding in this critical area.

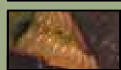
Government support for forest biosecurity research

The importance of biosecurity research is acknowledged by the New Zealand Government, who makes funding available through the Foundation for Research, Science and Technology (FRST). The industry-funded FBRC projects described in this report are underpinned by substantial FRST support. This additional funding provides benefit to the forest industry through comprehensive research programmes, the largest of which is maintained by Ensis Forest Biosecurity and Protection (FBP). The Ensis FBP programme covers the entire risk management spectrum including:

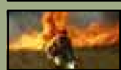

Forest ecology and health


Border Biosecurity


Pest and forest environments


Biological control


Forest weeds


Fire Research

For full information of these programmes, see the Ensis Forest Biosecurity and Protection Annual Science Report 2004/2005 – available through Ensis

FBRC Research Projects

This section of the report summarises projects co-funded by the FBRC.
A brief summary of the project titles and funding contributors is given below.

Allocation of effort spent on each of the FBRC projects ($000)

Project	**FBRC**	**FRST**	**BNZ**	**Industry**	**Total**
Pitch Canker update	80	65			145
Understanding *Nectria fuckeliana*	113	115		50	278
Biological control of *Paropsis charybdis*	27	125			152
Remote sensing for forest health	20	20			40
Improving pest eradication	40	85			125
Stem injection of pesticides	45		53		98
Beneficial organisms to enhance tree health	25	376		81	482
Scottish fungi to combat bark beetles	25	142		50	217
Total	**375**	**928**	**53**	**181**	**1537**

Pitch Canker Update

Pitch canker of *Pinus radiata*, caused by the fungus *Fusarium circinatum*, is viewed as a serious potential threat to New Zealand plantations. The disease is characterised by the excretion of copious amounts of resin and can suppress growth or kill the tree at all stages of its development, from seed to maturity.

All species of pine and one non-pine species, Douglas fir, are considered susceptible to *F. circinatum*, although *P. radiata* is regarded as the most susceptible species. The disease has been problematic in plantations, nurseries and native forest stands worldwide. Countries with confirmed reports of pitch canker include USA, South Africa, Spain, Chile, Japan, Mexico and Haiti.

An international literature review was undertaken over the past year to improve the understanding of this disease and the likelihood of its establishment in this country, should *F. circinatum* ever be introduced. This project, conducted by post-doctoral fellow, Dr Rebecca Ganley, involved meeting researchers and groups involved in pitch canker in the US and South Africa and establishing contacts worldwide with research groups and potential collaborators.

This study focused on the risk of pitch canker becoming established in New Zealand. Known vectors of the pathogen are water, wind, soil and insects. Spores of *F. circinatum* have been found on most insects, including wasps and flies, and they can also be carried by machinery and equipment. The ability of possums to act as vectors is unknown, but it seems likely that spores could be carried in fur.

Although spores may be present, successful infection cannot occur unless the tree is damaged and the wound remains moist, providing an entry point for the fungus. Injuries that can result in pitch canker can be caused by weather (eg. wind or hail), insects, mechanical damage/pruning or animals. However, there is a lot of variation between countries in the frequency of infections caused by weather-related or insect wounds, suggesting that climate could be a factor. Based on the distribution of this disease worldwide, the areas believed to be at highest risk in New Zealand are warmer coastal regions and parts of Northland with semi-tropical conditions. Colder inland regions are expected to be at a lower risk.

Variations between different types of insect wounds and the incidence of pitch canker have also been observed. The types of insect closely associated with pitch canker in the US are not present in New Zealand. Although 150 species of insect have been recorded on *P. radiata* in New Zealand, it is unlikely that any of the insects currently present are capable of creating wounds suitable for infection.

Investigations into the effect of silvicultural practices showed that the incidence and severity of pitch canker is higher in overstocked stands, therefore lower stand density and/or thinning can reduce the incidence or impact of the disease. There is also evidence to suggest that the disease is more severe on sites where trees have high levels of foliar nitrogen, which could have particular implications for ex-farm sites in New Zealand. These data will be used in risk analysis models to predict the likely impact of the disease in New Zealand if the fungus were to become established here.

Although greenhouse trials have shown that *P. radiata* has low levels of genetic resistance to pitch canker, the apparent remission of the disease in California suggests that trees can build resistance to infection. However, with the increasing spread of this disease worldwide there is still much to learn and understand.

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Funded by FBRC and FRST

Understanding Nectria

Stem malformation associated with infection by the fungus *Nectria fuckeliana* has arisen in *Pinus radiata* plantations in Southland and Otago. To increase understanding of this little-known disease, a number of field trials have been established with support from the FBRC, FRST and the Nectria Focus Group.

The ultimate goal of this research is to assist with developing management strategies for affected forests, to aid in decisions about quarantine and movement of forest products, and to prevent spread of the disease to other parts of New Zealand.

The first confirmed record of the wound pathogen *N. fuckeliana* was from Otago in 1996 and it has since been found extensively in Otago and Southland. It has more recently been recorded in a couple of locations in South Canterbury.

After Ensis scientists formally identified the pathogen, research began on many aspects of the disease, including surveys of the distribution, and how the season of pruning affects susceptibility. However, many aspects of the basic biology, ecology, and epidemiology of the purported causal agent, *N. fuckeliana*, are still unknown. A two-year research program to examine these issues was started in January 2005 with the arrival of post-doctoral scientist, Dr Patricia Crane from Canada.

Dr Crane's research is broadly divided into three categories:

1. The infection mechanism and disease development in the host.
2. Effect of key organisms on the host.
3. Relationship of disease incidence to environmental conditions.

Studies associated with these objectives are well underway, and preliminary results are becoming available.

Infection mechanism and disease development

In order to understand the cause of the disease and how it spreads, it is necessary to confirm the role of the central pathogen. The most common fungus isolated from flutes and branch stubs of infected radiata pine is *N. fuckeliana*. However, this fungus is known from Europe and North America as a weak wound parasite, mainly of spruce *(Picea spp.)* Although the pathogen is closely associated with the symptoms observed in New Zealand, its role in killing pine cells is currently unknown.

In Otago, the fungus has been found growing on pruned branch stubs in the absence of fluting. In other cases, there has been a failure to isolate the fungus from flutes. The causal agent of the pine fluting disease needs to be confirmed by satisfying Koch's postulates, a scientific process aimed at proving that a particular organism is causing a disease. This process involves consistent isolation of the fungus from diseased trees, reproducing the disease symptoms artificially by inoculation, and reisolating the fungus. Experiments are being conducted to determine the role of *N. fuckeliana* in this disease following these criteria.

In addition to *N. fuckeliana*, many other organisms have been isolated from pine stems infected with the pine fluting disease, including common saprophytes, decay fungi, and bacteria. Observing their interactions may clarify their roles in disease development. A key focus of this work is to understand the competitive ability of *N. fuckeliana* and to explain its common association with pruned branch stubs.

Effect of key organisms on the host

Stem fluting is associated with death or damage to the cambium above pruned branch whorls. This damage can cause significant value loss in the pruned log. To develop methods for managing this disease, it is necessary to understand the role of *N. fuckeliana* in cell damage and death of the cambium.

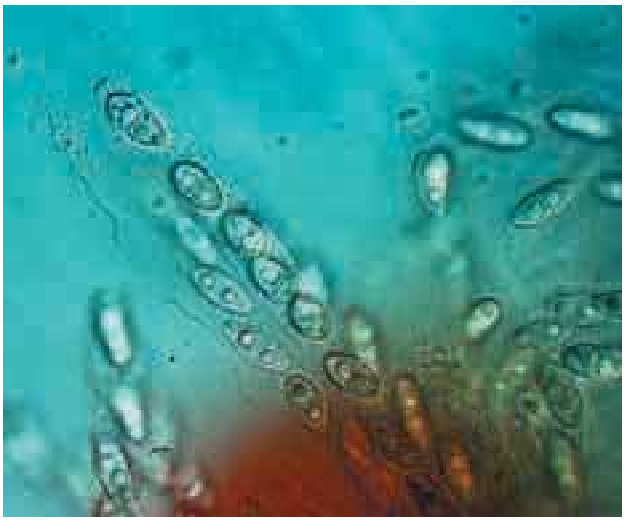
Anatomical studies of the early stages of infection are being undertaken, to shed light on the processes that initiate fluting. In cross sections of fluted stems, there is often a wedge-shaped area of whitish wood extending radially from a pruned branch stub to the pith. This "pathological whitewood" extends upwards into the flute, and *N. fuckeliana* is often confined to these areas. It is not yet known whether the whitewood is a physiological response to the wounding after branch pruning or whether it is caused by cell death from fungal infection.

Relationship of disease incidence to environmental conditions

Little is known about the environmental conditions required by *N. fuckeliana* for development of fruiting bodies, spore formation, spore dispersal, and spore germination. Such information is crucial to the management of the disease.

Experiments in both the laboratory and under field conditions are helping to reveal the basic biology of the fungus and to relate biological events to weather conditions. This experimental work is designed to investigate when spores are present, which spore state is most infective, and how long spores remain viable in fruit bodies. Information from these trials will assist in understanding the risk of disease development in new areas, the reasons for the current disease distribution, and how it is influenced by the biology of *N. fuckeliana* and by plantation management. Results from a major silvicultural trial funded by the Nectria Focus Group showed that fluting incidence is higher after pruning in winter, and that stubs under 30 mm diameter are rarely associated with fluting.

Many fungi of this type disperse their spores by wind currents, but little information is available on the dispersal mechanism in *N. fuckeliana*. Preliminary laboratory and field observations suggest that spores are dispersed through water droplets, and therefore the presence of moisture is required in order to spread the fungus.



Surveys

A survey was undertaken to determine whether *N. fuckeliana* is present in forests outside the known infected regions. Surveys in the Central North Island focused on areas planted with seedlings imported from Otago and Southland. *Nectria fuckeliana* was not detected in either the upper South Island or in the Central North Island.

Further regional incidence and delimiting surveys have been prepared to learn the extent and incidence of *N. fuckeliana* in the southern part of the South Island. Once completed, the information may provide some idea of whether environmental conditions are important for disease development as well as indicating the current range of the disease. Microsites prone to disease may be identified, allowing forest owners to target management control measures to these sites. Diagnostic protocols have been developed for field use, and a non-destructive technique has been identified to assist in this project.

Infection of nursery stock

In the period 1997- 2004 many seedlings and cuttings of *P. radiata* were transported from South Island nurseries for planting out in the North Island. Although there are no records of the fungus from the North Island there is concern that *N. fuckeliana* may have been, or may in the future, be transported to the North Island via the nursery material and become established in the plantations there. A study is underway to determine the risk of spreading infection through nursery stock.

As *N. fuckeliana* is a wound pathogen, intact seedlings or cuttings are very unlikely to have the opportunity to become infected. If topping of nursery material is undertaken there is theoretically the possibility that, if there is an inoculum source nearby, then the wound could become infected. Equally, dead portions of nursery plants could theoretically become colonised with *N. fuckeliana* if inoculum were available.

An inoculation trial was conducted to determine whether nursery seedlings are able to carry the fungus. While initial results indicate no symptom development on plants living in quarantine, the fungus was able to survive on the plants. For this reason, it is important to follow up this work with exposure of topped and wounded seedlings in a natural environment. The effect of weather and the complement of other organisms that could behave as niche competitors on inoculum survival may lead to an entirely different result. A field trial has been established to investigate this important question.

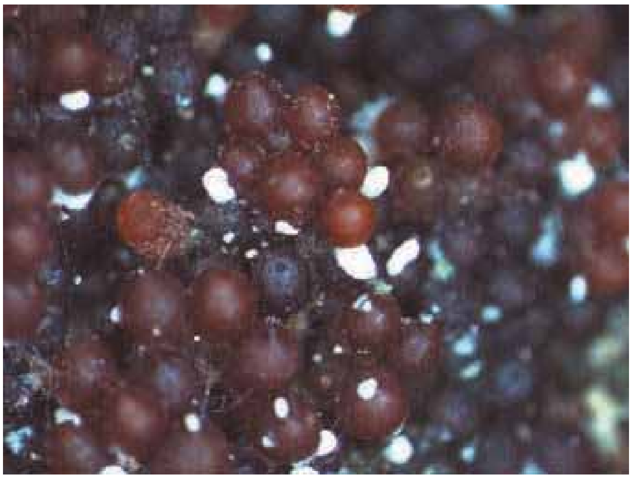
Susceptibility of other conifers

Overseas, *N. fuckeliana* has been recorded as a relatively weak pathogenic agent, primarily on species of spruce and fir. Prior to its arrival in Otago, it was not viewed at a threat to commercial pine species. Since the behaviour of this pathogen in New Zealand appears to be quite different from any previous recordings, it is necessary to determine whether conifers other than radiata pine can become infected, and the wood similarly degraded, by *N. fuckeliana.*

An inoculation study is underway to determine the susceptibility of other species grown in New Zealand. Six species of 'other conifers' have been inoculated with *N. fuckeliana* in a pilot trial to determine whether there is any resistance to canker development.

Three species *Cupressus macrocarpa, Sequoia sempervirens* and *Pseudotsuga menziesii*, along with *Pinus radiata* for comparison, were inoculated with *N. fuckeliana* in April 2005. *Larix decidua, Pinus contorta* and *Pinus ponderosa* were inoculated in June 2005, plus *Pinus radiata* for comparison. Control plants were treated with sterile water.

April treatments were assessed in June 2005, and no symptoms were apparent. Results from the next assessment will be available in late 2005.



Management recommendations

The fungus is a wound parasite that has taken advantage of pruning treatments. Currently, management recommendations include the avoidance of pruning during winter months, fungicide application on stubs under 30 mm diameter should not be done, and where possible, select trees with small branches.

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Funded by FBRC, FRST and industry

Biological Control of Paropsis

Paropsis charybdis is a serious defoliator of *Eucalyptus* species in New Zealand plantations. When this pest found its way across the Tasman early last century, it proceeded to repeatedly strip favoured species of their leaves. Since chemical sprays proved impractical, scientists began the long search for an alternative solution.

In the late 1970s, entomologists at the Forest Research Institute introduced *Cleobora mellyi* as a biological control agent from Australia. Although the tiger-striped ladybird feeds on *Paropsis* eggs and larvae, it failed to thrive in New Zealand eucalypt plantations. *Cleobora* was liberated at two sites, one in the central North Island and one in the Marlborough Sounds. It became established only at the latter, where a mixture of *Eucalyptus* and *Acacia* species appeared to host a more balanced diet, which enabled the *Cleobora* to breed.

When *Cleobora* proved unsuccessful as a control agent, scientists began looking for other options. This search resulted in the introduction of *Enoggera nassaui* in 1987. This parasitoid wasp from Australia proved very effective at attacking clusters of *Paropsis* eggs and laying its own eggs inside them. Initially *Enoggera* was successful in reducing the *Paropsis* population, until the unexpected arrival in 2001 of a new hyperparasitoid, *Baeoanusia albifunicle,* that began to prey on *Enoggera*. While *Enoggera* was laying its eggs in *Paropsis*, *Baeoanusia* was, in turn, laying its eggs in *Enoggera*, thereby undoing all the good that the biological control programme had achieved.

As the struggle between parasitoid and hyperparasitoid continued, forest managers and scientists saw a fresh role for *Cleobora*. Due to the significant challenges associated with importing new biological control agents into New Zealand, farm forester, Dean Satchell, initiated a project with support from the MAF Sustainable Farming Fund, aimed at giving *Cleobora* another chance. To this end, a *Cleobora* population was collected from the Marlborough Sounds and scientists are now mass-rearing them in containment for another attempt at releasing them into North Island plantations.

While *Cleobora* did not establish well when it was first introduced, changes have occurred in the plantation forest ecosystem that may make conditions more favourable for the predatory insect. Since new species of Australian insects regularly find their way into the country, there is a much bigger range of psyllids present in the North Island forests than there was twenty years ago. This is expected to suit *Cleobora*, which prefers a mixed diet of *Paropsis* eggs and psyllids.

A key question of the FBRC-funded research was to determine whether the reintroduction of *Cleobora*, as a generalist predator, would improve or disrupt the biological control achieved by *Enoggera*. Studies show that *Cleobora* tends to favour *Paropsis* eggs that do not contain the parasitoid. It is therefore likely that both insects will be able to successfully co-exist as biological agents and, hopefully, their combined impact may help to compensate for the setback created by the detrimental hyperparasitoid, *Baeoanusia*.

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Funded by FBRC

Improving Pest Eradication

Bacillus thuringenesis kurstaski (Btk) is a commonly used insecticide for aerial operations over urban areas. Considered to be environmentally benign, Btk is highly specific to a limited number of insect species. Due to its relatively low toxicity, it is important to use adequate application rates in order to achieve success in eradication programmes.

A study was undertaken on Btk and associated pest mortality to give improved information on insecticide application rates, using painted apple moth as the target species. The purpose of this information is to assist operational planners in applying appropriate spray doses, and to potentially avoid costs associated with excessive spray volumes.

This study revealed that the effect of Btk on the insect was greatly determined by the host plant on which it is feeding. When an insect is chewing on its preferred host species it exhibits higher resilience, so requires larger doses of Btk. Conversely, insects living on poor hosts will die, even when exposed to very low doses of insecticide.

This study concluded that larval growth rate is a strong predictor for the efficacy of Btk on different host plants. This effect has important implications for the design of eradication programmes. By determining the hosts that provide the highest larval growth rates within the terrain to be sprayed, it is possible to monitor the overall effectiveness of the applied dose in a highly focused and simple manner.

Favoured plants will not only promote the fastest and most prolific population growth, but will also be home to those larvae least affected by Btk. The role of secondary hosts can largely be ignored when spraying mixed species canopies. Larvae on these trees naturally grow more slowly, produce fewer offspring and are more susceptible to both natural mortality and particularly to Btk.

Consequently, a sufficient kill rate achieved on favoured host plants will provide confidence that the rest of the population has likely been decimated. Although this study was carried out using painted apple moth and Btk, the same host effect is expected when targeting other caterpillar species using most organic, and possibly synthetic, insecticides.

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Funded by FBRC and FRST

Remote Sensing for Forest Health

Productivity demands within the forest are driving an increased need for forest health related information. This information can be used for tailoring regimes to suit specific sites with the aim of managing risk, optimising productivity and minimising costs.

Over the past year, an FBRC-supported project has clarified the information and reporting needs of the forest industry. The purpose of this ongoing project is to determine cost-effective methods for reporting on long-term trends for forest health, pest status, and canopy condition.

At present, most forest health-related surveillance is undertaken using standard visual assessments. Recent advances in remote sensing, in particular the use of hyperspectral imagery, has opened up the potential for surveillance of pest and disease impacts, nutritional disorders, and weed distribution over extensive land areas.

Hyperspectral technology enables the analysis of digital images that use a colour range extending from standard visible colours through to infrared light waves. Hyperspectral images of forest stands can reveal subtle changes in foliage pigmentation that can indicate a range of health issues. For forestry, potential applications could include the mapping of the incidence and severity of foliage diseases such as Dothistroma needle blight, and the distribution of weeds such as gorse and broom.

Remote sensing technologies may be able to determine canopy structure and have application with forest condition monitoring. Notwithstanding the potential application of advanced technologies such as hyperspectral imagery and LIDAR, other technologies such as digital photography and visual assessment may also be useful and should not be overlooked.

A list of forest health issues was compiled after discussions with industry personnel during May and June 2005. Methods to quantify the severity of Dothistroma, Cyclaneusma, weeds, and nutrient deficiencies, and a need for an objective measure of overall forest health condition were the issues rated most significant. Wind damage, Armillaria, and bark beetle mortality were rated as very important. Remote sensing techniques, either now or in the future, may be able to provide information that can address many of these issues.

Such information can be used to satisfy standard reporting needs within the industry. Annual, or quarterly, forest health reports at the forest level are required in order to identify significant problems, preferably with maps included. To keep costs down production of reports should be automated and simple.

In addition to applied forest management needs, MAF has international requirements to report on forest health status at a regional or national level. The Montreal Process reports are provided every five years. Global forestry resource assessment needs required by the Food and Agricultural Organisation of the United Nations (FAO) have been recently broadened to include environment, criteria indicators and processes by forest type. This involves disturbance relating to health and vitality – fire, disease, insect, and abiotic influences. MAF's main interest would focus on changes over time of diseases that are present and well established, and changes in status of newly established pests, particularly if these changes were destructive.

Remote sensing technologies applied to the collection and management of high-level information for national reporting purposes could have enormous value to the industry by helping to address long-term risk management and sustainability issues. The next stage of the project involves evaluating the cost and efficacy of remote sensing techniques to satisfy the needs identified during industry consultation.

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Funded by FBRC and FRST

Stem Injection of Pesticides

Techniques for injecting pesticides into individual trees were investigated to develop a method of protecting trees in urban areas where traditional spraying methods are not appropriate.

An insecticide injected directly into the stem can be translocated rapidly to the leaves through the sap of the tree, where it is ingested by herbivores feeding on those leaves. This targeted method avoids the risks associated with spraying, because the active ingredient is contained within the tree, greatly reducing the chances of exposure to it.

Six insecticides were evaluated for their efficacy to control herbivorous insects on *Eucalyptus* species in the greater Auckland region. All of the insecticides tested were registered products on the New Zealand market, and they were chosen to represent a range of toxicities. The insecticides were injected by force directly into the xylem of *Eucalyptus cinerea, E. saligna* and *E. globulus*. The insect species targeted in these trials were, *Uraba lugens* (Gum Leaf Skeletoniser) and *Paropsis charybdis* (Eucalyptus Tortoise Beetle), both of which are serious defoliators of important *Eucalyptus* species in New Zealand.

Foliage from injected trees was randomly sampled and used in bioassays. Of the insecticides tested for their stem injection potential, only one was rapidly and reliably translocated to the foliage, and appears to provide good protection for more than 60 days. The successful product, Tamaron (Methamidophos), is an organophosphate insecticide that consistently inflicted more then 95% mortality on target insect larvae. Effective insect control was achieved within two days after injection and lasted beyond 128 days. None of the other selected insecticides achieved sustained or acceptable insect larval control.

The success of other insecticides appears to have been limited by commercial formulations for traditional spray applications. While Confidor (Imidacloprid), for example, is widely used overseas for stem injections, the formulation available in New Zealand is designed to ensure the product sticks to the outside of leaves. This prevented it from translocating easily within the stem due to its low solubility. Ongoing work should confirm the efficacy of this potentially promising insecticide, which has a lower toxicity than Tamaron.

The study concluded that direct injection of insecticides to control herbivorous insects in an urban environment is undoubtedly a viable option using Tamaron. Further work to optimise rates and injection methods is required before the technique can be applied on an operational basis. Since this product was largely formulated for foliar application, a label recommendation would be required for stem injection. Insecticide persistence and tree wound recovery should also be further investigated and monitored.

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Funded by FBRC and BNZ

Beneficial Organisms to Enhance Tree Health

Armillaria root rot is an economically important disease of *Pinus radiata* in New Zealand. In some areas, up to 50% of new plantings may die within the first 5 years and up to 60% of the surviving trees may have chronic infections, which would cause a 6-13% loss in potential volume at harvest. Annual losses due to Armillaria infection in New Zealand are estimated to be between $20 million and $37 million.

Dr Robert Hill, a scientist with BioDiscovery New Zealand Ltd and a member of the National Centre for Bio-protection Technologies, Lincoln University, has been collaborating with PF Olsen and Company Ltd on research to find an effective solution to reduce the extent of this problem. Initial results were promising leading to more effort into this area with contributions from FRST, FBRC and continued support from PF Olsen.

Earlier nursery trials investigated the effects of 10 treatments on radiata pine container-grown seedlings. The initial results were very promising and showed significant benefit for improving health and vigour in the nursery stock. 7000 seedlings were planted into sites with a record of severe Armillaria infection in Kinleith and Kaingaroa Forests to investigate the ability of the treatments at reducing losses caused by the disease in the field.

More recent nursery trials have investigated the effects of over 20 different treatments in which beneficial organisms were applied to seed or cuttings. The results have been impressive with the best treatments increasing seedling height up to 33% and increasing stem diameter up to 25% over the untreated control.

The field trials have also shown outstanding results with a Trichoderma treatment (ArborGuard) reducing mortality in the forest by 35% at two years, and what appears from preliminary analyses to be a similar level of reduced mortality after four years. These are extremely encouraging results and indicate a world-first for demonstrating that nursery-applied treatments can persist for several years in field plantings.

Results from this research have demonstrated the benefits of applying beneficial organisms to radiata pine nursery stock, enhancing tree growth and health while at the same time eliminating the need to apply fungicide. Based on these results, at least one commercial nursery has now switched away from fungicides to the use of beneficial organisms and is promoting its product as having superior growth and vigour characteristics in initial field plantings. The research has also discovered new mixes of beneficial organisms that appear to be even more promising and which could provide even greater benefit to the forest industry.

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Funded by FBRC and FRST

Scottish Fungi to Combat New Zealand Bark Beetles

Dr Travis Glare of AgResearch and colleague Dr Steve Reay (part of the Bio-protection CORE) has made a world first discovery that a species of the fungus - *Beauveria*- is highly pathogenic to Hylastes - a species of bark beetle that damages young radiata pine in New Zealand. This is exciting for the forest industry as it means that it should be possible to develop a biopesticide (non-chemical) using a fungus that is already in the country, thereby avoiding many regulatory hurdles that would otherwise make commercialisation too slow and expensive.

The fungal genus *Beauveria* is well known as containing species that are pathogenic to a range of insect species. However *Beauveria caledonica* is an exception. This fungus was originally isolated from moorland soil in Scotland and has not been reported as a pathogen. Of course no one knows how it arrived in New Zealand, but possibly on the boots of an early Scottish settler over 100 years ago.

The ultimate goal of the research is the development of an effective biopesticide that can be used operationally to control the level of bark beetles in young plantations, and thereby reducing mortality and damage to young seedlings. *Beauveria* fungi can be easily mass-produced and biopesticides based on isolates with activity against other pests have been developed overseas, demonstrating the potential of *Beauveria*.

A component of the current research programme is investigating the use of beetle attractants to improve the efficacy of *Beauveria* in the field. While the fungus has been shown to be toxic to the beetles, the challenge is to infect the insects, and that is where attractants have their place. Current efforts are looking at combinations of *Beauveria* spores, the infective units, and a number of attractants to determine if higher levels of bark beetle control can be achieved through this approach compared to spores of the fungus alone. Work completed to date has investigated methods for formulating potential attractants with spores and developing assay methods for the most promising attractants.

Previous work demonstrated that Hylastes and Hylurgus bark beetles are attracted to á- and â-pinenes, raw turpentine and ethanol. To be an effective attractant however, the chemicals must be non-toxic to the *Beauveria* spores.

Therefore, a major component of the research programme is to investigate the toxicity of attractants to develop technology to cost-effectively package the attractants with the spores for application in the field. Research is also conducting field trials with selected strains of Beauveria to determine the most appropriate method of delivery to a forestry operation. Options being investigated include adding the attractant and spores to seedling potting mix and/or soil inoculum around stumps.

The FBRC is partially funding this research project with the bulk of the money coming from FRST. Carter Holt Harvey Forests is also providing substantial support to assist with the field component of the study.

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Funded by FBRC and industry

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For more information on FBRC, membership details and science reports *and more*.

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