Risk analysis of the *Puccinia psidii*/ Guava Rust fungal complex (including *Uredo rangelii*/Myrtle Rust) on nursery stock



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Approved for general release

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1 Executive summary

Purpose

The purpose of this document is to assess the risks associated with the rust fungus *Puccinia psidii* entering New Zealand via the myrtaceous nursery stock import pathway and consider options for effectively managing these risks. This risk analysis was undertaken to support a review of the risk management provisions for myrtaceous nursery stock in the import health standard (IHS) 155.02.06: Importation of Nursery Stock, after a variant of *P. psidii* named *Uredo rangelii* was detected in Australia in April 2010.

Background

P. psidii causes rust disease, known variously as guava rust, eucalyptus rust, ohia rust or myrtle rust, of a wide range of host plants in the family Myrtaceae. As New Zealand has myrtaceous species of economic, environmental and socio-cultural importance, *P. psidii* is considered a potential hazard to New Zealand. Since a variant of *P. psidii* established in Australia, the number of genera containing host species has increased by 114% (as at 13 June 2011) and now totals 45 genera. The Australian variant affects 101 myrtaceous species. Since 2005, the majority of imported myrtaceous nursery stock was sourced from Australia, whilst tissue culture was sourced from Australia, India and the United States.

Risk assessment findings

In the absence of specific risk management, the likelihood of *P. psidii* s.l. entering New Zealand on myrtaceous nursery stock is considered to be moderate to high. Once the fungus has entered New Zealand on this pathway, it is considered highly likely that it will be exposed to new host plants. It is also considered highly likely that *P. psidii* s.l will be able to establish and spread within New Zealand.

Key factors that contribute to the high likelihood of establishment are:

- the New Zealand climate is suitable for *P. psidii* (year-round in Auckland);
- there are many natural and modified habitats in New Zealand that could support the biology of *P. psidii*;
- all myrtaceous species in New Zealand are considered potential hosts of *P. psidii*;
- spores are easily and rapidly dispersed, and;
- the experience of Australia and Hawaii demonstrates that once *P. psidii* is established beyond a confined area, it is highly likely that eradication will be technically unfeasible.

The potential consequences within New Zealand are uncertain but considered to be moderate to high. The consequences are dependent on the number of species that are found to be susceptible to *P. psidii* in New Zealand, and on the severity of infections on susceptible hosts. At one extreme, some species may die on a landscape scale, and at the other extreme, some species may become infected but be otherwise unaffected in terms of growth, development and fruit/seed production.

Examples of potential impacts include:

- there are at least four domestic and export industries in New Zealand that depend on myrtaceous species and are potentially at risk: eucalyptus forestry, nurseries growing myrtaceous species, feijoa orchards, manuka honey production.
- environmentally, the impact could range from low to high. Included in the native species considered at risk are three known host species: *Metrosideros excelsa* (pohutukawa), *M. kermadecensis* (Kermadec pohutukawa) and *Lophomyrtus bullata* (ramarama or New

Zealand myrtle); and the 'nationally critical' species *Metrosideros bartletti* (Bartlett's rata).
- the socio-cultural impacts are considered to be moderate to high because of the importance of native myrtaceous species, particularly pohutukawa, to the people of New Zealand.

Risk estimation conclusion

The risk estimation for *P. psidii* is non-negligible and the fungus is considered to be a risk on myrtaceous nursery stock. Therefore, the risk is worth considering and further analysis was undertaken to decide if additional measures are warranted.

Analysis of risk management options

The analysis of the risk management of *P. psidii* prescribed by the current IHS concluded the following: the schedule entitled *Eucalyptus* was considered to be adequate; however, the basic entry conditions, the specifications for tissue culture, and the schedules entitled *Acca sellowiana, Agonis, Eugenia* and *Metrosideros*, were considered inadequate for managing the risk associated with *P. psidii* on imported myrtaceous nursery stock. Therefore, the efficacy of further measures were considered and analysed.

Of the further measures that were considered and analysed for the myrtaceous nursery stock pathway, 'pest free area' and 'fungicide treatment' each had limitations in their efficacy to manage the risk of *P. psidii* on nursery stock. Whilst an efficacious 'pest-free place of production' is technically possible, further consideration is required to determine whether this risk management option would be viable.

If tissue culture import specifications are modified to address limitations of the current IHS, then the use of tissue culture would provide the greatest reduction of risk associated with *P. psidii* on imported myrtaceous nursery stock.

2 *Puccinia psidii* sensu lato (s.l., in the broad sense) complex (guava rust complex)

Scientific name:	*Puccinia psidii* s.l. Winter 1884 (Pucciniales/ Pucciniaceae)
Other relevant scientific names:	*Uredo psidii* J.A. Simpson, K. Thomas & Grgur. 2006 (anamorphic name of *P. psidii*) *Uredo rangelii* J.A. Simpson, K. Thomas & Grgur. 2006 (Myrtle rust) *Uredo seclusa* H.S. Jacks. & Holw. 1931
Common names:	guava rust, eucalyptus rust, ohia rust, myrtle rust

Puccinia psidii is a rust fungus that infects plants of the family Myrtaceae. Many variants have been recognised and collectively they are known as the *P. psidii* s.l. complex (*P. psidii* s.l.) (Carnegie et al 2010) and it will be referred to as such in this analysis. The complex includes the newly described taxon *Uredo rangelii,* which was detected in Australia in April 2010. *U. rangelii* had 37 known host species as at 2 February 2011; this had increased to 101 known host species as at 13 June 2011. Refer to Appendix 3 for the *U. rangelii* host list as at 13 June 2011 (NSW Department of Primary Industries, 2011; Queensland Department of Primary Industries, 2011)

P. psidii s.l. could enter New Zealand via the importation of nursery stock, especially via nursery stock of the family Myrtaceae.

2.1 Purpose

The purpose of this report is to assess the risks associated with *P. psidii* s.l. entering New Zealand via the nursery stock import pathway and consider options for effectively managing these risks. This risk assessment will support the development of a Risk Management Proposal for any amendments considered necessary to the import health standard (IHS) 155.02.06: Importation of Nursery Stock, particularly to the import requirements for species in the family Myrtaceae.

This risk analysis will also serve as a platform for future assessment of the risks associated with *P. psidii* s.l. entering New Zealand via other potential pathways such as cut flowers and foliage, or seed for sowing.

2.2 Background

Myrtaceous nursery stock (whole plants, cuttings, and tissue culture) are eligible for import into New Zealand under the import health standard (IHS) 155.02.06: Importation of Nursery Stock. Imports of myrtaceous whole plants and cuttings since January 2005 have been sourced from Australia, while tissue cultures of myrtaceous species have been sourced from Australia, India, and the United States of America.

Since *Uredo rangelii* was detected in Australia in April 2010, the known host range of *P. psidii* s.l. has expanded significantly. Consequently, the *P. psidii* s.l. complex is now known to infect plants from 45 genera of the family Myrtaceae, demonstrating that it has an extremely broad host range (see Appendix 1). The consequence is that many of the newly described hosts within the current IHS have not been assessed for the biosecurity risks posed by *P. psidii* s.l. and the import health standard may not provide sufficient management of the risk for myrtaceous nursery stock from countries where *P. psidii* s.l. is present (refer to Appendix 2 for a summary of the current import requirements).

All imports of whole plants and cuttings from Australia were imported prior to *U. rangelii* being detected in Australia in April 2010. Following the detection, MAF responded by suspending the issuance of permits for myrtaceous whole plants and cuttings from Australia, i.e. these items cannot be imported from Australia at present. MAF is considering requests to import myrtaceous whole plants and cuttings from other countries on a case by case basis. Myrtaceous tissue cultures are still eligible for import.

A risk analysis of *P. psidii* s.l on nursery stock is required to ensure the IHS for this material is managing the risk appropriately.

2.3 Scope

In this analysis, the likelihood of *P. psidii* s.l. entering New Zealand on myrtaceous nursery stock (whole plants, cuttings, tissue culture) is examined. Also examined is the likelihood of *P. psidii* s.l. establishing and causing unwanted impacts in New Zealand.

The scope of this analysis does not include import pathways involving seeds, cut flowers or foliage. Neither does it cover the risk associated with wind-borne *P. psidii* s.l. spores from Australia, or any other risk pathway. The risks associated with these pathways may be considered in separate risk assessments.

The analysis is intended to consider the risk of *P. psidii* s.l as a whole complex, rather than individual variants. It considers all countries, not just those countries known to have *P. psidii* s.l. present. This report does not take into account current risk management practices in New Zealand, and assumes that production methods used in nurseries overseas in growing and preparing their plants for export do not include specific risk management activities for *P. psidii* s.l..

2.4 Hazard identification

2.4.1 Summary description of the *P. psidii* s.l. hazard

P. psidii s.l. is a complex of rust fungi that causes disease to plants of the family Myrtaceae, to which pohutukawa (*Metrosideros excelsa*), manuka (*Leptospermum scoparium*), kanuka (*Kunzea ericoides*) and rata (various *Metrosideros* species) belong. Symptoms of the disease begin as small golden yellow powdery eruptions in a circular pattern on the leaf or stem. These spots expand and the tissue becomes necrotic, spreading over the entire leaf, stem or shoot. Floral buds and fruit can also be affected. Leaves and stems become deformed and growing tips can die back in severe infections (Killgore & Heu, 2007). The plant disease is known as guava rust, eucalyptus rust, ohia rust or myrtle rust.

Host species exhibit varying degrees of susceptibility; at one extreme the less susceptible hosts develop lesions and support spore development, but their health and viability are otherwise unaffected. At the other extreme, highly susceptible host species are defoliated and can die, as happened to whole stands of *Syzygium jambos* in Hawaii (Loope, 2010), and to *Pimenta officinalis* in Jamaica (MacLachlan 1936). The *P. psidii* s.l. complex is unique among rusts in that it has an extremely wide host range, e.g. the taxon *Uredo rangelii* in Australia currently has 101 known host species (NSW Department of Primary Industries, 2011; Queensland Department of Primary Industries, 2011) and the tally is expected to expand as the rust spreads further in the Australian environment. *P. psidii* s.l. spores are wind-borne and so spread easily and quickly. Eradication is technically exceedingly difficult once the fungus is established in the environment (NSW Department of Primary Industries, 2010).

Further detail about *P. psidii* s.l. epidemiology, host range, and impact on plants is provided in the following sections.

2.4.2 Taxonomy

Puccinia psidii Winter sensu lato is the name given to the teleomorph (i.e. the sexual state). It has several described anamorphs (i.e. asexual state) including *Uredo psidii*, *U. rangelii* and *U. seclusa*. Many synonyms have been referred to in the literature and are summarised by Simpson et al (2006) and Glen et al (2007).

Uredo rangelii was described as a new rust species in 2006 (Simpson et al 2006). However, it has subsequently been considered in the scientific literature to be part of the *P. psidii* s.l. complex (Carnegie et al 2010), and the 'new species' distinction has been controversial as explained in the following paragraphs.

- *P. psidii* was first described on guava (*Psidium guajava*) by Winter (1884) in Brazil. This taxon can be considered as *P. psidii* sensu stricto (s.s., in the strict sense). *P. psidii* was later found on other host plants from the family Myrtaceae, described from Central and South America, and in the USA [Florida (since 1977), California (since at least 2005), Hawaii (since 2005)] and these records can all be considered as *P. psidii* sensu lato (s.l., in the broad sense).

- A morphologically distinct rust was named by Simpson et al (2006) as the new species *Uredo rangelii*. This species had previously been placed in the *P. psidii* s.l. complex, but was separated and renamed *U. rangelii* on the basis that it had different shaped urediniospores with a tonsure or bald patch on one side[1](Simpson et al 2006; Walker 1983). This taxonomic distinction is controversial because the description of *U. rangelii* was made based on only two samples (one from Argentina, one from Jamaica), the morphological variations described by Simpson et al (2006) are not uncommon in rust fungi (Langrell et al 2008), and the description of *U. rangelii* did not include any molecular analysis.

- The isolate of *U. rangelii* detected in Australia in April 2010 is genetically indistinguishable from *P. psidii* s.l. at the rDNA ITS locus. *U. rangelii* was thereby placed within the *P. psidii* s.l. complex (Carnegie et al 2010)[2].

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[1] A study of several collections identified as *P. psidii* showed that most agreed with the original *P. psidii* specimen in having completely spikey, ellipsoidal to obovoid (egg-shaped) spores (uredinospores). But two collections, on *Myrtus communis* from Argentina and *Syzygium jambos* from Jamaica, respectively, had different shaped spores [obovoid (egg-shaped) to pyriform (pear-shaped)] showing a smooth patch free of spikes (Walker 1983, cited in Carnegie et al 2010).

[2] A 'Pathogen of the Month' bulletin (authored by Dr Morag Glen, and published by the Australasian Plant Pathology Society), states that DNA sequencing of other gene regions of elongation factor 1-α and β-tubulin also failed to distinguish *U. rangelii* and *P. psidii* (http://www.australasianplantpathologysociety.org.au/Publications/POTM/index.htm).

- To distinguish the disease caused by *U. rangelii,* from guava rust caused by *P. psidii* s.s., authorities managing the incursion in Australia named it myrtle rust (Chief Plant Protection Officer, 2010), based on the name of the type host *Myrtus communis* (Carnegie et al 2010).

For the purposes of this risk analysis, the taxon that is present in Australia will be referred to in this document as *U. rangelii*. However, it is assumed that *U. rangelii* is synonymous with *P. psidii* s.l. (in the broad sense) and is considered to be a distinct taxon of the rust complex. As *U. rangelii* was only recently separated from *P. psidii* s.l. (Simpson et al 2006), the literature pertaining to *P. psidii* and guava rust will be considered directly relevant as it will include reference to disease caused by the taxon *U. rangelii*, including host range and impact data.

2.4.3 Biology

Like all rust fungi, *P. psidii* s.l. is obligately dependent on host plants to complete its life cycle and obtains its nutrients by feeding on the living tissues of its hosts.

Disease spread: The disease caused by *P. psidii* s.l. (guava rust, eucalyptus rust, ohia rust or myrtle rust) is easily spread from host to host by the movement of the highly mobile infectious spores by wind, rain, and insects (e.g. honeybees (Carnegie et al 2010)). Rust spores can travel very long distances when air-borne, e.g. the poplar rust fungi *Melampsora larici-populina* and *M. medusa* travelled from Australia to New Zealand on wind currents in 1973 (Viljanen-Rollinson et al 2006; McKenzie, 1998). Like other rust fungi, *P. psidii* s.l. is believed to have several life stages characterised by the different types of spores produced. The infectious spore forms are: aeciospores (but not recognised in nature due to similarity to uredinospores), urediniospores (the type most commonly observed), and basidiospores (rarely seen). Reproduction is mainly by repeated generations of urediniospores, though teliospores (resting, or wintering spores) are occasionally produced (summarised by Glen et al 2007). As the production of aeciospores is not confirmed, it is uncertain what role teliospores and basidiospores play in the life cycle of *P. psidii* (s.l.) (Simpson, pers. comm., 2011).

The infection process firstly involves *P. psidii* s.l. spore (urediniospore) germination, formation of a specialised infection structure (an appressorium) and subsequent direct penetration of plant cells. On a susceptible host, the fungus spreads and branches out intracellularly, i.e. inside the host tissue. The optimal temperature for mycelial growth within the host is 15˚C. The progression of disease can be first observed by the naked eye 3-5 days after inoculation. Lesions are brown to grey and after 12 days yellow urediniospore pustules are visible. After the first uredinial pustules appear, secondary infections arise on host tissue (Coutinho et al, 1998; Glen et al, 2007). Occasionally both urediniospores and teliospores occur together in the same lesion, the latter being medium to dark brown in appearance (Glen et al 2007).

Under optimal conditions, *P. psidii* s.l. produces abundant urediniospores, a feature that enables it to be easily dispersed and rapidly colonise new locations (Ferreira, 1983, cited in Glen et al 2007). Refer to Figure 1 for a diagrammatic summary of a proposed *P. psidii* s.l. lifecycle.

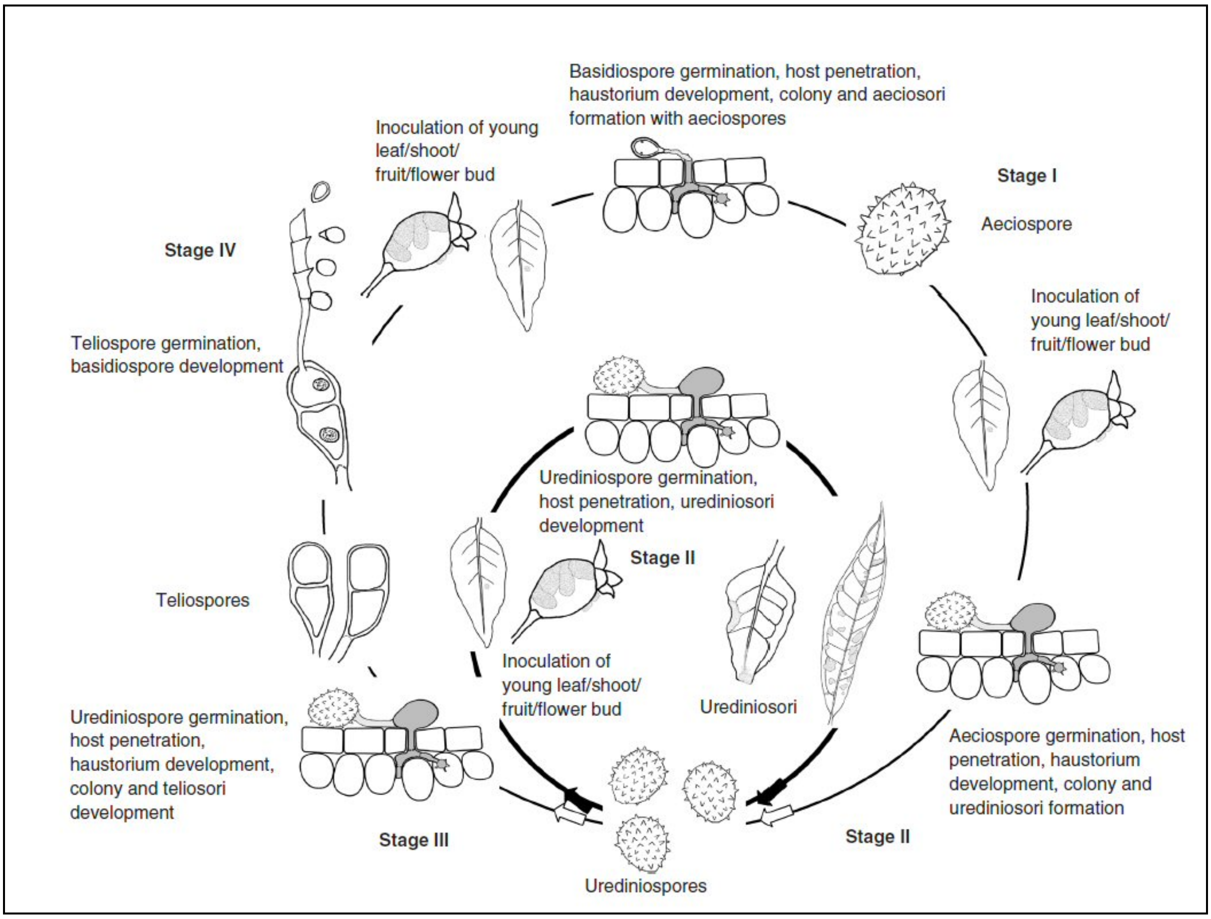

Figure 1: Diagrammatic representation of a proposed lifecycle of *Puccinia psidii* (from Glen et al. 2007).

Optimal conditions: Generally speaking, mild temperatures from approximately 15 to 23˚C favour the biology of *P. psidii* s.l.. Urediniospore germination and infection are affected by temperature, leaf wetness, light intensity and photoperiod (Ruiz et al 1989b, cited in Glen et al 2010). Several studies agree that high humidity or leaf wetness and low light for a minimum of 6 h following inoculation are necessary for successful germination (Piza and Ribeiro 1988; Ruiz et al 1989a, 1989c; cited in Glen et al 2007)):

- Germination: The highest rates of urediniospore germination have been measured at various temperatures (from 15˚C to 21˚C); this variation may be due to either study methodology or variation among the rust taxon (summarised by Glen et al 2007).
- Sporulation (urediniospores): the ideal temperature for the generation of urediniospores is 20˚C (Ferreira 1981, cited in Coutinho et al 1998). Either cool (<15˚C) or hot (~30˚C) temperatures inhibit uredinial sporulation (Ruiz et al (1989a), cited in Coutinho et al 1998).
- Sporulation (basidiospores): Basidiospore production on *Syzygium jambos* occurs across a range of temperatures from 12 to 24˚C, and was particularly high at 21˚C (Aparecido et al 2003, cited in Glen et al 2007).

The findings cited above are consistent which what is observed in the environment; in a study on *Syzygium jambos* in Brazil, disease incidence and severity was highly correlated with periods of relative humidity over 90% or leaf wetness periods greater than 6 h and nocturnal temperatures between 18 and 22˚C (Tessman et al 2001). Consequently, the progress and severity of rust disease caused by *P. psidii* s.l. varies from year to year according to the environmental conditions.

Spore survival: The viability (ability to germinate) of urediniospores of *P. psidii* s.l. lasts for up to 150 days (Salustiano et al, 2008) but depends on the temperature and relative humidity at which the spores are maintained. Spores maintain viability longer at cold temperatures and low relative humidity as shown in the study by Suzuki & Silveira 2003 (cited in Glen et al 2007), of spores taken from guava fruits:

- at cold temperatures (4˚C) combined with low relative humidity (40% RH), 3% of spores were viable for 100 days (> 3 months). But a more recent study by Salustiano et al (2008) using similar storage conditions reported spores being viable for 150 days.
- at 15˚C and 50% RH, spores were viable for only 67 days (2 months).
- at 30˚C and 50% RH spores were viable for only 18 days; and for only 15 days if the RH was 90%. (< 1 month).

Thereoretically, teliospores (survival-stage spores that withstand harsher conditions) survive longer than urediniospores. However, there is less empirical information available for teliospores of *P. psidi* s.l..

Conditions for spore survival have not been tested for all variants of *P. psidii* s.l. and there may be some variation in response to temperature. However, if variation exists it is not expected to be large.

2.4.4 Host range / plant associations

P. psidii s.l. infects and causes disease in species within the family Myrtaceae, a large family of plants containing about 155 genera and over 3000 species predominantly distributed in the southern hemisphere (Govaerts & Lucas, 2008; Wilson et al 2001). The full host range is unknown. However, the currently known range of *P. psidii* s.l hosts is already extremely wide and is increasing as the establishment and spread of *U. rangelii* (a taxon belonging to the *P. psidii* s.l. complex) is being monitored in Australia. As at June 2011 *P. psidii* s.l. was known to cause disease in 45 genera (See Appendix 1 for genera affected by *P. psidii* s.l., and see Appendix 3 for the *U. rangelii* host species list as at 13 June 2011).

The arrival of *P. psidii* s.l. in Hawaii resulted in a similarly rapid increase in known hosts. Consequently, all genera of the family Myrtaceae can be regarded as potentially susceptible to *P. psidii* s.l.

New Zealand has known myrtaceous hosts of *P. psidii* s.l., and all other myrtaceous species in New Zealand are considered to be potential hosts of *P. psidii* s.l. In New Zealand the family Myrtaceae is represented by some of our best known plants such as the iconic pohutukawa, rata, kanuka and manuka, and some lesser known plants like swamp maire (*Syzygium maire*) and ramarama (*Lophomyrtus bullata*). Three native species are known to be susceptible to *P. psidii* s.l.. These are pohutukawa (*Metrosideros excelsa)*[3], Kermadec pohutukawa *(M. kermadecensis)*, and *Lophomyrtus bullata* (Forest Health Highlights, 2009; Simpson et al 2006; NSW Department of Primary Industries, 2010).

New Zealand also has a large number of exotic species from the family Myrtaceae, many of which have commercial value, such as *Eucalyptus* species; and some myrtaceous species grow in New Zealand as weeds, e.g. *Syzygium smithii*.[4]

[3] In Hawaii, the susceptible plants were grown in non-optimal conditions (tropical forest, shady situation) and it is unclear whether this contributed to the susceptibility of these specimens (MAF, pers. comm. 2011). Both *M. excelsa* and *M. kermadecensis* are susceptible to *U. rangelii* in Australia.

[4] http://www.arc.govt.nz/albany/index.cfm?63E0F20E-14C2-3D2D-B905-50098EBBE4B9&plantcode=Acmsmi

Despite the extremely wide host range of the *P. psidii* s.l. complex, there is strong evidence of host specialisation, with individual variants collected from one host species not necessarily infecting other known host species (summarised by Coutinho et al 1998, and Loope 2010). There is also strong evidence that within host species there is variable susceptibility between individuals (Zauza et al 2010; Rayamajhi et al 2010; Alfenas et al 2003; Dianese et al 1984).

2.4.5 Plant parts affected / Commodity association

P. psidii s.l. lesions are produced on young, actively growing leaves, shoots, floral buds, as well as on fruits (Glen et al 2007).

P. psidii s.l. is likely to be associated with imported nursery stock of myrtaceous species, particularly whole plants or parts of plants imported for growing purposes including cuttings, budwood, off-shoots, scions and marcots. *P. psidii* s.l. is much less likely to be associated with tissue cultured plants generated and grown in aseptic conditions and is unlikely to be associated with root divisions.

2.4.6 Genetic diversity of *P. psidii* s.l.

Several variants of *P. psidii* s.l are known to exist, although very little is known about the genetics of them (summarised by Loope, 2010). The presumed existence of genetically distinct races or biotypes is supported by a recent genetic analysis of approximately 150 isolates of *P. psidii* s.l collected from diverse host species and locations in Brazil, and 50 isolates collected from Uruguay, Paraguay, Hawaii, and California (Graca et al 2010). Graca et al (2010) analysed 10 microsatellite loci for each isolate collected. The data indicated that for the Brazil isolates, there is considerable genetic diversity; host species strongly influence *P. psidii* s.l. population structure; and distinct multilocus haplotypes (genetic fingerprints) are uniquely associated with specific hosts across diverse geographic locations.

2.4.7 New Zealand status

P. psidii s.l. is not known to be present in New Zealand (recorded as “absent from region” by Landcare NZ Fungi, December 2010, not recorded in PPIN database, June 2011).

2.4.8 Geographic distribution

P. psidii s.l. is a native to Brazil and probably also to other South American countries. It is present throughout much of Central and South America (Crop Protection Compendium, 2011) [Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, Guatemala, Jamaica, Puerto Rico, Trinidad and Tobago, Argentina, Brazil, Colombia, Ecuador, Paraguay, Uruguay, Venezuela], Mexico, in selected states of the USA [Florida (since 1977), California (since at least 2005) (Mellano 2006), Hawaii (since 2005)], and was recently found in Japan (Kawanishi et al 2009). It has been reported once in Taiwan (Wang, 1992) but has not been found since.

It is also in Australia. It was identified as *U. rangelii*, firstly in NSW in April 2010, and subsequently in Queensland in December 2010. These regions are a regular source of myrtaceous nursery stock imports to New Zealand (MAF Border Standards, pers. comm.)[5].

2.4.9 Hazard identification conclusion

Given that *Puccinia psidii* s.l.

- is associated with a very wide range of myrtaceous species, affecting species from at least 45 genera;
- is present in countries/regions that export myrtaceous nursery stock to New Zealand;
- is not recorded from NZ;
- is known to cause disease and therefore may have unwanted impacts on plant species of economic, environmental or cultural importance to New Zealand;

P. psidii s.l. is therefore considered a hazard on myrtaceous nursery stock in this risk analysis.

[5] MAF import records from 2007 onwards show that imports of Myrtaceae species nursery stock come from Australia (originating from NSW, Queensland and Western Australia) and the USA (originating from South Carolina).

2.5 Risk assessment

2.5.1 Entry assessment

This section assesses the likelihood of *P. psidii* s.l. entering New Zealand via importation of myrtaceous nursery stock. Notwithstanding existing measures designed to prevent entry of pests into New Zealand, the likelihood of *P. psidii* s.l entering on nursery stock is examined as if no measures were in place[6]. Consequently, the assessment assumes that only basic measures are being taken by exporters and that there are no inspections on arrival in New Zealand, and no post entry quarantine measures in New Zealand. It is also assumed that pre-export phytosanitary inspection does not occur in the country of export.

Myrtaceous nursery stock poses considerable risk as an entry pathway, as shown by the following evidence:

- Nurseries have in the past been unrecognised reservoirs of *P. psidii* s.l.,

  e.g. Australian nursery stock is considered by Australian authorities to be a source of *U. rangelii*. Extensive tracing work carried out by the Australian authorities traced most infections in Australia back to nurseries and the work of bush regenerators (Eyles & Burnip, 2010). During the active response phase coordinated by the Myrtle rust National Management Group, infected nurseries were closed down, treated to eradicate *U. rangelii* and reopened (Eyles & Burnip, 2010).

- Nurseries in countries where *P. psidii* s.l. is established are likely to harbour *P. psidii s.l.* from time to time.

  e.g. In Australia, now that the Myrtle rust National Management Group has transitioned from an eradication focus to a management focus (NSW Department of Primary Industries, 2010) it is unlikely that nurseries will be closed down for eradication of *U. rangelii*. However, the Australian and Garden Nursery Industry are promoting best practise management plans to manage *U. rangelii* in nurseries (McDonald, 2011). The implementation of these plans is likely to reduce the occurrence of *U. rangelii* in nurseries somewhat, but as it is not mandatory, practise will vary across the industry and it is likely that Australian nurseries will harbour *U. rangelii* from time to time.

- Nursery stock is one suspect for transmission of *P. psidii* s.l. to at least one location, Hawaii.

  P. psidii s.l. was intercepted several times on foliage shipped from California during the period from December 2006 to June 2007 (Loope, 2010). Myrtaceous nursery stock always possesses foliage because the leaves are evergreen. Therefore, it is assumed that nursery stock that is shipped from the same areas that contaminated foliage is shipped from, is likely to be contaminated with *P. psidii* s.l. also.

It is assumed that nursery stock with established infections of *P. psidii* s.l. would have yellow urediniospores or aeciospores, which would be visible during handling at packing, and so would not be included in a consignment to New Zealand.

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[6] This approach to assessment is used because it ensures that all relevant risks are encapsulated in the entry assessment, rather than just those that remain after a particular measure is in place. This approach ensures that the entry assessment does not become obsolete when changes are made to measures.

However, *P. psidii* s.l. could enter New Zealand on nursery stock if the plants had very small lesions, latent infections, or if the plants were contaminated with spores or mycelia of *P. psidii* s.l.. Contaminating spores, either germinated or ungerminated, would be on the surface of plant tissue, whereas the mycelia of an early stage of *P. psidii* s.l. infection would be inside plant tissues. Individual spores are not visible to the naked eye, (e.g. the largest dimension for urediniospores is $\leq$ 27 µm [7]) and would require a trained mycologist and specialist tools and tests to be identified. Consequently, they would be undetectable prior to export. However, clumping of spores is quite common and if the clumps are large enough they would be visible as yellow pustules.

Because spores are viable for up to 150 days, and transportation to New Zealand is highly likely to be via air cargo (taking less than a day from either the USA or Australia), it is likely that contaminating spores on nursery stock will be viable at the time of entry into New Zealand. Early-stage infections in which *P. psidii* s.l. mycelia occurs intracellularly would certainly be viable. Therefore, imported nursery stock contaminated with *P. psidii* s.l. spores or intracellular mycelia is likely to become diseased and be a source of further *P. psidii* s.l. spores capable of spreading.

The risks of *P. psidii* s.l. entry may be higher during times of the year when the climate of the exporting country is most suitable for *P. psidii* s.l. infection and sporulation. There is currently insufficient information about seasonal prevalence of *P. psidii* s.l. in current and potential exporting countries to assess seasonal risks with certainty.

The likelihood of entry on specific types of nursery stock is considered:

Whole plants or cuttings: *P. psidii* s.l attacks young actively growing leaves, shoots, floral buds and fruits. Therefore, myrtaceous nursery stock in the form of whole plants or cuttings, could conceivably be contaminated with *P. psidii* s.l spores because they would each be exposed to the spores from an infected source plant.

Plants in vitro, i.e. tissue culture: The likelihood of entry on this commodity is low. Assuming that aseptic lines of a tissue culture have been developed, and the tissue culture has been prepared for export under sterile conditions, plants *in vitro* have a very low likelihood of harbouring *P. psidii* s.l.. However, contaminations of tissue culture by fungi are known to occur (Liefert & Cassells, 2001). No reports of *P. psidii* s.l in tissue culture have been identified, but it is conceivable that contamination could occur. If aseptic processes are inadequate and contamination with *P. psidii* s.l. occurs, the contamination will only be detected if sufficient time has elapsed to enable an infection to occur and disease to develop and become visible. Because *P. psidii* s.l. favours young actively growing tissue and high humidity, any *P. psidii* s.l. contaminant is expected to cause visible disease symptoms within 12 days of contamination if the plantlets are actively growing and maintained at temperatures between 15 to 23˚C. Twelve days would provide sufficient time for an infected plantlet to enter New Zealand and be transferred or replanted into a greenhouse or an open nursery where potential hosts may be present.

[7] Refer to http://www.issg.org/database/species/ecology.asp?si=1538&fr=1&sts=&lang=EN and references therein.

Given that:

- Nurseries growing myrtaceous species that have been infected with *P. psidii* s.l. have a high likelihood of being so in the future;
- The nursery stock pathway is a suspected route for *P. psidii* s.l. to have entered a new location, Hawaii.
- Whole plants or cuttings can be readily contaminated with *P. psidii* s.l. spores or intracellular mycelia prior to export;
- Plants *in vitro* (i.e. tissue culture) have a very low likelihood of being contaminated with *P. psidii* s.l. spores or intracellular mycelia, but if they were they could enter New Zealand before symptoms became apparent;
- Established infections would be easily detected at pre-export quality inspections, but early-stage infections or individual *P. psidii* s.l. spores could go undetected at inspection;
- Invisible *P. psidii* s.l. contaminants on nursery stock are likely to be viable because transportation to New Zealand takes less than a day and urediniospores are viable for up to 150 days.

The likelihood of entry is considered to be moderate to high for whole plants and cuttings, and low for tissue cultures, and is therefore non negligible.

2.5.2 Exposure assessment

This section assesses the likelihood that *P. psidii* s.l. will be exposed to a new host plant post-entry and it is based on the assumption that there are no post-entry quarantine measures in place on arrival in New Zealand.[8] The assessment also assumes that viable spores of *P. psidii* s.l. have entered the country on nursery stock.

Contaminated myrtaceous nursery stock would initially be distributed around New Zealand to nurseries where it would be planted in pots/containers (or possibly in bare root beds) and placed in glasshouses or outdoor nursery environments, possibly under shade cloth, and likely to be in close proximity to other Myrtaceae. They would be regularly watered and also exposed to rainfall, likely resulting in prolonged periods of leaf wetness. In the summer months, when temperatures are often in the range for the fungus to grow and infect, conditions would be suitable for viable urediniospores to germinate and infect susceptible host plants (Glen et al 2007). If an infection is established in a nursery plant, new urediniospores would be produced after 12 days (Coutinho et al 1998; Glen et al 2007). Spores could then be easily dispersed by wind, insects, rain splash or by human assistance to neighbouring myrtaceous plants both within and beyond the boundaries of the nursery.

Host availability would be high in nurseries because it is assumed that any nursery that has received a myrtaceous plant contaminated with *P. psidii* s.l. would have numerous other myrtaceous plants in stock, either from the same shipment or from other sources. The density of potential hosts beyond the boundaries of the nursery would probably be lower than in the nursery, however there may be more species available. Because myrtaceous species are grown widely in New Zealand it is likely that wind-borne spores would be exposed to suitable hosts outside the nursery, particularly given that rust spores can travel very long distances on wind-currents (Viljanen-Rollinson & Cromey, 2002; Grgurinovic et al, 2006; Close et al, 1978). New

[8] This assumption is used because it ensures that all relevant risks are encapsulated in the risk assessment, rather than just those that remain after a particular quarantine measure is in place. This practice also ensures that the risk assessment does not become obsolete when changes are made to quarantine measures. Furthermore, the consideration of management options is simplified.

Zealand has at least 29 native myrtaceous species (6 genera)[9], and at least 200 species of exotic Myrtaceae[10]. The vast majority of exotic myrtaceous species originate from Australia (Webb et al, 1988). At least twenty three of the exotic species have become fully naturalised; others occur as "casual" wild species (Howell and Sawyer, 2006).

Given that:

- nursery stock are likely to be initially planted and placed next to other suitable hosts of *P. psidii* s.l. within nurseries; and there is a wide availability of suitable hosts outside the nursery;
- climatic conditions in nurseries are suitable for *P. psidii* s.l. urediniospores to germinate and infect host species;
- an actively growing nursery stock plant with a primary infection could produce new urediniospores within 12 days;
- urediniospores are easily dispersed by wind, rain, insects and by human assistance;

The likelihood of exposure is considered high in the parts of New Zealand, and during seasons, that provide the ideal climate for P. psidii *s.l.. For example, Northland and Auckland have an ideal climate for* P. psidii *s.l. all year round. Other parts of the North Island and some parts of the South Island have an ideal climate for* P. psidii *s.l. during summer months. Therefore, the likelihood of exposure is non negligible.*

2.5.3 Assessment of establishment and spread

This section assesses the likelihood that *P. psidii* s.l. could establish and spread in New Zealand and is based on the assumption that it has already entered New Zealand and reached a suitable host.

Climate and habitat are key factors in whether an organism can establish and spread in New Zealand. As demonstrated below, many parts of New Zealand have excellent conditions for the establishment and spread of *P. psidii* s.l. The climate is suitable and there is an abundance of potential host species.

Climate suitability: The climatic suitability of New Zealand for *P. psidii* s.l. was modelled using three approaches by Kriticos & Leriche (2008) and included future climates. Under current climate conditions, *P. psidii* s.l. appears to be capable of establishing and persisting in all of the mid- to low-altitude areas of the North Island and parts of the east coast of the South Island. The most suitable locations climatically include Northland, Bay of Plenty, Hawkes Bay and coastal parts of the Canterbury Plains. The Chatham Islands also appear to be climatically suitable. Analysis of season suitability for *P. psidii* s.l. in Auckland showed there is a year round potential for infection to occur. Summer conditions are most favourable because conditions for spore germination would be near optimal (Kriticos & Leriche, 2008).

[9] This figure includes the *Kunzea* species identified in a recent taxonomic review, and multiple *Leptospermum* species which also require taxonomic review (Peter de Lange, DOC, pers. comm 2011).
[10] Scion Ltd, pers. comm.. 2011. Early estimates by Palmer (1982) and Webb et al (1988) underestimate the number of exotic Myrtaceae species in New Zealand.

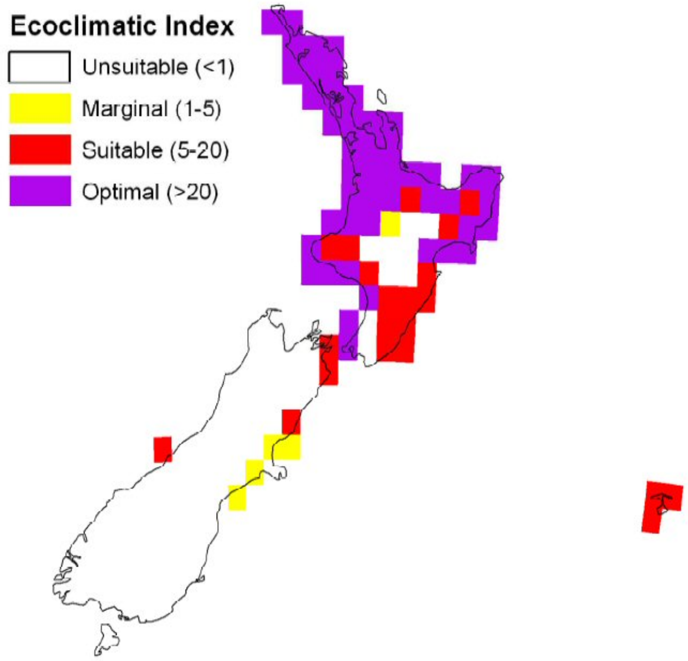

Figure 2: New Zealand showing climate suitability for *P. psidii* s.l. under current climate, as modelled using 'CLIMEX Compare Locations' (Kriticos & Leriche, 2008).

According to the model, cold stress and an inadequate annual heat sum for development appear to limit the southern distribution of *P. psidii* s.l. in New Zealand. In 'fringe suitability' areas it is likely that any germinating spores will not complete a lifecycle unless they are in a favourable microsite that is considerably warmer than indicated by the model. It is highly likely that there will be small areas along the north western coast of the South Island where meso-climatic conditions would favour the establishment and persistence of *P. psidii* (Kriticos & Leriche, 2008). It is also possible that the geothermal areas in the central North Island may support microclimates suitable for the establishment of myrtle rust.[11]

Under future climates, the projected threat to New Zealand from *P. psidii* s.l. increases somewhat by the year 2030, and further again by the year 2070. Under these warmer scenarios the area suitable for habitat extends to the south eastern coastal fringe of Southland. The area around Mt Ruapehu remains climatically unsuitable under all scenarios examined (Kriticos & Leriche, 2008), although geothermic areas may support suitable microclimates (see footnote 11).

Habitat and host suitability: *P. psidii* s.l. is expected to find multiple new myrtaceous hosts in New Zealand, as it has in Hawaii and in Australia. As discussed in the previous section, New Zealand has at least 200 exotic and at least 29 native myrtaceous species (Ramsfield et al 2010; Peter de Lange, DOC, pers comm. 2011; and see Appendix 4) and they are widely grown across the country (Ridley et al 2000) either in tracts of native forest and regional parks, or on farmland or in urban settings. Some occur as weeds in New Zealand, such as the species *Syzygium smithii*[12].

[11] Such microsites already support fern species more typically associated with warm moist climates. See http://www.nzpcn.org.nz/flora_details.asp?ID=162 and http://www.nzpcn.org.nz/flora_details.asp?ID=785)
[12] http://www.arc.govt.nz/albany/index.cfm?63E0F20E-14C2-3D2D-B905-50098EBBE4B9&plantcode=Acmsmi

All species of the family Myrtaceae occurring in New Zealand must be considered potential hosts of *P. psidii* s.l., because the fungus has demonstrated in both Australia and Hawaii that it finds new myrtaceous host species which were not known hosts previously. This phenomenon has resulted in the rapid expansion of the known host range with each introduction of the fungus into a new environment. For example, since *U. rangelii* was detected in Australia the number of genera containing host species had increased by 67% as at 2 February 2011 (14 new genera in addition to the previous tally of 21; new total, 35 genera) and by 114% as at 13 June 2011 (24 new genera in addition to the previous tally of 21; new total, 45 genera). Refer to Appendix 1; (NSW Department of Primary Industries, 2011; Queensland Department of Primary Industries, 2011).

Besides the myrtaceous species in New Zealand that are potential hosts, there are many known hosts growing here, including at least three native species (Forest Health Highlights, 2009; Simpson et al 2006; NSW Department of Primary Industries, 2010):

- *Metrosideros excelsa* (pohutukawa)
- *M. kermadecensis* (Kermadec pohutukawa),
- *Lophomyrtus bullata*.

As at 2 February 2011, the known host species growing in New Zealand include (native species are in bold type):

> *Acca sellowiana* (feijoa), *Agonis flexuosa* (willow myrtle), *Angophora costata*, *Callistemon salignus, C. viminalis* (bottle brush), *Chamelaucium uncinatum* (Geraldton wax), *Corymbia citriodora, C. maculata*, 11 species of *Eucalyptus [E. botryoides, E. camaldulensis, E. citriodora, E. globulus, E. grandis, E. nitens, E. regnans, E. saligna, E. tereticornis, E. viminalis, E. pilularis]*, *Eugenia brasiliensis, E. uniflora*, ***Lophomyrtus* bullata (ramarama or New Zealand myrtle)**, ***Metrosideros excelsa* (pohutukawa)**, *M. collina*, ***M. kermadecensis* (Kermadec pohutukawa)**, *Myrciaria cauliflora, Myrtus communis, Pimenta dioica, Psidium guajava* (yellow guava), *P. cattleianum* (purple guava), *Syncarpia glomulifera* (sometimes present), *Syzygium australe, S. jambos, S. cumini, S. paniculatum* (Manaaki Whenua Landcare Research, 2011; Allan, 1982).

As can be seen from the data in the table in Appendix 4, the distribution of most of the native myrtaceous species coincides with regions where the climate is suitable or optimal for *P. psidii* s.l.. Therefore, the fungus is likely to establish across a large part of the North Island, and some localised areas in the South Island.

The native myrtaceous habitats would have plentiful young, actively growing leaves, shoots, floral buds and fruits which *P. psidii* s.l. favours. Young native myrtaceous trees and bushes are readily found in regenerating bush/forest and often in new urban landscapes; and mature trees are continually generating new leaves, shoots and flowers.

The biology of *P. psidii* enables this pathogen to easily spread: the spores are easily dispersed and can remain viable in the environment for several weeks (see section on spore survival, p10). Therefore, once established in New Zealand, *P. psidii* s.l. is likely to spread quickly and be impossible to eradicate, as was the experience in Hawaii and Australia (Killgore & Heu, 2007; Loope & La Rosa, 2008; Eyles & Burnip 2010). Within four months of the first detection in Hawaii, it was found throughout the main Islands of Hawaii. In NSW, Australia, initially the spread was thought to have been less rapid, due to the eradication response put in place, and because there was initially limited evidence of wind-dispersal. However, in some sites in NSW where infected nursery stock was planted, the disease spread well beyond the area of initial plantings and it was recently found in Queensland as far north as Cairns (Queensland

Department of Primary Industries, 2010 & 2011). Australian officials have subsequently agreed that eradication is not technically feasible (NSW Department of Primary Industries, 2010).

The rate of spread of the disease will be influenced by whether one or more host species in New Zealand become severely affected because this will determine the quantity of urediniospores that are produced and dispersed, i.e. the inoculum loading. One reason that *P. psidii* s.l spread quickly throughout the Hawaiian Islands was that *Syzygium jambos* was so severely affected that it became a good source of spores in the environment, enabling the rapid spread of the fungus, and exposing many more myrtaceous hosts to *P. psidii* s.l. (Uchida & Loope 2009). In a New Zealand example the willow rust *Melampsora coleosporioides* spread throughout the country within two years (Spiers 1989).

Given that:

- there are known susceptible hosts in New Zealand
- the New Zealand climate, particularly in the North Island, is suitable for *P. psidii* s.l., e.g. the climate is suitable year-round in Auckland;
- there are many natural and modified habitats in New Zealand, within areas that are climatically suitable, that could support the biology of *P. psidii* s.l., including amenity plantings, plantations and New Zealand's native scrub and forests containing Myrtacous species;
- all myrtaceous species are considered potential hosts of *P. psidii* s.l. at this time because the experience of Hawaii and Australia demonstrates that the fungus affects hosts not previously predicted;
- the experience of Australia and Hawaii demonstrates that, once established beyond a confined area, it is highly likely that eradication will be technically unfeasible;
- *P. psidii s.l.* spores are easily and rapidly dispersed (e.g. Australia; Hawaii);
- the rate of spread of *P. psidii* is influenced by the severity of infections on myrtaceous species and the consequent spore inoculum loading;

The likelihood of establishment is considered to be high.

The likelihood of the organism distribution within New Zealand spreading is considered to be high.

2.5.4 Consequence assessment

Impact summary

It is expected that *P. psidii* s.l. will cause disease on many different plant species of the family Myrtaceae in New Zealand, both on those already known to be hosts, but also on new host species. The severity of disease is expected to vary from species to species. At one extreme, some species may die on a landscape scale, as happened to *Syzygium jambos* (rose apple) in Hawaii (Loope, 2010), and *Pimenta officinalis* in Jamaica (Maclachlan, 1936). At the other extreme, some species may become infected and support sparse urediniospore production, but their growth, development and production of fruit may not be much affected.

The short-term impacts of an invasion of *P. psidii* s.l. are directly related to the variant of *P. psidii* s.l that arrives in New Zealand because this will determine which host species are susceptible (Graca et al 2010; Loope et al 2010). The long-term impacts of an invasion of *P. psidii* s.l. depend on whether additional *P. psidii* s.l. variants arrive, whether further genetic variation results in mutation or selection pressure and whether the host-range widens. In a single-variant scenario, *P. psidii* s.l. is likely to exert selection pressure on myrtaceous populations, resulting in the more susceptible provenances/cultivars diminishing and the more resistant ones dominating populations. The long-term consequence of this in the natural environment is that whilst the disease will continue to be sustained, the severity of disease may lessen.

There is uncertainty about the precise impact of an *P. psidii* s.l. incursion because we cannot know what variant of *P. psidii* s.l. will establish in New Zealand, which myrtaceous species will be susceptible, or how susceptible they will be. It is hoped that in the near future, susceptibility testing of New Zealand's myrtaceous species in other countries will reduce this uncertainty. In the meantime, possible impact scenarios can be explored, as has been done in the following sections.

Economic consequences

There are at least four domestic and export industries in New Zealand that depend on myrtaceous species, and so will be at risk if *P. psidii* s.l. establishes in New Zealand. If economically important myrtaceous species are severely affected, the profitability of these industries will be negatively affected until sustainable methods of controlling *P. psidii* s.l. are developed or resistant cultivars are established. Most of the industries considered below are relatively small at present, with the exception of the manuka honey industry.

- <u>Eucalyptus timber/log/pulp industry:</u> By international standards, and compared to other tree species grown commercially in New Zealand, the commercial growth and log production of eucalyptus in New Zealand occurs on a relatively small scale. New Zealand has approximately 24,000 hectares planted in eucalypts, representing 1.4% of New Zealand's total plantation area (NZFOA, 2011). Eucalyptus plantations produced 725 cubic metres of rough-sawn timber in 2009 (representing 0.02% of New Zealand's total output) (NZFOA, 2009).

  Much of the harvestable timber available at present is located in regions where *P. psidii* s.l. could survive (the Central North Island; small quantities are also becoming available in Northland and Auckland regions). The 10,000 hectares of *E.*

nitens in Southland, which is used for wood-chip[13], is unlikely to be affected by *P. psidii* s.l. because the fungus is unlikely to establish in that part of the country.

The species that produce sawn wood product in New Zealand are (in decreasing output in cubic metres): ***E saligna*** > ***E. botryoides*** > *E. delegatensis* > ***E. pilularis*** > *E. fastigata* > ***E. regnans***, *E. obliqua* (NZ Wood, 2010). The species in bold are known hosts of *P. psidii* s.l.. However, it should be noted that ***E. saligna, E. botryoides***, *E, delegatensis* and ***E. regnans*** are now no longer planted for timber production due to the combined effects of unfavourable characteristics (Colley, 2005).

The species most likely to be important to the New Zealand Eucalyptus industry in the future are *E. fastigata*, ***E. nitens***, the stringybacks *E. mulleriana, E. globoidea* (and others) as well as the related ***E. pilularis*** (Colley, 2005). Of these, ***E. nitens*** *and* ***E. pilularis*** are known hosts of *P. psidii* s.l.. ***E. nitens*** is used for chip, pulp, veneers and laminated veneer lumber, whereas ***E. pilularis*** is used for furniture, veneers, and as an external structural building material (Colley, 2005).

The Brazil experience shows that *P. psidii* s.l. can severely affect commercial plantations of *Eucalyptus* by damaging seedlings in nurseries, young trees in the field, new growth on coppiced trees and on shoots in clonal gardens (Alfenas et al 1997; Alfenas et al 2003, cited in Glen et al 2007, p7). Damage to young trees causes them to be stunted, multi-branched, and of reduced market value (Tommerup et al, 2003). Costs would also be incurred for replanting and controlling the disease. An establishment of *P. psidii* s.l. in New Zealand would likely lead to only some, but not all, trees within a stand being affected, as disease severity is variable among plants within eucalyptus species (Dianese et al, 1984; Tommerup et al 2003). For example, typically 10-20% of a stand can be highly susceptible (grossly malformed and possibly killed). Infection of 20–30% of the canopies of young trees or second-rotation coppice regeneration has been reported in Brazilian plantations, enough to significantly affect growth rates and plantation profitability (Tommerup, 2003). If damage from *P. psidii* s.l. is similar to that occurring in Brazil, it may be enough to make *Eucalyptus* forestry unprofitable in New Zealand. The industry may respond by planting and growing species that are not affected by *P. psidii* s.l.

A precise value of the Eucalyptus industry in New Zealand (for timber, wood-chip and pulp) could not be found, but the commercial potential for solid timber production has been investigated. A recent study indicated that the Net Present Value (NPV) for production of sawn timber and pulp from 18 year old *E. regnans* grown in New Zealand is approximately $10,000 per hectare (Satchell & Turner, 2010).

- <u>Nurseries growing myrtaceous species:</u> There are numerous nurseries throughout New Zealand that produce myrtaceous seedlings and young trees. The size of this industry is unknown. Based on the experience in Australia with *U. rangelii*, nurseries are likely to be among the first sites where *P. psidii* s.l. is detected. The initial impact on nurseries will be some financial loss and increased costs due to temporary nursery closure and the costs/losses from treating or destroying plants.

[13] Southland Plantation Forest Company of New Zealand Limited (SPFL) http://www.spfl.co.nz/

However, *P. psidii* s.l. is controllable within nurseries (Eyles & Burnip, 2010; McDonald, 2011). The ongoing need to control or eradicate *P. psidii* s.l. from nurseries may result in additional costs. The exportation of New Zealand myrtaceous nursery stock may be prevented temporarily, and in the long-term may also be a driver of extra costs if extra phyto-sanitation measures are required for export.

- Feijoa industry: *Acca sellowiana* (feijoa) (synonym *Feijoa sellowiana*) is a known host of *P. psidii* s.l. and is grown commercially in New Zealand by 200 growers. Fruit is exported to the United States, United Kingdom, Germany, Netherlands, France and Japan. The industry is small, with 2007 data showing that the value of the export and domestic markets were $0.1 million and $1.7 million respectively (HortResearch, 2007). *P. psidii* s.l. could reduce the profitability of the feijoa industry because of increased control and sanitation costs. If fruit is damaged or reduced in size, the pricing and marketability of fruit will be impacted.

- Manuka Honey: Manuka (*Leptospermum scoparium* J.F.Forst. & G.Forst) or tea tree is a native New Zealand plant. Honey obtained from manuka is considered to be of high quality and is sought after for its unique flavour and medicinal properties. There are numerous New Zealand companies marketing manuka honey, many doing so under the trademark Unique Manuka Factor (UMF). The value of all honey exports was $94 million in 2009, but it is not known what proportion of this was from sale of manuka honey. Manuka honey fetches from $7 to $37 per kilogram depending on the concentration of 'active ingredients' in the honey; it is worth significantly more than clover honey, which fetches only $4-6 per kg (MAF, 2010). If manuka is moderately susceptible to *P. psidii* s.l., pollen production would be reduced resulting in less honey production. In a worst case scenario, whole tracts of manuka may die and the honey industry would be severely affected. It would not recover until resistant cultivars of manuka are regenerated.

The potential economic consequences of P. psidii *s.l. within New Zealand are considered to be moderate.*

Environmental consequences

Previous introductions of rust fungi into New Zealand (there are approximately 108 introduced species of rust fungi) have caused little damage to native plants and ecosystems (Beever et al 2007), largely due to the fact that rusts tend to be highly host specific. However, it is noted that the fungi that cause poplar rust have had a significant impact on the exotic poplar species grown in New Zealand (Spiers, 1989).

Puccinia psidii s.l is unusual among rusts in that it has a very broad host range and is known to affect at least 45 myrtaceous genera (see previous sections). Given the broad host range of *P. psidii* s.l., all of the native myrtaceous species are considered potential hosts. It is expected that the known host range of *P. psidii* s.l. will expand if it is introduced to New Zealand, as occurred in Hawaii and Australia after it established in those locations. The Hawaiian and Australian experience also suggests that some of the new hosts may be severely affected (Loope, 2010; NSW Department of Primary Industries, 2011).

Beever et al (2007) concluded that there are too many variables involved to predict whether the introduction of *P. psidii* s.l. will have significant impacts at the ecosystem level. But in terms of what could potentially happen, there is sufficient evidence to suggest that the ecosystem impact could be more damaging than what occurs at the species level. Myrtaceous species have a large influence on the structure, composition and function of New Zealand's indigenous ecosystems (Stephens et al 2004; Affeld et al 2009; Burrows 2006) (see below for more detail). Any change in the fitness of these species could have cascading effects through the ecosystems in which they occur, even if it does not result in the widespread loss of these species (McAlpine & Wotton, 2009). Competitive interactions are very influential and it may be possible that slight decreases in fitness of myrtaceous species might be sufficient for other species, both native and exotic to out-compete them more successfully (Harris et al, 2004).

At the species level, the following species are considered to be at particular risk because they are already threatened or are known hosts:

a) there are three native species known to be hosts, *Metrosideros excelsa* (pohutukawa), *M. kermadecensis* (Kermadec pohutukawa) and *Lophomyrtus bullata* (Ramarama or New Zealand myrtle); and,

b) there are ten species that are already uncommon or in decline. These are *K. ericoides* var. *linearis*[14], *Kunzea sinclairii, M. kermadecensis,* four unnamed species similar to *K. ericoides, L. scoparium* var *incanum* and two unnamed species similar to *L. scoparium* (see table 1);

c) *Metrosideros bartletti* (Bartlett's rata), which is nationally critical. It is found only in the northern tip of New Zealand.

The following descriptions of selected myrtaceous species native in New Zealand are provided as evidence of their ecological role, so that the potential environmental impact of *P. psidii* s.l. can be better understood.

Metrosideros excelsa (pohutukawa):

- Pohutukawa is an important species of New Zealand's coastal forest ecosystem. It is a coloniser of bare, coastal rock and it facilitates colonisation by a broader range of species (Simpson 1994). The tree supports birdlife by providing nectar to kaka, tui, bellbird and stitchbird (as well as short-tailed bats, pekapeka) and by providing a nesting place for shags, white-faced herons and the tieke (saddleback) (Simpson, 1994). Insects live on all plant parts – feeding on foliage, the fruit, the bark and wood, and dead leaves and twigs that form the litter on the ground beneath (Hutcheson and Hosking, 1991).
- Whilst pohutukawa as a species is not threatened, pohutukawa forest is extremely rare as it has been severely depleted and few good examples are left (Simpson 1994).
- Although *M. excelsa* is a known host of *P. psidii* s.l.[15] (see Fig 3), the environmental impact of a *P. psidii* s.l infection on pohutukawa in the New Zealand environment will depend on how susceptible the regional provenances of pohutukawa (Simpson, 1994) are in their natural environment. It is possible that defoliation caused by *P. psidii* s.l. could compound the stress that individual trees already experience from defoliation caused by possum browsing. In a worst case scenario, in which all provenances of pohutukawa

[14] *Kunzea ericoides* var. *microflora* also has a biostatus 'uncommon' and so could be considered at risk. However, it is unlikely to be impacted by *P. psidii* s.l. because it is confined to the Taupo Volcanic Zone which has an unsuitable climate for the rust fungus.

[15] *U. rangelii* affects *M. excelsa* in Australia. A few individuals of *M. excelsa* were seriously damaged by the Hawaiian variant of *P. psidii* in Lyon Arboretum, Hawaii (Loope, 2010), although it is noted their health may already have been compromised because they were growing in non-optimal conditions (MAF, pers comm. 2011).

may be severely affected, the disease may cause severe defoliation and subsequent death of mature trees over time.

Figure 3. *M. excelsa* infected with *P. psidii* on Oahu, Hawaii, June 2006. Source: MAF.

Metrosideros kermadecensis (Kermadec pohutukawa):

- *M. kermadecensis* is the dominant tree species of the forest that covers most of Raoul Island (almost 1000 km northeast of New Zealand), the largest of the Kermadec Islands (West, 2002). Therefore, it has an important ecological role in a unique and largely untouched ecosystem.
- *M. kermadecensis* is a known host of *P. psidii* s.l. (Loope 2010; NSW Department of Primary Industries, 2011) (see Fig 4).

Figure 4. *M kermadecensis* infected with *P. psidii* on Oahu, Hawaii, June 2006.
Source: MAF.

- If *K. kermadecensis* becomes severely affected like the rose apple (*Syzygium jambos*) in Hawaii, there could be significant changes to the structure, composition, and the function of the Kermadec Islands forest on a landscape level. Any fauna and flora that depend on the habitat in *M. kermadecensis* forest would be affected.

M. bartletti (Bartlett's rata):

- There are only 34 wild adult specimens remaining (NZ Plant Conservation Network, 2011). This species would be at greater risk of extinction if it is severely affected by *P.*

psidii s.l. *M. bartletti* is also the only known host of a highly threatened epiphytic liverwort, which by association would also be at risk of extinction.[16]

L. scoparium (manuka) and *K. ericoides* (kanuka):

- The species *L. scoparium* and *K. ericoides* form important hill country protection forest and act as early colonisers in disturbed sites, facilitating regeneration of other native species. They are also a habitat that supports distinct insect assemblages (Harris et al 2004).
- If these species are moderately susceptible, *P. psidii* s.l. is likely to lead to epidemics in cultivated plants. The impact in the wild is likely to be less, but given the widespread distribution of the host at least some natural genotypes are likely to be affected (Beever et al 2007).
- If severe defoliation occurs on some natural genotypes, there may be localised areas of tree death. Subsequent erosion of hill country where forest is regenerating will depend on the severity of the disease (Rowe et al 1999).
- Some threatened plant species (e.g. the orchid *Gastrodia minor*) are associated with manuka shrubland and may be affected by changes to shrubland structure and composition caused by *P. psidii* s.l. infection (Stephens et al 2004).
- The 'at-risk' biostatus of several *Kunzea* and *Leptospermum* species (see Table 1) may decline further if they become severely affected or defoliated.

The Australian and Hawaiian experience of *P. psidii* s.l. introduction into their environments also provides an indication of what to expect at the ecosystem level if *P. psidii* s.l. establishes in New Zealand.

- In Hawaii, where there is currently only one variant of *P. psidii* s.l., the impact on native forests has been low to moderate. This is due to the fact that the dominant forest tree, *Metrosideros polymorpha* or ohia, has to date been little affected. In spite of billions of wind-dispersed rust spores produced from the exotic rose apple (*Syzygium jambos*), which suffered widespread crown dieback causing landscape scale visual impact, (see Fig 5), *P. psidii* is found on less than 5% of the ohia trees in the wild. On those ohia trees on which the rust is found, it is normally found on less than 5% of the leaves (Loope 2010).

  The concern in Hawaii is that a new strain could impact ohio more severely. Because ohia comprises 80% of the native forest, there is potential for *P. psidii* s.l. to cause significant changes to the structure, composition, and the function of forests on a landscape level. The most extreme possibility would be for ohia to succumb to a future transported or evolved variant of *P. psidii* s.l. the way that *S. jambos* has.

  There are two species native to Hawaii, which are currently severely damaged by *P. psidii* s.l.: the endangered *Eugenia koolauensis* (nioi) and the non-endangered *Eugenia reinwardtiana* (Loope 2010).

[16] See http://www.nzpcn.org.nz/flora_details.asp?ID=4989

Fig 5 Landscape in Hawaii showing dead rose apple (*Syzygium jambos*) caused by *P. psidii* infection.
Source: MAF, 2007.

- In Australia, *U. rangelii* has found many new hosts since it was detected in April 2010. It has established in at least 25 native bushland sites, the known host list has expanded rapidly, and there are severe infestations on 29 species (NSW department of Primary Industries, 2011; Queensland Department of Primary Industries, 2011). However, at the ecosystem level, the environmental impact has not yet been reported.

In summary of the evidence, it is considered that *P. psidii* s.l. has the potential to cause direct mortality to New Zealand's native forest plant species that belong to the family Myrtaceae, including areas where these are dominant species. Indirect effects on the ecosystem are uncertain but have the potential to be severe and may include habitat loss for native fauna and flora, reduced regeneration and recruitment of young plants, increased erosion in some areas, resulting in reduced water quality, and reduced water retention in soil and vegetation.

There is considerable uncertainty about the likely level of environmental impact of P. psidii *s.l. within New Zealand but it could reasonably be considered to be from low to high.*

Human health consequences

No reported incidences of *P. psidii*, s.l causing harm to people were found.

The potential human health impact of P. psidii *s.l. within New Zealand is negligible.*

Socio-cultural consequences

The socio-cultural consequences of severe infections of native myrtaceous species would be varied depending on the values of individual New Zealanders, but for many people the socio-cultural consequence would be significant. For those who value New Zealand's native flora and fauna, a severe *P. psidii* s.l. attack on any of the native myrtaceous species would result in a sense of loss and grief. There is recent evidence from Australia that people respond in this way; there was a degree of public and political outrage when the Australian authorities made a decision to not attempt eradication of *U. rangelii* (Eyles & Burnip, 2010). If pohutukawa becomes severely affected, these emotions may be felt more so by North Islanders because of their increased knowledge, awareness and experience of pohutukawa, or to those Maori who place a spiritual value on this species. There are many myrtaceous species, both exotic and native, that are used in private and public gardens and parks. If important species are severely affected the enjoyment of use of these spaces may be diminished.

Evidence of the socio-cultural value of two myrtaceous species is provided below:

- *Metrosideros excelsa* (pohutukawa) is a nationally iconic species and an integral part of the New Zealand brand. Maori regarded pohutukawa as one of the chiefly trees (rakaurangatira) and there are individual pohutukawa that are venerated (Simpson, 1994). It is renowned for its spectacular crimson flower which appears across the whole tree canopy at once in early summer – at that time of the year it is a tourist attraction and has been dubbed 'New Zealand's Christmas tree'. The image of both the pohutukawa tree and the flower is used on cards and calendars, and they inspire paintings and ceramics. An image of the flower has also recently been incorporated into the logo of the newly formed 'supercity', Auckland Council (see Fig 6.).

Fig 6 Logo of the Auckland Council.

- The cultural status of *L. scoparium* (manuka) is varied. For many decades it was considered a weed, particularly on farm land. However, it is increasingly valued as an ornamental plant (there are now more than 70 cultivars), as a source of essential oils and honey, and for its medicinal purposes (Derraik, 2008).

The potential socio-cultural consequences of P. psidii *s.l. within New Zealand are considered to be moderate to high.*

Overall, the potential consequences within New Zealand are considered to be moderate to high, depending on the variant of P. psidii *s.l. that establishes in New Zealand, what its host range is and how severe the host infections are. Therefore the consequences are non-negligable.*

2.6 Risk estimation

The likelihood of *P. psidii* s.l. entering New Zealand on myrtaceous nursery stock is considered to be moderate to high. Once the fungus has entered New Zealand on this pathway, it is considered highly likely that it will be exposed to new host plants. It is also considered highly likely that *P. psidii* s.l will be able to establish and spread within New Zealand.

The potential consequences within New Zealand are uncertain but considered to be moderate to high. The consequences are dependent on the number of species that are found to be susceptible to *P. psidii* s.l. in New Zealand, and on the severity of infections on susceptible hosts.

As a result, the risk estimation for P. psidii *s.l. is non-negligible and it is considered to be a risk on myrtaceous nursery stock. Therefore, the risk is worth considering and further analysis may be undertaken to decide if additional measures are warranted.*

2.7 Risk management

This section provides information and analysis of the efficacy of options available to manage, to an acceptable level, the biosecurity risk posed by *P. psidii* s.l associated with myrtaceous nursery stock. Recommended options will be presented in a separate document (the Risk Management Proposal).

The risk management for *P. psidii* s.l. needs to provide a practical way of dealing with a host range that is continually expanding – each month the tally of hosts is bigger than in the previous month. It is expected to expand for some time as *U. rangelii* spreads in Australia. The potential for new hosts in Australia is extremely high because it is the centre of myrtaceous biodiversity, being home to 70 genera and 1646 species of native myrtaceous species, approximately half of the world's myrtaceous species (Glen et al, 2007). The known host range will also expand in the future if new genetic variants of *P. psidii* s.l. establish in places like Hawaii or Australia. Therefore, a major consideration is whether the risk management measures of the Import Health Standard will apply to only known hosts, or whether it will apply to potential hosts, i.e. all species of the family Myrtaceae.

Another risk worth considering is the immediate exposure to the environment of the rust spores at the ports of arrival (usually an Air Cargo transitional facility) during inspections by the MAF Quarantine Inspectors. The "MAF Biosecurity New Zealand Standard 155.02.06: Importation of Nursery Stock" requires that 600 randomly selected units must be inspected prior to transportation to a PEQ facility. Further investigation is required to determine whether the inspection procedures[17] and facilities (a closed, air conditioned room), including the hygiene practices required of the inspectors (wearing of protective clothing and disposable gloves, and full cleaning and decontamination of these items before they leave the facility)[18] is sufficient to reduce the risk of spore escape and exposure to potential hosts in the environment. Without proper decontamination of protective clothing, the risk of environmental exposure may arise because contaminated protective clothing may transfer some spores onto the quarantine inspectors' personal clothing and as they leave their workplace may end up exposing the rust spores, which are easily airborne, to the environment.

In summary, the current procedures for inspection of myrtaceous nursery stock at the place of first arrival (usually an air-cargo transitional facility), warrant further review and consideration.

[17] Border Clearance Procedure Documents: http://intranet.maf.govt.nz/intra/business/biosecurity/bcp/bcp-ins/index.htm

[18] The requirements are specified in the "Guidance Document for the Standard for General Transitional Facilities for Uncleared Goods, Annex E".

The following risk management options have been analysed in this risk analysis:

- **The status quo**, i.e. the current import requirements for myrtaceous nursery stock. Species can enter under 'basic conditions'; or under specific schedules requiring additional measures; or under measures for tissue culture. Refer to Appendix 2 for further details of the requirements of each of these criteria, including the exporting countries for which the additional measures apply.
    - Current basic conditions for whole plants and cuttings are stated in section 2.2.1 of the "IHS 155.02.06: Importation of Nursery Stock" (sourced February 2011); (this currently applies to 62 of the 539 myrtaceous species eligible for import).
    - Current entry conditions for tissue culture are stated in section 2.2.2 of the IHS;
    - Additional phytosanitary conditions are prescribed in the specific schedules of the IHS (which currently only apply to 477 of the 539 myrtaceous species eligible for import). The prescribed conditions in the specific schedules include post-entry quarantine level and period, growing season inspection, and testing.
- **Pest free place of production**.
- **Pest free area**.
- **Fungicidal treatment**.
- **Additional conditions for tissue culture**.

2.7.1 Analysis of the status quo: Current basic conditions in the nursery stock IHS for whole plants and cuttings

Under the current import health standard for whole plants and cuttings, there are two 'basic' conditions that reduce some, but not all, of the likelihood of *P. psidii* s.l. entry and establishment. These are:

- Cleanliness: plants must be packaged in inert/synthetic material and free from soil and other extraneous matter.

- Pre-export phytosanitary inspection: prior to issuing a phytosanitary certificate, the exporting National Plant Protection Organisation (NPPO) must inspect the nursery stock to ensure it is free from visually detectable regulated pests, and it conforms to New Zealand's import requirements.

There is no treatment required for fungi generally[19].

The 'basic conditions' of the IHS also require that all whole plants and cuttings must undergo post-entry quarantine (PEQ) on arrival in New Zealand, during which time they undergo growing-season inspections by a MAF Biosecurity Inspector. A period of PEQ helps to manage the risk of contaminants or symptoms that are not visible at the border inspection. The Level of PEQ required in specified in the IHS.

There are currently 539 species of the family Myrtaceae eligible for import into New Zealand as nursery stock. Of these, 62 species are only required to meet the basic conditions, with no specific requirements for *P. psidii* s.l.. These species must enter a Level 2 PEQ facility for a

[19] Although, all species of nursery stock from specifically listed countries must be treated for a root rot fungus called *Helicobasidium mompa*. Specific measures are required for two other fungi also.

minimum growing period of three months. The other 477 were previously determined by MAF to be hosts or potential hosts of *P. psidii* s.l., so require measures for *P. psidii* s.l. either prior to export or while in PEQ (see Appendix 2). Note that these 477 species require a period in either Level 2 or Level 3 PEQ for at least a minimum of three months. No myrtaceous whole plants or cuttings undergo PEQ in a Level 1 facility (refer to the Appendix 2 for further details).

Level 2 PEQ facilities are intended to minimise the risk of establishment of pests that are likely to be transmitted by wind, water, insects or other vectors. This is achieved by facilities being fully enclosed in glass, polythene, or other continuous material, except for entry/exit and ventilation, and there must be an anteroom or porch with a double door system. Whilst windows and vents in Level 2 PEQ facilities are insect-proofed using mesh, they are not capable of preventing the escape of fungal spores because the required maximum aperture of the mesh, 0.6 mm[20], is much larger than *P. psidii* s.l. spores (urediniospores are ≤ 0.027 mm and teliospores are ≤ 0.048 mm[21]). Therefore, spores could readily escape from Level 2 PEQ facilities into the environment.

If *P. psidii* s.l. spores were present on the plant in a Level 2 PEQ facility, spores would be released from lesions and disseminated in the air within the facility. Air currents within the facility would circulate the spores and they would reach the windows and air vents (Katan & Katan 1997; Frinking et al 1987; Pfender et al 2006; Chavarria et al 2009). Spores that escape outside the facility could be dispersed several kilometres in the environment, depending on the weather. However, the deposition level (number of spores/m^2) would be low because the source spore concentration would be low (Pfender et al 2006).

The hygiene procedures in a Level 2 PEQ facility are also not sufficient to stop transfer of spores onto personal clothing and subsequent movement outside the facility (refer to footnote 18).

Therefore, the current basic entry conditions, which utilize Level 2 PEQ, are inadequate to reduce the risk of P. psidii *s.l. spore exposure to the environment to an acceptable level.*

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[20] See MAF Biosecurity Authority Standard PBC-NZ-TRA-PQCON Specification for the Registration of a Plant Quarantine or Containment Facility, and Operator; http://www.biosecurity.govt.nz/regs/trans/stds

[21] Refer to http://www.issg.org/database/species/ecology.asp?si=1538&fr=1&sts=&lang=EN and references therein.

2.7.2 Analysis of the status quo: additional phytosanitary conditions prescribed in the species schedules (including tissue culture)

The majority of myrtaceous species (477 out of 539) eligible for import into New Zealand must undergo specific phytosanitary measures for risk management of *P. psidii* s.l.. This is in addition to the basic conditions for whole plants and cuttings.

There are currently five specific schedules for myrtaceous species, entitled as follows: "*Acca sellowiana*", "*Agonis*", "*Eucalyptus*", "*Eugenia*", and "*Metrosideros*". Each of these schedules prescribe slightly different phytosanitary measures. Each of the 477 myrtaceous species eligible for import into New Zealand, is imported under one of these five schedules. Refer to Appendix 2 for details about which species are assigned to which schedule.

The specific measures prescribed in one or more of the five schedules are listed in the table below. The extent to which these measures reduce the likelihood of entry and establishment of *P. psidii* s.l. is analysed in the following table.

Table 1: Analysis of the efficacy of existing risk management measures for *P. psidii* s.l. on imported myrtaceous species.

Measure used in existing IHS schedules	Efficacy analysis	Conclusion about risk reduction
Approved exporting countries and additional declaration required	Three of the five schedules allow exports from all countries, whereas, two of the five schedules (the "*Acca sellowiana*" and "*Eugenia*" schedules) allow import of whole plants and cuttings from approved countries only. In these cases the phytosanitary certificate must be endorsed with the additional declaration that "*Puccinia psidii* is not known to occur in (the country or state of origin)". Current approved countries include countries that now have *P. psidii* s.l. e.g. Australia, USA. The declaration only gives assurance that *P. psidii* is not known to occur. It is possible that *P. psidii* occurs, but has not yet been identified. This situation would have occurred for a period of time in both Australia and Hawaii prior to *P. psidii* being identified. During that period, this declaration would have been meaningless and offer no risk reduction. This type of declaration is not the same as a 'pest-free place of production' declaration, or a 'pest-free area' declaration certified by the exporting national plant protection organisation because it is not based on official pest surveys or inspections.	Current country restrictions and the 'additional declaration' offer very limited risk reduction.
Level 2 PEQ	Level 2 PEQ manages pests that can be spread by wind, water, insects or other vectors/means. The facility is fully enclosed in glass, polythene, or other continuous material, except for entry/exit and ventilation. The facility must have an anteroom or porch with double door system. Windows and vents must have insect proof mesh, aperture of 0.6 mm. It differs from Level 3 PEQ in that it does not require mandatory, pre-determined tests for detection of pests, it has markedly less-stringent operational procedures/record-keeping requirements, it is not climate controlled, and it has different structural requirements. There are three major inadequacies of Level 2 PEQ for risk management of	Level 2 PEQ provides insufficient risk reduction because of three major inadequacies.

	P. psidii: • The mesh on vents is not capable of preventing escape fungal spores and so *P. psidii* s.l. spores could spread into the environment via exit through the vents (vent aperture is 0.6mm; urediniospore size is much smaller, 0.027 mm). • The climate cannot be controlled, therefore the facility would not be able to ensure conditions are optimal for observing *P. psidii* s.l. contamination (see section below on quarantine period for further details). • The operational procedures and record keeping are not sufficient to enable audits that would give assurances about the management of Level 2 PEQ.	
Level 3 PEQ	Compared to Level 2, Level 3 PEQ greenhouses have additional requirements for: record keeping; maintenance of operational procedures which relate to quality system requirements; an optional provision for spore-proof ventilation systems; climate control. All three of the Level 3 PEQ facilities in New Zealand are climate-controlled and under negative pressure. At least one is fitted with air filters that are effective against microbes (i.e. HEPA filtration); The MAF-owned Level 3 PEQ facility can be readily upgraded to meet the standard for air filtration (MAF, pers. comm., 2011)	Level 3 PEQ would provide adequate risk management of *P. psidii* s.l., assuming that spore-proof ventilation systems and adequate climate control are mandated.
Minimum quarantine period of three months active growth, with two growing-season inspections	If plants are grown at 15-23˚C, high humidity, including overhead watering to promote leaf wetness, then disease caused by *P. psidii* s.l. can be expected to be visible after three to 12 days, and probably within a three month PEQ period (summarised by Glen et al 2007). However, spores can remain viable up to 150 days, which is longer than three months (Salustiano et al, 2008; Suzuki & Silveira, 2003). Teliospores are theoretically more persistent, but there is no data about teliospore survival time. If temperatures are cool (< 15˚C) and relative humidity is low (~ 50% or lower) then three months of PEQ may not be sufficient to ensure that spore viability is lost (Suzuki & Silveira, 2003; Salustiano et al 2008). Temperatures of 15-23˚C and high humidity (i.e. optimal conditions for *P. psidii* s.l.) only be guaranteed in Level 3 PEQ facilities with climate control (climate control is currently not available in any Level 2 PEQ facilities in New Zealand). The “Border Clearance Procedure” document specifies that for a three month PEQ period there should be two growing-season inspections by a Biosecurity Inspector (BSI). Although not specified, the usual practice is for the first inspection to be carried out by a BSI around four to five weeks after transferring the consignment from the border to the PEQ facility. The second inspection is done between two and a half to three months after transfer to PEQ. The first inspection can be delayed if the plants are dormant and the inspection is carried out when there are 40-50% plants in active growth in the whole consignment. This inspection frequency is too low as the fungus can have a life cycle of 10-25 days Some Level 2 PEQ operators or representatives undertake regular checks on plant health and notify the BSI if there is any concern of pest and disease. Inspection is done once a week by some facility operators or representatives, but it does not happen for all facilities. Weekly plants inspection is mandatory in Level 3 PEQ facilities and all records must be maintained by the operator or representatives (MAF, pers comm. 2011). Due to the fact that not all Level 2 PEQ operators or representatives	As spores remain viable for up to 150 days, a three month quarantine period is too short to manage the risk of *P. psidii* s.l.. Currently, only Level 3 PEQ provides an adequate plant inspection regime.

	undertake regular plant health checks, there is too much variability in the inspections that occur within Level 2 PEQ facilities. This is inadequate for providing sufficient risk reduction for *P. psidii* s.l.. In contrast, the inspection regime in Level 3 PEQ, including weekly inspections and record keeping by the operator (or representative), is adequate.	
Minimum quarantine period of 6 months active growth, with 4 growing-season inspections.	As urediniospores are viable for up to 150 days (Salustiano et al, 2008), not all of them can be expected to lose viability within a three month quarantine period. However, a six month quarantine period is highly likely to ensure that un-germinated urediniospores are no longer viable. However, spore viability is sensitive to elevated temperature and humidity. A quarantine period less than six months (e.g. 3 to 4 months) might be considered adequate if conditions within the quarantine facility can be guaranteed to be maintained at 15-23˚C, and >50% relative humidity (Salustiano et al 2008; Suzuki & Silviera 2003). Note, some schedules of myrtaceous species (e.g. *Eucalyptus*) require a six month PEQ period due to other regulated pests and diseases associated with the host.	Six months quarantine is highly likely to ensure *P. psidii* s.l. urediniospores are no longer viable.
Diagnostics	Under the current IHS measures, pest diagnostic testing occurs in Level 2 PEQ <u>only</u> if disease symptoms appear during quarantine. These tests would be required to confirm the identity of *P. psidii* s.l.. The alternative is for mandatory testing of specified pests to occur whilst plants are in PEQ; this is particularly important to detect latent infections and occurs in Level 3 PEQ. Mandatory testing for *P. psidii* is unlikely to be necessary because there is no evidence from modern literature that *P. psidii* s.l. mycelia exist for weeks as latent intracellular infections[22]. Therefore, mandatory testing is unlikely to detect a pre-symptomatic infection with any greater confidence than would visual inspection. Urediniospores are viable for 150 days (Salustiano et al, 2008). Therefore non-germinated urediniospores are expected to lose viability within 6 months, but not within three months. Under a six month quarantine period the *P. psidii* s.l risk is expected to be eliminated in PEQ, and thereby negate the need for mandatory testing.	Mandatory testing of specified pests is not necessary.
A pre-export prophylactic treatment for *P. psidii* s.l: treatment with a fungicide deemed effective against rust fungi by exporting NPPO.	In order for a pre-export fungicidal treatment to be effective as a risk management tool, the entire plant would need to be treated with fungicide (Azoxystrobin, Triadimenol, Mancozeb or Chlorothalonil). Such a treatment can not be reasonably expected to protect against spores that inoculated the plant 6 or more days previously, nor can it protect against spores inoculating the plant after 10-21 days post-treatment, (depending on the fungicide used) (Ruiz et al, 1987; Ruiz et al 1991; Alfenas, 1993; Ferrari, 1997). Fungicidal treatment would reduce the risk of *P. psidii* s.l., but there would remain a level of uncertainty about whether the plants had been exposed to spores outside the period in which the fungicide is effective.	Likely to reduce the risk. Not sufficient on its own.
Tissue culture can be imported under the Standard Entry Conditions for Tissue Culture, Section 2.2.2 of	Tissue cultures are generated aseptically, markedly reducing the risk of *P. psidii* s.l. contamination. But contaminations with fungi do occur (Liefert, 2001; Ormsby, 2009) and so contamination by *P. psidii* s.l is a possibility if cultures come from a country where the fungus is established and *P. psidii* s.l. spores populate the environmental/atmospheric flora (see section below	The current specifications for tissue culture are inadequate for risk management

[22] It is noted that the Australian Pest Specific Contingency Plan for *P. psidii* cited a reference from 1936 (MacLachlan, 1936), saying that it can survive for several months in a lightly infected leaf. The relevant paragraph in MacLachlan, 1936 does not specifically refer to latent infections, but rather makes the point that the fungus dies in a severely infected leaf due to death of the leaf, whereas on a lightly infected leaf, the fungus can live for several months. No report has been found in the modern literature that describes the fungus living in plant tissue for weeks as a latent infection.

the Import Health Standard.	about tissue culture for more explanation). The current IHS specification for tissue culture requires aseptic production of plantlets, absence of fungicides or antibiotics in the growth media, and a pre-export phytosanitary inspection by the exporting national plant protection organisation prior to issuing a phytosanitary certificate. Plantlets that are removed from *in vitro* tissue culture are eligible for import, provided they were not removed from the media more than 48 hrs prior to export, and the phytosanitary certificate is endorsed with an additional declaration that confirms this. For species other than *Eucalyptus*, cultures are visually inspected on arrival by quarantine inspectors in a transitional facility, and can be released if there is no visible contamination. *Eucalyptus* species must also be inspected in a MAF-registered laboratory before clearance. The current measures for tissue culture do not give certainty of the absence of *P. psidii* contaminants. Uncertainty could be reduced if there was a period of PEQ, or a requirement that cultures have to be a certain age prior to export; both of these measures would provide sufficient time for a contaminant to generate visible disease symptoms. Further consideration is required to determine whether cultures should remain in culture or be deflasked during PEQ. Therefore, under the current procedures there is a risk, albeit low, for Myrtaceae tissue culture plantlets contaminated with *P. psidii*.sl spores to enter New Zealand.	of *P. psidii* s.l..

Based on the analysis above it is concluded that the basic conditions, the current specifications for tissue culture, and the schedules for Acca sellowiana, Agonis, Eugenia *and* Metrosideros, *under which myrtaceous species are imported, offer inadequate risk reduction for* P. psidii *s.l. on nursery stock.*

The schedule for Eucalyptus*, which requires Level 3 PEQ for six months, offers adequate risk reduction* P. psidii *s.l. on nursery stock.*

Pest-free place of production (PFPP)

The International Standards for Phytosanitary Measures number 10: 'Requirements for the establishment of pest free places of production and pest free production sites' 1999 (ISPM No 10) describes the requirements for the establishment and use of pest free places of production as a risk management option for meeting phytosanitary requirements for the import of plants. A pest free place of production (PFPP) is defined under the International Plant Protection Convention as a "place of production in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained for a defined period". Pest free status is established via surveys and/or growing season inspections and maintained as necessary by other systems to prevent the entry of the pest into the place of production. The IHS refers to the definition of a PFPP from ISPM 10.

When sufficient information is available to support a PFPP declaration, this phytosanitary measure is usually considered to provide a high level of protection depending on the epidemiological characteristics of the organism or disease in question.

In order to establish an efficacious PFPP for myrtaceous nursery stock in an area where *P. psidii* s.l is present in the environment, the minimum requirements would be a facility with a solid-structure that has entry/exit points and ventilation systems that are spore proof. It would need to be operated using best practice phytosanitary processes and procedures, much like a Level 3 PEQ facility. Molecular diagnostic testing of the nursery stock, using PCR tests specific for *P. psidii* s.l., would be required to demonstrate a PFPP.

The Australian authorities have stated: "Nurseries outside the rust risk area may also need to implement controls as the environmental conditions within nurseries are similar to those preferred by the rust" (Office of the Chief Plant Protection Officer, 2007). Therefore, the PFPP facility specifications required to establish a PFPP within rust-areas may also be required to establish a PFPP outside the rust risk-areas of a country where *P. psidii* s.l has established.

Although a PFPP might be an efficacious risk management option, whether a PFPP is a viable option for the production of myrtaceous nursery stock will require further consideration.

It is concluded that it would be technically possible to establish an efficacious PFPP, however further consideration is required to determine whether an efficacious PFPP is a viable risk management option for myrtaceous nursery stock in countries where P. psidii *s.l. is established. MAF would need to assess the PFPP in accordance with ISPM 10.*

Pest-free area

The International Standards for Phytosanitary Measures number 4: Requirements for the establishment of pest free areas, 1995 (ISPM No 4) describes the requirements for the establishment and use of PFAs as a risk management option for meeting phytosanitary requirements for the import of plants. A pest free area (PFA) is defined under the International Plant Protection Convention as "an area in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained". ISPM 4 identifies three main aspects that must be considered in the establishment and subsequent maintenance of a PFA:

- Systems to establish pest-free status
- Phytosanitary measures to maintain pest-free status
- Checks to verify pest-free status has been maintained.

Normally PFA status is based on verification from specific surveys such as an official delimiting or detection survey. It is accepted internationally that organisms or diseases that have never been detected in, or that have been detected and eradicated from an area, should not be considered present in an area if there has been sufficient opportunity for them to have been detected. When sufficient information is available to support a PFA declaration, this phytosanitary measure is usually considered to provide a very high level of protection. The assumptions embodied in the PFA declarations are not without risks – the period during which *U. rangelii* was established in NSW without the knowledge of Australian authorities is unknown, but if it coincided with the period between checks to verify freedom of the pest, declarations of PFA may have been made, even though in reality the area was not a PFA. Further consideration would need to be given to the frequency and locations of checks to verify freedom.

It is unclear whether it is possible to establish PFAs for *P. psidii* s.l.. The PFA could be a country, or an area within a country that is free of *P. psidii* s.l. (based on official survey data), or an area not likely to have *P. psidii* s.l. introduced by natural dispersion, or does not have a climate that is likely to be suitable for *P. psidii* s.l. (e.g. arid parts of Australia are considered unsuitable for *P. psidii* s.l. (Booth et al, 2000)). However, as is the case with trying to establish a

PFPP, because the environmental conditions within nurseries are similar to those preferred by the rust (Office of the Chief Plant Protection Officer, 2007), it is conceivable that the place of production within the PFA could have an outbreak of *P. psidii* s.l.. If that scenario is possible, a declaration of a PFA would give no protection.

In conclusion, pest-free areas will provide some risk reduction, in countries where P. psidii *s.l. is not known to be present, if this can be confirmed with scientific evidence. It is uncertain whether a PFA provides risk reduction in countries where* P. psidii *s.l. is established. PFA should not be used in isolation, and in situations where the PFA is within a country that has* P. psidii s.l., *it does not address the risk that the place of production within the PFA may have an outbreak of* P. psidii *s.l.*.

Fungicidal treatment

Studies of fungicide ability to control and prevent disease caused by *P. psidii* s.l., done in the 1980s and 1990s, have focused on Guava (*Psidium guajava*) and *Eucalyptus* species and involved a range of systemic and non-systemic fungicides (Ruiz et al, 1987; Ruiz et al 1991; Alfenas et al, 1993; Ferrari et al, 1997; Furtado & Marino, 2002).

- Fungicides used in the field were not able to provide 100% protection or control of the disease (Alfenas et al1993; Ferrari et al, 1997).
- Fungicides used in green houses and growth chambers reportedly provided both preventative control of disease (i.e. pre-treatment of plants prior to exposure to spores) and curative effects (i.e. disease development halted by treatment after exposure to spores), but effectiveness was highly dependent on the period between treatment and inoculation, and vice versa (Ruiz et al 1987 and 1991). Specifically:
    - preventive fungicide treatment was effective against inoculations occurring up to 10 days post-treatment, but it is not known how long protection lasts beyond this because it was not tested[23]. If fungicide treatment was to be considered as a risk management treatment on nursery stock, the entire plant would need to be treated with fungicide, because leaves that were not directly exposed to fungicide, had diminished protection as early as 5 days post-treatment (Ruiz et al 1991).
    - fungicides were only curative if they were applied to the plant within six days of them being inoculated with spores[24] (Ruiz et al 1991).

A more recent study by Zauza et al in 2008 reported on effectiveness against *P. psidii* s.l. of a range of additional fungicides, both as curative agents (i.e. fungicide applied after inoculation with spores), and as protective agents (i.e. fungicide applied before inoculation with spores). The most effective fungicide was Azoxystrobin (0.1 g/l). Azoxystrobin was 100% curative if sprayed within 7 days of *P. psidii* spore inoculation, and was 100% protective against *P. psidii* spore inoculation for up to 21 days post-treatment (Zauza et al 2008). Compared with Triadimenol, Mancozeb and Chlorothalonil (Ruiz et al 1991), Azoxystrobin provides preventative protection for approximately twice as long, but offers curative protection for approximately the same period.

The mode of action of these fungicides is as follows:

Fungicide	Chemical	Mode of Action

[23] Triadimenol (0.75 g/l) was most effective, followed by Mancozeb (1.6 g/l) and Chlorothalonil (1.5 g/l), and Triforine (0.28 ml/l).
[24] Triadimenol (0.75 g/l), Triforine (0.28 ml/l), Oxicarboxin (0.75 g/l) were effective if used within 6 days of spore inoculation.

	Group	
Azoxystrobin	Strobilurin	Systemic. Inhibits mitochondrial respiration in fungi. It inhibits spore germination, mycelial growth, and spore production of fungi.
Triadimenol	Triazole	Systemic. Demethylation inhibitor in sterol biosynthesis pathway.
Mancozeb	Carbamate	Non-systemic, i.e. a contact fungicide; inhibits respiration.
Chlorothalonil	Benzo-nitriles	Non-systemic, i.e. a contact fungicide. A multi-site inhibitor affecting various enzymes and other metabolic processes in fungi. Inhibits spore germination, and is toxic to fungal cell membranes.

In order for a fungicidal treatment to be effective as a risk management tool, the entire plant would need to be treated with fungicide (e.g. Azoxystrobin, Triadimenol, Mancozeb or Chlorothalonil)[25]. Such a treatment can not be reasonably expected to protect against spores that inoculated the plant 6 or more days previously, nor can it protect against spores inoculating the plant after 10-21 days post-treatment.

The finding that the fungicides are not 100% effective against inoculations that occurred more than 6-7 days previously is taken to mean that if a plant was detected in PEQ with disease symptoms, that a fungicidal treatment would not be 100% effective at eradicating the rust/disease.

In conclusion, fungicidal treatment is not sufficiently reliable that it can be used as a measure on its own. There would remain a level of uncertainty about whether plants had been treated effectively, and if the plants had been exposed to spores outside the period in which the fungicide is suitably effective.

Additional conditions for tissue culture

Tissue cultures are generated aseptically, markedly reducing the risk of *P. psidii* s.l. contamination. But contaminations with fungi are known to occur (Liefert, 2001; Ormsby, 2009). The potential for contamination from *P. psidii* arises primarily from the parent material (e.g. an infected or contaminated parent plant). There is also a very small possibility for contamination from air contaminants exposed to *in-vitro* plant material during the in-flight transportation to New Zealand. Contamination originating during air transport of the tissue culture occurs as a result of air exchange that can occur when flask seals fail at altitude (Ormsby, 2009; MAF pers. com. 2011); *P. psidii* contamination via this method may be a possibility if the environmental spore loading was very high in the exporting country. These sources of contamination are distinct from contamination arising from inadequate *in-vitro* handling, which is considered negligible for the following reasons: it is assumed that staff adhere to basic hygiene measures during *in vitro* handling (hair tied back, wearing of lab coats, gloved hands); culturing work is done in laminar flow hoods with air flows designed to prevent the culture from being

[25] All of these fungicides are approved for use in New Zealand; refer to https://eatsafe.nzfsa.govt.nz/web/public/acvm-register

exposed to particles in the laboratory air – air is either pushed out toward the worker, or is sucked up and down at the front edge of the laminar flow hood; furthermore, culturing work is generally done at the back of the hood (MAF, pers. comm., 2011).

P. psidii s.l. is not documented to behave as a long term endophyte or as having latent intracellular infections, and so it is expected that if a tissue culture plantlet was contaminated with *P. psidii* s.l., symptoms would be visible within two to four weeks if the cultures are maintained at 15-23˚C in high relative humidity (Glen et al 2007).

The measures specified for tissue culture in the current IHS do not sufficiently manage the low risk of plantlets being contaminated with *P. psidii* s.l spores (see Table 1, p29). Options to remedy this include:

- Both in-flight contamination and contamination sourced from parent material could be managed by: a) transporting the culture containers/flasks within an asceptic container that will remain sealed during the transportation by air; and b) requiring a PEQ period of four weeks at 15-23˚C, in high relative humidity.
- Contamination sourced from parent material could be managed by requiring cultures to be maintained, at 15-23˚C in high relative humidity, for 4 weeks prior to the pre-export inspection. Further consideration would be required to determine whether a period of PEQ is required both before export and after inspection at the place of arrival.
- Mother plant contamination could be managed by a declaration along the lines of "the tissue cultures have been derived from mother plants that have been tested by [an approved methodology] and found free of *P. psidii* s.l.".
- All, or some, of the above could be included in a protocol for managing mother stock and all other aspects of the tissue culture production system to reduce risk of contamination.

In conclusion, if the tissue culture import specifications were modified to address the risks outlined above, tissue culture would provide the greatest reduction of the risk of P. psidii *s.l. entering New Zealand on nursery stock.*

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Appendix 1: Myrtaceous genera with species susceptible to *P. psidii* s.l.

Prior to the Australian incursion, the known number of genera with species susceptible to *P. psidii* s.l was 21; they are printed below in black italics with no highlighting.

As at 2 February 2011, the 14 genera that are highlighted with yellow were new to the host list since the detection of *U. rangelii* in Australia in April 2010, bringing the total to 35.

As at 13 June 2011, 10 additional genera (highlighted in green) were new to the host list since 2 February 2011, bringing the total to 45 genera. This represents a 114% increase of new host genera.

Acca (synonym *Feijoa*)
Acmena
Acmenosperma
Agonis
Anetholea
Astereomyrtus
Austromyrtus
Angophora
Backhousia
Callistemon
Calothamnus
Campomanesia
Chamelaucium
Choricarpia
Corymbia
Decaspermum
Eucalyptus
Eugenia
Gossia
Heteropyxis
Kunzea
Lenwebbia
Leptospermum
Lophomyrtus
Marlierea
Melaleuca
Metrosideros
Myrcia
Myrcianthes
Myrciaria
Myrtus
Pilidiostigma
Pimenta
Psidium
Rhodamnia
Rhodomyrtus

Ristantia
Stockwellia
Syncarpia
Syzygium
Tristania
Ugni
Uromyrtus
Waterhousea
Xanthostemon

Appendix 2: Summary of current import requirements for myrtaceous nursery stock

The import requirements for approved species of myrtaceous nursery stock are specified in the import health standard (IHS) 155.02.06: Importation of Nursery Stock.

1. Basic conditions for whole plants and cuttings

The IHS specifies Basic Conditions that must be met for all nursery stock imported into New Zealand, as well additional specific measures for some genera that are associated with greater biosecurity risks. The following phytosanitary measures are prescribed in section 2.2.1 of the IHS for all whole plants and cuttings imported into New Zealand:

- Cleanliness: plants must be packaged in inert/synthetic material and free from soil and other extraneous matter.

- Pre-export phytosanitary inspection: prior to issuing a phytosanitary certificate, the exporting National Plant Protection Organisation (NPPO) must inspect the nursery stock to ensure it is free from visually detectable regulated pests, and it conforms to New Zealand's import requirements.

- Insects and mites: pesticide treatments are required to ensure freedom from insects and mites.

- Fungi: dependent on the country of origin, "pest free area" endorsements and fungicide treatments may be required for *Helicobasidium mompa* and *Phymatotrichopsis omnivora*.

- *Phytophthora ramorum*: known hosts of *P. ramorum* may only be imported from MAF approved "pest free areas".

- *Xylella fastidiosa*: known hosts of *X. fastidiosa* may only be imported from MAF approved "pest free areas"; or imported from a "pest free place of production" with specific testing for *Xylella fastidiosa* in post entry quarantine.

- Post entry quarantine: all whole plants and cuttings must undergo a period of post entry quarantine (PEQ) on arrival in New Zealand, during which time they undergo growing seasons inspections by a MAF Biosecurity Inspector.

2. Current phytosanitary measures for myrtaceous nursery stock

In addition to the basic conditions for whole plants and cuttings, some species of the myrtaceous family must undergo specific phytosanitary measures for *P. psidii* s.l.. The specific phytosanitary measures are prescribed in the schedules of the IHS, in section 3.

Table 2 summarises the specific phytosanitary measures for the 539 species in the myrtaceous species that are eligible for import into New Zealand as nursery stock. All species are eligible for import into New Zealand as whole plants, cuttings, and tissue culture. The number in brackets after each genus is the number of species of that genus that are approved for import into New Zealand.

Table 2. Summary of import requirements for myrtaceous nursery stock

Schedule	Genus	Approved exporting countries	Quarantine pests	Phytosanitary measures
No specific schedule; only needs to meet the Basic Conditions **62 species**	• *Actinodium* (1) • *Astartea* (2) • *Austromyrtus* (1) • *Backhousia* (2) • *Baeckea* (10) • *Beaufortia* (3) • *Calothamnus* (9) • *Calytrix* (9) • *Darwinia* (9) • *Hypocalymma* (2) • *Lophostemon* (1) • *Micromyrtus* (1) • *Thryptomene* (8) • *Verticordia* (4)	All	No specific pests identified.	• Section 2.2.1. • Level 2 PEQ. • Three months active growth. • Two growing season inspections.
Acca sellowiana **84 species**	• *Acca* (1) • *Callistemon* (25) • *Melaleuca* (48) • *Myrciaria* (2) • *Pimenta* (1) • *Psidium* (7) • *Feijoa* (synonym of *Acca sellowiana*)	Australia, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Luxembourg, Norway, The Netherlands, Portugal, Spain, Sweden, Switzerland, United Kingdom, USA	*Puccinia psidii*	• Section 2.2.1. • Additional declaration required "*Puccinia psidii* is not known to occur in (the country or state of origin)". • Level 2 PEQ. • Six months active growth. • Four growing season inspections.
Agonis **73 species**	• *Agonis* (8) • *Angophora* (3) • *Kunzea* (15) • *Leptospermum* (44) • *Lophomyrtus* (3)	All	No specific pests identified	• Section 2.2.1. • Pre-export prophylactic treatment with a fungicide deemed effective against rust fungi by the exporting NPPO. • Level 2 PEQ. • Three months active growth. • Two growing season inspections.
Eucalyptus **263 species**	• *Eucalyptus* (263)[26]	All	*Puccinia psidii; Endothia havanensis; Mycosphaerella parva.*	• Section 2.2.1. • Level 3 PEQ. • Six months active growth. • Four growing season inspections
Eugenia **31 species**	• *Eugenia* (22) • *Syzygium* (9)	Australia, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Luxembourg, Norway, The Netherlands, Portugal, Spain, Sweden, Switzerland, United Kingdom.	*Puccinia psidii; Xylella fastidiosa*	• Section 2.2.1. • Additional declaration required "*Puccinia psidii* is not known to occur in (the country or state of origin)". • Level 2 PEQ. • Six months active growth. • Four growing season inspections.
Metrosideros **26 species**	• *Luma* (1) • *Metrosideros* (19) • *Myrtus* (6)	All	*Puccinia psidii*	• Section 2.2.1. • Additional declaration required "*Puccinia psidii* is not known to occur in (the country or state of origin)". • Level 2 PEQ. • Three months active growth. • Two growing season inspections.

[26] The genus *Eucalyptus* as listed in the IHS includes species that are sometimes included in the genus *Corymbia*.

3. Entry conditions for tissue culture

The following phytosanitary measures are prescribed in section 2.2.2 of the IHS for all tissue cultures imported into New Zealand:

- Cleanliness: tissue culture media must not contain fungicides or antibiotics. Cultures must be produced in a facility under conditions that prevent contamination with regulated pests.

- Pre-export phytosanitary inspection: prior to issuing a phytosanitary certificate, the exporting National Plant Protection Organisation (NPPO) must inspect the nursery stock to ensure it is free from visually detectable regulated pests, and it conforms to New Zealand's import requirements. For cultures removed from media, the NPPO must certify that the cultures were removed no more than 48 hours prior to export.

- On arrival inspection: on arrival in New Zealand the cultures are inspected by a MAF Quarantine Inspector to ensure they are free from visual symptoms of pest or disease.

As tissue culture media must not contain fungicides, any plants infected with *P. psidii* s.l. are likely to be exhibiting visual symptoms of contamination during either the pre-export phytosanitary inspection, or the on arrival inspection, as long as conditions have been sufficient for disease symptoms to appear; i.e. the plantlets are at least 12 days old, they are actively growing and have been maintained at temperatures between 15 to 23˚C. Tissue cultures exhibiting symptoms of fungal infection during the pre-export inspection are not exported to New Zealand. Tissue cultures exhibiting symptoms of fungal infection during the on arrival inspection are not eligible for biosecurity clearance.

Appendix 3: Current host list of *U. rangelii* in Australia as at 13 June 2011 2011

As at 2 February 2011 there were 37 known host species for *U. rangelii*.
As at 13 June 2011, there were 101 known host species for *U. rangelii* (based on analysis of the Queensland and the NSW regional host lists, accessed on 13 June 2011).

Note: The Australian national host list (below) was valid as at 19 May 2011. It was accessed on 13 June 2011 from this URL:
http://www.outbreak.gov.au/pests_diseases/pests_diseases_plant/myrtle-rust/national_host_list.html

Missing from the national list are:
One species from the NSW list, which totalled 67 when accessed on 13 June 2011:
http://www.dpi.nsw.gov.au/biosecurity/plant/myrtle-rust/hosts

Five species from the Queensland list, which totalled 59 when accessed on 13 June 2011:
http://www.dpi.qld.gov.au/4790_19789.htm

Host species in the table that are highlighted in yellow are native to New Zealand:

- *Lophomyrtus bullata* (Ramarama, New Zealand Myrtle)
- *Metrosideros excelsa* (Pohutukawa)
- *Metrosideros kermadecensis*) (Kermadec pohutukawa)

Explanation of Australian National Host list
All QLD records are confirmed under microscope, with botanical ID confirmed by an expert. NSW records confirmed either by field inpsection, photograph or by microscopic examination, and botanical ID confirmed by recognised expert.

* terms used reflect state legilsation. Q = Queensland, N = NSW

** severity is influenced by environmental conditions and may range from low where only a few lesions are found, to high where plant parts are killed by infection. Plants with no rating may also be severely affected, but have not been recorded as such during official surveys.

Source: http://www.outbreak.gov.au/pests_diseases/pests_diseases_plant/myrtle-rust/national_host_list.html

Myrtle rust national host list as at 19 May 2011

	Species	Common Names/Cultivar	NSW	QLD	Status*	Moderate to severe damage observed in the field**
1	*Acmena hemilampra syn. Syzygium hemilamprum*	blush satinash		Y		
2	*Agonis flexuosa*	After Dark', 'Burgundy', 'Nana', 'Westland Burgundy', 'Jeddas Dream'	Y	Y		Y
3	*Angophora floribunda*	rough-barked apple	Y			
4	*Asteromyrtus brassii*	Brass's Asteromyrtus		Y		
5	*Austromyrtus dulcis*	Midgen berry	Y	Y		
6	*Backhousia angustifolia*	curry myrtle or narrow-leaved myrtle		Y		
7	*Backhousia citriodora*	lemon-scented myrtle	Y	Y		Y
8	*Backhousia myrtifolia*	grey myrtle	Y			
9	*Backhousia sp. 'Prince Regent'*			Y		
10	*Callistemon viminalis x C. citrinus*	Mary Mackillop'	Y			
11	*Callistemon salignus*	weeping bottlebrush	Y			
12	*Callistemon viminalis*	willow bottlebrush	Y	Y		
13	*Chamelaucium uncinatum*	geraldton wax	Y			
14	*Choricarpia leptopetala*	brown myrtle or rusty turpentine	Y			
15	*Choricarpia subargentea*	giant ironwood		Y	near threatened (Q), endangered (N)	
16	*Decaspermum humile*	silky myrtle		Y		Y
17	*Eucalyptus agglomerata*	blue-leaved stringybark	Y			
18	*Eucalyptus deanei*	mountain blue gum or Deane's gum	Y			
19	*Eucalyptus elata*	river peppermint gum	Y			
20	*Eucalyptus pilularis*	blackbutt	Y			
21	*Eucalyptus tindaliae*	white stringybark, tindale's stringybark	Y			

Myrtle rust national host list as at 19 May 2011						
-	**Species**	**Common Names/Cultivar**	**NSW**	**QLD**	**Status***	**Moderate to severe damage observed in the field****
22	*Eugenia reinwardtiana*	beach cherry	Y	Y		Y
23	*Gossia acmenoides*	scrub ironwood	Y	Y		
24	*Gossia bidwillii*	scrub python tree		Y		
25	*Gossia floribunda*			Y		
26	*Gossia fragrantissima*	sweet myrtle		Y	endangered (Q), endangered (N)	Y
27	*Gossia gonoclada*	angle-stemmed myrtle	Y		endangered (Q)	
28	*Gossia hillii*	scaly myrtle	Y	Y		Y
29	*Gossia inophloia syn. Austromyrtus inophloia*	thready barked myrtle, 'Aurora', 'Blushing Beauty'	Y	Y	near threatened (Q)	Y
30	*Gossia macilwraithensis*			Y	near threatened (Q)	
31	*Gossia punctata*			Y		
33	*Lenwebbia prominens*	southern velvet myrtle	Y	Y	near threatened (Q)	
34	*Lenwebbia sp. 'Blackall Range'*			Y	endangered (Q)	
35	*Leptospermum petersonii*	lemon-scented tea tree	Y			
36	*Leptospermum rotundifolium*	round-leaved tea tree	Y			
37	*Lophomyrtus bullata*	Rainbow's end'	Y			
38	*Lophomyrtus x ralphii*	'Red Dragon', 'Black Stallion', 'Krinkly'	Y			
39	*Melaleuca alternifolia*	tea tree	Y			
40	*Melaleuca decora*		Y			
41	*Melaleuca fluviatilis*		Y	Y		
42	*Melaleuca linariifolia*	'Claret tops'	Y			
43	*Melaleuca nesophila*		Y			
44	*Melaleuca nodosa*	prickly-leaved paperbark	Y			
45	*Melaleuca quinquenervia*	broad-leaved paperbark	Y	Y		Y
46	*Melaleuca sieberi*		Y			
47	*Metrosideros collina*	Tahiti', 'Fiji', includes Metrosideros thomasii 'Spring Fire', 'Fiji Fire'	Y	Y		Y

Myrtle rust national host list as at 19 May 2011						
-	**Species**	**Common Names/Cultivar**	**NSW**	**QLD**	**Status***	**Moderate to severe damage observed in the field****
48	*Metrosideros excelsa*	'Moon maiden'	Y			
49	*Metrosideros kermadecensis*	'Variegatus'	Y			
50	*Myrtus communis*	common myrtle	Y			Y
51	*Pilidiostigma glabrum*	plum myrtle	Y	Y		Y
52	*Pilidiostigma rhytispermum*		Y			
53	*Rhodamnia angustifolia*	narrow-leaved malletwood	Y	Y	endangered (Q)	Y
54	*Rhodamnia arenaria*		Y	Y		Y
55	*Rhodamnia argentea*	silver myrtle or malletwood	Y	Y		Y
56	*Rhodamnia costata*	malletwood		Y		Y
57	*Rhodamnia dumicola*	rib-fruited malletwood		Y		Y
58	*Rhodamnia glabrescens*			Y	near threatened (Q)	Y
59	*Rhodamnia maideniana*	smooth scrub turpentine	Y	Y		Y
60	*Rhodamnia pauciovulata*			Y		Y
61	*Rhodamnia rubescens*	scrub turpentine	Y	Y		Y
62	*Rhodamnia sessiliflora*	iron malletwood		Y		Y
63	*Rhodamnia spongiosa syn. R. glauca*			Y		Y
64	*Rhodomyrtus psidioides*	native guava	Y	Y		Y
65	*Rhodomyrtus trineura subsp. capensis*			Y		
66	*Ristantia waterhousei*			Y		
67	*Stockwellia quadrifida*		Y		near threatened (Q)	
68	*Syncarpia glomulifera*	turpentine	Y			Y
69	*Syzygium angophoroides*	watergum		Y		

Myrtle rust national host list as at 19 May 2011						
-	**Species**	**Common Names/Cultivar**	**NSW**	**QLD**	**Status***	**Moderate to severe damage observed in the field****
70	*Syzygium anisatum syn. Backhousia anisata; Anetholea anisata*	aniseed myrtle	Y	Y		Y
71	*Syzygium armstrongii*			Y		
72	*Syzygium australe*	Meridian Midget', 'Golden Hedge'	Y	Y		
73	*Syzygium bamagense*		Y			
74	*Syzygium canicortex*	yellow satinash		Y		
75	*Syzygium hedraiophyllum syn. Waterhousea hedraiophylla*	gully satinash		Y		
76	*Syzygium jambos*	rose apple	Y	Y		Y
77	*Syzygium luehmannii*	small-leaved lillypilly, riberry	Y	Y		
78	*Syzygium luehmannii x S. wilsonii*	Cascade'	Y			
79	*Syzygium moorei*		Y		vulnerable (Q), vulnerable (N)	
80	*Syzygium oleosum*	blue lilly pilly	Y	Y		
81	*Syzygium paniculatum*	brush cherry	Y		vulnerable (N)	
82	*Syzygium pseudofastigiatum*		Y			
83	*Syzygium smithii*		Y			
84	*Syzygium tierneyanum*	river cherry	Y			
85	*Tristania neriifolia*	water gum	Y	Y		Y
86	*Ugni molinae*	Tazziberry, Chilean Guava	Y			
87	*Uromyrtus australis*	peach myrtle	Y		endangered (N)	
88	*Uromyrtus lamingtonensis*	lamington peach myrtle	Y		vulnerable (Q)	
89	*Waterhousea floribunda syn. Syzygium floribundum*	weeping lilly pilly		Y		

Myrtle rust national host list as at 19 May 2011						
-	**Species**	**Common Names/Cultivar**	**NSW**	**QLD**	**Status***	**Moderate to severe damage observed in the field****
90	*Waterhousea mulgraveana syn. Syzygium mulgraveanum*		Y			
91	*Xanthostemon chrysanthus*	golden penda	Y			
92	*Xanthostemon oppositifolius*	southern penda		Y	vulnerable (Q)	Y
93	*Xanthostemon youngii*	crimson penda		Y		Y
94	*Rhodomyrtus macrocarpa*		Y			
95	*Backhousia sciadophora*	shatterwood		Y		
96	*Rhodomyrtus canescens*	crater ironwood		Y		
			66	**54**		

Appendix 4: List of native myrtaceous species in New Zealand (distribution; whether they occur in areas suitable for *P. psidii* s.l.; and biostatus).

Native species	Common name	Distribution (Sources: Salmon, 1980; Allan, 1982; Manaaki whenua Landcare Research Databases, 2011; NZ Plant Conservation Network, 2011; de Lange, DOC, Pers. comm. 2011)	In areas optimal or suitable for *P. psidii?*	Biostatus
Kunzea ericoides var. *linearis* (Kirk) W.Harris	rawiri, manuka-rauriki	Endemic to the northern North Island where it is most abundant from Kaitaia north. In the west it extends south to the Pouto Peninsula but it is very disjunct and generally scarce. In the east it extends almost to Pakiri, then occurs locally around the Waitemata Harbour with spot occurrences on Great Barrier Island, near Miranda and on the Hapuakohe Range.	Yes	At risk/ Declining As per de Lange et al 2009
Kunzea ericoides var. *microflora* (G.Simpson) W.Harris	prostrate kanuka, geothermal kanuka	Endemic to Taupo Volcanic Zone. Lowland to montane (up to 500 m).	No/Possibly[27]	At risk/ NaturallyUncommon As per de Lange et al 2009
Kunzea ericoides (A.Rich) Joy Thomps. var. *ericoides*	manuoea, titira, atitira, manuka-rauriki, kanuka	Endemic to the northern South island, north of the Buller and Wairau Rivers; it is most common in North-West Nelson. Ranges from sea level to 1600 m, in the Peel range, Kahurangi National Park.	Yes	Not threatened
Kunzea aff. ericoides (a)	Rawiritoa	Endemic. North and South Islands – mostly westerly in sand country from Te Paki to Wellington (in the northern and southern parts of its range it extends onto clay soils). On Kapiti Island. Common around the Kaipara and Pouto Sand Tombolo (its national stronghold). In the South Island confined to North-West Nelson where it is common on Farewell Spit. Coastal and lowland sites only.	Yes	At Risk/Declining As per de Lange et al. (2009)
Kunzea aff. *ericoides* (b) (includes *K*. aff. *ericoides* (f) of de Lange & Murray 2004; de Lange et al. (2005))	Rawirinui, Manuka, Manutoeha	Endemic. North and South Islands (to Dunedin and about Roxburgh). This is the most common Kunzea in New Zealand and the one that is widely mistaken for K. ericoides. It ranges from sea level to 800 m There are at least three races in this species, each is geographically confined.	Yes	Not Threatened
Kunzea aff. *ericoides* (c)	Makahikatoa	Endemic. North and South Islands – mostly montane to subalpine. In the North Island virtually confined to the Central Volcanic Plateau and eastern Axial Ranges; In the South Island mostly found in the east along the Southern Alps (altitudinal range 100-2000 m)	No/ Possibly (see footnote 8)	Not Threatened
Kunzea aff. *ericoides* (d)		Endemic. North Island, Bay of Plenty (Thorndon (Walker Road), Ohiwa Harbour (Whangaopikopiko Island). Coastal – on mobile sand	Yes	Threatened/Nationally Vulnerable As per de Lange et al. (2009)

[27] It might be possible that the geothermal areas where this species grows may support microclimates suitable for the establishment of P. psidii s.l.. Such microsites already support fern species more typically associated with warm moist climates (e.g. see http://www.nzpcn.org.nz/flora_details.asp?ID=162 & http://www.nzpcn.org.nz/flora_details.asp?ID=785)

Native species	Common name	Distribution (Sources: Salmon, 1980; Allan, 1982; Manaaki whenua Landcare Research Databases, 2011; NZ Plant Conservation Network, 2011)	In areas optimal or suitable for *P. psidii?*	Biostatus
Kunzea aff. *ericoides* (e)		Endemic. Three Kings Islands (Manawatawhi (Great Island), South-West, West Islands). Coastal (up to 400 m a.s.l.) but only on small islands with a coastal climate	Yes	At Risk/Naturally Uncommon (as per de Lange et al. 2009)
Kunzea aff. *ericoides* var. *microflora*		Endemic. Moutohoura (Whale Island), Bay of Plenty. Coastal including the geothermally active parts of that island	Yes	At Risk/Naturally Uncommon (as per de Lange et al. 2009)
Kunzea sinclairii (Kirk) W.Harris	Great Barrier Island kanuka	Endemic to Great Barrier Island, where it is only known from the central portion of the island.	Yes	??
Leptospermum scoparium J.R.Forst. et G.Forst. var. *scoparium*[28]	manuka, tea tree, kahikatoa	Indigenous. Throughout both the North, South and Stewart islands. Scarce north of the central plateau. From sea level to subalpine areas about 1,000 m. Also occurs on the Chatham Islands. It forms extensive areas of scrub. (Also present in Tasmania).	Yes	Non-threatened
Leptospermum scoparium var. *incanum* Cockayne	kahikatoa	Endemic. Found in Northland. Coastal in sand country and podzols – rarely extending onto clay podzols. Found from Te Paki South to at least Kaitaia.	Yes	Not Listed – deserves listing of either At Risk/Naturally Uncommon or At Risk/Declining
Leptospermum aff. *scoparium* (a)	Kahikatoa (manuka)	Endemic. North Island (Northland, Auckland, Waikato, Bay of Plenty, Taranaki, Whanganui; less common in Manawatu, Horowhenua, Wellington)	Yes	Not Threatened
Leptospermum aff. *scoparium* (b)	Kahikatoa (manuka)	Endemic. Three Kings, North Island (mostly easterly and coastal from Te Paki to the Mercury Islands (probably further south than this).	Yes	Not Listed - deserves listing as At Risk/Naturally Uncommon.
Leptospermum aff. *scoparium* (c)	Kahikatoa (manuka)	Endemic. North Island, Waikato and Bay of Plenty – confined to peat bogs, mostly lowland but with a few sites on the northern Kaimai Range and near Rotorua (at 300 m).	Yes	Not Listed – deserves listing as At Risk/Declining
Lophomyrtus bullata Burret	Ramarama, New Zealand myrtle	Endemic genus. Throughout the North Island and in the Nelson and Marlborough districts of the South Island up to 600 m above sea level in coastal and lowland forests.	Yes	Non-threatened

[28] Leptospermum in New Zealand is a species complex awaiting proper study to determine the current diversity; there are probably 15 species (Peter de Lange, Department of Conservation, pers. comm., 2011).

Native species	Common name	Distribution (Sources: Salmon, 1980; Allan, 1982; Manaaki whenua Landcare Research Databases, 2011; NZ Plant Conservation Network, 2011)	In areas optimal or suitable for *P. psidii?*	Biostatus
Lophomyrtus obcordata (Raoul) Burret	Rohutu, New Zealand myrtle	Endemic genus. Throughout the North and South Islands from sea level to 1,050 m in coastal and lowland areas.	Yes	Non-threatened
Metrosideros albiflora Sol. ex Gaertn.	white rata	Endemic. Endemic. North Island. Kaitaia south to Pukemokemoke (north of Hamilton). Mostly in kauri forest – Also on Hauturu (Little Barrier Island) and Aotea (Great Barrier Island).	Yes	Non-threatened
Metrosideros bartlettii J.W.Dawson	rata moehau, Bartlett's rata	Endemic. Te Paki (Radar Bush, Kohuronaki and Unuwhao). Seriously threatened with extinction – about 34 trees[29] left in the wild.	Yes	Nationally critical
Metrosideros carminea W.R.B.Oliv.	crimson rata, carmine rata	Endemic. North Island. Te Paki south to Taranaki in the west and Mahia Peninsula in the east. Mostly coastal forest but extending inland up to 500 m.	Yes	Non-threatened
Metrosideros colensoi Hook.f.	Rata	Endemic. North and South Island coastal and lowland forests; scarce north of Auckland with a northern limit at Mangamuka. Mostly on calcareous rocks.	Yes	Non-threatened
Metrosideros diffusa (G.Forst.) Sm.	white rata	Endemic. Found throughout the North, South and Stewart Islands	Yes	Non-threatened
Metrosideros excelsa Sol. ex Gaertn.	pohutukawa, New Zealand Christmas tree	Endemic. In coastal sites around the north island, particularly in the north-east and coromandel. Found inland on the shores of the lakes in the Rotorua district. Pohutukawa has also been planted extensively in parks and gardens, particularly in the North Island, but also around Nelson, on Banks Peninsula and as far south as Dunedin in the east and Jacksons Bay in the West. It is naturalised on the Chatham and Norfolk islands.	Yes	Non-threatened
Metrosideros fulgens Sol. ex Gaertn.	rata	Endemic. Three Kings, North and South Island. Coastal and lowland forest to south of lat. 44° 30'; west of divide in South Island. Awaiting transfer to its own endemic genus.	Yes	Non-threatened
Metrosideros kermadecensis W.R.B.Oliv.	Kermadec pohutukawa	Endemic. Found naturally in the Kermadec Islands. Naturalised in parts of Auckland and on Norfolk Island. On mainlaind New Zealand it is planted as a street tree in a number of places, including the streets of Wellington. Hybridises freely with M. excelsa and many 'wild' occurances in the North Island are hybrids.	Yes [30]	Uncommon
Metrosideros parkinsonii Buchanan	Parkinsons rata	Endemic. On Aotea (Great Barrier Island – Hirakimiata) and Hauturu (Little Barrier Island, Orau) and in the South Island in the north-west Nelson area and the Paparoa ranges, south to near Greymouth. The tree grows from sea level to 920 m.	Yes	Non-threatened

[29] According to the NZ Plant Conservation Network, 2011; See http://www.nzpcn.org.nz/flora_details.asp?ID=24

[30] Although the Kermadec Islands were not included in the modelling by Kriticos & Leriche, 2008, it is expected that the climate is suitable because these islands lie north east of New Zealand in a sub-tropical to tropical climatic zone.

Native species	Common name	Distribution (Sources: Salmon, 1980; Allan, 1982; Manaaki whenua Landcare Research Databases, 2011; NZ Plant Conservation Network, 2011)	In areas optimal or suitable for *P. psidii?*	Biostatus
Metrosideros perforata (J.R.Forst. et G.Forst.) A.Rich.	white rata	Endemic. Three Kings, North and South Islands. Coastal to lowland forest and margins to Banks Peninsula on east and Martin's Bay on west.	Yes	Non-threatened
Metrosideros robusta A.Cunn.	Northern rata	Endemic. North and South Island (to Lake Mahinepua south of Hokitika). Coastal to montane forest; formerly widesprerad but now scarce over larger parts of its range due to forest clearance and possum browse.	Yes	Non-threatened
Metrosideros umbellata Cav.	Southern rata	Endemic. North, South, Stewart and Auckland Islands. North Island scarce. Widespread in the western portion of the South Island but scarce in the east until the Catlins. Common on Stewart and Auckland Islands. In the North Island it is virtually confined to sites above 500 m. Otherwise from sea level to 1200 m.	Yes	Non-threatened
Neomyrtus pedunculata (Hook.f.) Allan	rohutu, myrtle	Endemic Genus. Throughout North, South and Stewart Islands but uncommon north of Auckland (lowland to montane forest) – northern limit Awanui (Kaitaia)	Yes	Non-threatened
Syzygium maire (A.Cunn.) Sykes et Garn.-Jones	swamp maire, maire tawake	Occurs in lowland swampy and boggy forests from sea level to 450 m throughout the North Island, and northern tip of the South Island (Rarangi, near Blenheim).	Yes	Non-threatened