Risk analysis for cypress species relevant to forestry to inform biosecurity response

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Report information sheet

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Cover figure: advanced cypress canker damage in a *Cupressus nootkatensis* shelterbelt near Rotorua. Taken by I. Hood.

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Executive summary

The problem

The Ministry for Primary Industries (MPI) has to make decisions on whether to attempt eradication of new cypress pests based on incomplete information. Under GIA Deed partnership the forest industry will need to start paying a share of the costs of these should a decision be made to proceed with eradication or management of new incursions. The Forest Biosecurity Committee has determined that there is a need to ensure decisions are made based on up-to-date and complete scientific evidence.

This project

The project aimed to:

- Review previous incursions in MPI database
- Interview key commercial growers
- Assess current and future biosecurity risk
- Evaluate management alternatives – e.g., biocontrol
- Provide a strategic evaluation of the biosecurity risk

Possible pest management alternatives that could be applied in the event of an incursion and whether an increased research effort is warranted were also considered.

Key results

There are a number of pests and pathogens (hereafter referred to as “pests”) recorded on cypress in New Zealand with the most damaging being cypress canker caused by *Seiridium cupressi* and *Seiridium cardinale*. Scale insects and aphids are commonly found on many species but generally cause little damage. Overseas, *Phytophthora lateralis*, cause of root rot, and *Cinara cuppressi*, the cypress aphid, are the most significant pest threats. It appears that other pests do not pose a serious threat to New Zealand cypress.

With the exception of cypress canker, which causes problems in New Zealand and overseas, it is likely that management techniques could be developed for most cypress pests, based on known outcomes of research aimed at management of pine and eucalypt pests. There is hope that a breeding solution for cypress canker can be found.

The prospects for cypress are very good, especially if canker was mitigated. The market, particularly overseas, is very large and undersupplied. Cypress offers opportunity in terms of a new market and as a backup softwood if a serious pine pest arrived in New Zealand

We recommend that an incursion response for a significant cypress pest should be attempted as long as it is deemed feasible.

The above recommendation is based on our conclusions that

- The likelihood of frequent, high impact cypress pest incursions is very low
- Apart from cypress canker, cypresses do not have significant damaging pests or diseases in New Zealand
- Cypresses may be an alternative softwood option if a devastating new pest became established on *Pinus radiata*
- Although the current resource is small the future prospects for cypresses are high

Implications of results for the client

This risk analysis puts the biosecurity risk to forestry cypress into perspective. It should assist decision making should a serous new pest of cypress be found in New Zealand.

Risk analysis for cypress species relevant to forestry to inform biosecurity response

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Introduction

The Ministry for Primary Industries has been making decisions on whether to attempt eradication of some forest pests based on incomplete information. Under the Government Industry Agreement (GIA) Deed partnership the forest industry will need to start paying a share of the costs of these should a decision be made to proceed with eradication or management of new incursions. The Forest Owners Association/Farm Forestry Association Forest Biosecurity Committee has determined a need ensure decisions are made based on up-to-date and complete scientific evidence.

It was agreed to undertake a strategic evaluation of the cost/benefit of responding to incursions on cypress, in order to provide the forest growing sector with evidence on which to base a decision, especially of the potential impact of a new pest on commercial cypress production.

The biosecurity risk to cypress is reviewed and summarised here to inform decisions on the response should a new cypress pest be found.

Cypresses are members of a conifer family (Cupressaceae) grown throughout the world. The family is large and diverse, with about 30 genera and 140 species in total. Cypress have been planted in New Zealand for over 150 years. There are 17 species widely planted from the genera *Callitris*, *Chamaecyparis*, *Cryptomeria*, *Cunninghamia*, *Cupressus*, *Juniperus*, *Libocedrus*, *Sequoia*, *Taxodium* and *Thuja*, including two native *Libocedrus* species. The most common forestry genera in New Zealand are *Chamaecyparis*, *Cupressus*, *Juniperus*, *Sequoia* and *Thuja*. The planted area is just over 10,000 ha and that has remained static since 2010. Breeding for resistance to canker and other traits started in 1983, and two large progeny trials were established in 1985. Clonal cypress trials were established between 1994 and 1998. In 2009, a development plan for cypress was published that outlined a focus on breeding for durability and canker resistance. A number of cypress growing groups have been formed over that time, primarily driven by members of the Farm Forestry Association.

Cypress forestry in New Zealand

There were 10,140 ha of cypress planted in New Zealand as at 1 April 2016 (NEFD 2016). The area has been relatively stable over the past 10 years (9,000 ha in 2008) and it amounts to less than 1% of the total planted forest estate. Most of the cypress resource is planted in the South Island, mainly on the West Coast (7,300 ha), with 2,800 planted in the North Island. Almost half the estate is aged between 11 and 20 years, with 480 ha aged between 1-5 years.

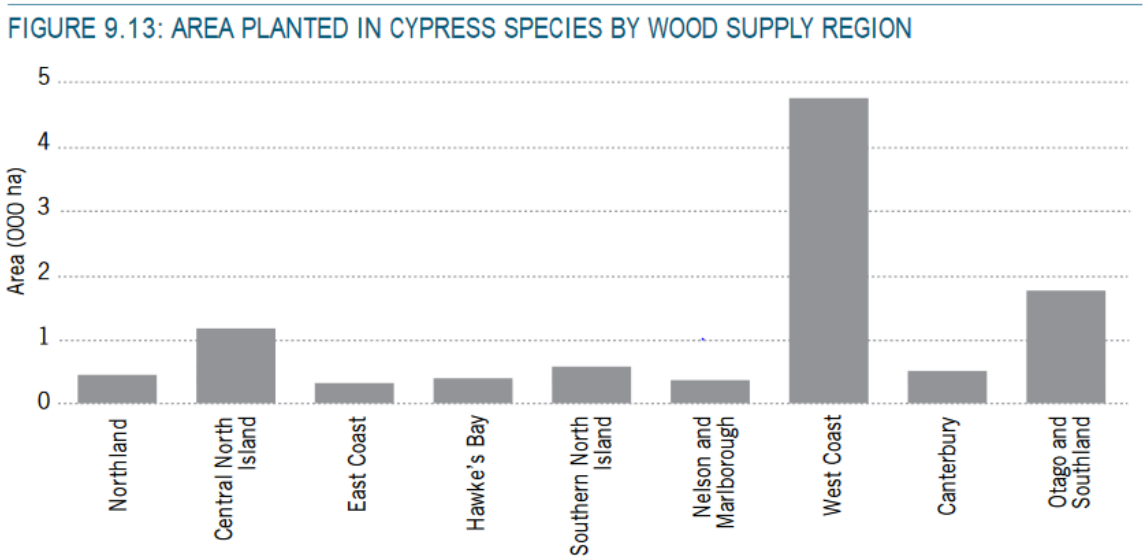

Fig. 1- Area planted (from NEFD 2016)

Cypresses have yellow to brown or red coloured heartwood and paler sapwood, with fine and even texture. *Cupressus macrocarpa* wood is particularly attractive and has application for furniture and joinery. There are problems with surface and internal checking. Many species have moderately durable heartwood but the sapwood is not considered durable.

Significant pests and pathogens in New Zealand

Table 1 shows pathogens and insect pests, listed by the type of damage they cause in order of frequency reported. The reports were from samples taken by specialist surveyors, researchers, growers and the public. Pests or pathogens with more than 20 records are listed. The number of records does not necessarily equate to severity of damage. Numbers may reflect prevalence of the host, frequency of inspection or some other factor.

Table 1 – Pests and pathogens of significant cypress species (records of formal identifications from the Forest Health Database).

Type	Pest	Chamaecyparis lawsoniana	Cryptomeria japonica	Cupressus × leylandii	Cupressus lusitanica	Cupressus macrocarpa	Cupressus sempervirens	Cupressus sp.	Juniperus spp.	Sequoia sempervirens	Sequoiadendron giganteum	Thuja plicata	Grand Total
Pathogens													
Canker	*Seiridium cupressi*	75	1	26	30	103	4	22	2		5	16	304
Canker	*Seiridium cardinale*	10		9	3	31		4	2			1	66
Dieback	*Phomopsis* sp	5		1	6	26	2	3	4	9	1		62
Dieback	*Pseudocercospora thujina*	43			1			2				3	55
Dieback	*Botryosphaeria* sp	2	9		4			1	1	26	9		54
Dieback	*Botrytis* sp				3	18			1	6	4		37
Dieback	*Fusicoccum* sp		6					1		6	9		31
Dieback	*Fusarium* sp	2	3	1	2	11		3	3	2			28
Dieback	*Botrytis cinerea*	2			4	11			1	7			26
Dieback	*Diaporthe juniperovora*		1			21			1				23
Insect pests													
Bark borer	*Phloeosinus cupressi*	7	2	1	13	36		4		1			67
Foliage feeder	*Hierodoris atychioides*	2	2		1	6	1	9	4	2			29
Sap sucker	*Carulaspis juniperi*	1		1		4	5	6	4		4		37
Sap sucker	*Cinara fresai*				1	7	1	3	7		1		24
Wood borer	*Kalotermes brouni*[1]	11	2		2	29		5		6		3	69
Wood borer	*Ambeodontus tristis*	4	3		2	14		6		2		1	35
Wood borer	*Eburilla sericea*[1]	8	7			4		1		4		5	30
Wood borer	*Prionoplus reticularis*[1]	7	1	1	1	6				1		4	22
Wood borer	*Calliprason pallidus*	5	5		2	2		2		2		3	21
	Grand Total	**362**	**210**	**74**	**295**	**676**	**32**	**202**	**72**	**281**	**78**	**104**	**2808**

[1]Native

Pathogens

Cypress canker

The most significant disease affecting cypress in New Zealand is cypress canker (Table 1, Fig. 2 and cover). It is caused by two fungal species, *Seiridium cupressi* and *Seiridium cardinale.* They affect most cypress species. The following species are listed in order of susceptibility.

Very susceptible
Cupressus macrocarpa

Moderately susceptible
Chamaecyparis lawsoniana, × *Cupressocyparis leylandii*, *Cupressus sempervirens*,

Low susceptibility
× *Cupressocyparis ovensii*, *Cupressus arizonica*, *Cupressus goveniana*, *Cupressus lusitanica*, *Cupressus torulosa*, *Calocedrus decurrens*, *Thuja occidentalis*, *Thuja plicata*

Rarely susceptible
*Cryptomeria japonica**, *Juniperus communis*, *Sequoiadendron giganteum*

Fig. 2 – Cypress canker on a *Cupressus macrocarpa* stem

Cankers may form on stems or branches and cause shoot or leader dieback. Trees of any age may be killed. Older trees are prone to malformation and wind breakage. The disease affects plantations, shelterbelts and amenity plantings. It has caused serious damage throughout the world. The first outbreak was noted in California in 1928 on *Cupressus macrocarpa.* Plantations in the inland districts were completely destroyed by the disease. It is probable that the canker pathogens were spread throughout the world on this species. The disease is present in Australasia, North and South America, Europe and Africa. It is particularly severe in the Mediterranean where 70% and 90% of trees in some plantations in central Italy and Greece, respectively, have been affected. Cypress canker is limiting the plantation of cypress in the Mediterranean basin and elsewhere in the world, including New Zealand.

The disease is present throughout the country (Fig 3) and there appears to be no difference in geographic range between the two pathogens. Two significant surveys have been undertaken, one a field survey published in 1984, the other was in the form of a questionnaire to growers and this was published in 2001. Both surveys concluded that there was large variation in disease incidence and severity and it was difficult to determine any effects of age class or climate on disease. However there was a tendency for disease to be higher in warmer regions and in older stands in forest plantations. Over 50% of the stands surveyed had dead trees present.

Control options are limited. Some systemic and contact chemicals (not copper based) have shown efficacy but there are registration and application challenges to overcome, and the cost-benefit of chemical application has not been determined. *Trichoderma* and *Pseudomonas* metabolites have inhibited growth of the canker pathogens in culture and the latter has prevented development of cankers in Italian cypress. Biological control may be considered “promising” at this stage.

Cypress shows large within and between species variability when inoculated with *Seiridium.* Canker resistance has been examined in New Zealand as part of a breeding programme that started in the 1980s but resistant breeds have yet to be fully developed and commercially available. However, Rotoehu 2/20 clone was released in the 1970s by Martin Bannister (Forest Research Institute) and is still available as a cypress canker resistant clone and others that farm foresters have released include Barr Hybrid and Rangitoto #3 (D. Satchell, pers. comm. and http://www.nzffa.org.nz/special-interest-groups/cypress-development-group/cypress-development-group-reports/angus-gordons-cypress-trial-at-taihape-december-2016/). Rotoehu 2/20 is a *C. lusitanica* clone, a species generally more resistant to canker than *C. macrocarpa*. Rangitoto #3 is a *C. macrocarpa* clone. A number of selections have been released commercially from the Scion breeding programme, underpinned in the last 10 years by a breeding and deployment strategy co-developed through the Future Forests Research programme. Recent releases include *C. lusitanica* clones selected for good growth and for the absence of canker.

There is an on-going breeding programme at Scion for cypress in New Zealand, supported through the Specialty Woods Partnership Programme. A key selection criteria for all cypresses is health, with specific attention given to canker. A breeding strategy is in place to select for growth, form, wood quality and canker resistance. A new *C. macrocarpa* seed orchard has been established with canker resistant material. During 2018 these new selections will be established across a number of canker-prone sites to confirm resistance before commercial release, which will be expected in the next 3-7 years. This is very encouraging and may help to see this species planted more widely.

The pathogens are dispersed by rain splash and spread is mainly local, allowing the disease to build up within stands if not attended to. Stand hygiene can therefore be used to suppress disease development, although difficult to adopt on a plantation scale. For instance, planting stock should be pathogen free, and nearby trees or branches where cypress canker is present should be removed and burnt as soon as disease is seen to prevent spread to other trees. It has been reported that excessive nitrogen will increase disease levels.

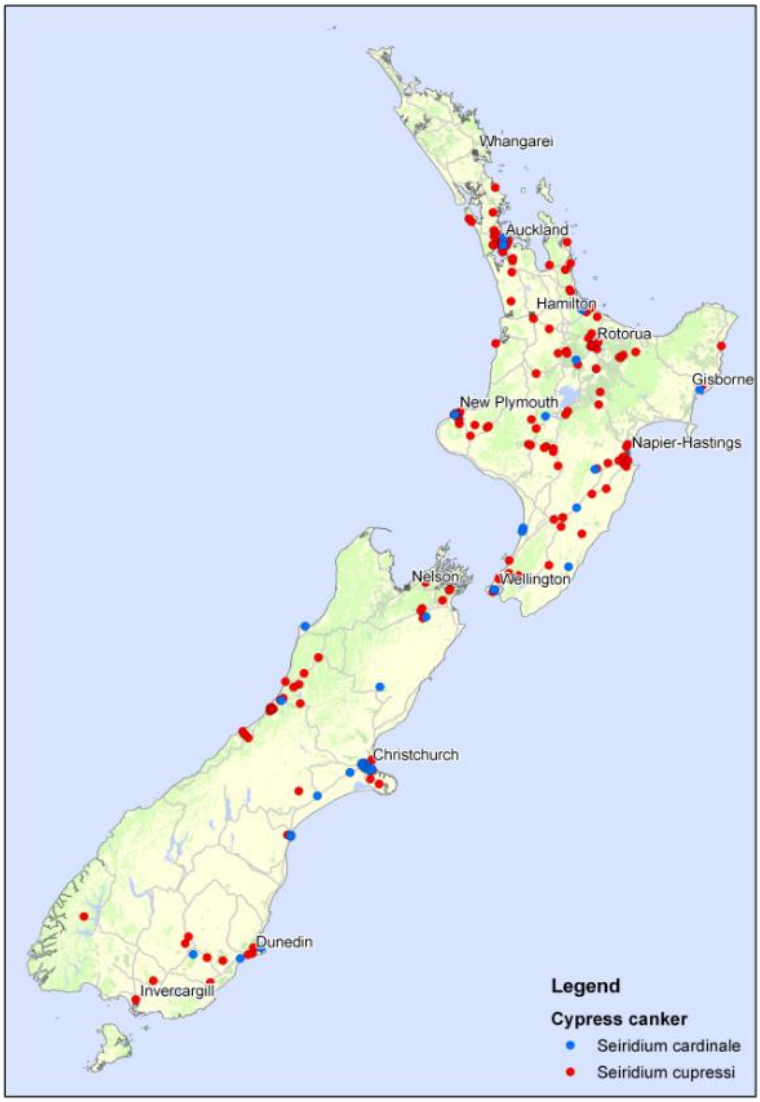

Fig. 3 – *Seiridium* records (Forest Health Database 1960-2007)

Other pathogens

Diaporthe juniperovora (formerly known as *Phomopsis juniperovora*) is considered a serious pathogen on *Juniperus* and several other cypress species, including *Cupressus macrocarpa*, in the United States but causes only isolated damage in New Zealand. The pathogen causes mainly leaf and shoot infection in young plants and on new growth of older plants.

Insect pests

There are several insect pests recorded on cypress in New Zealand. None cause any significant economic impact.

A number of stem and wood borers that infest dead wood. These are *Ambeodontus tristis*, *Calliprason pallidus*, *Eburilla sericea* (native), *Kalotermes brouni* (native), and *Prionoplus reticularis* (native). An introduced bark borer, *Phloeosinus cupressi* is also common.

The juniper scale *Carulaspis juniperi* and an aphid *Cinara fresai* may reach high populations on individual hosts but rarely cause significant damage.

Biosecurity risk

Cypresses have been grown in New Zealand for over 150 years. Over that time only two economically significant pathogens and no significant insect pests have established. Since 1988 only six pests of cypress have established and all have been low impact (Table 2).

Table 2 – First records of pests and pathogens on cypresses in New Zealand.

Date	Organism	Host	Impact	Disorder	Location
30-Nov-90	*Lophodermium juniperinum*	*Juniperus squamata*	L	Leaf blight	Waiouru
1-Jan-95	*Camarosporium sp.*	*Cupressus macrocarpa*	L	Stem canker	Christchurch
10-Aug-98	*Sarcostroma mahinapuense*	*Chamaecyparis lawsoniana*	L	Branch damage	Mahinapua Forest,
5-Dec-99	*Pseudocercospora nogalesii*	*Chamaecytisus palmensis*	L	Leaf spot	Auckland
14-Sep-00	*Kabatina thujae*	*Thuja plicata*	L	Leaf spot	Timaru
3-Aug-09	*Carulaspis minima*	*Juniperus chinensis*	L	Sap sucker	Hamilton

Pathogens not present in New Zealand

Phytophthora lateralis is an aggressive pathogen that mainly affects *Chamaecyparis lawsoniana*. It generally firstly infects the roots and girdles the root collar, causing rapid decline and death of the plant. The pathogen may also be spread though water droplets which can result in stem or branch infections and dieback. The pathogen is considered to be of Asian origin, most probably from Taiwan, but has been in the Pacific Northwest of USA since the 1920s. There it has killed many *Chamaecyparis lawsoniana* in their native range and has caused significant economic and environmental impact there. It was first recorded in France in 1996, and subsequently in Netherlands, Scotland, and Ireland.

It is likely this pathogen would cause damage to *Chamaecyparis lawsoniana* if it were to establish in New Zealand. Long distance dispersal is possible by water, live plants, and soil. Spread to Europe, and then within, was attributed to movement of infected nursery stock.

Passalora sequoia, the cause of cercosporidium blight, is a serious pathogen on a wide range of conifers. It turns foliage brown and eventually results in defoliation, sometimes severe. It was first reported in 1887 on *Sequoiadendron giganteum* in USA. Now, × *Cupressocyparis leylandii*, *Juniperus virginiana* and *J. silicicola* have become important hosts.

Cedar leaf blight caused by *Didymascella thujina* causes damage to *Thuja plicata* and *T*. *occidentalis* in North America and Europe. It also occurs on *Chamaecyparis lawsoniana* seedlings. In North America, *Thuja plicata* seedling mortality of up to 97% has been recorded. In the field, growth loss attributed to the disease is estimated to be 30% in some locations. A short-cycle breeding programme for cedar leaf blight in British Columbia has seen significant improvement in the health of new cedar plantings.

Kabatina juniperi and *Sclerophoma pythiophila* are known to cause similar type of damage in North America and Europe to *Diaporthe juniperovora*. The former causes tip blight of juniper and can also cause tip and shoot dieback and cankers on *C. macrocarpa*. *Sclerophoma pythiophila* causes tip dieback very similar to those caused by *Phomopsis*. The fungus generally attacks weakened or damaged tips. *Diplodia cupressi* is responsible for foliage and shoot dieback and causes stem cankers/cankering on *Cupressus sempervirens* in the Mediterranean region and on *Juniperus* and *Cupressus* × *leylandii* in North America.

Armillaria and *Phytophthora* species have been recorded on cypress in many countries and may cause localised damage. Phytophthora root rot can cause damage in nurseries especially.

Fig. 4 - *Phytophthora lateralis* on *Chamaecyparis lawsoniana* in Landrévarzec, France. Photo D. Piou, http://forestphytophthoras.org.

Insect pests not present in New Zealand

Cinara cupressi, the cypress aphid, has caused serious damage to commercial and ornamental plantings and native stands of *Cupressus*, *Juniperus*, *Widdringtonia* and other cypress in Europe, Africa, South America and the Middle East. It can turn the entire tree crown red. There is a suggestion that in parts of Africa damage caused by the aphid was aggravated by unfavourable soils and climate. It has established in the Middle East, Africa and South America since the 1980s, through the movement of infested nursery stock. The aphids are difficult to see with the naked eye and therefore can easily escape detection during quarantine inspection. It is listed as one of the 100 "worst" invasive species in the Global Invasive Species Database.

The cypress tip moth, *Argyresthia cupressella*, affects *Chamaecyparis lawsoniana, Thuja plicata,* and *Juniperus* species in North America, where it is native, and was introduced to the United Kingdom in 1997. It results in foliage and shoot death.

There are very few insect pests that cause serious damage to cypress apart from *Cinara cupressi.*

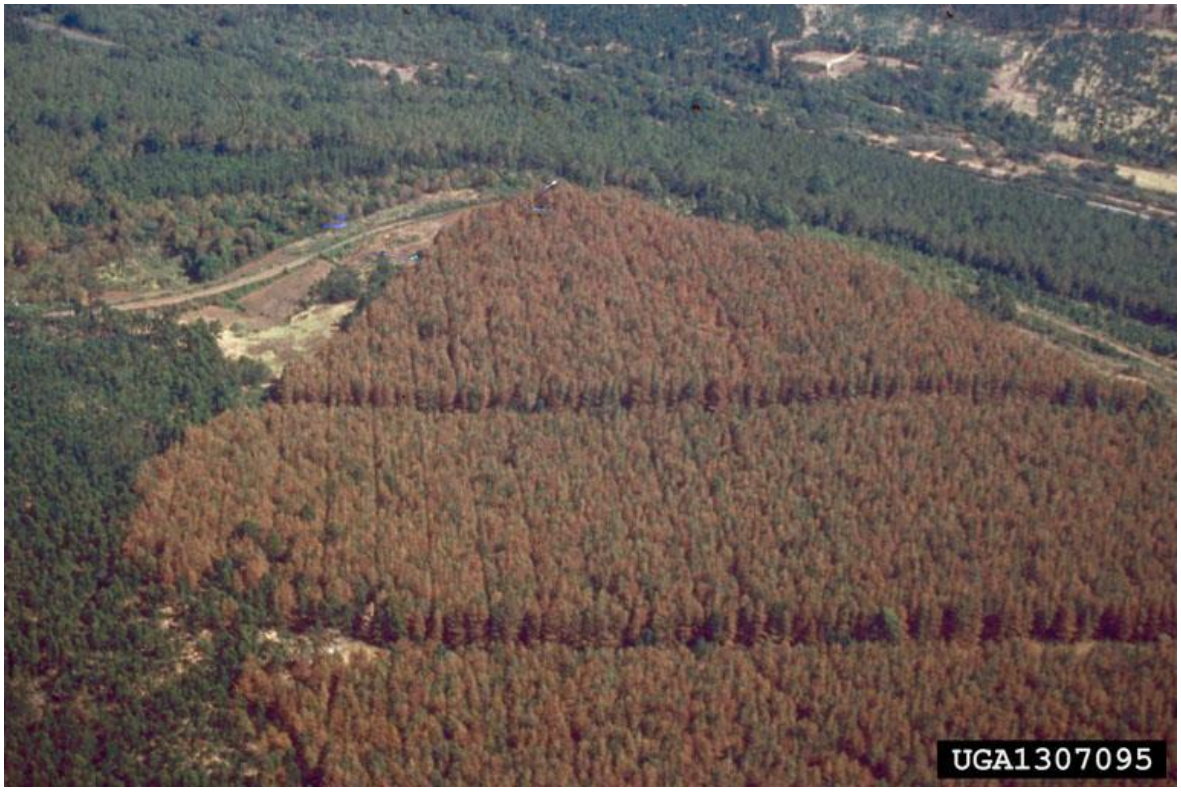

Fig. 5 - *Cinara cupressi* damage on *Cupressus lusitanica* in Kenya. Photo: James Denny Ward, USDA Forest Service, Bugwood.org.

Other risks

A mistletoe, *Phoradendron densum*, is present in western USA of several species of cypress and juniper. Some individual hosts may be severely infested but on a stand scale it causes minimal loss.

It has been stated that as a rule, for every two known threats there would be one unknown threat of equal potential for damage. The *Pinus radiata* pathogens *Neonectria fuckeliana* and *Phytophthora pluvialis* are examples. Neither were known pathogens of *Pinus radiata* but when they established on that host they both caused damaging diseases (nectria flute canker and red needle cast) in some locations.

Mitigating factors

There are a number of factors that mitigate biosecurity risk in New Zealand for cypress or otherwise encourage their adoption on biosecurity grounds.

Lack of damage overseas and in New Zealand from some threats

Several overseas foliage and shoot dieback pathogens are recorded as causing similar damage to *Diaporthe juniperovora*, which is present in New Zealand. Given that *D*. *juniperovora* does not cause widespread damage here, it is unlikely that the overseas pathogens such as *Kabatina juniperi* and *Sclerophoma pythiophila* pose a significant threat.

Kabatina thujae is known in both Europe and North America to cause leaf tip death of a range of hosts in *Cupressus, Chamaecyparis, Thuja* and *Juniperus*. Only minor damage has been reported on *Chamaecyparis lawsoniana* and *Thuja plicata* since it was discovered in New Zealand in 2009. The damage reported overseas does not appear to be replicated here.

Apart from *Cinara cupressi* there are no known widely reported insect pests of significance. This aphid is particularly invasive, having spread from North America to most parts of the world. The main mode of transport was on live plant material. New Zealand's import health standards should be sufficiently robust to prevent the establishment of this insect.

Cypresses provide risk mitigation for other forestry species

Pinus radiata comprises over 90% of New Zealand's plantation forest estate. That biosecurity risk is mitigated by the fact that the species is planted over a very wide geographic and climatic range and that the plantings are not clonal, with a few exceptions, and are generally based on a diverse number of seedlots containing a number of families. However, from a biosecurity perspective, it would be prudent to have some species not in the Pinaceae family that were suitable for forestry to act as a long term replacement or alternative to *P. radiata* if a serious pest incursion of that species or perhaps Douglas-fir occurred. Cypress could fill that role.

Management of new incursions

Mitigation of damage from most new forest pests and pathogens has been successful after research effort. For example, dothistroma needle blight on *Pinus radiata* has been controlled by application of copper at low doses, generally only 3-5 times per rotation. Nectria flute canker is managed by avoiding pruning in winter and limiting the size of branch stubs by heavier stocking and more frequent pruning. This disease has changed in status from being extremely damaging on some sites to a rarity. Cyclaneusma needle cast is no longer a common disease. Elimination of lines that showed poor needle retention through the breeding programme has been successful. The *Eucalyptus* pests brown lace lerp (*Cardiaspina fiscella*) and the eucalypt sawfly have been successfully controlled by the introduction of biological control agents.

For cypress, if eradication was not an option, the alternative treatments that are successful for other species outlined above should be appropriate. The most challenging disease to treat could be a *Phytophthora* root rot such as *Phytophthora lateralis*. This can be mitigated to some extent by correct siting of the species and their hybrids.

Selected industry experts' views

Biosecurity risks

Cypress canker is the biggest challenge to growing cypress. Genetics, site selection and nutrition offer the best chance of finding solutions. There are seedlots that are showing resistance to canker, so genetics can mitigate its effects. Researchers should look at planted stands – a performance survey (looking at all traits, not just canker) should be undertaken. Cypress need fertile soils, otherwise they are at risk. Hybrids, i.e. x *Cupressocyparis ovensii* mills well and has no health problems. One respondent mentioned the cypress aphid.

Commercial risks

The domestic market has the potential to be fully priced but the Chinese market is strong. There is excellent demand for cypress and prices are attractive. Very little market risk – either in New Zealand or overseas. Market is huge. The market is undersupplied, there is little good quality *C. macrocarpa* in the pipeline and this may affect the processors as they need surety of supply to continue specialising in that species.

Willingness to contribute to an incursion response

Would "do our bit" and fund our share (unanimous among respondents). Would offer in-kind support. Growers should be prepared to contribute but they have to contribute to decision making process. Financial contribution equals a seat at the table.

Outlook for cypress

Significant – hindered only by canker. Cypress is compatible with the New Zealand environment, can grow over a wide geographical range, on different sites. As adaptable as *P. radiata*. Aside from *P. radiata* and Douglas-fir, cypress is the only other viable softwood. We have confidence in cypress, similar to *P. radiata* to manage and harvest – although silviculture needs a little more management and effort.
We have made mistakes in the past, a different approach will increase prospects for the species enormously. For instance, the formal breeding programme has not delivered any improved germplasm whereas self-selected stock is improved. We need to take advantage of the practical experience of growers and note genotypes that have performed well in the field.

Conclusions

Cupressaceae is a wide and diverse family comprising many genera and species, some of which are of interest to forestry. The estate is about 10,000 ha and has remained at about that level over the last 10 years. There have been a number of initiatives to promote cypress as a high value plantation forest option but none have gained much traction.

There are several cypress pests and pathogens recorded in New Zealand but only one causes significant damage. This is cypress canker caused by *Seiridium cupressi* and *Seiridium cardinale*. It is the primary biological impediment to planting many cypress species, particularly on warm sites.

Overseas, cypress are largely free of damaging pests or diseases, apart from cypress canker and Port Orford cedar root disease caused by *Phytophthora lateralis*. Cypress pests have established

in New Zealand since cypresses were planted 150 years ago. Since 1988, six new pests (one insect and five fungi) have been recorded.

Of the known overseas pathogens for which we have some information, none appear to pose a serious threat to New Zealand cypress. Two notable exceptions are *Phytophthora lateralis* and the very invasive aphid, *Cinara cupressi*.

With the exception of cypress canker, which causes problems in New Zealand and overseas, it is likely that management techniques could be developed for most cypress pests, based on known outcomes of research aimed at management of pine and eucalypt pests. On-going breeding programmes are currently addressing the canker issue (see section on cypress canker above).

Some cypress are recognised as good backup and useful alternative species to radiata pine, because of their better wood properties and possibly to mitigate long term damage from a serious radiata pine pest or pathogen becoming established. However this review suggests for this to happen there should be greater focus on improving canker resistance either via choice of species (e.g. *C.* x *ovensii* and possibly *C. lusitanica*), screening clones that are purportedly resistant, or by breeding (*C. macrocarpa*). In the latter case this should probably be done in conjunction with efforts to improve form, branch habit and yield. While some of this is addressed through the breeding programme, more resources would speed up the development of new planting stock.

The prospects for cypress are very good. The estate currently is small and not expanding quickly, but that could well change if canker was mitigated. The market, especially overseas, is very large. Cypress offers opportunity in terms of a new market and as a backup softwood if a serious pine pest arrived in New Zealand.

Recommendations

An incursion response for a significant cypress pest should be attempted as long as it is deemed feasible.

This recommendation is based on the following:

- The estate is small but the opportunity cost of allowing a pest to establish when there is a high chance of eradication (i.e. if the known distribution is small, the biology is understood and there is an immediate response with no delay)
- Cypress may be an alternative softwood option if *Pinus radiata* was threatened by a devastating new pest
- The likelihood of frequent, high impact cypress pest incursions is very low
- Apart from cypress canker, which is problematic, cypress in New Zealand do not suffer from economically significant pests or diseases.

Acknowledgements

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