BIOSECURITY NEW ZEALAND

Import Risk Analysis: Fresh *Citrus* Fruit (7 species) from Samoa

FINAL

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Ministry of Agriculture and Forestry
Te Manatū Ahuwhenua, Ngāherehere

Cover image: Tahiti lime fruit (*C. aurantiifolia*), Samoa July 2007.
Photographer: DJE Anthony

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Policy and Risk
Biosecurity New Zealand

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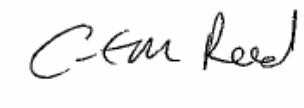

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Glossary of definitions and abbreviations

AFFA	Australian Government Department of Agriculture Fisheries and Forestry
AQIS	Australian Quarantine and Inspection Service
APHIS	Animal and Plant Health Inspection Service (a department within USDA)
BORIC	Biosecurity Organisms Register for Imported Commodities
CPC	Crop Protection Compendium. Internet Database
Diapause	a physiological state of arrested development that enables an organism to survive more easily a period of unfavourable conditions
ED	abbreviated from the term "effectiveness of the treatment (dose)" and is the effect of a measure on mortality within a target population, expressed as xx.xxxx% at a 95% level of confidence.
Endemic	an animal, plant, pest, or disease that is native to and is not naturally found outside a defined geographical area
Establishment	perpetuation, for the foreseeable future, of an organism or disease within an area after entry.
Exposure	the process of the hazard organism moving from the commodity it arrived on to another host
Exotic	this word has different meanings in different fields, but in this document is defined as an animal, plant, pest or disease that is not indigenous to New Zealand.
Exuviae	cast skins, shells, or coverings of animals; any parts of animals which are shed or cast off, whether recent or fossil.
Hitch-hiker organism	an organism that has an opportunistic association with a commodity or item with which it has no biological host relationship.
Indigenous	native; organism originating or occurring naturally in a specified area.
Introduced	not indigenous, not native to the area in which it now occurs, having been brought into this area directly or indirectly by human activity.
IHS	Import Health Standard
IRA	Import risk analysis
MAF	Ministry of Agriculture and Forestry, New Zealand

MAFBNZ	MAF Biosecurity New Zealand
MAFFM Samoa	Ministry of Agriculture, Forestry, Fisheries and Meteorology, Samoa.
QuanCargo	database of commercial consignments and interceptions of pests made by quarantine inspection.
PPIN	Plant Pest Information Network database, MAF.
Regulated Pest	a pest of potential economic importance to New Zealand and not yet present here, or present but either not widely distributed and being officially controlled, having the potential to vector another organism, or a regulated non-quarantine pest.
Risk	in the context of this document risk is defined as the likelihood of the occurrence and the likely magnitude of the consequences of an adverse event.
USDA	United States Department of Agriculture.
Viable	capable of living; able to maintain a separate existence (on its own accord).
Vector	an organism or object that transfers a pest, parasite, pathogen or disease from one area or host to another.

1. Executive summary

The Government of Samoa has requested access for the export of fresh *Citrus* fruit to New Zealand. There is currently no import health standard (IHS) issued for the import of fresh *Citrus* fruit from Samoa into New Zealand. This import risk analysis examines the biosecurity risks associated with the importation of fresh *Citrus* fruit from Samoa.

A draft risk analysis was released for public consultation on 8 August 2008. MAFBNZ received three submissions from stakeholders and these were analysed in a review of submissions that was also published on 23 October 2008. One change was made to Chapter 15 as a result of a submission. The ant *Solenopsis geminata* was removed from the risk analysis, leaving the assessments on *Paratrechina longicornis* and *Anoplolepis gracilipes*. The conclusion was unchanged. Minor changes of wording were made to this document, but the conclusions of this document are unchanged.

Fruit will be sourced from registered farms where farmers follow advised measures for the production of exported fruits (MAFFM Samoa 2007). There is a specific focus on control of the fruit flies *Bactrocera kirki* and *B. xanthodes.*

Organisms and diseases are grouped according to their taxonomy and biology and members of the same group are considered within one pest risk assessment, unless there is sufficient difference to warrant a separate assessment. The groups include tephritid fruit flies (Diptera), moths (Lepidoptera), thrips (Thysanoptera), mites (Acari), whitefly, mealybugs, scales and bugs (Hemiptera), ants (Hymenoptera) and fungi.

Ninety-one organisms and pathogens were identified as associated with *Citrus* fruit from Samoa. Of these, 42 species were considered to be potential hazards, for which risk assessments were carried out. These species were assessed on the likelihood of entry, exposure and establishment within New Zealand and their potential impact on the economy, the environment and human health.

Thirty-eight species were eventually assessed to be hazards associated with *Citrus* fruit from Samoa for which risk management measures are justified including: fruit flies, a moth, thrips, a mite, whiteflies, mealybugs, scale insects, a bug, ants and fungi (see Table 1).

This risk analysis concluded that there was no stand-alone treatment that could be applied to all 7 species and varieties of *Citrus* fruit, nor a stand-alone treatment that could be applied to all the hazard species. Therefore a range of treatment options were considered.

Considerations in determining risk management measures include:

- more than one measure is likely to be required because measures effective against external organisms are not so effective against organisms inside the fruit;
- the various tolerances of *Citrus* fruit to chilling and heating;
- the efficacy of each measure against the range of hazards.

Possible risk management measures are discussed in Chapter 5 and a range of options for reducing the risk are presented for each hazard in the following chapters.

There is uncertainty around the efficacy of some measures therefore it is likely this may result in residual unmanaged risk.

Table 1 Organisms identified as hazards in this risk assessment

Group	Hazard Organism
Tephritid fruit fly (Diptera)	*Bactrocera kirki*
	Bactrocera xanthodes
Moth (Lepidoptera)	*Pray citri*
Thrips (Thysanoptera)	*Thrips palmi*
	Thrips hawaiiensis
Mite (Acari)	*Tetranychus neocaledonicus*
Whitefly (Hemiptera)	*Aleurodicus dispersus*
	Parabemisia myricae
	Paraleyrodes bondari
Mealybugs (Hemiptera)	*Ferrisia virgata*
	Planococcus citri
	Planococcus minor
	Pseudococcus cryptus
	Dysmicoccus brevipes
	Dysmicoccus neobrevipes
Scale insects (Hemiptera)	*Aonidiella inornata*
	Aspidotus destructor
	Chrysomphalus aonidum
	Chrysomphalus dictyospermi
	Coccus viridis
	Howardia biclavis
	Ischnaspis longirostris
	Lepidosaphes gloverii
	Parlatoria cinerea
	Parlatoria pergandii
	Pinnaspis strachani
	Pseudaulacaspis pentagona
	Unaspis citri
Bug (Hemiptera)	*Leptoglossus gonagra*
Ants (Hymenoptera)	*Anoplolepis gracilipes*
	Paratrechina longicornis
	Solenopsis geminata
Fungi	*Capnodium citri*
	Meliola citricola
	Phaeosaccardinula javanica
	Corticium koleroga
	Elsinoë australis
	Phytophthora palmivora

The following table (Table 2) gives a very brief summary of the treatment options against the hazard groups and which *Citrus* fruit might tolerate the treatment. It should be noted that this table does not reflect the degree of efficacy or residual risk associated with a treatment. This information (where available) is in the chapter relevant to each hazard group.

Table 2 Summary of treatment options against hazard groups for *Citrus* fruit

Treatment / Hazard group	In-field sanitation	Post-harvest cull, wash, wax, visual inspection	High temperature forced air	Cold disinfestation	Hot water immersion	Visual Inspection at border	Sprays
Fruit fly	All citrus *	All citrus *	Grapefruit Pomelo ?Orange ?Tangerine †	Orange Mandarin Tangelo ?Lemon †		All citrus *	
Moth	All citrus *	All citrus *	Grapefruit Pomelo ?Orange ?Tangerine †	Orange Mandarin Tangelo ?Lemon †		All citrus *	
Thrips	All citrus *	All citrus *	Grapefruit Pomelo ?Orange ?Tangerine †		Lime †	All citrus *	
Mite	All citrus*	All citrus*	Grapefruit Pomelo Orange? Tangerine? †		Lime †	All citrus *	
Whitefly	All citrus *	All citrus *	Grapefruit Pomelo ?Orange ?Tangerine †	Orange Mandarin Tangelo ?Lemon †	Lime	All citrus *	
Mealybug	All citrus *	All citrus *	Grapefruit Pomelo ?Orange ?Tangerine †		Lime †	All citrus *	
Scale	All citrus *	All citrus *	Grapefruit Pomelo ?Orange ?Tangerine †		Lime *	All citrus *	
Bug	All citrus *	All citrus *	Grapefruit Pomelo ?Orange ?Tangerine †	Orange Mandarin Tangelo ?Lemon	Lime *	All citrus *	
Ants	All citrus *	All citrus *	Grapefruit Pomelo ?Orange ?Tangerine †	Orange Mandarin Tangelo ?Lemon *	Lime †	All citrus *	
Fungi	All citrus *	All citrus *			Lime *	All citrus *	All citrus †

Key

† Treatment effective against hazard species
* Treatment only partially effective, it is likely other measures will be required
? May damage fruit

2. Risk analysis background and process

2.1. Background

Samoa has requested access for the export of fresh citrus fruit to New Zealand. The import of this new commodity has the potential to introduce exotic pests and diseases to New Zealand. An analysis of the biosecurity risks is therefore required.

2.2. Scope of the risk analysis

The scope of this risk analysis is the potential hazard organisms associated with fresh fruit of *Citrus* species imported from Samoa. For the purposes of this analysis "fresh fruit" means the fruit complete with skin, flesh and seed, without attached stems or leaves. The calyx is exempt from this definition as removing this part would often cause the fruit quality to be impaired.

2.3. Risk analysis process and methodology

The following briefly describes the Biosecurity New Zealand process and methodology for undertaking import risk analyses. For a more detailed description please refer to the Biosecurity New Zealand Risk Analysis Procedures (Biosecurity New Zealand 2006). Figure 1 (pg 6) presents a flow diagram of the risk analysis process.

2.3.1. Commodity and pathway description

The first step in the risk analysis process is to describe the commodity and entry pathway of the commodity. This includes relevant information on:

- the country of origin, including characteristics like climate, relevant agricultural practices, phytosanitary system;
- pre-export processing and transport systems;
- export and transit conditions, including packaging, mode and method of shipping;
- nature and method of transport and storage on arrival in New Zealand;
- characteristics of New Zealand's climate, and relevant agricultural practices.

This information provides context for the assessment of the potential hazard organisms.

2.3.2. Hazard identification

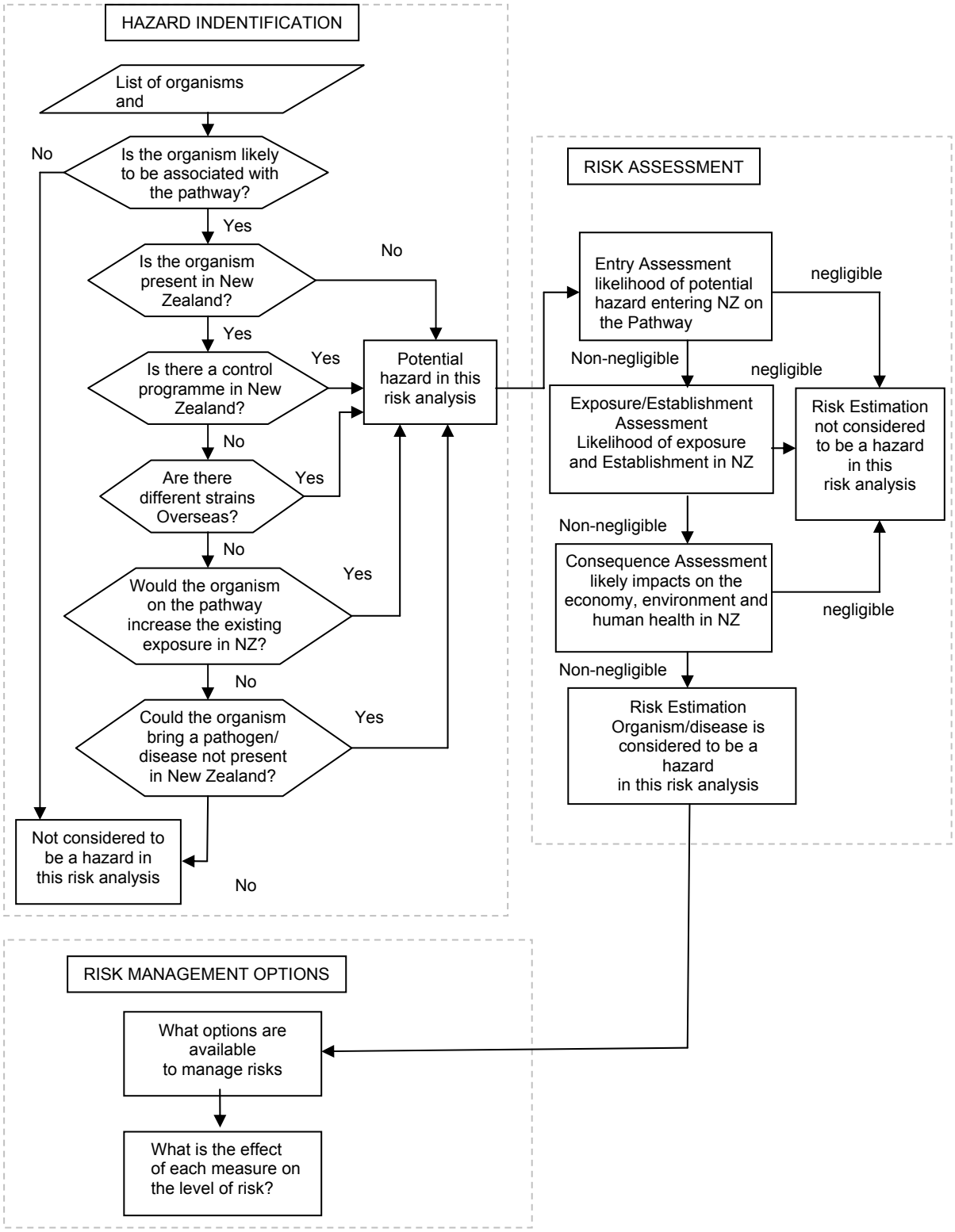
Hazard identification is the essential step conducted prior to a risk assessment. Unwanted organisms or diseases which could be introduced by risk goods into New Zealand, and are potentially capable of causing harm, must be identified. This process begins with the collation of a list of organisms that might be associated with the commodity in the country of origin. This list is further refined and species removed or added to the list depending on the strength of the association and the information available about its biology and life cycle. Each pest or pathogen is assessed mainly on its biological characteristics and its likely interaction with the New Zealand environment and climate. Hitch-hiker organisms sometimes associated with a commodity, but which do not feed on it or specifically depend on that commodity in some other way are also included in the analysis. This is because there may be economic, environmental and human health consequences of these organisms entering and/or establishing.

2.3.3. Risk assessment of potential hazards

Risk assessment is the evaluation of the likelihood of entry, exposure and establishment of a potential hazard, and the environmental, economic, human and animal health consequences of the entry within New Zealand. The aim of risk assessment is to identify hazards which present an unacceptable level of risk, for which risk management measures are required. Descriptors are used in assessing the likelihood of entry, exposure and establishment, and the economic, environmental, social and human health consequences. These are defined in the Risk Analysis Procedure manual (BNZ 2006).

The approach taken in this Risk Analysis is to assume the commodity is imported without any risk management. In this risk analysis hazards have been grouped where appropriate to avoid unnecessary duplication of effort in the assessment stage of the project.

Figure 1 Diagrammatic representation of the risk analysis process



2.3.4. Analysis of measures to mitigate biosecurity risks

Risk management in the context of risk analysis is the process of identifying measures to effectively manage the risks posed by the hazard(s) associated with the commodity or organisms under consideration.

Since zero-risk is not a reasonable option, the guiding principle for risk management should be to manage risk to achieve the required level of protection that can be justified and is feasible within the limits of available options and resources. Risk management identifies ways to react to a risk, evaluating the efficacy of these actions, and presenting the most appropriate options.

The uncertainty noted in the assessments of economic consequences and probability of introduction should also be considered and included in the consideration of risk management options. Where there is significant uncertainty, a precautionary approach may be adopted. However, the measures selected must nevertheless be based on a risk assessment that takes account of the available scientific information. In these circumstances the measures should be reviewed as soon as additional information becomes available. It is not acceptable to simply conclude that, because there is significant uncertainty, measures will be selected on the basis of a precautionary approach. The rationale for selecting measures must be made apparent.

Each hazard or group of hazards will be dealt with separately using the following framework:

2.3.5. Risk evaluation

If the risk estimate determined in the risk assessment is non negligible, measures can be justified.

2.3.6. Option evaluation

Measures that are expected to be effective against the hazard species are considered. A package of risk management measures is likely to be required to address the risk from all identified hazards.

While there are currently three established pathways (Australia, New Caledonia, and USA) for fresh *Citrus* fruit coming into New Zealand, border interception for these pathways cannot be extrapolated to predict any possible level of slippage or efficacy of treatments. However border interceptions can be used as evidence of hazard organism association with the commodity. Each new pathway must be regarded as unique, given differing pre and post harvest practices and treatment measures. Different pest species are associated with each pathway and measures therefore must be tailored to the individual organisms.

2.3.7. Review and consultation

Peer review is a fundamental component of a risk analysis to ensure it is based on the most up-to-date and credible information available. Each analysis must be submitted to a peer review process involving appropriate staff within those government departments with applicable biosecurity responsibilities, plus recognised and relevant experts from New Zealand or overseas. The critique provided by the reviewers where appropriate, is incorporated into the analysis. If suggestions arising from the critique were not adopted the rationale must be fully explained and documented.

2.4. References

MAF Biosecurity (2007) Importation and Clearance of Fresh Fruit and Vegetables into New Zealand. MAFBiosecurity Standard 152.02 August 2007-10-05 http://www.biosecurity.govt.nz/files/imports/plants/standards/152-02.pdf

Biosecurity New Zealand (2006) Risk Analysis Procedures Version 1. 12 April 2006 Ministry of Agriculture and Forestry, Wellington

3. Commodity and pathway description

This chapter provides information on the commodity that is relevant to the analysis of biosecurity risks and common to all organisms or diseases potentially associated with the commodity. It also provides information on New Zealand's climate and geography to lend context for assessing the likelihood of establishment and spread of potential hazard organisms.

3.1. Commodity description

In this risk analysis fresh *Citrus* species from Samoa is defined as the harvested individual fresh fruits of:

- *C. latifolia* Tanaka (Tahiti lime);
- *C. grandis* Osbeck (pomelo);
- *C. x meyeri* (L) Burm.f. (Meyer lemon);
- *C.* x *paradisi* MacFad. (grapefruit);
- *C. reticulata* Blanco (mandarin/tangerine);
- *C. reticulata* x *C. paradisi* (tangelo); and
- *C. sinensis* (L.) Osbeck (orange).

with all vegetative parts removed and that have been cultivated, harvested, packed and transported to New Zealand.

3.1.1. Genus description

Citrus is a familiar term and genus of flowering shrubs in the Rutaceae family (Class: Magnoliopsida, Order: Sapindales). *Citrus* are large evergreen shrubs or small trees, between 5-15m tall, often with sharp spines on the stems (Timmer *et al.* 2000.)

Most *Citrus* cultivars are self-pollinated, some are parthenocarpic. Generally only tangerines and their hybrids require cross-pollination. *Citrus* have the unusual ability to form nucellar embryos (maternal clones) as well as zygotic embryos (by fertilisation) allowing horticulturists to clonally propagate from seed. Because *Citrus* can hybridise so easily and to avoid the long juvenile period most commercially grown cultivars are grafted onto hardy, disease resistant rootstock (Timmer *et al.* 2000; Smith *et al.* 1997; CPC 2007; Sunkist 2007).

Citrus is in cultivation either commercially or in home gardens roughly between 55˚N and 55˚S worldwide. Most perform best in fertile, well drained soil in a consistently sunny, humid environment, ideally subtropical climes. Typically they are not frost hardy although they can withstand short periods just below freezing. Climate affects the appearance and taste of the fruit. For instance in Mediterranean climates the peel is thicker, rougher and has a better colour; the acid content is higher and sugar content lower; and on tree storage better than in subtropical climates. Subtropical climates produce fruit with a higher sugar and juice content. All *Citrus* are non-climateric fruit therefore gradually ripen over 5-18 months depending on the variety and growing conditions and are slow to abscise from the tree. Lemons and limes bloom throughout the year in warm, wet climates, and oranges and grapefruit may bloom several times a year in tropical climates with no cool periods or well defined dry season (Timmer 2000).

The primary use of *Citrus* fruit is as food (Timmer *et al.* 2000; Smith *et al.* 1997; Reiger 2006; CPC 2007; Sunkist 2007).

3.1.2. Species description

***Citrus latifolia* Tanaka – Tahiti lime**

Common names: Tahitian lime; Persian lime (Morton 1987).

Limes are divided horticulturally into sweet or sour (acid) limes. *C. latifolia* is an acid lime and is thought to have originated from a hybridisation of *C. aurantiifolia* (Mexican lime) and *C. medica* (citron). The Tahiti lime tree grows between 4.5-6m, is moderately vigorous with nearly thornless, widespread drooping branches. The fruits are oval, obovate, oblong or short-elliptical, usually rounded at the base. The apex is rounded with a small nipple. The peel is a bright green ripening to a pale yellow, smooth and thin in texture. The pulp is greenish-yellow, in 10 segments, usually seedless, is tender and acidic. Fruits ripen and fall 5-6 months after flowering. The flowers have no viable pollen. The Tahitian lime is hardier than the Mexican lime which is very cold intolerant (Morton 1987).

***C. maxima* (Burman) Merr.- pomelo, pummelo**

Synonyms: *C. grandis* Osbeck, *C. aurantium* var. *grandis* L., *C. decumana* L. nom illeg. (Morton 1987).

Common names: pomelo, pummelo, shaddock, limau abong, limau betawi, limau bali, limau besar, limau jambua, limau bol (CPC 2007).

C. grandis is a low branching tree 5-15m high, young branches can be densely hairy. The flowers are large and fragrant. The fruits are subglobose to pyriform, 10-30cm in diameter and weighing as much as 10kg. The peel may be pale-yellow to greenish-yellow, with minute hairs and very small green glands. The pulp can be pink or red through to greenish-yellow or pale-yellow, and divides into 11-18 segments (Morton 1987).

***C. limon* (L.) Burm. f. – lemon**

Synonyms: *C. medica* var. *limon*. L.; *C. limon* Risso.

Common names: lemon, limone, manao farang, citron, limonero, lima, yang ning meng, khatta, remon, laymûn, citronier (CPC 2007).

NOTE: *C. limon* is not included in the scope of this risk analysis. A description is given here to outline the difference between *C. limon* and the Meyer lemon *C.* x *meyeri*, which is included in this risk analysis.

C. limon has a vigorous, upright and spreading habit, reaching a height of about 6m. The fruits are oval with a nipple like protuberance at the apex, 7-12 cm long. The peel is usually light to mid yellow, dotted with oil glands and aromatic. The pulp is pale yellow and has 8-10 segments.

Lemon trees tolerate very poor infertile soils, growing in a variety of soil types but require good drainage. They do not cope well with humid subtropical or tropical conditions due to susceptibility to fungal diseases but flourish in semi-arid to arid subtropical regions with mild winter temperatures. Cool coastal conditions enhance the continual blooming characteristics allowing several harvests in a year (Morton 1987).

Varieties: *C. x meyeri* "Meyer" – a hybrid, possibly lemon x mandarin orange from China. The fruit is obovate, elliptical or oblong, round at the base, occasionally faintly necked and furrowed or lobed, apex rounded or with short nipple, of medium size, peel yellow to light-orange with numerous small oil glands, 3-6 mm thick, pulp pale orange-yellow, usually in 10 segments with tender walls, melting, juicy, moderately acid with medium lemon flavor; seeds small, 8 to 12. Meyer lemons tend to be everbearing but fruit mostly through winter. The tree is small, with few thorns, prolific, cold-resistant, and is only moderately subject to greasy spot and oil spotting. This variety has been fairly extensively planted in Texas, Queensland, Australia, and New Zealand (Morton 1987).

***C. x paradisi* MacFad. – grapefruit**

Synonyms: *C. decumana* var. *racemosa, C. grandis* var. *racemosa, C. paradisi* MacFad
Common names: grapefruit, toronja, pamplemousse, pompelmo, paradisapfel (CPC 2007).
Grapefruit trees grow to 10-15m tall, the foliage is quite dense and canopy rounded. The fruit is round to oblate and 10-15cm wide. The peel is smooth and pale yellow, aromatic, sometimes with a pink blush. The pulp can be nearly white to pale yellow, or pink to deep red, in 11-14 segments. The fruit grow in a cluster similar to grapes hence the common name. *C. x paradisi* thrives in a warm subtropical climate. The fruit take approximately 7-13 months to ripen, and high humidity will increase the thinness of the peel. Grapefruit will grow on a variety of soil types but require good drainage (Morton 1987).

***C. reticulata* Blanco – mandarin/tangerine**
Synonyms: *C. tangerine.*
Common names: mandarin, mandarin orange, tangerine, naranjo mandarina, mandarinier, santara, mikan (CPC 2007).
C. reticulata is native to the Philippines and Southeast Asia. It is predominantly grown in Japan, India, southern China, and the East Indies.
Very old mandarin trees may reach 7.5m. The fruit is oblate. When ripe the peel is bright orange and easily removed. The pulp is a rich orange colour. *C. reticulata* grow in well drained soil, are reasonably drought and cold tolerant, although fruit are sensitive to the latter. Most mandarins will bear fruit twice in the year (Morton 1987).

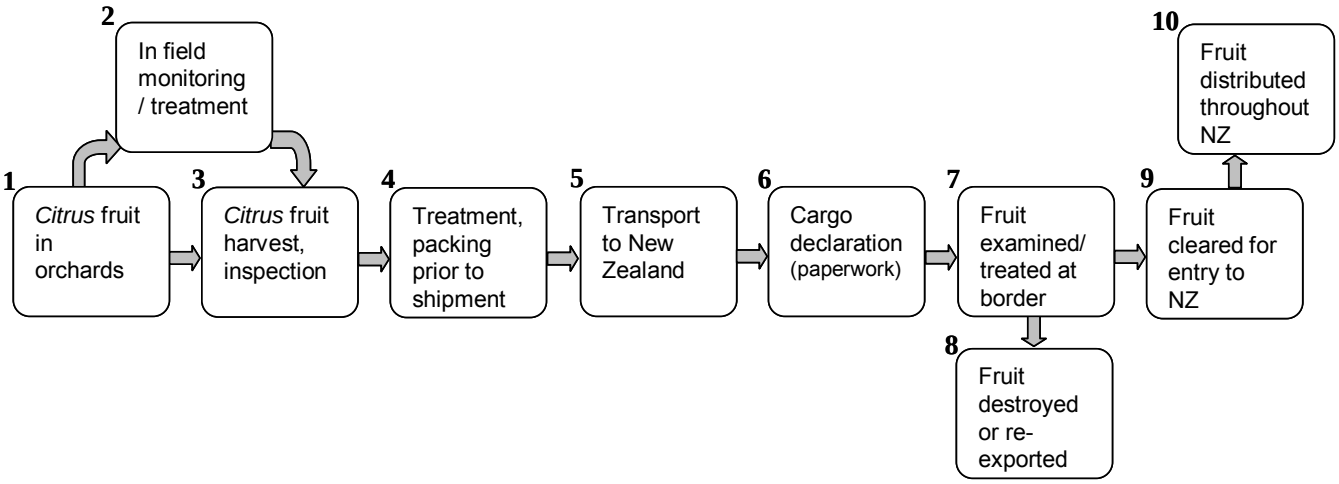
***C. paradisi x C. reticulata* – tangelo**
Synonyms: *C. reticulata* x *C. paradisi*, *C. tangelo* (*C.* x *tangelo*) Ingram and Moore.
Common names: tangelo (CPC 2007).
Tangelos are thought to have originated in Southwest Asia 3,500 years ago as a result of hybridisation between either grapefruit or pomelo and mandarin orange (tangerine). The trees are large and not as cold tolerant as the mandarin, but more so than grapefruit.
Most cultivars are self sterile so most are produced true from seed.
The fruit are about the size of an ordinary orange through to grapefruit size with a slight neck at the base. The peel is a rich orange, as is the flesh, which is very juicy (Morton 1987).

***C. sinensis* (L.) Osbeck – orange**
Synonyms: *C. aurantium* var. *sinensis* L., *C. macrantha* Hassk., *C. aurantium sinensis*.
Common names: navel orange, Valencia orange, sweet orange, orange, naranja, sanguine, oranger doux, laranjeira, Apfelsine, Orangebaum, arancio dolce, moli ‘aina, narang.
C. sinensis is considered to have originated in northeastern India and the area bordering China and Vietnam. Orange trees reach 6-15m in height, with a rounded crown. The fruit mature 6-9 months after bloom. They are subglobose, 4-12cm diameter with a greenish-yellow to bright orange glandular peel. Pulp is yellow to orange in colour and forms 10-14 segments.
Sweet oranges prefer subtropical rather than tropical climates and well drained soils, with a defined change in seasons to encourage flowering (Morton 1987).

3.1.3. Description of proposed import pathway

For the purpose of this risk analysis *Citrus* fruit are presumed to be from anywhere in Samoa. Fruit would be sea or air freighted to New Zealand, and after Biosecurity clearance would then be distributed to fruit and vegetable markets, supermarkets and shops for sale and consumption.

Figure 2 The proposed import pathway for fresh *Citrus* fruit from Samoa into New Zealand



3.2. Background information on exporting country

3.2.1. Samoa- climate and geography

Samoa is situated in the South Pacific Ocean, at 13˚ 35' S and 172˚ 20' W. It comprises two main islands (Savai'i and Upolu), several smaller islands and numerous uninhabited islets. Samoa has a total landmass of 2,934 sq km and coastline of 403 km. The highest point is Maunga Silisili on Savai'i at 1,857m, and the lowest point is sealevel. The coastal plain is narrow and rises into a rugged, rocky, volcanic interior. About 24.3% of the land is in permanent crops (includes coconuts, bananas, taro, yams, coffee, and cocoa) (CIA World Factbook 2007).

The climate of Samoa is tropical, divided into two seasons defined primarily by rainfall and dominated by south-easterly trade winds and the South Pacific Convergence Zone. The hot and wet season is from November to April and the cool and dry season is from May to October. The net annual temperature variation is 1^{o}C (CIA World Factbook 2007; Samoa Meterology 2007).

Climate normals (average values calculated over a 30yr period) between 1971 and 2000 show a total rainfall per annum of 2965.1mm (mean =247.1mm), total sunshine of 2230.2 hrs pa (mean = 185.9), mean temperature pa of 26.8^{o}C and mean % relative humidity of 80 (Samoa Meterology 2007).

3.2.2. *Citrus* phenology, production and pest control in Samoa

The following information on *Citrus* phenology and production in Samoa has been provided by Ministry of Agriculture, Forestry, Fisheries and Meterology Samoa (MAFFM Samoa 2007).

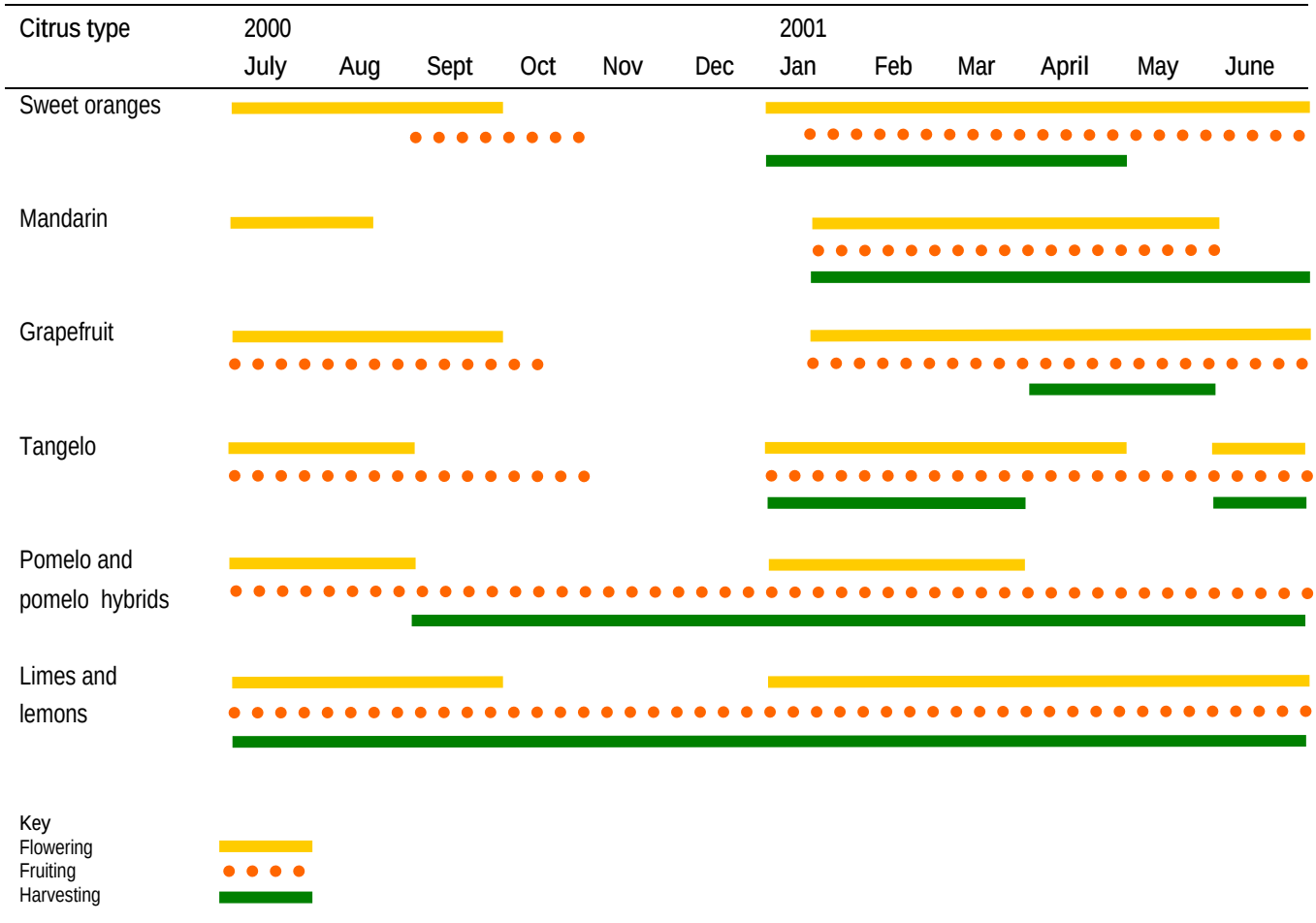
Citrus fruits are currently cultivated and grown in Samoa on a casual basis around villages and as scattered trees in plantations. Varieties that are grown include:

Valencia orange (late cultivars)(*C. sinensis*)
Mandarin (*C. reticulata*)
Ellendale mandarin (*C* x *reticulata*)
Meyer Lemon (*C. x Meyeri*)
Kaffir lime (*C. hystrix*)
Tahiti lime (*C. latifolia*)
Carrizo (Citrange)
Rough lemon (*C. jambhiri*)
Sour orange (*C. aurantium*)
Citron (*C. medica*)
Minneola tangelo (*C. paradisi* x *C. reticulata*)
Rarotongan Seedless (Cultivars)
Orlando tangelo (*C.* x *tangelo*)
Pomelo (*C. maxima*)
Lime (*C. aurantifolia*)
Grapefruit (*C. x paradisi*)
Troyer (Citrange)
Sweet orange (*C. sinensis*)
Rangpur lime (*C.* x *limonia*)
wild orange (*C. macroptera*)
Calamondin (*C. mitis*)

3.2.2.1 Phenology

The following table (Table 3) presents the flowering, fruiting and harvesting periods for the seven species of *Citrus* fruit Samoa wishes to export. Oranges, grapefruit, lemons and limes flower for about 9 months of the year, (January to end of September). Pomelo, mandarin and tangelos flower for 5-7 months of the year. Fruit of lemons and limes are found all year round on the trees and can be harvested at any time of year. For all the species there will be fruits and flowers on the trees at the same time over most of the summer, which is the intended harvest period.

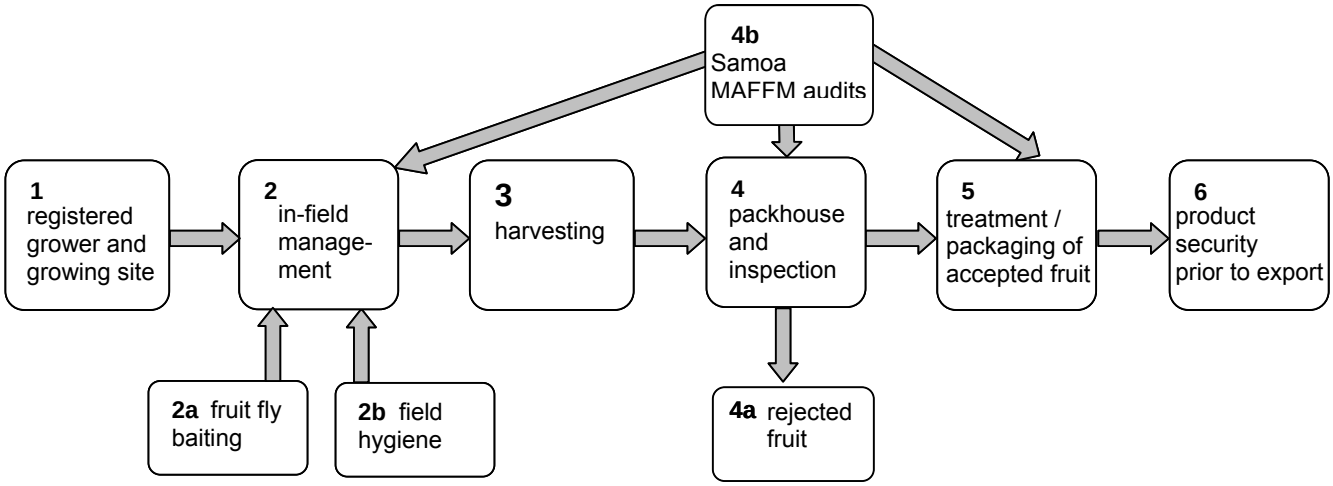
Table 3 The flowering and fruiting patterns of *Citrus* species and the time they are harvested as observed at Atele Research Station, Nuu Crop Division, Samoa during 2000-2001



3.2.2.2 Production

The following diagram represents the production and harvesting process and how the fruit will be treated prior to export.

Figure 3 Production, harvest, inspection and treatment of *Citrus* fruit in Samoa (based on information provided by MAFFM Samoa 2007)



1. Growers who intend to produce *Citrus* fruit for export to New Zealand will sign a declaration which is held by a MAFFM licensed packing house. These declarations are available for inspection by Quarantine Samoa and /or MAFBNZ at any time. The declaration form includes:
   - a map of the farm;
   - number of *Citrus* trees;
   - field control measures, number and names of fruit fly host plants in the area;
   - estimation of the quantity of fruit;
   - the number of harvests per year.

Citrus fruit will not be accepted for export to New Zealand from any grower(s) who have not lodged a declaration of intent.
MAFFM Samoa will register both the grower and the site where *Citrus* fruit is grown for export to New Zealand.

2. In-field management comprises fruit fly monitoring (for *Bactrocera kirki* and *Bactrocera xanthodes*) and field sanitation to minimise disease and pest potential

a) Growers will apply protein bait insecticide spray as recommended by MAFFM Samoa, and monitored by MAF (NZ). The grower will maintain records of all spraying for MAF (NZ) inspection purposes. These records include:
   - protein bait component used;
   - spray solution for each application (quantity);
   - date of each application;
   - total number of trees sprayed at each application including other fruit fly host plants;
   - date of first harvest;
   - date of last harvest.

b) *Citrus* fruit and other fruit fly host crops that are ripe or over-ripe and have fallen to the ground or been discarded during harvesting will be removed from the registered site and surrounding area. They will be disposed of by deep burying or burning.

3. The harvesting will be done by hand with fruit being twisted off the tree. Fruit on the ground will not collected because of the likely damage and increased fungal infection that can occur. *Citrus* fruit for export will be transported from orchard to pack house with minimal delay to reduce losses from fungal breakdown. Fruit will be graded to select unblemished, undamaged, export quality fruit.

4. Pack houses wishing to pack and export *Citrus* fruit to New Zealand will be approved and licensed by Quarantine Samoa and issued with a unique number.

   At the pack house a Quarantine Samoa officer will inspect 450 units from a pack house line of 1000 units or less in total, or 600 units from a line greater than 1000 units. The requirements to be met are no fruit flies or other quarantine pests. *Citrus* fruit that meet these requirements will then be identified and segregated for treatment. The quarantine officer will record the following information for all inspections:
   - inspection date;
   - name of exporter;
   - sample size;
   - pests found;
   - action taken (rejected or accepted for treatment and export);
   - quantity of *Citrus* for transfer to HTFA chamber.

Quarantine Samoa holds these records which are available for inspection by MAF NZ.

a) *Citrus* fruit not meeting the requirements are rejected and not exported to New Zealand.

b) MAFFM Samoa conducts audits as required, maintaining records of each audit including:
- date of the audit;
- the pack house number;
- what pack house requirements were checked;
- any non-conformances detected and corrective actions taken;
- date of next audit.

Any pack house not complying with the requirements of the procedures will be suspended from packing *Citrus* fruit for export to New Zealand, until MAFFM Samoa is satisfied these requirements can be met. Exporters found to breach the established export procedures can have their export licenses suspended or cancelled.
Audit records will be held by Quarantine-MAFFM Samoa's main office and will be available for inspection by MAF NZ.

If a pack house detects fruit fly-infested *Citrus* fruit during packing they will advise MAFFM Samoa of the grower(s) who supplied *Citrus* fruit for packing on the particular day. MAFFM Samoa will visit each grower to ensure appropriate phytosanitary measures are being maintained.

5. High Temperature Forced Air (HTFA) is the disinfestation method currently available in Samoa. The commodity for export will be raised from ambient temperature to 47.2˚C for 20 minutes then cooled. All cartons treated at one time constitute a batch and will be recorded as such. All cartons will be traceable to a unique batch.

6. MAFFM Samoa ensures the produce will be held in an insect-proof area at Air terminal Services, Cargo Area, Falelo Airport, or packed in insect-proof cartons or containers for export.

NOTE: This pre-export management programme is currently not implemented for *Citrus* fruit as *Citrus* fruit is not yet being exported from Samoa. There is no information on the extent to which it would reduce the likelihood of entry of hazards to New Zealand. Therefore this system has not been assessed as a risk mitigation measure for each individual hazard, but its likely effect is discussed in section 5.2 Production and harvest measures.

3.3. International transportation of commodity

3.3.1. Sea freight

Most large consignments of *Citrus* fruit from overseas are sea-freighted into New Zealand. Apia to Auckland by the Sofrana Shipping Line with one port visit *en route* usually takes about 7 days (Shipping Gazette, 17 Feb 2007).

3.3.2. Air freight

Limes from USA, Vanuatu and New Caledonia are flown into New Zealand, as these consignments are usually small (mostly under 1,500kg). Most *Citrus* fruit coming from Samoa is likely to be by air-freight as consignments are not expected to be in large volumes. Flights via Air New Zealand from Apia to Auckland are about 4 hours long (Air New Zealand 2007).

3.4. Movement and distribution of commodity in New Zealand

From the port of entry fruit is either taken to market to sell-on to distributors and retailers, or importers with fixed arrangements send the fruit straight to supermarkets or fruit and vegetable shops. It is also likely that the fruit is destined for small outdoor weekend markets.

There are several scenarios around the disposal of *Citrus* fruit waste material. Fruit that is found to be damaged at unpacking in a shop, market or supermarket is most likely to be put into a rubbish bin or skip. Some of these have closed tops and some are open (pers. obs. 2007). Fruit that is purchased by customers and found to be damaged may be discarded in a public rubbish bin, thrown on the roadside, into wasteland or reserve areas, disposed of in a domestic rubbish bin or onto an open compost pile or closed compost bin. It is unknown how much waste is put into household compost, and how much is sent to municipal waste disposal facilities either completely sealed in plastic bags or unsealed. There is no quantitative value available for this uncertainty.

3.5. Background information on importing country

3.5.1. Climate and geography

New Zealand is situated between 34˚ 00’ S, 166˚ 00’ E and 48˚ 00’ S, 179˚ 00’ E in Oceania. The maritime climate of New Zealand varies from warm subtropical in the far north to cool temperate in the far south, with severe alpine conditions in the mountainous areas. The South Island is divided by a chain of mountains that provide a barrier to westerly winds thus separating the island into two distinct climatic regions. The West Coast of the South Island is wettest, whereas the regions to the east, just over 100km away are driest (NIWA 2007).

Most parts of New Zealand get between 600 and 1600mm of rainfall annually, with a dry period during the summer months. Four individual locations on the West Coast of the South Island (Westport, Hokitika, Mt Cook, and Milford Sound) recorded a mean annual rainfall of between 2200 and 6800 mm from 1971-2000. Higher rainfall occurs in winter over the northern and central areas of New Zealand, whereas for most of the southern regions winter has the least rainfall (NIWA 2007).

Mean annual temperatures range from 10˚C in the south to 16˚C in the north. New Zealand's coldest month is usually July and the warmest is usually January or February. Mostly there is little variation between summer and winter temperatures, however inland and to the east of the ranges the variation can be up to 14˚C. For every 100m increase in altitude there is a temperature drop of 0.7˚C (NIWA 2007).

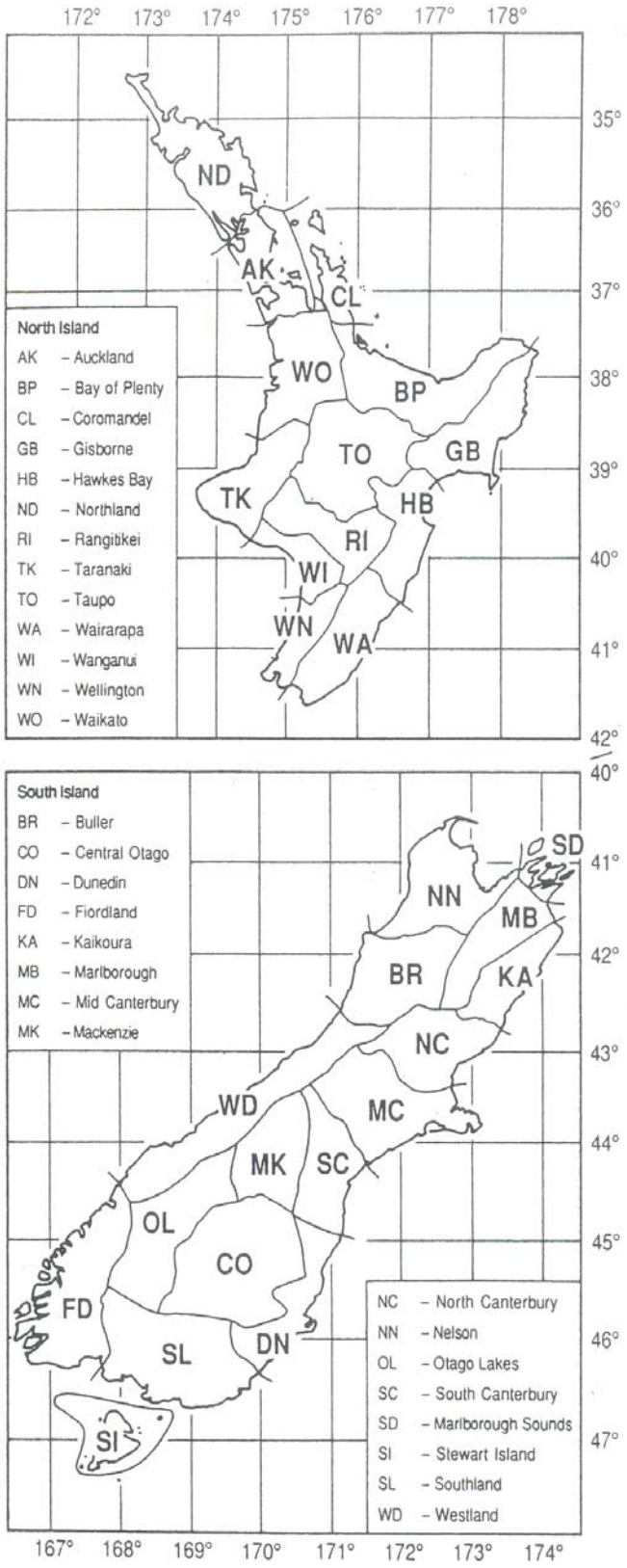
Most of New Zealand has on average at least 2000 sunshine hours annually, more in areas sheltered from the west. Tauranga for example experiences at least 2200 hours. In summer the midday solar radiation index (UVI) is often very high throughout New Zealand and can be extreme in Northland and mountain regions (NIWA 2007). South-westerly winds prevail for much of the year. Sea breezes often occur on warm summer days. Winter usually has more rain and is the more unsettled time of year. In summer and autumn storms of tropical origin may bring high winds and heavy rainfall from the east or northeast (NIWA 2007).

Snowfall is typically in the mountains. Very rarely does any coastal area of the North Island or west of the South Island have snow fall, although the east and south of South Island will occasionally experience snow in winter. Frosts usually form on cold nights with clear skies and little wind and can occur anywhere in New Zealand (NIWA 2007).

3.5.2. Map of New Zealand

The following map (Figure 4) is used here to give the reader an idea of the location of some of the regions and their corresponding latitudes and longitudes mentioned in this document. The Crosby Codes were not used in this risk analysis as full names are considered easier to read.

Figure 4 Map of New Zealand portraying Crosby Codes for New Zealand and presenting latitudes/longitudes (from Fauna of NZ Series).



3.5.3. Rutaceae and main *Citrus* growing areas in New Zealand

Citrus species are members of the Rutaceae family. There are 8 genera within Rutaceae in New Zealand. Of these 2 are endemic to New Zealand, 6 are introduced with 5 genera naturalised and 1 found in cultivation only (New Zealand Flora 2007). The two genera endemic to New Zealand are *Melicope* (*M. simplex* A. Cunn. 1839; *M. ternata* J. R. Forst and G. Forst; and *M. mantellii* Buchanan 1871) and *Leionema* (*L. nudum* (Hook.) Paul G. Wilson. Neither the *Leionema* nor *Melicope* species are considered threatened (New Zealand Flora 2007).

Citrus is widespread throughout New Zealand with households commonly having lemon trees in their gardens. If conditions allow, other species of *Citrus* can be found growing in home gardens. The main *Citrus* growing areas of New Zealand are Northland, Auckland, Bay of Plenty and the Gisborne region.

The northern part of New Zealand is the most climatically suitable for the establishment of new pests and pathogens coming from a sub-tropical/tropical country such as Samoa. The area includes Kaitaia, Kerikeri, Whangarei, Auckland (New Zealand's largest city), and Tauranga (see section 3.5.2 for map of regions). The latter two cities both contain large active sea ports. Kerikeri is a well known orcharding town with many varieties of *Citrus* fruit grown there. Avocado, kumara, macadamia and tamarillos are the other main crops grown there (HortResearch 2005). This is a sub-tropical zone, with warm humid summers and mild winters. Typical summer daytime maximum air temperatures range from 22˚C to 26˚C, but seldom exceed 30˚C. Winter daytime maximum air temperatures range from 12˚C to 17˚C (NIWA 2007).

The Auckland region produces *Citrus* species such as mandarins and lemons, also Asian vegetables, brassicas, chestnuts, greenhouse crops, lettuce, olives, onions, persimmons, pumpkin and silverbeet (HortResearch 2005). Auckland has the highest rate of naturalised plants of any city in New Zealand. The prime reasons for the high numbers of plant species are considered to be the moderate climate favouring species from many climatic zones, and availability of habitats (Esler 1988).

Auckland also has the largest population in the country, with the greatest influx of incoming goods and people and contains the largest sea and air ports. Therefore it is likely to be one of the first places potential hazards could establish.

The Bay of Plenty, besides growing *Citrus*, also grows avocado, asparagus, tamarillos and kiwifruit (HortResearch 2005).

The region surrounding Gisborne on the East Coast of the North Island, is the largest *Citrus* producing area in New Zealand. This area also produces squash and sweetcorn (HortResearch 2005). On average the annual temperature range is 2˚C lower than Northland, and the sunshine hours are marginally less (NIWA 2007).

Hawkes Bay, although producing little commercial *Citrus*, produces 61% of the pipfruit grown in New Zealand (Pipfruit New Zealand 2007). It is a significant wine grape growing area and also grows stonefruit, asparagus, olives, cucurbits, sweetcorn and tomatoes (HortResearch 2005). The climate is very similar to Gisborne.

Figures for 2005 show there were 1,702 hectares in commercial *Citrus* production. A recent survey in Gisborne showed the area planted in *Citrus* is about 6% higher than government figures. Estimated value of the domestic crop at the end of June 2004 was $16 million and the

crop for export was valued at $5 million at end of March 2006. The yield, for oranges and mandarins alone, at the end of March 2006 was 65 tonnes/hectare (MAF 2006).

In December 2006 the USA market opened up to New Zealand *Citrus* exports and is currently estimated at being worth $2 million per annum. It is predicted to expand rapidly to being worth $10 million annually to New Zealand in addition to current export markets (New Zealand Government 2006).

3.5.4. Fruit fly surveillance in New Zealand

New Zealand operates a fruit fly surveillance programme as part of a systems approach to border biosecurity. The programme has been in place since 1989 and is designed as an early warning system.

It also provides evidence of the absence of fruit fly to our trading partners. There are two parts to the system: passive surveillance, which involves using a variety of existing information sources such as agricultural and horticultural sources and active surveillance programmes such as the trapping system for fruit fly. If treatment of the fruit has failed pre-export, and visual inspection does not pick up individuals at the border then this surveillance system is designed to monitor populated areas, centres for trade, tourism, ports, areas with a climate suitable for fruit fly and areas of significant horticultural activity.

This latter system involves 7,385 traps nationwide in which three types of lures are used (Cuelure, Trimed lure and methyl eugenol lure). *Bactrocera xanthodes* responds to methyl eugenol and *Bactrocera kirki* to cue lures. All traps nationwide are checked at fortnightly intervals except those in the lower South Island during the winter. The final part of the system is the exotic disease and pest response programme. If a pest such as fruit fly is found in a surveillance trap, an eradication programme based on a pre-defined management strategy is implemented. In the case of fruit fly, specialist teams are immediately mobilised for mapping, fruit monitoring, intensive bait and lure trapping, baiting and fruit disposal. There is also immediate communication with our trading partners who then evaluate how serious they consider the event to be (MAF 2007).

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4. Hazard identification

4.1. Introduction

A list of organisms or diseases recorded to be associated with *Citrus* species in Samoa was generated from literature and database searches (Appendix 1). Organisms were classed as potential hazards if they were likely to be present on the import pathway and were not known to be present in New Zealand.

Forty-two potential hazards have been identified and risk assessments for them follow in Chapters 7-17. Appendix 2 lists the organisms assessed and discounted as potential hazards based on criteria listed in that appendix (eg: lack of association with commodity).

For organisms present in New Zealand and known to be vectors of other hazard organisms such as viruses, or organisms of different strains not present in New Zealand a full risk assessment is given.

Hitch-hiker pest species included (eg: Ants) are those where an association with the commodity prior to export was considered possible.

4.2. Potential hazard groups

Pests and pathogens have been grouped on the basis of taxonomy and biology. If organisms are hitch hikers or vectors this is noted in the individual pest risk assessment. The following potential hazard groups are used in Chapter 6:

Tephritid Fruit Flies (Diptera)
Moths (Lepidoptera)
Thrips (Thysanoptera)
Mites (Acari)
Whitefly (Hemiptera)
Mealybugs (Hemiptera)
Scale Insects (Hemiptera)
Bugs (Hemiptera)
Ants (Hymenoptera)
Fungi

4.2.1. Organisms intercepted at the border on *Citrus* fruit on existing pathways

In the year 2005-2006 New Zealand accepted *Citrus* imports from Australia, USA, Vanuatu, New Caledonia, Spain, Thailand, and Mexico. For that period the total volume of *Citrus* fruit entering New Zealand was just under 20,780 tonnes spread over a total of 1473 imports. Of these, 328 consignments had regulated pests found in them when inspected by New Zealand quarantine inspectors at the border. Table 4 summarises these results. The most common intercepted regulated organisms recorded were mites and mealybugs, with scale insects being the next most common. A proportion of these consignments had been treated prior to export and others were not.

Table 4 Interceptions of lab identified regulated pests in *Citrus* imports to New Zealand from Jan 2005- Jun 2006 (MAF 2007)

Commodity name	Total quantity in kilograms	Number of consignments	Number of consignments with regulated pests	% Interception per consignment
Grapefruit	505,507	101	9	8.9 %
Lemon	689,297	116	22	19 %
Lime	240,558	162	106	65.4 %
Mandarin	1,818,508	143	15	10.5 %
Orange	16,046,295	807	150	18.6 %
Pommelo	86,773	27	13	48.1 %
Tangelo	523,743	62	8	12.9 %
Tangerine	868,836	55	5	9.1 %
Total	20,779,517	1473	328	N/A

4.3. References

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5. Review of management options

5.1. Introduction

This chapter provides background information on possible measures to mitigate the biosecurity risk associated with importing *Citrus* from Samoa.

5.1.1. Disinfestation treatments

Disinfestation treatments are treatments that remove or kill hazard organisms that may be contaminating commodities. Some of the treatments discussed are usually considered "stand alone" disinfestation treatments but these can also be integrated into a systems approach. This depends on a number of variables, such as the commodity type, its tolerance for the treatment/s, the biology of associated hazard organisms and what is available to the exporting country. These disinfestation treatments are discussed individually in sections 5.5 to 5.9.

5.1.2. Systems approach

A "systems approach" is the implementation of multiple safeguard actions in the country of export that result in the commodity meeting the phytosanitary standards of the importing country (Shannon 1994). These actions have a scientifically derived basis and can be used at key points in the production-to-export system. Jang and Moffit (1994) describe in detail how a systems approach can achieve quarantine security through integrating biological, physical and operational factors to reduce the incidence, viability and reproductive potential of hazard organisms . These concepts have been recently incorporated into an international standard, (ISPM-14 2002) approved by the International Plant Protection Convention (IPPC).

In brief, a systems approach includes the following steps:

- consistent and effective management for reducing pest populations in the field and monitoring this management;
- preventation of contamination after harvest;
- culling in the packhouse of damaged and diseased fruit;
- inspection and certification of the critical parts of the system based on effective traceback procedures;
- shipping using methods that prevent reinfestation.

The knowledge on the pest-host biology and phenology is intrinsic in the use of a systems approach (Jang and Moffit 1994; Jang, 1996; Mb TOC 2006). Some components of the systems approach are discussed in this chapter. Disinfestation treatments can be combined into a system to mitigate risk.

5.2. Production and post-harvest measures

MAFFM Samoa has provided information about the production and post harvest procedures that *Citrus* farmers are expected to use (see section 3.2.2).

5.2.1. Monitoring programmes in production areas

Monitoring of in-orchard pest and pathogens is the key to optimizing production while reducing pest and/or disease-related problems, for instance:

- fruit flies – trapping to monitor population levels in and around orchards;

- surface pests - regular inspection of leaves, stems, fruit etc. to monitor invertebrate population levels eg: coloured sticky boards (white, blue or yellow are attractive to thrips) are commonly used to sample thrips populations (Capinera 2004; Culliney 1990);
- disease organisms – inspection for presentation of symptoms.

Knowledge of pest levels allows for timely and appropriate control measures to be implemented, thus adding to risk reduction.

5.2.2. In-field sanitation

In-field sanitation requires the removal of fallen fruits, debris, weeds and other undergrowth that can harbour disease or pests from around and between *Citrus* trees.

Any infected growth on *Citrus* trees should be pruned out and removed from the orchard for disposal. Regular inspection and pruning of trees facilitates the health and growth by removing dead and weak wood, reducing the incidence of various fungal diseases and allowing in more sunlight. Fallen fruits should also be removed for disposal to reduce inoculum sources for disease, and breeding sites of fruit fly (Smith *et al.* 1997). In China fruit fly infested fruit was handpicked, buried to a depth of one metre and insecticide sprayed on the soil surface. Fruit that had dropped and decayed on the ground were sprayed with insecticide to kill emerging larvae and pupae. This procedure reduced fruit fly infestations in the orchards (Yang 1991).

5.2.3. Pest control measures

Commercial orchard operations usually have spray programmes which operate in conjunction with monitoring. When pests or diseases reach a volume over a set percentage on the tree, the grower will use insecticide, fungicide or mineral oil sprays for control. Other forms of control that can be used are pheromone disruption for specific invertebrates such as certain moth species or scale insects, and the introduction of biocontrol agents such as entomophagic fungi or parasitising invertebrates.

Insecticidal and/or fungicidal dips can be used as part of the packhouse process. New treatments are always becoming available. For instance, Hollingworth (2005) has shown Limonene (an extract from *Citrus* peel) has promise as an in-field spray treatment or post harvest dip against mealybugs and scale as it can penetrate the insects waxy covering. The limiting factor is phytotoxicity to certain plants and as yet *Citrus* leaves and fruit have not been tested.

5.2.4. Washing and fruit coatings

The USDA-PPQ Treatment Manual (2007) states that water used for washing, treatments and cooling must be fortified with sodium hypochlorite (household bleach) and constantly maintained at a chlorine level not to exceed 200ppm.

The FAO (2004) advocates harvested fruit should be trimmed of any leaves or stem and well washed to remove any superficial dirt, plant debris, pests and pathogens. The water should be clean and contain the appropriate concentration of sanitizers to minimise the transmission of pathogens from water to fruit, from infected fruit to healthy fruit within a single batch and from one batch of fruit to another batch over time (FAO 2004).

Adding surfactants to water increases the washing efficacy. Surfactants break the surface tension allowing water to reach otherwise protected areas such as under the calyx. The waxy coating on grape mealybugs and woolly aphids were reduced when in contact with a particular organosilicone surfactant (Hansen *et al.* 2006).

Coatings such as an approved food grade wax applied to fruit can be used in addition with other measures to reduce the likelihood of entry of hazard organisms. Citrus Lustr 402 has been shown to kill *Anastrepha ludens* immatures in grapefruit, possibly by inhibiting gaseous exchange, but is not considered sufficient as a quarantine measure on its own (Hallman 1997). Hallman (1997) suggests coatings could be incorporated as a component of an integrated systems approach to quarantine security where a series of pest infestation reducing steps decrease the risk to insignificant levels.

Gould and McGuire (2000) tested 4 different coatings (2 petroleum based, 1 vegetable oil and a soap) on limes. The coatings were applied at a 3% (vol:vol) rate in 10L of water. The limes, in groups of 60 were immersed for 10 minutes, removed and rinsed with tap water for 10 minutes then held for 2-3 days. Mortality of nymphs and adult mealybugs was then assessed. Results varied between 30-65% mortality. However one petroleum oil, AMPOL (Caltex Australia, Sydney, New South Wales) provided 94% mortality, although the number of invertebrates tested is not stated. The very low number of dead and living invertebrates recovered from the treatments versus controls implied the oil repelled the invertebrates causing them to leave the fruit. As a quarantine measure the AMPOL coating does not provide 99.9968% mortality (probit 9), however, applied as a postharvest dip before shipment it is thought it would reduce the number of actionable pests (Gould and McGuire 2000).

An additional benefit of coating fruit is the decrease of moisture loss from the fruit during cool storage or during cold disinfestation treatment (Irtwange 2006). Wild (1993) observed a reduction in the susceptibility of grapefruit and oranges to chilling injury after a thorough application of wax.

Although efficacy data is not available it is noted that limes imported into the USA from Chile undergo a soapy water wash and wax treatment against *Brevipalpus chilensis* (Chilean false spider mite). The treatment schedule (T102-b-1) specifies a 20 seconds immersion in a soapy water bath of one part soap solution (such as Deterfruit) to 3,000 parts water. This is followed by a pressure shower rinse to remove excess soap. The fruit is then immersed for 20 seconds into an undiluted wax coating (such as Johnson's wax Primafresh 31 Kosher fruit coating). This coating must cover the entire fruit (USDA-PPQ 2007).

To conclude, water used for washing should be fortified with sodium hypochlorite to ensure that pathogen transfer is minimised. The use of surfactants increases the efficacy of the washing process, so will contribute to reducing risk. Wax coatings minimise risk further and provide some protection for the fruit from chilling or moisture loss.
To increase the effectiveness of washing, fruit should be submersed in the water, and brushed to remove any superficial invertebrates or dirt.
Washing and coatings are a component of a systems approach towards risk mitigation of hazard organisms.

5.2.5. Visual inspection and culling of imperfect fruit

Visual inspection can happen along the whole production and post harvest pathway. In-field monitoring and selection by certain criteria at harvest are considered good orchard practise. If the washing process is conducted by hand this also allows for visual inspection to ensure the

fruit meet export standard. The grading process enables a final check and selection. Each batch of fruit is then subject to quarantine inspection in the country of export.

Visual inspection is useful for identifying imperfections and abnormalities in the commodity that may indicate the presence and/or effect of hazard organisms

Further discussion of visual inspection as a measure is presented in section 5.3

5.2.6. Conclusion

The production and postharvest measures, in combination with other procedures listed in section 3.2.2 constitute elements of a systems approach, and can be combined with an approved treatment such as High Temperature Forced Air or Cold Disinfestation.

Whilst information is not available to determine the degree by which production and post harvest measures would reduce the likelihood of entry of hazards associated with *Citrus* fruit, it is assumed they will reduce risk over time and can therefore be considered as a supplement to other risk management measures.

5.3. Visual inspection

Visual inspection by a trained inspector can be used in three main ways for managing biosecurity risks on goods being imported into New Zealand, as:

- a biosecurity measure, where the attributes of the goods and hazard organism provide sufficient confidence that an inspection will be able to achieve the required level of detection efficacy;
- an audit, where the attributes of the goods, hazard organisms and function being audited provide sufficient confidence that an inspection will confirm that risk management has achieved the required level of efficacy;
- a biosecurity measure in a systems approach, where the other biosecurity measures are not able to provide sufficient efficacy alone or have significant levels of associated uncertainty.

In the case of inspection for audits, this is considered a function of assurance and is part of the implementation of the identified measures. Inspection as a biosecurity measure uses the direct comparison of required efficacy to manage risk versus actual efficacy of an inspection (maximum pest limit versus expected measure efficacy).
However in practise it is not possible to precisely define either efficacy or pest limits.

The following chapters consider the ability of visual inspection to detect the individual hazards both prior to export and upon arrival in New Zealand.

Inspection as a biosecurity measure in a systems approach is anticipated as being part of the production and post harvest management system as mentioned in section 5.2 above.
It could act either directly, as a top-up to the efficacy achieved by other measures in the system, or indirectly as a check to ensure an earlier measure was completed appropriately. In the latter case an appropriate inspection for the target organism may not be practical (the sample size may be too large) and an indirect sign of less-than-adequate efficacy may be used. Examples of indirect indications of failed treatments include:

- surviving non-target organisms that are more easily detected;
- symptoms of infestation such as frass.

5.4. High-Temperature Forced-Air (HTFA) treatment

Samoa has a HTFA chamber available and this is described in section 5.5.3

5.4.1. Introduction

Heat treatments for quarantine pests have been used on a variety of fresh agricultural and horticultural commodities for more than 70 years (Hallman, 2000). HTFA has primarily been used to kill eggs and larvae of certain fruit fly species found in the centres of fresh fruit prepared for export. It has subsequently been used for other invertebrate quarantine pests. These methods lost favour when fumigants such as ethylene dibromide (EDB) and methyl bromide (MB) became more convenient. EDB use was discontinued in the mid 1980s because of concerns with carcinogenicity and MB is being phased out having been identified as causing significant ozone depletion (Mangan and Hallman, 1998). This has necessitated the return of heat treatments and instigated further research into other alternatives.

5.4.2. Mode of action

HTFA treatment uses forced hot air across the surface of the fruit to raise the core temperature to a specified level for a set duration. Heat transfer is by convection with relative humidity sometimes as low as 30% to avoid desiccation of the commodity. Ideally the dew point should be 2-3˚C below the fruit surface temperature to maintain appropriate humidity (Sharp 1994). Unlike vapour heat treatment (defined by USDA-APHIS as 100% RH) no condensation should form on the produce surface during treatment. Dry heat treatment is different again and should not be confused with HTFA as it has no added humidity and is usually operating at 80-100˚C (Hallman and Armstrong, 1994).

There is a ramping up time (sometimes of several hours) for the chamber temperature to reach the target temperature. The length of this time differs for a few reasons such as the size and number of fruit within the chamber, variation between chambers and different target temperatures.

5.4.3. Description of the HTFA chamber in Samoa (Atele packing house)

Air circulation in the HTFA chamber is unidirectional from the bottom of the stacks through the fruit to the top and is heated by hot water (50-60˚C) pumped through a heat exchanger. Sensors regularly monitor and adjust relative humidity. If additional moisture is required clean water enters the system by two small misting nozzles and vapourises into the circulating air. The chamber ceiling is insulated to avoid condensate forming and dripping onto fruit. Condensate forming on walls leaves via floor drains that have a fitted water trap to prevent fruit fly access (Williamson 2002). Once treatment is complete the fruit in the chamber is hydro-cooled. Clean, filtered water is sprayed through jets fitted just above the top shelf of fruit. Probe sensors monitor the internal temperature of the commodity which provides the base data for the treatment determined by the computer. The computer runs specifically designed software for data acquisition, analysis and system control (Williamson 2002).

5.4.4. Treatment efficacy experiments

In some of the efficacy experiments mentioned below, the entire time for treatment is given, and in others the researchers refer only to the time it takes to kill the target pest, eg: this may be 20 minutes at the target temperature out of the several hours it takes to reach the target temperature. This causes some difficulty in comparing results. Other fruit species (eg: papaya, Armstrong 1989) and plant material are considered here because either they are part of the

founding research for testing *Citrus* fruit with HTFA or they provide data for certain pests and pathogens (eg: moths, mites, thrips, fungi) also associated with *Citrus*.

Time/temperature treatments that are lethal to some target pests in specific fruits without compromising the quality and appearance of these fruits have been established (table 4). *Citrus* fruits can vary widely in their heat tolerance, even within the same variety. For instance; early, mid and late season grapefruit were treated with hot air at 46, 48 and 50˚C for 3, 5 or 7 hours, showing early and late season grapefruit were more easily damaged than midseason fruit (McGuire and Reader, 1992; in Yahia, 2006). 'Oroblanco' fruit suffers extensive damage at 47˚C and some minor damage at 44˚C which may be alleviated by rapid cooling (Lurie *et al.* 2004). Valencia oranges can be heated at 44˚C for 100min or 46˚C for 60 min with no damage. Thus each treatment schedule should be specifically tested on the fruit that needs disinfesting to ensure that it will effectively meet quarantine requirement and not cause damage to the product.

5.4.5. Efficacy against fruit fly in *Citrus*

Marsh grapefruit have been treated with HTFA at 48 ± 0.3˚C for ≥ 150 minutes, until the centre pulp reached ≥ 44˚C and killed Caribbean fruit fly *Anastrepha suspensa* (Loew) eggs (not quantified) and 11,991 larvae. Hydrocooling of the fruit did not reduce the effectiveness of the heat treatment (Sharp and Gould 1994). Sharp and McGuire (1996) attained 100% mortality of 113, 676 mature third stage instars of *Anastrepha suspensa* when Florida grown Golden Navel oranges were heated with 48 ± 0.3˚C forced air until the centre pulp temperatures were ≥ 44˚C.

"Dancy" tangerines at an air temperature of 45˚C took a mean of 115 minutes to reach the same temperature at the fruit centre, "Valencia" oranges and "Rio Star" grapefruit at 46˚C required a mean of 145 and 220 minutes respectively to reach 45˚C at the fruit centre. Mangan *et al*. (1998) estimated that holding the fruit centre temperature at 45˚C for100 minutes would enable > 99.9968% mortality of Mexican fruit fly *Anastrepha ludens* (Loew).

For control of Mediterranean fruit fly *Ceratitis capitata* unwaxed Oroblanco fruit (triploid pummelo-grapefruit hybrid) can be heated to 44˚C for 60 minutes with minor heat damage to the peel but no other quality loss. This killed the first instars, considered the most heat resistant form of *C. capitata* from mortality tests the researchers carried out. If conducted in 0.05% oxygen the temperature could be reduced to 43˚C, with a treatment time of 30 minutes and still be effective (Lurie *et al.* 2004), thus reducing the effect on the peel. This study was done in a CATTS (Controlled Atmosphere Temperature Treatment System) chamber and the researchers do not specify whether their final statement was based on atmosphere comparable with a standard HTFA chamber.

5.4.6. Efficacy against fruit fly in papaya

Probit 9 is the probability of one individual surviving treatment from an estimated treated population of 30,000 at the 95% ConfidenceLevel (Baker 1939). Armstrong *et al.* (1989) tested eggs, first and third instar lifestages of Mediterranean fruit fly *Ceratitis capitata*, melon fly *Bactrocera cucurbitae* and oriental fruit fly *Bactrocera dorsalis* in papaya under HTFA treatment. When the core temperature of the fruit reached 47.2˚C there was one survivor each of *Ceratitis capitata*, *Bactrocera cucurbitae* and *Bactrocera dorsalis* from estimated treated populations of 328,071; 329,984 and 322,918 individuals respectively. This exceeded the probit 9 standard. This study used 4 air temperature stages to reach the target temperature of 47.2˚C. Armstrong (1990) repeated the study using 50,000 eggs and 50,000 first instar larvae

of *C. capitata* and *B. dorsalis* at one air temperature stage (to reach 47.2˚C) reducing the overall time and achieving 100% mortality. He also determined that pomelo, mango and atemoya tolerated the target temperature with no indication of external or internal damage.

Waddell *et al*. (1993, 1996) developed a treatment schedule for *Bactrocera melanotus* and *Bactrocera xanthodes* in papaya from the Cook Islands. *B. xanthodes* is associated with *Citrus* in Samoa. In their verification trial for the commercial unit at Rarotonga Airport they used *B. melanotus* eggs, the most heat resistant fruit fly species and life stage, to artificially infest papaya. Complete mortality of 17,750 eggs held at 47.2˚C (fruit centre temperature) for 20 minutes was achieved. This method was considered effective for disinfesting Cook Islands papaya of any potential *B. melanotus* and *B. xanthodes* fruit flies. As a result, since 1994 the Cook Islands have been exporting HTFA-treated papaya to New Zealand.

5.4.7. Other pest species and commodities

Other species that have been killed by hot air treatment are light brown apple moth *Epiphyas postvittana*, longtailed mealybug *Pseudococcus longispinus*, greenhouse thrips *Heliothrips haemorrhoidalis* and *Thrips obscuratus* (Sharp 1994). Air temperatures between 48-50˚C for about 4 hours (including a 2 hour warming up period) were required to kill 99% of fifth instar light brown apple moth and longtailed mealybug found on persimmons (Dentener *et al*.1996). However Dentener *et al*.(1996) do not state how many of the invertebrates died, and put the persimmons into 'coolstorage' for three days at 20˚C before the mortality assessment so it is not clear how many deaths are directly attributable to the hot air treatment.

Trials have been conducted on acarids to assess quarantine control. Mixed life stages of the mite *Rhizoglyphus robini* on freesia corms suffered 100% mortality at 45˚C for 24 hours hot air treatment (Muller 1980: in Jamieson *et al.* 2005). One thousand five hundred and thirty *Orthotydeus californicus* adults underwent hot air treatment at 40˚C for 89 minutes achieving 99% mortality (Waddell *et al.* 1993 in: Jamieson *et al.* 2005). Waddell *et al.* (1993) estimated it would take 10 hrs at 45˚C to achieve mortality of two-spotted mites in hot air, recognising that these mites seemed quite heat tolerant and this may well be a factor of their long preheat warm up exposure.

HTFA at 46˚C for 5 hours delayed the development of green mould *Penicilium digitatum* on grapefruit (Shellie and Skaria 1998). However, there is no evidence of HTFA being a suitable tool for disinfestation of fungi from produce.

5.4.8. Factors affecting treatment efficacy

Both static and ramped pre-treatments can heat-condition the quarantine pest (Waddell *et al.* 1997) thereby having a significant effect on the efficacy of the heat treatment.
The temperature experienced by insects inside fruit is effectively that of ramped heating The location of the pest within the fruit, the thermal conductivity of the fruit, the heat transfer coefficient at the fruit-medium interface and the medium (air or water) temperature (Alderson *et al.* 1998), all affect the potential for thermotolerance and the time taken to mortality. This is demonstrated by Mangan *et al.* (1998) who comment on a preliminary test for HTFA treatment of grapefruit (Mangan and Ingle 1994) for disinfestation of Mexican fruit fly, saying the stepped treatment they used was unsuitable for small fruit such as oranges and tangerines as the fruit centre reached 48˚C too quickly resulting in survivors.

5.4.9. Effects of HTFA treatment on *Citrus* fruit

Most of the data available for *Citrus* fruit that has been treated with HTFA has come from research targeting *Anastrepha* species of fruit fly. Navel and other oranges, tangerines and grapefruit can be treated using HTFA by increasing the fruit centre temperature to 44˚C within a minimum approach time of 90 minutes, and keeping it at 44˚C or hotter for 100 minutes (USDA treatment schedule T 103-a-1). However, for treatment targeting *Ceratitis capitata, Bactrocera dorsalis* and *B. cucurbitae* fruit centres are required to reach 47.2˚C by constant or increasing temperature for at least 4hours. Of the *Citrus* species tested to date, grapefruit has shown the highest tolerance to the treatment (USDA treatment schedule T103-b-1) and Armstrong (1990) stated pomelo at 47.2˚C tolerated HTFA with no external damage.

This suggests *Anastrepha* species die at the lower fruit core temperature (44˚C for a determined time) whereas a higher temperature (47.2˚C for 20 minutes) is required for mortality of *Bactrocera* species. As the fruit fly species of concern in Samoa are *Bactrocera xanthodes* and *Bactrocera kirki,* the *Citrus* being treated will need to reach a core temperature of 47.2˚C (thus an air temperature that is 2-3˚C higher) and be held at that or slightly higher for 20 minutes (Waddell *et al.* 1993; 1996), then cooled. This whole process will most likely take around 6 hours. It is uncertain all 7 species of *Citrus* considered in this risk analysis will tolerate this treatment without some damage to the fruit. The USDA manual advises that users of this treatment should test the specific cultivar to determine how well it will tolerate the required heat treatment.

Lemons and limes do not appear to have been tested by HTFA treatment. Lemons are reasonably resistant to *Anastrepha suspensa* (Greany *et al.* 1983), but do host other fruit fly species such as *Ceratitis capitata* and *Bactrocera orientalis*. Both lemons and limes carry other potential hazard organisms such as scale, mites and mealybugs.

5.4.10. Conclusion

A number of potential hazard species have been tested, achieving 99-100% mortality using HTFA (a summary is below in Table 5) without significant damage to the commodity.

A narrow margin exists between the high or low temperature that is needed to kill the pest and the tolerance of the infested commodity to the treatment. Therefore it is essential the exposure temperature and exposure time are determined and applied precisely (Sharp 1993). This is especially important for any untested organisms or commodities where this treatment has been proposed.

High-temperature forced-air is approved as a method of disinfestation for quarantine purposes of certain fruit fly in a number of commodities by APHIS-USDA, and MAF Biosecurity New Zealand accepts this method for fruit fly (*Bactrocera melanotus* and *B. xanthodes*) disinfestation in papaya from the Cook Islands and breadfruit from Samoa.

However, as a method for disinfestation of *Bactrocera* species in *Citrus* there is no supporting literature at this time to suggest that the fruit condition and appearance will not be significantly affected by HTFA. Most countries dealing with *Bactrocera* species in *Citrus* are using cold disinfestation treatments instead (see section 5.6)

Table 5 Efficacy of HTFA treatment for certain potential hazard organisms on a variety of fresh fruit. Note: ED means the estimated effect of this treatment on a population at a 95% CL and is expressed as xx.xxxx% (as per Couey and Chew 1986)

Target quarantine pest species	Fruit	Forced air temp (˚C)	Fruit core temp (˚C)	Duration of treatment (min)	% ED	Reference
Anastrepha ludens (Loew) Mexican fruit fly	Dancy tangerine	not given	45	100*	99.9971	Mangan *et al.* 1998
	Rio Red grapefruit	not given	46	100*	99.9968	Mangan *et al.* 1998
	Valencia orange		46	100*	99.9970	Mangan *et al.* 1998
Anastrepha suspensa (Loew) -Caribbean fruit fly	golden Navel orange	48 ± 0.3	≥ 44	105#	99.9986	Sharp and McGuire 1996
	Marsh grapefruit	48 ± 0.3	44	≥ 150	not given	Sharp and Gould 1994
Bactrocera cucurbitae Coquillett -melon fly	papaya	43-49	47.2	210-420#	99.9985	Armstrong *et al.* 1989;
		48-48.5	47.2	210 ± 25#	99.9970	Armstrong 1990
Bactrocera dorsalis Hendel -oriental fruit fly	papaya	43-49	47.2	210-420#	99.9985	Armstrong *et al.* 1989;
		48-48.5	47.2	210 ± 25#	99.9970	Armstrong 1990
Bactrocera melanotus (Coquillett)	Waimanalo papaya	not given	47.2	20*	99.9831	Waddell *et al.* 1996
Bactrocera xanthodes (Broun) -Pacific fruit fly	Waimanalo papaya	not given	47.2	20*	asumed to be the same as above	Waddell *et al.* 1996
Ceratitis capitata (Weidemann) -Medfly	papaya	43-49	47.2	210-420#	99.9985	Armstrong *et al.* 1989;
		48-48.5	47.2	210 ± 25#	99.9970	Armstrong 1990
Ceratitis capitata (Weidemann) -Medfly	Oroblanco	not given	44	60*	not given	Lurie *et al.* 2004
Epiphyas postvittana Walker -light brown apple moth	persimmon	48-50	not applicable	240#	not given	Dentener *et al.* 1996
Pseudococcus longispinus Targioni-Tozetti -long tailed mealybug	persimmon	48-50	not applicable	240#	not given	Dentener *et al.* 1996

Key: * refers to the lethal exposure time within the total time of treatment
refers to the total time of treatment

5.5. Hot water immersion (HWI)

This treatment has mostly been used as a postharvest microbial disease control rather than insect control. However hot water is a more effective heat transfer medium that hot air and, when properly circulated through the load of fruit, quickly establishes a uniform temperature profile (Couey 1989).

5.5.1. HWI for microbial disease control

Phytophthora citrophthora on grapefruit was controlled by HWI at 48˚C for 3 minutes (Schiffman-Nadel and Cohen 1966) and *Penicillium digitatum* on lemons by HWI at 52˚C for 5-10 minutes (Houck 1967). On oranges *Diplodia* sp., *Phomopsis* sp. and *Phytophthora* sp. were treated at 53˚C for 5 minutes, although this resulted in poor degreening (Smoot and Melvin 1965) and only reduced incidence of decay by about 50%.

Aragaki *et al.* (1981) state young infections of *Phytophthora palmivora* on papaya are difficult to recognise and frequently escape culling. An experiment they conducted showed *P. palmivora* innoculations of 24 hrs old are efficiently eradicated using HWI at 48˚C for 20 minutes, but 30% of papayas with 48 hr old innoculations developed disease 3 days after the HWI. Aragaki *et al.* (1981) suggest that although the pathogen was sensitive to the treatment it may have survived in deep-seated infections as the heat failed to penetrate the large fruit mass.

5.5.2. HWI for invertebrate control

Hot water immersion (HWI) has been suggested as a suitable method for disinfestation of mealybugs (*Planococcus citri* Rossi and *Pseudococcus odermatti* Miller and Williams) on limes (Gould and McGuire 2000). In the trial 7,200 limes were treated at 49˚C for 20 minutes by hot water immersion, and 1,308 insects were killed with zero survivors providing an effective dose mortality of 99.7706% at a 95% confidence level (Couey and Chew 1986). Included in the arthropods that were killed by this treatment were small numbers of Coleoptera, Hymenoptera, Lepidoptera, Thysanoptera and unidentified mites found externally or under the calyx (Gould and McGuire 2000).

Similar results have been found using this treatment on cut flowers for disinfestation of scale, aphids, thrips, ants and mealybugs (Hara *et al.* 1993; 1994; 1995; 1996, 2005). Aphids infesting red ginger flowers were destroyed after a HWI at 47˚C for 5 minutes (Hansen *et al.* 1991; Hansen and Hara 1994) and Hara *et al*. (1993) treated bird of paradise flowers by HWI for 10 minutes at 49˚C obtaining 100% mortality (11,150 adult females, 22,622 nymphs, 14,077 crawlers and 54,506 eggs) of the magnolia white scale *Pseudaulacaspis cockerelli.* HWI at 49.5˚C for 15 seconds and 20 seconds reduced the mean number of thrips per *Dendrobium* blossom by 88% and 95% respectively. The limiting factor in this case was phytotoxicity (Hara *et al.* 1995). It was concluded that for *Dendrobium* cultivars HWI could be used as part of a systems approach rather than a stand alone disinfestation treatment (Hara *et al.* 1995).

HWI has been used on papaya for disinfestation of fruit flies (Couey and Hayes 1986) However this does not appear to have been fully tested in *Citrus* fruit. Therefore HWI should not be considered for use against internal hazard organisms in *Citrus* until there is evidence to support that an acceptable level of protection can be achieved

5.5.3. Conclusion

It is clear there are some limitations around the use of HWI as a stand alone treatment. It is not yet determined suitable as a disinfestation treatment for internal hazard organisms in *Citrus* fruit. Although useful in the control of postharvest fungal diseases it appears to be less effective on deeper seated infections, which increases the level of residual risk.
As the tolerance of *Citrus* (other than limes) to this treatment is uncertain it would be useful to have further research undertaken in this area.

5.6. Cold disinfestation

Cold disinfestation has the advantage of being applied in two or three ways. The treatment can be carried out entirely in the exporting country; in transit; or in a combination of these options.

Many tropical fruits are intolerant of cold treatment for the length of time required for disinfestation of the insects. Most *Citrus* fruit is compatible with cold disinfestation but grapefruit, lemon and lime show little tolerance for it (Hatton 1990).

Most *Citrus* fruit from other countries exported to the USA undergoes cold disinfestation between 0˚C-2.2˚C for 11 up to 22 days depending on the species of fruit fly targeted (*B. tryoni, Anastrepha spp., C. capitata*) (USDA-PPQ treatment schedules T107-a to T107-d) (USDA-PPQ 2007). *Citrus* fruit currently coming into New Zealand is either coming from ‘areas of freedom’ or undergoes cold disinfestation prior to arrival.

Research on Eureka and Lisbon lemons showed *Bactrocera tryoni* and *Ceratitis capitata* were killed at 12 or 14 days respectively at 1˚C ± 0.2˚C. Mortality was 100% with no pupal development (Jessup *et al.* 1993). Valencia and Navel oranges treated for 16 days at 1˚C ± 0.5˚C achieved 100% mortality of the most cold-tolerant lifestages of *B. tryoni* and *C. capitata* (Hill *et al.* 1988). Heather *et al.* (1996) tested cold disinfestation against *B. tryoni* and showed mandarins treated for 16 days at 1˚C achieved probit 9 efficacy. They commented that it was highly proabable this could be achieved in 14 days at the same temperature or in 16 days at a slightly higher temperature.

Currently, Australian *Citrus* fruit for export receiving cold disinfestion against Mediterranean fruit fly *Ceratitis capitata* and the Queensland fruit fly *Bactrocera tryoni* undergoes 16 days at 1˚C (oranges, mandarins and tangelos) or 14 days at 1˚C (lemons) (de Lima *et al.* 2007). The Australian *Citrus* industry found that in order to cold disinfest *Citrus* at 1˚C the thermostats needed to be set at 0.4˚C in the cold rooms or refrigerated containers (reefers), and as the probe records can vary by ± 0.6˚C fruit suffered damage when the temperature dropped below 0˚C for any time. If temperatures could be elevated slightly, without compromising the quarantine efficacy there would be a bit more flexibility of treatment, with less damage to the fruit.

De Lima *et al*. (2007) recently completed large-scale export trials on 5 citrus cultivars (Navel and Valencia oranges, Murcott and Ellendale mandarins, and Lisbon lemons) at 2˚C and 3˚C against *Ceratitis capitata* and *Bactrocera tryoni.* They used 2nd instar *C. capitata* and 1st instar *B. tryoni*, as these are the most cold-tolerant stages of both fruit fly species. The total number of fruit used in this trial is given for *C. capitata* (126,400) but no total number of fruit for *B. tryoni* is stated. For *C. capitata* each replicate trial consisted of 420 cartons each containing ~120 fruit (19kg), stacked on pallets as 10 cartons per layer, and 7 layers high (70 cartons/pallet), and 6 pallets per cold room. A similar procedure (not described) was used for testing against *B. tryoni* (de Lima *et al.* 2007).

Treatment periods were selected based on consecutive 100% mortalities (see EDs in Table 7) of the most tolerant life stage, for each species, as established in previous trials. For *C. capitata* this was 2˚C for 18 days and 3˚C for 20 days for oranges and mandarins, and 2˚C for 16 days and 3˚C for 18 days for lemons. For *B. tryoni* the oranges and mandarins received 16 days at 2˚C and 3˚C and lemons 14 days at both temperatures. Lemons appeared not as favourable to *B. tryoni* females as mandarins. The criterion used to assess the success of the treatment was the inability of 'surviving' larvae to produce apparently normal puparia (de Lima *et al.* 2007).

From data collected over the last 15 years de Lima *et al*. (2007) state it has been consistently shown that all life stages of *B. tryoni* are killed in 12 days at 1˚C. They found no decrease in mortality with an increase in temperature from 1˚C to 2˚C and 3˚C (de Lima *et al.* 2007). In fact, Burditt and Baker (1985) showed that 12 days at 2.8˚C ± 1.1˚C resulted in complete mortality of pre-adult lifestages of the Oriental fruit fly *Bactrocera dorsalis* and the same result was achieved for melon fruit fly *B. cucurbitae* at 2.8˚C ± 1.1˚C for 10 days.

It was concluded that cold disinfestation treatment for 16 days below 3˚C provided 95% confidence of being effective against *C. capitata* and *B. tryoni* in oranges, mandarins and lemons (de Lima *et al.* 2007).

Japan has accepted cold treatment of 3˚C or less for 16-20 days for fruit fly disinfestation of *Citrus* exported from Australia. The AQIS advice to industry notice (No. 2007/34 Horticulture Japan Citrus Exports: 21 Sept 2007) gives the revised treatment schedule as below (Table 6):

Table 6 AQIS advice to industry notice (No. 2007/34 Horticulture Japan Citrus Exports: 21 Sept 2007) cold treatments for *Citrus*

Schedule	Fruit pulp temperature (°C)	Exposure period (consecutive days)	Commodities
1	1°C or below	16	Fresh Sweet Oranges, Imperials, Ellendales, Murcots and Minneolas of the Valencia or Washington Navel Varieties
2	1°C or below	14	Fresh Lemons
3	2.1°C or below	18	Fresh Sweet Oranges, Imperials, Ellendales, Murcots and Minneolas of the Valencia or Washington Navel Varieties
4	2.1°C or below	16	Fresh lemons
5	3.1°C or below	20	Fresh Sweet Oranges, Imperials, Ellendales, Murcots and Minneolas of the Valencia or Washington Navel Varieties
6	3.1°C or below	18	Fresh lemons

This new temperature regime proposed by de Lima *et al*. (2007) has not yet been approved for use for produce entering New Zealand. Therefore the option presented in this risk analysis is the current MAFBNZ approved treatment of 13 days at 0˚C or below, or 1˚C +/- 0.6˚C for 16 days for *Citrus* spp. This may be reviewed if the above temperature treatment regime is approved by MAFBNZ.

There does not appear to have been any research on cold treatment for fruit fly in limes. Morton (1987), states that *C. aurantiifolia* is very susceptible to cold and *C. latifolia* is hardier in the orchard situation. Under refrigeration at 7˚C, *C. aurantiifolia* suffers chilling injury and *C. latifolia* will remain in good condition for 6-8 weeks, although a temperature is not given for the latter (Morton 1987). However, there seems to be no supporting literature that suggests Tahitian limes (*C. latifolia*) would tolerate cold disinfestation for fruit fly.

The IPPC Technical Panel for Phytosanitary Treatments (IPPC-TPPT) recently reviewed, approved and recommended the cold disinfestation treatments for *Citrus* of 2˚C and 3˚C (duration specific to fruit and fruit fly) for consideration of inclusion in the International Treatment Standard. The efficacies of these treatments against both *C. capitata* and *B. tryoni* are in Table 7.

Table 7 Efficacies of cold treatments for some *Citrus* fruits (from selected data; Anon 2007a,b,c,d; deLima *et al.* 2007)

***Citrus* species and cultivar**	**ED at 2ºC**	**ED at 3ºC**
Med Fruit Fly (*Ceratitis capitata* (Wiedemann)**)**		
Orange 'Valencia' (*Citrus sinensis*)	99.9979 (18 days)	99.9979 (20 days)
Orange 'Navel' (*Citrus sinensis*)	99.9982 (18 days)	99.9980 (20 days)
Orange 'Washington Navel', 'Salustiana' and 'Lue Gim Gong' (*Citrus sinensis*)	99.9917 (21 days)	-
Lemon 'Lisbon' (*Citrus limon*)	99.9977 (16 days)	99.9975 (18 days)
Tangor 'Ellendale' and 'Murcott' (*Citrus reticulata* and *Citrus sinensis* x *C. reticulata*)	99.9972 (18 days)	99.9972 (20 days)
'Clementinas Group' (*Citrus reticulata,* Clemenule)		
'Nova' (*C. reticulata* x Tangelo)	99.9918 (23 days)	
'Orlando' (*Citrus reticulata* x *C. paradisi)*		
Grapefruit (*Citrus paradisi*)	99.9917 (19 days)	99.9916 (23 days)
Queensland Fruit Fly (*Bactrocera tryoni* (Froggatt)**)**		
Orange 'Valencia' (*Citrus sinensis*)	99.9960 (16 days)	99.9976 (16 days)
Orange 'Navel' (*Citrus sinensis*)	99.9973 (16 days)	99.9988 (16 days)
Lemon 'Lisbon' (*Citrus limon*)	99.9935 (14 days)	99.9928 (14 days)
Tangor 'Ellendale' and 'Murcott' (*Citrus reticulata* and *Citrus sinensis* x *C. reticulata*)	99.9968 (16 days)	99.9989 (16 days)

5.6.1. Conclusion

This treatment is in wide use for *Citrus* fruit. Although this treatment has tested mortality of *B. tryoni*, it is thought, given *B. tryoni* is considered one of the more cold tolerant of the *Bactrocera* fruit flies that this treatment would be suitable against *B. kirki* and *B. xanthodes.* Cold disinfestation will be suitable for oranges, mandarins, tangelos, lemons and grapefruit within strictly defined temperature regimes. However, there are no data available for pomelo, and limes will not tolerate this treatment.

5.7. Fumigation

Methyl bromide is being phased out of use as a biosecurity treatment and is known to be phytotoxic to *Citrus* (de Lima *et al*. 2007). Alternative fumigants for fruit fly disinfestation of *Citrus* were investigated by Australian researchers.

Williams *et al*. (2000) established that phosphine fumigation had potential for disinfesting *Citrus* of fruit fly. Using *Bactrocera tryoni* larvae in Washington navel oranges they achieved a mortality of 99.998% with exposure of more than 48,000 larvae over 48 hours at 23 or 25˚C to phosphine concentrations of 1.67g m-3, topping up to ~ 0.7 g m-3 after the first 24 hours. No adverse effects on the oranges were observed. Grapefruit have also been fumigated at concentrations sufficient to kill *Anastrepha suspensa* (Caribbean fruit fly) without causing injury to the commodity (von Windeguth *et al.* 1977 in: Bond 1989).

5.7.1. Conclusion

Phosphine is approved for use on particular perishables in certain countries (MbTOC 2006) and appears to be a promising option. Further research of this could prove useful. However the USDA treatment manual still uses methyl bromide for disinfesting *Citrus*.

5.8. Assessment of residual risk

Residual risk can be described as the risk remaining after measures have been implemented. Assuming:

- the measures have been implemented in a manner that ensures they reduce the level of risk posed by the hazard(s) to a degree anticipated by the risk analysis; and
- the level of risk posed by the hazard(s) was determined accurately in the risk assessment.

The remaining risk while being acceptable may still result in what could be interpreted as failures in risk management. There are a range of risk management measures, or combinations of measures which will reduce the risk associated with this pathway by varying amounts. Whatever options are chosen it is advisable to monitor whether the residual risk is the expected level. Residual risk information in this case would be interception data from the *Citrus* consignments coming into New Zealand from Samoa.

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6. Assumptions and uncertainties

The major uncertainties encountered in this risk analysis are identified here. The assumptions made to take account of them are explicitly identified where relevant in the text.

6.1. Hazard biology and identification

- The biology of insects that have been reared in the laboratory for several generations is often different to wild counterparts established in field conditions (Mangan and Hallman 1998). Aspects such as life cycle, preovipositional period, fecundity and flight ability (Chambers 1977), as well as cold or heat tolerance can be influenced by the highly controlled laboratory environment. Laboratory reared insects may differ in their responses to environmental stress and exhibit tolerances that are exaggerated or reduced when compared with wild relatives. For example longevity and fecundity of adult *Aphis gossypii* in a greenhouse was longer and higher than those in a growth chamber with similar conditions (Kim and Kim 2004).

- If a pest species occurs in New Zealand often its full host range or behaviour in the colonised environment remains patchy. It is difficult to predict how a species will behave in a new environment, particularly if it has not become established as a pest elsewhere outside its natural range. Therefore there will be considerable uncertainty around the likelihood of an organism colonising new hosts or the consequences of its establishment and spread on the natural environment. Where indigenous plants are discussed as potential hosts this is extrapolated from the host range (at genus and family level) overseas and is not intended as a definitive list.

- Where there is uncertainty about the identity of an organism, e.g. *Prays citri* vs *P. nephelomima*, the more serious pest is considered in the RA. The conclusions may need to be revisited if evidence to the contrary becomes available.

- There is uncertainty around the efficacy of risk management measures for many of the hazards identified in this Risk Analysis. In some cases efficacy data for similar species has had to be used.

6.2. Assumption regarding transit time of fruit on the air pathway

An assumption is made around the time the fruit takes to get from the field in Samoa to New Zealand ready for wholesale if it is transported by aircarrier. It is assumed that the harvesting, treatment, packing and transit of *Citrus* fruit from Samoa, inspection and release in New Zealand will take a minimum of 24 hours, and on average will take 48 hours.

6.3. Assumption and uncertainty around disposal of infested fruit

It is not known what proportion of imported *Citrus* will be consumed or discarded.
It is assumed that a proportion of *Citrus* that is infested or damaged will be disposed of in a manner that exposes any potential hazard organisms on that fruit to suitable hosts. Disposal would include discarding fruit or peel on urban or rural roadsides, in bush reserves, in open rubbish bins in public places, and on open composts in domestic areas.

6.4. Assumption and uncertainty around risk management measures

A lot of uncertainty exists around the efficacy of risk management measures. Interception data is one way of estimating efficacy, as records of live and dead organisms indicate the success of a treatment and the thresholds for growth and development of each individual organism. A sample audit is required to monitor efficacy. Currently this is 600 units of fruit/vegetable product per consignment. The assumption is that this monitoring will adequately record type and number of organisms associated with each fresh produce commodity.

This approach makes the following assumptions, that:

- the consignment is homogeneous (fruit are harvested inspected and packaged in similar conditions, and have received similar treatments before arrival into New Zealand). Heterogeneous or non-randomly distributed consignments would require a higher sampling rate to achieve the same confidence levels. Level of sampling depends on the degree of heterogeneity;
- the samples are chosen randomly from the consignment;
- the inspector is 100 percent likely to detect the pest if it is present in the sample. Because of uncertain distribution of pests within the consignment some pests will not be detected if they are present outside the 600 unit sample. Some pests are difficult to detect because of their small size and behaviours;
- it is acceptable that the sampling system is based on a level (percentage) of contamination rather than a level of surviving individuals;
- because for lines of less than 600 units, 100 percent inspection is required, it is therefore acceptable that the effective level of confidence gained by the sampling method significantly increases as the consignment size moves below 10,000. This is because a sample of around 590 provides 95 percent confidence that a contamination level of 1 in 200 (0.5 percent) will be detected in consignments larger than about 25,000 individuals.

Interception records can rarely be used quantitatively because of limitations in the identification and recording processes.

There is a paucity of information on the efficacy of the available risk mitigation options in managing the hazards associated with *Citrus*. In the absence of efficacy data, assumptions are made on the basis of data for similar species or similar treatments.

6.5. References

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7. Tephritid fruit flies

7.1. *Bactrocera xanthodes* (Pacific fruit fly)

7.1.1. Hazard identification

Scientific name: *Bactrocera (Notodacus) xanthodes* (Broun)
Synonyms or changes in taxonomy or combination: *Chaetodacus xanthodes, Dacus xanthodes, Tephritis xanthodes;*
Taxonomic position: Insecta: Diptera: Tephritidae
Common name: Pacific fruit fly
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: ESNZ 1977: Spiller and Wise 1982; PPIN (24/7/2007); Scott and Emberson 1999

7.1.2. Biology

The Pacific fruit fly *Bactrocera xanthodes* is a polyphagous, multivoltine tropical/subtropical fruit fly (Waterhouse, 1993; Tunupopo Laiti *et al.* 2002). It belongs to a species complex of closely related sibling species. Other species in the complex are *B. paraxanthodes* Drew and Hancock present in New Caledonia, *B. neoxanthodes* Drew and Romig in Vanuatu and a yet undescribed species in Samoa (Tunupopo Laiti *et al.* 2002). *B. xanthodes* occurs in several commercial fruit species. In terms of biology and behaviour *B. xanthodes* is closest to *Bactrocera cucurbitae* (Coquillet), the melon fly (R.A.I. Drew pers. comm. to Cowley *et al.* 1993). Given the paucity of documented information on *B. xanthodes* in the wild, some of the information given below is based on *B. cucurbitae* biology.

Fruit flies generally locate their host plants by the shape, colour and odour of fruit, leaves and the bacteria on the surface of both. Adults feed on the juices from fruit, nectar, flowers, honeydew, bird faeces and bacteria (Tunupopo Laiti *et al.* 2002). Immature females require protein to bring them to sexual maturity and produce viable eggs. Reproduction in *B. xanthodes* is biparental and adults mate at dusk. The female oviposits just under the skin of fruit, usually at the start of ripening. At the same time as the eggs are laid, bacteria are also introduced into the fruit, which is spoiled. The rotting flesh provides the developing larvae with a food source (Tunupopo Laiti *et al.* 2002).

There are three larval instars before pupation. The fruit falls to the ground and the larvae exit to pupate within the soil. Developmental rates for the different life stages correlate directly to temperature (see Table 8) (Cowley *et al.* 1993). Adults emerge from pupation and will immediately seek mates. The whole life cycle from egg to egg at 26 ± 1˚C (under laboratory rearing conditions) is a minimum of 35 days (Clare 1997). It is assumed adults have a life span of 1-5 months (possibly longer in some cases), with females capable of laying about 1000-1300 eggs during their lifetime (Cowley *et al.* 1993).

Table 8 Duration and point of change for the life stages of *Bactrocera xanthodes* reared in the laboratory (based on Clare 1997 and Liu and Lee 1987).

Life stage	Duration or time of change at 26 ±1˚C
Median time to egg hatch	44 hours
3rd instar reached by	Day 6
Mean egg - pupa development time	10 days
Pupation starts*	Day 8.5
Duration of pupation	8 days at 30˚C and 39 days at 14˚C
Mean egg-adult development time	23 days
Adult females begin oviposition	Day 35 (at the adult age of 12 days)
Minimum life cycle from egg-egg	35 days

*only 10% of the *B. xanthodes* larvae had pupated by Day 9.

The temperature range for the countries in which *B. xanthodes* occurs is (Anon 1983 in Cowley *et al.* 1993):
January: 22-24˚C daily minima, 27-32˚C daily maxima;
July: 16-23˚C daily minima, 22-24˚C daily maxima.

If temperatures in winter prevent breeding then it is assumed *B. xanthodes* would behave similarly to *B. cucurbitae* and remain relatively inactive in sheltered refuges until spring temperature increases. However, Baker and Cowley (1991) record *B. xanthodes* continued to breed in Tonga when minimum temperatures fell to 9˚C in 1986.

Moisture has a direct effect on survival, fecundity, movement and indirectly on host fruit availability. In dacine fruit flies so far studied, tolerance of a maximum temperature is greater at high humidity as this reduces the rate of water loss in the flies. Suboptimal humidity can prolong developmental rates of the immature stages and inhibit adult maturation. Highly significant correlations between rainfall and population density for a number of fruit fly species have been made (Fletcher 1987). In Taiwan a population increased substantially in a year that had higher than usual rainfall. It is thought the moistened soil allowed more adults to emerge from pupae. However, successively heavy rains from typhoons the following season depressed the population to a low level (Liu 1982).

Adult *B. xanthodes* are active fliers and it is assumed they can cover similar distances to *B. cucurbitae.* Melon fly has been recorded covering distances of 34-56km (Kawai *et al.* 1978) and one sterile male was recorded at a distance of 200km from his release site (Miyahara and Kawai 1979). However, dispersal seems to be limited if host availability is plentiful (Fletcher 1989).

7.1.3. Hosts

B. xanthodes infests 4-31% of the "Sunset" variety of papaya and 19-37% of a local variety of papaya in Samoa. In American Samoa it attacks 62% of ripe breadfruit.
It is known to attack 40 host plant species in 30 genera and 22 families including the following (Pacifly 2007):

Annona muricata (soursop), *Artocarpus altilis* (breadfruit), *Artocarpus heterophyllus* (jackfruit), *Barringtonia edulis*, *Burckella richii*, *Capsicum annuum*, *Carica papaya* (papaw), *Cerbera manghas*, *Citrus maxima*, (pomelo), *Citrus reticulata* (mandarin), *Excoecaria agallocha*, *Lycopersicon esculentum* (tomato), *Mangifera indica* (mango), *Ochrosia oppositifolia, Passiflora edulis, Passiflora ligularis*, *Passiflora quadrangularis* (giant

granadilla), *Persea americana* (avocado), *Psidium guajava* (guava), *Pouteria cainito* (abiu), *Solanum melongena* (eggplant), *Terminalia catappa* (tropical almond) (Pacifly 2002; Tunupopo Laiti *et al.* 2002).

7.1.4. Distribution

B. xanthodes is only found between 13-21˚S in the following countries: American Samoa, Austral Islands of French Polynesia, Cook Islands, Fiji, Nauru, Niue, Samoa, Tonga, Wallis and Futuna (Tunupopo Laiti *et al.* 2002; Heimoana *et al.* 1997; Purea *et al.* 1997)

7.2. *Bactrocera kirki*

7.2.1. Hazard identification

Scientific name: *Bactrocera kirki* Froggatt.
Synonyms or changes in taxonomy or combination: *Dacus kirki, Stumeta kirki*
Taxonomic position: Insecta: Diptera: Tephritidae
Common name: fruit fly
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: ESNZ 1977: Spiller and Wise 1982; PPIN (24/7/2007); Scott and Emberson 1999

7.2.2. Biology

There is very little information available on *B. kirki.* The biology is assumed to be similar to that of *B. xanthodes* and *B. cucurbitae*. Eggs are laid just beneath the fruit skin and hatch within a day or slightly longer. The larvae go through three instars, feeding 10-35 days in the fruit. Pupation occurs in the soil under the host plant for approximately 10-30 days. Adults occur throughout the year and begin mating 1-2 weeks after emergence (Waterhouse, 1993; CPC, 2007; Christenson and Foote 1960). *B. kirki* mate late morning to early afternoon when the light is most intense (Tunupopo Laiti *et al.* 2002). They may live 1-3 months depending on temperatures (Christenson and Foote 1960).

7.2.3. Hosts

B. kirki is known to infest 45-99% of ripe guavas in Samoa (and 90% of those in Tonga)
It has 49 recorded host species in 32 genera and 22 families including the following:

Annona muricata (soursop), *Annona reticulata* (bullocks heart), *Averrhoa carambola* (carambola), *Capsicum annuum* (bell pepper), *Carica papaya* (papaya), *Calophyllum inophyllum* (Indian laurel), *Citrus maxima* (pomelo), *Citrus reticulata* (mandarin), *Citrus sinensis* (orange), *Cucurbita pepo* (pumpkin), *Elaeocarpus tonganus, Eryobotria japonica, Eugenia brasiliensis, Eugenia uniflora* (Surinam cherry), *Inocarpus fagifer* (Tahiti chestnut), *Mangifera indica* (mango), *Morinda citrifolia, Ochrosia oppositifolia*, *Passiflora edulis* (passionfruit), *Passiflora quadrangularis* (giant granadilla), *Persea americana* (avocado), Pometia pinnata (Pacific lychee), *Psidium cattleianum* (strawberry guava), *Psidium guajava* (guava), *Pouteria cainito* (abiu), *Solanum melongena* (eggplant), *Spondias cytherea* (golden apple), *Spondias mombin* (hog-plum), *Syzygium corynocarpum, Syzygium deleatum, Syzygium jambos* (rose-apple), *Syzygium malaccense,* (mountain apple), *Syzygium neurocalyx, Syzygium richii, Terminalia catappa* (tropical almond), *Terminalia littoralis*.
(CPC 27/3/2007; Pacifly database 27/3/2007; Laiti Tunupopo *et al.* 2002)

7.2.4. Distribution

B. kirki is found in American Samoa, Fiji (on Rotuma only), French Polynesia (but not the Marquesas), Niue, Samoa, Tonga, Wallis and Fortuna.
(CPC 27/3/2007; Tunupopo Laiti *et al.* 2002)

7.3. Hazard identification conclusion

Given that *Bactrocera xanthodes* and *Bactrocera kirki*

- are not known to be present in New Zealand;
- are present in Samoa;
- eggs are laid in, and larvae develop in *Citrus* fruit;
- are highly fecund and highly mobile, internationally recognised pest species of economic importance in the Pacific;

Bactrocera xanthodes and *Bactrocera kirki* are considered potential hazards on fresh *Citrus* fruit coming from Samoa.

7.4. Risk assessment for *B. xanthodes* and *B. kirki*

7.4.1. Entry assessment

Bactrocera eggs will hatch within one to two days of oviposition. Eggs laid inside *Citrus* fruits just prior to harvest are most likely to enter New Zealand as eggs or larvae, given the time from harvest to arrival in New Zealand would be 24- 48 hours.

There do not appear to be records of how many eggs are laid at any one time by either *B. xanthodes* or *B. kirki* in citrus. Dacine (subfamily of the Tephritidae to which the genus *Bactrocera* belongs) females do not discriminate against fruits that already contain eggs or larvae, nor do they deposit a pheromone to deter oviposition by subsequent females (Fitt 1984), so it can be assumed any number of larvae could be present in any single fruit entering the country. For instance, approximately 750 *B. xanthodes* larvae were found in a single breadfruit from Niue (Baker and Cowley 1991) indicating several females had oviposited in the one fruit. Since the average egg to pupation period is ten days, there is a higher likelihood of larvae entering in fruit arriving by air than arriving by sea. As pupation occurs in the soil it is considered unlikely pupae would enter with *Citrus* fruit.

Given the duration of each life stage of both species the likelihood of entry of eggs and larvae is considered to be medium.

7.4.2. Exposure assessment

Citrus imports from Samoa are expected during the New Zealand summer, increasing the likelihood of exposure to hosts as the greatest number of host species will be coming into fruit at this time (see Table 9).

Citrus fruit are most likely to enter New Zealand through Auckland. A number of the host species used by *Bactrocera* and many other potential hosts are grown in this region, providing food and oviposition sites all year round (Baker and Cowley 1991). The main host crops in the area are *Capsicum annuum* (bell pepper), *Persea americana* (avocado), various *Citrus* fruits, *Citrullus lanatus* (watermelon), *Cucumis melo* (rockmelon), *Lycopersicon esculentum* (tomato) and a commonly grown fruiting ornamental *Psidium cattleianum. Citrus* fruit will be distributed more widely after arrival so this increases exposure to host material.

Waste fruit discarded onto open domestic compost increases the likelihood of exposure to local hosts and the spread of individuals.

Longevity of adults, the overwintering strategy and their acclimation ability increase the likelihood of invading *Bactrocera* spp. mating and subsequently egglaying. Fallen fruits can also serve as major breeding sites and create a reservoir population according to overseas data (Liquido 1991), and *B. xanthodes* have been observed ovipositing into fallen fruit (Allwood 1996).
The likelihood of exposure is considered to be medium.

Table 9 Peak fruit production periods of some potential fruit fly hosts in New Zealand (adapted from Baker and Cowley 1991).

Host	Peak fruit production periods
Berryfruit	October-April
Citrus	All year
Native trees (*Syzygium maire, Aristotelia, Beilschmiedia* etc)	November-May
Pipfruit	January-May
Stonefruit	November-April
Subtropical fruit (avocado, feijoa etc)	All year

7.4.3. Establishment assessment

Most dacine flies overwinter as adults. Adults can spend prolonged periods at temperatures above 30˚C or below 5˚C. Acclimation during late larval stage also aids adult survival at low temperatures (Baker and Cowley 1991). Koidsumi (1937) reported that if melon fly pupae were subjected to varying temperatures below 15˚C for 2-6 days tolerance to low temperatures was greatly increased.

The areas of New Zealand most at risk from the establishment of permanent populations lie northwards of 37˚S (Auckland, Coromandel and Northland). However, there is also potential for widespread summer populations in Waikato, Bay of Plenty, Gisborne, Hawkes Bay, Nelson and Marlborough, with isolated summer populations in Wanganui and Wairarapa (Cowley *et al*. 1993).

There are no threshold data for *B. xanthodes*. Developmental thresholds for this species are assumed to be similar to those for melon fly as documented by Meats (1989, in Robinson and Hooper 1989) (Table 10). Similar data have also been put forward by Fletcher (1989a) where no pupal survival was observed below 12˚C or above 34˚C, and optimal survival temperatures were 20-27˚C.

Table 10 Temperature thresholds for *B. cucurbitae* life stages

Life stage	Developmental threshold in ˚C	
	Lower	Upper
Egg	10-12	34-40
Larva	12	34
Pupa	14	32-34
Adult	Not determined	Not determined

Both species of fruit fly are multivoltine, polyphagous and assumed to be highly mobile. Considering these factors and the suitable climate in the far North, adequate rainfall and

abundant plant hosts, the likelihood of *B. xanthodes* and *B. kirki* establishing in Northland and other warm areas of the North Island in New Zealand is considered to be high.

7.4.4. Consequence assessment

7.4.4.1 Economic impact

B. kirki respond to Cue lures and *B. xanthodes* respond to Methyl eugenol lures (Tunupopo Laiti *et al*. 2002). Detection of fruit fly in the surveillance programme would require the findings to be reported internationally. An expected result would be a reduction in market access for New Zealand host crops to markets free of *Bactrocera xanthodes* and *B. kirki.* Fruit fly infestion of fruit causes early maturation and subsequent early drop thus significantly reducing harvestable crops. The domestic market would be adversely affected by costs for control and reduced yields. *Citrus*, kiwifruit, avocado, tomatoes and cucurbits are species vulnerable to *B. kirki* and *B. xanthodes*. The economic consequences due to entry and /or establishment are considered to be high.

7.4.4.2 Environmental impact

There are two plant genera attacked by both *Bactrocera* species represented in the native flora, *Passiflora* and *Syzgium*. Both contain endemic species found in lowland forests and remnants throughout the North Island and parts of the South Island. If these or other native species became hosts to *Bactrocera xanthodes or B. kirki* there would be some impact on the hosts and to other species reliant on those hosts. However fruit flies are not usually considered to be pests in natural ecosystems. The environmental consequences of establishment are uncertain but non negligible.

7.4.4.3 Human health impact

Sela *et al*. (2005) showed that the Mediterranean fruit fly *Ceratitis capitata* is a potential vector of human pathogens (eg: *Escherichia coli*) to fruits. Although there seems to be no evidence that *Bactrocera* spp. are directly or indirectly of human health significance, it is possible that they may play a similar role as vectors of human pathogens. Based on current information the impacts on human health are considered to be negligible.

7.4.5. Risk estimation

The likelihood of entry and exposure of *Bactrocera kirki* and *Bactrocera xanthodes* is medium, the likelihood of establishment is high. If they were to enter and /or establish then the consequences would be high. The risk estimate for *Bactrocera kirki* and *Bactrocera xanthodes* is non negligible therefore these organisms are classified as hazards in this commodity and risk management measures can be justified

7.5. Risk management of *B. xanthodes* and *B. kirki*

7.5.1. Options

7.5.1.1 Fruit fly non-host status option

In a published paper by Heimoana *et al.* (1996) fruit fly non-host testing, using the MAF Biosecurity New Zealand Standard 155.02.02: Specification for Determination of Fruit Fly Host Status as a Treatment, showed Tahitian limes to be a potential host to both *B. kirki* and *B. xanthodes.* This paper did not mention Meyer lemons in Samoa, but testing in Fiji showed Meyer lemons potentially hosted *B. xanthodes* and *B. passiflorae*. However, the authors do not state the developmental stage of the fruits tested.

An unpublished report by Tunupopo and Fonoti (2000) on fruit fly non-host testing (*B. kirki* and *B. xanthodes*), used the same MAF standard. In laboratory cage tests (LCT) no adults emerged from pupae from trials on lemons. In field cage tests (FCT) 3 pupae were recovered from trials using Tahitian limes but adults did not emerge from either limes or lemons. The methods for the FCT were not given, and 'mature green stage' of fruit tested was not defined. This is relevant as it is not clear whether tests were on 'ripe' or 'unripe' green fruit.

The report also states extensive field surveys have been conducted from 1991-2000 on fruit at varying stages of development, incuding fallen fruits. No fruit fly species emerged from any of the surveyed samples of Tahitian limes and Meyer lemons. However there are no details of methodology or numbers of fruit tested.

The report concluded that mature green stage of Tahitian limes and Meyer lemons are non hosts to *Bactrocera kirki* and *B. xanthodes* (Tunupopo and Fonoti 2000).

As this unpublished report discusses testing that was carried out more than 7 years ago, was not submitted to MAF, and is unclear in methodology, it is considered there is insufficient information to accept 'fruit fly non-host status' for Tahitian limes and Meyer lemons at this point in time.

Until the non-host status of Tahitian limes and Meyer lemons can be clarified other measures implemented for *Citrus* fruit against fruit fly should also include lemons and limes regardless of stage of maturity. It should be noted that lemons and limes do not appear to have undergone HTFA testing, and limes do not appear to have been tested for Cold Disinfestation.

7.5.1.2 In-field sanitation

Fruit fly infestation may be reduced by implementation of in-field sanitation such as removal of infested fruits, ripe or decaying fruits and use of protein bait insecticide as per section 3.2.2 of this document. This will assist in reducing the likelihood of entry of fruit fly but will not be sufficient as a single measure to mitigate the risk.

7.5.1.3 Post harvest culling, washing, waxing and visual inspection

The post harvest washing of fruit followed by visual inspection should be seen as a supplementary measure to be implemented in conjunction with the chosen disinfestation treatment to reduce pest numbers in fruit for export.

Citrus fruit harvested for export to New Zealand should be free from any scabbing, holes, cracks or damage to the skin, free from any abnormal discoloration and pests or pathogens. Fruit fly oviposition sites become raised, or turn brown after a few days or the rind around the oviopsition site may turn yellow, therefore attacked fruits should be easy to identify by visual inspection (Yang 1991), unless very recent. Fruit showing any sign of damage or infestation should be discarded.

Washing and waxing of fruit adds to the quarantine security but is insufficient on its own therefore should be used in conjunction with an approved fruit fly disinfestation treatment such as HTFA or Cold Disinfestation. Waxing is beneficial to the fruit if the treatment is cold disinfestation or cool storage (see section 5.3)

7.5.1.4 High temperature forced air (HTFA)

Waddell *et al*. (1993, 1996) developed a treatment schedule for *Bactrocera melanotus* and *Bactrocera xanthodes* in papaya from the Cook Islands. In their verification trial for the commercial unit at Rarotonga Airport they used *B. melanotus* eggs, the most heat resistant fruit fly species and life stage, to artificially infest papaya. Complete mortality of 17,750 eggs held at 47.2˚C (fruit centre temperature) for 20 minutes was achieved. This means the ED = 99.9831%, which is the estimated effect of this treatment on a population of fruit fly at a 95%CL (as per Couey and Chew 1986). This method was effective for disinfesting Cook Islands papaya of any potential *B. melanotus* and *B. xanthodes* fruit flies. Therefore it is expected HTFA will be a suitable measure against *B. xanthodes* and *B. kirki* in *Citrus* fruit.

For *Citrus* except lemons and limes: high temperature forced air treatment raising the internal temperature of the commodity from ambient temperature to 47.2˚C for a minimum of 20 minutes with the total treatment time being at least 4 hours or longer.
(**NB**. This is an approved treatment by the USDA-PPQ; however they note that of all *Citrus* tested to date, grapefruit has shown the highest tolerance for this treatment and specific cultivars should be tested to determine their tolerance to HTFA at this time/temperature regime.)

Please refer to Chapter 5 for detail of HTFA and its effect on *Citrus* fruit (section 5.4.9).

7.5.1.5 Cold disinfestation

This treatment is in wide use for the disinfestation of fruit fly from *Citrus* fruit. However, there are no data available for pomelo.

Cold disinfestation of *Citrus* fruit is currently:
13 days at 0˚C or below or
16 days at 1˚C + or – 0.6˚C
There is no supporting literature to suggest limes may be treated by cold disinfestation without damage to the fruit.
Please refer to Section 5.7 for further information on cold disinfestation.

7.5.1.6 Visual inspection at the border

Visual inspection of the consignment for oviposition punctures should reveal old puncture sites but it may be difficult to detect a new puncture in very recently infested fruit. The efficacy of detecting fruit fly infested fruit can be lower than for some other insects. Emerging larvae or adults on the fruit surface may be detected on arrival in New Zealand.

This will assist in reducing the likelihood of entry of fruit fly but will not be sufficient as a single measure to mitigate the risk.

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8. Moths

Four lepidoptera are considered potential hazards. All are well recognised pests of *Citrus*:
Eudocima fullonia Clerck
Phyllocnistis citrella Stainton
Prays citri Millière
Tiracola plagiata Walker

8.1. *Eudocima fullonia* (fruit piercing moth)

8.1.1. Hazard identification

Scientific name: *Eudocima fullonia* Clerck
Synonyms or changes in taxonomy or combination: *Othreis fullonia, Othreis fullonica, Ophideres fullonia, Ophideres fullonica*
Taxonomic position: Lepidoptera: Noctuidae
Common name: fruit piercing moth
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: ESNZ 1977: Spiller and Wise 1982; PPIN (24/7/2007); Scott and Emberson 1999, Dugdale 1988, Charles 1998.

8.1.2. Biology

Larvae are between 4mm (newly hatched) and 60mm (mature) in length, with variable colouration. The adult is large and robust, with a wingspan of 80-100mm and body approximately 50mm long (Martin-Kessing and Mau 1993; Fay 2005).

Eggs are laid in batches of up to 100 (when moth populations are low) or several hundred (when moth populations are high) on the undersides of the host plant leaves (often *Erythrina* spp.), though sometimes on bark or other nearby plants. At about 25˚C eggs will hatch in 3 days (Kumar and Lal 1983). There are 5 larval instars, the total duration of which is about 13-22 days (Cochereau 1977). Pupation occurs in a silk cocoon woven between leaves and lasts 16-18 days. After emergence the female usually feeds, mates then commences egg laying. She may lay up to 750 eggs in her lifetime. Females live 27-30 days and males 26-28 days (Kumar and Lal 1983) and both sexes continue feeding throughout their lifetime. Being nocturnal the moths feed and mate at night, and shelter during the day in dense, undisturbed foliage (Waterhouse and Norris 1987).

Adults can fly substantial distances. In New Caledonia they regularly move between the mountains and coastal plains (Cochereau 1977) and in Australia are thought to migrate over long distances such as from northern Queensland to the southeastern parts of the state.

8.1.3. Hosts

The adult of this species is a serious pest of ripening fruits, associated directly with *Citrus* fruit upon which it feeds. The adult host plants are different to larval host plants.
In the Pacific larvae develop almost exclusively on plants in the genus *Erythrina* with the exception of the creeper *Stephania forsteri* (Menispermaceae) (Cochereau 1977). Elsewhere the Menispermaceae are favoured, particularly plants of *Tinospora, Tiliacora, Triclisia* and *Stephania* genera (Cochereau 1977; Waterhouse and Norris, 1983).
There are no members of the Menispermaceae native to or naturalised or common in cultivation in New Zealand. The introduced *Erythrina* species in New Zealand are *E. crista-*

gall, E. caffra and *E.* x *sykesii*, the latter is common in Northland and all occur in cultivation (NZ Plants 2007).

Unlike most Lepidoptera it is the adult, not the larval stage that is responsible for damage to crops. Feeding occurs at night. The adult's mouthparts are about 2.5cm long and designed to pierce thick fruit skins giving access to the juice. The entry site allows bacterial and fungal infections to take hold. *E. fullonia* are known to attack more than 40 different types of fruit (Martin-Kessing and Mau 1993; Fay 2005) including the following:

Actinidia chinensis (kiwifruit), *Anacardium occidentale* (cashew nut), *Ananas comosus* (pineapple), *Annona muricata* (soursop), *Annona squamosa* (sugarapple), *Artocarpus altilis* (breadfruit), *Artocarpus heterophyllus* (jackfruit),*Averrhoa carambola* (carambola), *Capsicum annuum* (bell pepper), *Carica papaya* (papaw), *Casimiroa edulis* (white sapote), *Chrysophyllum cainito* (caimito), *Citrus limon* (lemon), *Citrus maxima* (pummelo), *Citrus x paradisi* (grapefruit), *Citrus reticulata* (mandarin), *Citrus sinensis* (navel orange), *Cocculus hirsutus*, *Coffea arabica* (arabica coffee), *Cucumis melo* (melon), *Dimocarpus longan* (longan tree), *Diospyros kaki* (persimmon), *Eichhornia* (waterhyacinth), *Erythrina subumbrans* (December tree), *Erythrina variegata* (Indian coral tree), *Eugenia dombeyi* (brazil cherry), *Ficus carica* (fig), *Litchi chinensis* (lichi), *Lycopersicon esculentum* (tomato), *Mangifera indica* (mango), *Malus sylvestris* (crab-apple tree), *Muntingia calabura* (Jamaica cherry), *Musa* (banana), *Nephelium lappaceum* (rambutan), *Opuntia* (Pricklypear), *Pachygone ovata*, *Passiflora edulis* (passionfruit), *Passiflora quadrangularis* (giant granadilla), *Pometia pinnata* (fijian longan), *Psidium cattleianum* (strawberry guava), *Psidium guajava* (guava), *Prunus americana* (apricot), *Prunus domestica* (plum), *Prunus persica* (peach), *Punica granatum* (pomegranate), *Salvinia molesta* (kariba weed), *Sandoricum koetjape* (santol), *Solanum melongena* (aubergine), *Syzygium malaccense* (malay-apple), *Tinospora cordifolia*, *Tinospora sinensis***,** *Vitis vinifera* (grapevine) (CPC 2007; Martin-Kessing and Mau 1993; Fay 2005; Waterhouse and Norris 1987; Herbison-Evans and Crosby 2007)

8.1.4. Distribution

E. fullonia is native to the Indo-Malay region and is widespread throughout Asia, Africa and the Pacific basin. In the South Pacific it is present in Australia, American Samoa, Belau, Cook Islands, Federated States of Micronesia, Fiji, French Polynesia, Guam, New Caledonia, Niue, Northern Mariana Islands, Papua New Guinea, Samoa, Solomon Islands, Tonga, Vanuatu, Wallis and Futuna (CPC 2007; Waterhouse 1997).

E. fullonia is an occasional vagrant in New Zealand- recorded under its synonym *Othreis fullonia* (Dugdale 1988), thought to be blown in from Australia on the prevailing westerly winds.

8.1.5. Hazard identification conclusion

Given that:

- the larvae and pupae are associated with specific non-citrus plants;
- adults shelter during the day in dense undisturbed foliage and feed externally at night;
- harvest occurs during daylight;

it is unlikely that any lifestage of *E. fullonia* will be found on fresh *Citrus* fruit coming from Samoa into New Zealand. In addition to this *E. fullonia* is an occasional immigrant that has not established in New Zealand (pers. comm. J. Dugdale 2007);

E. fullonia is not considered to be a potential hazard in this risk analysis.

8.2. *Tiracola plagiata* (banana fruit caterpillar)

8.2.1. Hazard identification

Scientific name: *Tiracola plagiata* Walker
Synonyms or changes in taxonomy or combination: *Agrotis plagifera*
Taxonomic position: Lepidoptera: Noctuidae
Common name: banana fruit caterpillar, cocoa armyworm
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: ESNZ 1977: Spiller and Wise 1982; PPIN (24/7/2007); Scott and Emberson 1999

8.2.2. Biology

The mature caterpillars reach about 60mm long, with adults having a wingspan of about 50mm (Smith *et al.* 1997).

Eggs are laid on the flowers, young fruit or young leaves of *Citrus* in spring. In Australia 6 larval stages which last 6-7 weeks in total were observed. The larvae will drop to the ground and pupate in the soil or leaf litter for approximately 4 weeks. The complete life cycle can take about 3 months. Larvae will feed externally on young fruit up to 30mm in diameter. In Australia 3-4 generations per year occur (Smith *et al.* 1997). By comparison, in Papua New Guinea eggs are laid in batches of about 200. They hatch within a few minutes of each other, the larvae dispersing on silken threads to feed on leaves for 15-17 days. They then fall or crawl to the ground and form a pupation cell, pupating about 4 days later. Pupation lasts about 12 days. Adults emerge at dusk or night and are nocturnal. The life cycle from egg to egg is usually 35-40 days (Catley 1963).

8.2.3. Hosts

The larvae of this species will eat the fruit and flowers of *Citrus*. It attacks all varieties but especially oranges (Smith *et al.* 1997). Damage done to fruit is highly visible with large areas removed by the caterpillar, often causing fruit to drop (Smith *et al.* 1997).
Hosts include:
Capsicum (peppers), *Citrus*, *Cocos nucifera* (coconut), *Hevea brasiliensis* (rubber), *Leucaena*, *Musa* (banana), *Musa x paradisiaca* (plantain), *Theobroma cacao* (cocoa) (CPC 2007)
Agave (Agavaceae); *Ageratum, Chromolaena, Emilia* (Compositae); *Manihot, Ricinus* (Euphorbiaceae); *Leucaena* (Leguminosae); *Musa* (Musaceae); *Piper* (Piperaceae); *Fagraea* (Potaliaceae); *Coffea* (Rubiaceae); *Capsicum, Nicotiana* (Solanaceae); *Theobroma* (Sterculiaceae); *Lantana, Tectona* (Verbenaceae); *Elettaria* (Zingiberaceae).
The range of diet is probably much wider than this. In Peninsular Malaysia *T. plagiata* has been reared from *Ricinus,* an association confirmed from a voucher specimen (Holloway 2007).
Banana (*Musa acuminata*), yam (*Discorea* spp.), striped cucumber (*Diplocyclos palmatus*), red cedar (*Toona australis*), young sucker growth of *Eucalyptus* spp., purslane (*Portulaca oleracea*), *Phytolacca octandra*, tomatillo (*Physalis ixocarpa*) (Herbison-Evans and Common 2004).
Passionfruit, pawpaw, pumpkin and maize (Smith *et al.* 1997).

8.2.4. Distribution

T. plagiata is found in Asia, Australia, American Samoa, Cook Islands, Federated States of Micronesia, Fiji, French Polynesia, Niue, Northern Mariana Islands, Papua New Guinea, Samoa and Tonga (CPC 2007).

8.2.5. Hazard identification conclusion

Given that:

- the adult *Tiracola plagiata* is a large (50mm), nocturnal species;
- eggs and young larvae are associated with small, young fruit (not harvestable);
- mature larvae are large (60mm) and feed externally on fruit and are therefore considered easily detectable at post harvest and packing;
- pupae are not associated with fruit as pupation occurs in the ground;

it is unlikely these life stages would enter New Zealand on *Citrus* fruit.
T. plagiata is not considered to be a potential hazard on this pathway and will not be considered further in this risk analysis.

8.3. *Phyllocnistis citrella* (citrus leafminer)

8.3.1. Hazard identification

Scientific name: *Phyllocnistis citrella* Stainton
Synonyms or changes in taxonomy or combination: *Lithocolletis citricola, Phyllocnistis citricola* Shiraki
Taxonomic position: Lepidoptera: Gracillariidae
Common name: Citrus leafminer
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: ESNZ 1977: Spiller and Wise 1982; PPIN (24/7/2007); Scott and Emberson 1999

8.3.2. Biology

P. citrella larvae are up to 3mm long and are translucent yellow-green. The pupa is usually in a pupal cell at the leaf margin, which is rolled over and showing a distinct orange colour within the cell. The adults are white and about 2mm long, with a 4mm wingspan (Smith *et al.* 1997).

Eggs are laid singly on the underside of the host leaf and hatch in 2-10 days. The larvae enter the leaf immediately and begin feeding. They will sometimes mine young fruit (Heppner 1995). Larvae never leave their mines to form new mines or to move between the upper or lower sides of the leaf (Smith *et al.* 1997). The mines they make in the leaves have a distinctive silvery appearance. *P. citrella* undergoes 5 instars to reach adulthood. The 3 larval instars last about 5-6 days, the pre-pupa about one day and the pupal stage about 6 days. Pupation occurs within the mine in a pupal cell near the leaf margin. The whole life cycle takes 14-17 days under favourable conditions in the Australian summer and autumn, in winter and spring it can take 2-3 weeks longer. Adults emerge in the early hours of the morning. Egg laying usually commences about 24 hours after mating with a female laying up to 50 eggs in her lifetime. Most adults will live about a week but some can live up to 160 days (Smith *et al.* 1997). Adults are active in the morning, at dusk or during the night (Heppner, 1998).

There is usually only one mine per leaf but heavy infestations may have two or three (Heppner 1998).

Generations per year seem to be almost continuous, from 6 in Japan to 13 in north-central India (Heppner 1998). In Tuscany the pupa is the overwintering stage (Beneand Landi 1999). Severe infestations are usually in late summer or autumn and are correlated to a drop in numbers of natural enemies (Smith *et al.* 1997).

Under laboratory conditions in Tuscany, Bene and Landi (1999) report a lowest thermal threshold of a constant 5˚C with pupae surviving 2˚C for at least one month. *P. citrella* is also known to exacerbate citrus canker (*Xanthomonas axonopodis* pv. *citri*) infection by creating a favourable microclimate within its mines for the bacterium to develop (Chagas *et al.* 2001), but there is no evidence to suggest it vectors the disease.

8.3.3. Hosts

Phyllocnistis citrella larvae are leafminers of *Citrus* species and in Florida sometimes will also attack young fruit (Heppner 1995).

Hosts in the Rutaceae include *Citrus aurantium* (sour orange), *Citrus x paradisi* (grapefruit), *Citrus maxima*, *Fortunella crassifolia* (kumquat), *x Citrofortunella microcarpa* (calamondin), *Aegle marmelos, Atalantia* sp., *Murraya paniculata, Poncirus trifoliata,* and *Jasminum sambac* (Oleaceae), *Loranthus* sp. on *Citrus* sp. (Loranthaceae), *Pongamia pinnata* (Leguminosae), *Alseodaphne semecarpifolia* (Lauraceae). There are records of other possible host species but the larvae do not complete their life cycle on them (Heppner 1998).

8.3.4. Distribution

P. citrella is found throughout the citrus growing areas of the world. It is also found in Australia, Belau, Caroline Islands, Guam, Northern Mariana Islands, Papua New Guinea, Samoa and the Soloman Islands (CPC 2007; Smith *et al.* 1997; Heppner 1998; Waterhouse 1997)

8.3.5. Hazard identification conclusion

Given that:

- eggs, larvae and pupae are primarily associated with leaves and only occasionally will larvae mine young fruit;
- larval lifestage lasts about 6 days;
- fruit take 5-18 months to ripen;
- fruit with mining damage is not suitable for export (as the fruit is immature and visibly damaged);
- the larval stage of *P. citrella* is usually about 6 days and the generation time is a maximum of 5 weeks it is unlikely *P. citrella* would be present in harvested fruit;

Phyllocnisitis citrella is not considered to be a potential hazard on this pathway and will not be considered further in this risk analysis.

8.4. *Prays citri*

8.4.1. Hazard identification

Scientific name: *Prays citri* Millière
Synonyms or changes in taxonomy or combination: none given
Taxonomic position: Lepidoptera: Yponomeutidae
Common name: citrus flower moth
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: ESNZ 1977: Spiller and Wise 1982; PPIN (24/7/2007); Scott and Emberson 1999

8.4.2. Biology

Adult *P. citri* have a wingspan of 10-12mm, grey with brown markings and heavily fringed. The larvae are pale and about 6.5mm long and 1.8mm wide when full grown.

Eggs are laid singly on the flowers and sometimes young fruit. An adult female can produce 60-156 eggs. After about 4 days, at 25˚C the eggs hatch and the larvae immediately bore into the flowers or young fruit, penetrating laterally via the receptacle.
They will also penetrate developed fruit by boring a gallery in the rind (HYPPZ 2007). The larval stage lasts about 12 days. Smith *et al.* (1997) note that only one larva of the congener *P. parilis* survives in each bud. It is assumed the same will apply to *P. citri*.
A larva will form a white cocoon for pupation on fruits, flowers or leaves and the pupal stage lasts about 6 days. The life cycle takes about 20 days to complete. At 10˚C the female lifespan can extend more than 37.2 days, yet at 26˚C she will live less than 5 days. The thermal threshold for development is about 10˚C (CPC 2007).

Adults fly at dusk and are largely nocturnal. During the day they shelter in their host tree foliage (CPC 2007; HYPPZ 2007).

8.4.3. Hosts

Citrus species, in particular *Citrus limon*, are the host plants for the caterpillar of *Prays citri.* The list of known hosts includes:
Citrus aurantiifolia (lime), *Casimiroa edulis* (white sapote), *Citrus aurantium* (sour orange), *Citrus limon* (lemon), *Citrus reticulata* (mandarin), *Citrus sinensis* (navel orange), *Citrus x paradisi* (grapefruit), *Ligustrum lucidum* (chinese privet), *Manilkara zapota* (sapodilla) CPC 2007; Ibrahim and Shahateh 1984; Sinacori and Mineo 1997)

8.4.4. Distribution

P. citri is found in parts of Asia, Africa and the Middle East. It is widespread in the Mediterranean and is present in Australia, Fiji and Samoa (CPC 2004, 2007). However CPC (2007) note there has been misidentifications of *Prays citri* in previous EPPO reportings. In some instances there has not been supporting voucher material and identifications of *P. citri* may be other species such as *P. endocarpa*, *P. endolemma* or *P. nephelomima.* For example, the latter species is known from Australia and the Western Pacific (Smith *et al.* 1997; Robinson *et al.* 1994), whereas *P. citri* is not.
As there is currently uncertainty around the presence or misidentification of *P. citri* in Samoa, it remains included in this risk assessment until there is definitive evidence of *P. citri* not being in Samoa.

8.4.5. Hazard identification conclusion

Given that Prays citri:

- is not known to be present in New Zealand;
- is present in Samoa;
- and the larvae (HYPPZ 2007) and pupae of *P. citri* can be associated with *Citrus* fruit

Prays citri is considered to be a potential hazard on fresh *Citrus* fruit coming from Samoa.

8.5. Risk assessment

8.5.1. Entry assessment

Prays citri adults are small and mostly nocturnal, and if disturbed during harvest it is likely adults would resettle in the trees under leaves to avoid daylight. Eggs are not associated with mature fruit (Smith *et al*. 1997). *Prays citri* larvae are small (<6.5mm) and will occasionally bore into developed *Citrus* fruit and can pupate on fruit (HYPPZ 2007; CPC 2007).
It is expected that boring damage to *Citrus* fruit would usually be detectable, but if it is very new, it could be overlooked.

Therefore the likelihood of any lifestage of *Prays citri* entering New Zealand in *Citrus* fruit is considered to be low but non negligible.

8.5.2. Exposure assessment

The flying distance of adults is uncertain, but as most domestic gardens in Auckland and Northland have *Citrus* trees it is feasible adults would find suitable hosts.
Citrus fruit would need to be discarded under *Citrus* trees to allow larvae to crawl onto fruit or leaves to pupate and complete their life cycle. It is unlikely that discarded fruit would contain more than one larva (Heppner 1998; Smith *et al.* 1997) and that there would be male and female adults emerging together to enable mating and egg laying.
Most damaged fruit would be discarded in rubbish bins, compost, rubbish dumps or randomly onto the roadside.
Therefore the likelihood of exposure is considered to be very low but non negligible.

8.5.3. Establishment assessment

Given that *P. citri* has a lower thermal threshold of 10˚C (CPC 2007) this species would be able to establish in the major *Citrus* growing areas of New Zealand (Northland, Bay of Plenty, Gisborne).
Likelihood of establishment is considered to be medium.

8.5.4. Consequence assessment

8.5.4.1 Economic impact

In Australia the damage by *Prays nephelomima* and *P. parilis* is often considered considered minor within the *Citrus* industry (Smith *et al.* 1997). Damage by boring of *Citrus* fruit would cause loss in yield, adversely affecting export and domestic volumes for the *Citrus* industry.
The economic consequences of establishment are considered to be medium.

8.5.4.2 Environmental impact

New Zealand endemic Rutaceae are mainly widespread lowland forest species (*Melicope* sp.) throughout New Zealand apart from *Leionema nudum* which has a more limited distribution. The preferred hosts for *Prays citri* are *Citrus* species, but because the host range is not strictly phylogenetic it is possible it will jump to native species. There is a low likelihood of it affecting native species should it establish.

8.5.4.3 Human health and social impact

There is no evidence that *P. citri* is of any significance to human health. Establishment of this moth would affect the home *Citrus* grower through reduced yield in fruit production and cost of control. The social impact is uncertain but is considered non negligible.

8.5.5. Risk estimation

The likelihood of *Prays citri* entering the country is low, being exposed to suitable hosts is very low and the likelihood of establishment is medium. If this species established the consequences is likely to be low to medium. The risk estimate for *Prays citri* is non negligible therefore this organism is classified as a hazard in this commodity and risk management measures can be justified.

8.6. Risk management

8.6.1. Options

There are a number of points on the import pathway where effective measures could be applied to reduce the likelihood of *Prays citri* entering New Zealand.

8.6.1.1 Population monitoring and trapping

This is part of a systems approach and will help determine the level of control required.

8.6.1.2 Post harvest culling, washing, waxing and visual inspection

The post harvest washing of fruit followed by visual inspection should be seen as a supplementary measure to be implemented in conjunction with the chosen disinfestation treatment to reduce pest numbers in fruit for export.
Citrus fruit harvested for export to New Zealand should be free from any scabbing, holes, cracks or damage to the skin, free from any abnormal discoloration and pests or pathogens. Inspection of fruit at harvest should detect any damage by boring or mining *P. citri* larvae unless it is very new. Damaged or infested fruit should be discarded.
Thorough washing and immersion of the fruit is likely to remove most external eggs, larvae or pupae, further reducing the risk of entry to New Zealand. Waxing (see 5.3) is insufficient on its own as a measure but can add to the overall mitigation of risk.

8.6.1.3 High temperature forced air (HTFA)

There is no specific efficacy data for the disinfestation of moth larvae in *Citrus* by HTFA. Dentener *et al.* (1996) found forced hot air temperatures at 48-50˚C for about 4 hours (including a 2 hour warm-up period) were required to kill 99% of *Epiphyas postvittana* (lightbrown applemoth) 5th instar larvae and *Pseudococcus longispinus* (longtailed mealybug) adults and larvae on the surface of persimmons.

These are both known as difficult organisms to treat against. The internal temperature of the persimmons would have been a degree or two lower than the effective air temperature, which would bring it closer to the internal temperature required to kill *Bactrocera* fruit flies.

It is anticipated that HTFA at 47.2˚C for of 20 minutes (and the additional hours it takes to reach lethal temperature) could be used against *Prays citri* larvae in *Citrus* with a low level of survivors post-treatment.

Please refer to Section 5.5.9 and 5.5.10 for detail of issues surrounding HTFA.

8.6.1.4 Cold disinfestation

There are no specific data available for disinfestation of moth larvae in *Citrus* fruit. Data for the Gracillariid lepidopteran *Conopomorpha sinensis* - litchi fruit borer (Su *et al.* 1993), suggests that at a temperature between 0-1ºC no larval forms of *C. sinensis* remained alive after 14 days. It is assumed that *P. citri* larvae will respond similarly to *C. sinesis* larave given they are both very small bodied, fruit boring lepidoptera (R. Hoare 18/7/2008 pers. comm). Therefore it is anticipated that cold disinfestation below 1ºC could be used against *Prays citri* larvae in *Citrus* fruit with a low level of survivors post-treatment

Cold disinfestation of *Citrus* fruit is currently:
13 days at 0˚C or below or
16 days at 1˚C + or – 0.6˚C
There is no supporting literature to suggest limes may be treated by cold disinfestation without damage to the fruit.
Please refer to Section 5.7 for further information on cold disinfestation.

8.6.1.5 Hot water immersion

Gould and McGuire (2000) found that various external arthropods (including Lepidoptera) on limes were killed after a hot water immersion at 49˚C for 20 minutes, as discussed in Section 5.6. It is unlikely to have the required efficacy for any internal larvae. The tolerance of *Citrus* other than limes for this treatment is uncertain.

8.6.1.6 Visual inspection at the border

The life stages of *Prays citri* are very small. However visual inspection of the consignment may detect eggs, larvae, pupae or adults on arrival in New Zealand. If larvae entered fruit just prior to harvest, the damage to the fruit is likely to be more obvious 2 days later (the expected time taken from harvest to arrival in New Zealand by air) than at the pre-export inspection. However, low frequency of occurrence is unlikely to be detected.

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9. Thrips

9.1. *Thrips palmi* (melon thrips)

9.1.1. Hazard identification

Scientific name: *Thrips palmi* Karny
Synonyms or changes in taxonomy or combination: *Thrips clarus* Moulton 1928, *T. nigiriensis* Ramakrishna 1928, *T. leucadophilus* Priesner 1936, *T. gossypicola* (Priesner 1939), *Chloethrips aureus* Ananthrakrishnan and Jagadish 1967, *T. gracilis* Ananthrakrishnan and Jagadish 1968;
Taxonomic position: Insecta: Thysanoptera: Thripidae
Common name: melon thrips, palm thrips
New Zealand Status: Not known to be present in New Zealand
Sources that record absence: ESNZ 1977: Spiller and Wise 1982; PPIN (24), (24/7/2007); Scott and Emberson 1999; MAF Country Freedom Report
(*Thrips palmi*) 2000 [Absent from NZ; full]
Vector: certain tospoviruses (see below)

9.1.2. Biology

Thrips palmi is a polyphagous tropical pest native to Sumatra (Smith *et al*. 1992).
It is a vector of viruses such as groundnut bud necrosis tospovirus in India and watermelon silvery mottle tospovirus (WSMV) in Japan and Taiwan. It was commonly thought to vector tomato spotted wilt virus (TSWV) but this has not been proven conclusively (Smith *et al*. 1992), although TSWV has been shown to replicate in *T. palmi* (Nagata *et al.* 2002). There is no evidence of these viruses occurring in Samoa.

T. palmi has a clear yellow body with black setae and slender fringed wings. The mouth parts are specialised for sucking. Adults are between 0.8-1.0mm long in body length, with females averaging slightly bigger than males (Capinera, 2004).

The adults emerge from pupae in leaf litter or soil and fly to young leaves and flowers of host plants. The females begin egg laying from between 1-5 days after emergence (Wang *et al.* 1989). The female will make an incision with her ovipositor in the green tissue of the host leaf and deposit an average of 3.8 eggs per day, an average of 59.6 eggs in her lifetime (Kawai, 1985), although up to 204 per lifetime has been observed (Wang *et al.* 1989). Both mated and virgin females will deposit eggs (Capinera, 2004; Wang *et al.* 1989). Mated females predominately produce female offspring, whereas for unmated females reproducing parthenogenetically the progeny is primarily male (Martin and Mau 1992).

There are two active larval instars and two relatively inactive pupal instars. Larvae resemble the adults but are without wings and are slightly smaller. They tend to feed in groups usually along the midrib and veins of older leaves. Towards the end of the second instar the larva descends to the soil or leaf litter where it creates a small earthen cavity for its pupation. The pre-pupa and pupa resemble the adult but have wing pads rather than wings (Capinera 2004). The mean developmental times for each life stage are given below in Table 11.

Table 11 Mean duration in days of each life stage at three different temperatures (from Capinera 2004)

Life stage	15˚C	26˚C	32˚C
Egg	16	7.5	4.3
Larva	14	5	4
Pupa	12	4	3
Adult	20	17	12

Based on the above data the life cycle from egg to egg at 15˚C is a mean of 72 days and at 26˚C a mean of 33.5 days. Adult females will live for 10-30 days and adult males for 7-20 days (Capinera 2004).

Huang and Chen (2004) found that the optimal temperature range for population growth in Taiwan on eggplant was 25-30˚C, with a lower developmental threshold of 7.7˚C and an estimated number of 25-26 generations per year.

In Japan *T. palmi* populations have been observed overwintering in glasshouses, and Nagai and Tsumuki (1990) reported no reduction in adult populations at temperatures as low as -3˚C to -7˚C in an unheated glasshouse.

The plant species that larvae and adults feed on during their growth stage has limited effects on pre-adult development and adult longevity, but very marked effects on fecundity (Murai 2002).

9.1.3. Hosts

Investigation of the female mouthparts show *T. palmi* is a sap feeder (Yasumi *et al*. 1994). Infestation of a host develops rapidly to numbers that cause severe injury (Smith *et al.* 1992). Adults and larvae feed gregariously on leaves, primarily along the midribs and veins. They also attack stems, particularly near the growing tips and feed amongst the petals and developing ovaries in flowers and on the surface of fruit, leaving numerous scars and deformities that can eventually kill the entire plant (Smith *et al.* 1992). Cermeli and Montagne (1993) note that *T. palmi* prefers leaves but will also damage flowers and fruit of hosts, and Sakimura *et al*. (1986) comment that this species will attack all plant parts.
T. palmi has been recorded on 117 plant species in 34 families in Japan alone (Miyazaki and Kudo 1988: in Murai 2002) and known hosts include:

Allium cepa (onion), *Benincasa hispida*, *Capsella bursa-pastoris*, *Capsicum annuum* (bell pepper), *Cerastium glomeratum*, *Chrysanthemum* (daisy), *Citrus* spp., *Cucumis melo* (melon), *Cucumis sativus* (cucumber), *Cucurbita pepo* (ornamental gourd), *Cucurbitaceae* (cucurbits), *Cyclamen*, *Fabaceae* (leguminous plants), *Glycine max* (soyabean), *Gossypium* (cotton), *Helianthus annuus* (sunflower), *Lactuca sativa* (lettuce), *Lycopersicon esculentum* (tomato), *Mangifera indica* (mango), *Nicotiana tabacum* (tobacco), Orchidaceae (orchids), *Oryza sativa* (rice), *Persea americana* (avocado), *Phaseolus* (beans), *Phaseolus vulgaris* (common bean), *Sesamum indicum* (sesame), Solanaceae, *Solanum melongena* (aubergine), *Solanum tuberosum* (potato), *Vicia sativa*, *Vigna unguiculata* (cowpea) (Sakimura *et al*. 1986; Smith *et al*. 1992; Cermeli and Montagne 1993; CPC 2007).

9.1.4. Distribution

T. palmi is found in Asia, Portugal, parts of Africa and North America, Central America and northern South America. In Oceania it is present in American Samoa, Australia, Belau, Federated States of Micronesia, French Polynesia, Guam, New Caledonia, Papua New Guinea, Samoa and Wallis and Futuna (CPC-2007).

9.1.5. Hazard identification conclusion

Given that *Thrips palmi*:

- is not known to be present in New Zealand;
- is present in Samoa;
- is associated with *Citrus* fruit;
- is a highly polyphagous and fecund internationally recognised pest species of economic importance in the subtropical and tropical zones;

Thrips palmi is considered a potential hazard on fresh *Citrus* fruit from Samoa.

9.2. *Thrips hawaiiensis* (Hawaiian flower thrips)

9.2.1. Hazard identification

Scientific name: *Thrips hawaiiensis* (Morgan 1913)
Synonyms or changes in taxonomy or combination: *Euthrips hawaiiensis* Morgan 1913, *Taeniothrips hawaiiensis* (Morgan), *Thrips albipes* Bagnall 1914, *Thrips nigriflava* Schmutz 1913, *Thrips sulphurea* Schmutz 1913, *Physothrips pallipes* Bagnall 1914, *Taeniothrips eriobotryae* Moulton 1928, *Thrips hawaiiensis form imitator* Priesner 1934, *Taeniothrips rhodomytri* Priesner 1938, *Taeniothrips pallipes* var. *florinatus* Priesner 1938, *Physothrips hawaiiensis* (Morgan) *Thrips versicolor* Bagnall 1926, *Thrips pallipes* Bagnall 1926
Taxonomic position: Insecta: Thysanoptera: Thripidae
Common names: Hawaiian flower thrips, flower thrips
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: ESNZ 1977; Spiller and Wise 1982; PPIN (24/7/2007); Scott and Emberson 1999; Mound and Walker 1982.

9.2.2. Biology

T. hawaiiensis is a common, polyphagous and variable flower thrips, about 1.2mm long. It can reproduce sexually and asexually with population numbers peaking when suitable host plants such as *Citrus* are flowering. In southern Taiwan Chiu *et al.* (1991) report the feeding and ovipositing of *T. hawaiiensis* on *Citrus* flowers and young fruit.

At 15-25˚C survival rates from egg hatch to adult were above 79% when *T. hawaiiensis* was raised on a diet of pollen and honey solution (Murai 2001). The development time from egg to adult can take about 30 days but significantly longer at lower temperatures. Murai (2001) estimated 153.8 degree days above a low temperature threshold of 10.4˚C were required to complete the life cycle from egg to adult oviposition in Japan. The mean fecundity on this diet was 536.9 eggs per female at 20˚C. *T. hawaiiensis* has more than 20 overlapping generations per year in southern Taiwan (Tang 1974), and Murai (2001) estimated 11-18 could occur outdoors in Western Japan. Mean adult longevity is affected by temperature, and at 15˚C adults can live for a maximum of 102.7 days, while at 25˚C longevity was as low as 27.8 days (Murai 2001).

Its strong association with flowers means *T. hawaiiensis* also acts as a pollinator for some species, especially oil palms. However, in Taiwan and India it causes damage to *Citrus* by feeding at the base of the anthers and on the developing ovules causing fruit set failure (Chiu *et al.* 1991; Shrivastava and Bhullar 1980), and damaging blooms in the cut flower trade. On bananas *T. hawaiiensis* causes scarring and corky scabs affecting fruit quality. It has the potential to damage ornamental species. When its host species is no longer flowering it moves to another host (Cheng 1985).

9.2.3. Hosts

T. hawaiiensis has been recorded from 141 plant species in Taiwan alone, although was not breeding on all of them (Chang 1995). It has a preference for plants in the Fabaceae and Convolvulaceae families (Mau and Martin 1993). At least 25 different crops have been recorded as being attacked by *T. hawaiiensis*. Known hosts include:

Abelmoschus esculentus (okra), *Acacia confusa, Acacia farnesiana, Acacia koa*, *Medicago sativa* (alfalfa), *Aleurites moluccana*, *Anacardium occidentale* (cashew nut), *Areca catechu* (betelnut palm), asparagus, *Astelia menziesiana*, aster, avocado, *Batis maritima*, *Benincasa hispida* (wax gourd), *Brassica juncea* var. *juncea* (Indian mustard), *Brassica rapa* ssp. *oleifera* (turnip rape), *Brassica rapa* subsp. *chinensis* (Chinese cabbage), *Cajanus cajan* (pigeon pea), *Camellia sinensis* (tea), *Capsicum annuum* (bell pepper), *Chrysanthemum vestitum*, *Cicer arietinum* (chickpea), *Citrus* sp., *Coffea arabica* (arabica coffee), Cucurbitaceae, *Gladiolus hybrids* (sword lily), *Psidium guajava* (guava), *Helianthus annuus* (sunflower), *Hibiscus, Jasminum sambac*, *Malus sp* (apple), *Mangifera indica* (mango), *Momordica charantia* (bitter gourd), *Musa* (banana), *Musa x paradisiaca* (plantain), Orchidaceae, *Pennisetum glaucum* (pearl millet), *Piper betle* (betel pepper), *Rosa rugosa* (Rugosa rose), *Syzygium samarangense* (water apple), *Tagetes erecta* (African marigold), *Telosma cordata*, *Vitis vinifera* (grapevine), *Zea mays* (maize) (CPC 2007; Mau and Martin 1993; Srivastava and Bhullar 1980).

9.2.4. Distribution

T. hawaiiensis is found throughout Asia, parts of Africa, southern and western North America, Mexico and Jamaica. In the Pacific it is in Australia, Fiji, Guam, Norfolk Island, Papua New Guinea, Samoa, Midway Island (CPC 2007).

There is a record from Campbell Island, New Zealand (1961) which states "seemingly represents hawaiiensis". It is unlikely it would survive subantarctic conditions as *T. hawaiiensis* current range is tropical to subtropical climates. Given this is a tentative identification and there are no other records for New Zealand it is not considered present.

9.2.5. Hazard identification conclusion

Given that *Thrips hawaiiensis*:

- is not known to be present in New Zealand;
- is present in Samoa;
- will oviposit on *Citrus* fruit and flowers;
- is a highly polyphagous and fecund pest species in the tropics and subtropics;

Thrips hawaiiensis is considered a potential hazard on fresh Citrus fruit from Samoa.

9.3. Risk assessment for *T. palmi* and *T. hawaiiensis*

9.3.1. Entry assessment

As eggs of *T. palmi* are deposited on leaves it is unlikely eggs will enter New Zealand. However, larvae and adults are found on fruit surfaces, and can seek shelter under the calyx of *Citrus* fruit.
The association of *T. hawaiiensis* with *Citrus* is primarily with the flower and with young *Citrus* fruit. As *Citrus* species can bloom throughout the year (Timmer 2000), it is likely larvae and adults of this species could be associated with the commodity as during the intended harvest season (summer) fruit and flowers are on the tree at the same time.
T. palmi is not easily detectable because of its small size, and is likely to be difficult to detect in low density situations. *T. hawaiiensis* is also very small and not readily detectable.
Likelihood of entry for *T. palmi* or *T. hawaiiensis* is considered to be high.

9.3.2. Exposure assessment

Given the polyphagous nature of both thrips species there will be potential hosts near any of the likely places of fruit disposal. Urban and rural areas will have most of the common hosts for both species such as cucurbits, *Citrus*, camellias, daisies, apple trees, avocados and capsicums. Thrips are weak fliers but can be blown long distances by wind (Lewis 1997).
The likelihood of exposure for both species is considered to be high.

9.3.3. Establishment assessment

Thrips palmi is likely to survive and establish populations if it were to arrive in New Zealand, particularly in mid-summer (Stephens and Dentener 2005). Using DYMEX modelling software, predictions have been made that indicate *T. palmi* would survive and develop all year round in Auckland and Kerikeri. Tauranga is slightly cooler therefore numbers would likely decline over the winter but still be sufficient to generate populations in the spring. Napier, Nelson and Christchurch regions experience frosts and are considerably colder so *T. palmi* is not predicted to establish long term field populations (Stephens and Dentener 2005). However, if *T. palmi* established in greenhouses, these overwintering populations could be founders for summer field populations, as it has happened in Japan (Stephens and Dentener 2005). *T. hawaiiensis* has lower optimal temperatures for development than *T. palmi* and unlike other flower thrips *T. hawaiiensis* prefers wet and shady areas (Sakimura and Krauss 1944). Therefore it is concluded it could survive and establish in New Zealand, most likely with a greater range of distribution than *T. palmi*.
The likelihood of establishment for both species is high.

9.3.4. Consequence assessment

9.3.4.1 Economic impact

T. palmi is known to build up heavy infestations rapidly, their gregarious feeding habits causing severe injury. To date there are few cultural methods known that are highly effective in controlling this species, and it is resistant to most insecticides (Martin and Mau 1992). Additionally *T. palmi* is noted as a resurgence pest reinvading with vigour after heavy insecticide usage.

The agricultural industry (maize), garden nursery industry and cut flower industry, are all likely to suffer some impact from either species through reduced quality and yields, and cost

of control. Flower loss from thrips damage also means reduced fruit set and this would impact on horticulture and viticulture sectors.

MacLeod *et al*. (2004) state revenue from lost exports is the single largest impact that could result from *T. palmi* establishing in England and go on to say "data from Australia provide an example of how *T. palmi* can reduce plant exports. *T. palmi* has a limited distribution in Australia. It was first recorded in the Northern Territory (NT) in June 1989. The Australian Quarantine and Inspection Service decided eradication would not be feasible and *T. palmi* became established and spread. In 1988 horticultural exports from NT were worth around Au$7 M. By 1992 exports had fallen to just over Au$2 M, not only due to damage to crops by *T. palmi*, but also due to quarantine measures imposed within Australia by other states (AAS 1996)."

The closure of export markets generally means that produce that would usually be exported would be fed into domestic markets increasing supply and lowering prices overall.

Although *T. hawaiiensis* may confer some pollination benefits these are very unlikely to offset the potential negative impacts.

The economic consequences of establishment are considered to be high.

9.3.4.2 Environmental impact

T. hawaiiensis is associated with plants in genera or families in which there are New Zealand natives represented, such as *Astelia,* Piperaceae, Rutaceae and Myrtaceae. Given the polyphagous nature of both thrips, it is assumed *T. palmi* and *T. hawaiiensis* would find a number of New Zealand plant species palatable.

Of particular concern is the impact *T. palmi* and *T. hawaiiensis* could have on plants in the Orchidaceae family, 20 species of which are listed by the New Zealand Plant Conservation network as sparse (11), national critical (4), serious decline (3) and range restricted (2).

Severe infestations of *Thrips palmi* and *Thrips hawaiiensis* are likely to damage flowers, leading to flower drop and a reduction of seeds, and possibly the death of the plant. This could in turn adversely affect species of native fauna that feed on pollen, nectar and seeds.

Beever *et al.* (2007) comment that phytophagous thrips in New Zealand are predominantly exotic and often highly polyphagous, yet only two species- one a specialist and one highly polyphagous, and both from Australia- have been recorded from native plants. They also say that although some of the introduced thrips are pests overseas they are rarely pests in New Zealand as the prolonged dry weather required to produce large populations occurs infrequently. As Sakimura and Krauss (1944) observed that *T. hawaiiensis* showed a preference for wet and shady areas, this species may find some New Zealand forest conditions acceptable.

It is uncertain what degree of competition could exist between native thrip species and *T. palmi* and /or *T. hawaiiensis*.
The environmental consequences of establishment are uncertain but non negligible.

9.3.4.3 Human health and social impact

Thrips can cause thysanoptera dermatitis by biting through human skin and sucking the epidermal lymph. The lesions formed are small, pink and itchy, often mistaken for mosquito bites. Thysanoptera dermatitis is not harmful and will resolve in a few days by itself (Leigheb *et al*. 2005).
Establishment of *T. palmi* and *T. hawaiiensis* would have adverse affects on amenity plantings and home gardens due to damage, cost and difficulty of control. Although it is uncertain the degree of impact this would have it is considered to be non negligible.

9.3.5. Risk estimation

The likelihood of *T. palmi* and *T. hawaiiensis* entering the country, being exposed to suitable hosts and establishing is high. The consequences of establishment are high. The risk estimation for *T. palmi* and *T. hawaiiensis* is non negligible therefore these organisms are classified as hazards in this commodity and risk management measures can be justified.

9.4. Risk management for *T. palmi* and *T. hawaiiensis*

9.4.1. Options

There are a number of points on the import pathway where effective measures could be applied to reduce the likelihood of *T. palmi* and *T. hawaiiensis* arriving in New Zealand.

9.4.1.1 Post harvest culling, washing, waxing and visual inspection

The post-harvest washing of fruit followed by visual inspection is a supplementary measure to be implemented in conjunction with the chosen disinfestation treatment to reduce pest numbers in fruit for export.
Citrus fruit harvested for export to New Zealand should be free from any scabbing, holes, cracks or damage to the skin, free from any abnormal discoloration and pests or pathogens. Thrips damage should be visible and damaged fruit discarded.
Both thrips species are very small as adults and larvae (<1.2mm) and whilst they only occur on the surface of the fruit, they may shelter under the fruit calyx escaping detection by visual inspection. Washing may dislodge some thrips but it may not be effective in removing any sheltering under the calyx. Waxing is more likely to repel or kill some thrips remaining on the fruit (please refer to section 5.3). However there are no efficacy data specific to thrips with regard to waxing.

9.4.1.2 High temperature forced air

There are no specific efficacy data for the disinfestation of thrips on *Citrus* fruits by HTFA. Cowley *et al*. (1992) conducted mortality tests using dry heat with 55-60% RH (HTFA) at 47˚C for 10 minutes on the thrips *Heliothrips haemorrhoidalis* (adults). From the 30 individuals tested at that temperature there were no survivors. This means the ED =90.0000%, which is the estimated effect of this treatment on a population of *Heliothrips haemorrhoidalis* at 95%CL (as per Couey and Chew 1986).
This research was to assess the feasibility of disinfesting persimmons of this species.

It could be anticipated that the treatment for *Citrus* would be similarly efficacious.

For *Citrus* except lemons and limes: high temperature forced air treatment raising the internal temperature of the commodity from ambient temperature to 47.2˚C for a minimum of 20 minutes with the total treatment time being at least 4 hours or longer.
(**NB**. This is an approved treatment by the USDA-PPQ; however they note that of all *Citrus* tested to date, grapefruit has shown the highest tolerance for this treatment and specific cultivars should be tested to determine their tolerance to HTFA at this time/temperature regime.)

Please refer to Section 5.5.9 and 5.5.10 for detail of issues surrounding HTFA

9.4.1.3 Hot water immersion

Gould and McGuire (2000) found that all the insects infesting the limes they tested were killed after a hot water immersion at 49˚C for 20 minutes. This included small numbers of Thysanoptera as mentioned in Section 5.5. The tolerance of *Citrus* other than limes for this treatment is uncertain.
Thrips obscurata on stone fruit for export from New Zealand has been successfully treated by hot water dip at 50˚C for 2 minutes or 48˚C for 3 minutes. Using naturally infested fruit at 50˚C for 2 minutes, 99.8% of adults, 100% of larvae and 99.65% of eggs were killed (McLaren *et al.* 1997).

9.4.1.4 Cold disinfestation

There are no efficacy data for disinfestation of *Citrus* for thrips by this treatment.
T. palmi has been reported overwintering in unheated glasshouses at sub-zero temperatures (Nagai and Tsumuki 1990). Therefore cold disinfestation would not be a sufficiently effective measure because there would be uncertainty as to the level of residual risk after such a treatment.

9.4.1.5 Visual inspection at the border

Both species of thrips are particularly small (adult *T. palmi* are less than 1mm long) and detection larvae and adults by visual inspection of the consignment on arrival in New Zealand would be difficult especially if the thrips are in low densities and can seek shelter under the fruit calyx.

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10. Mites

10.1. *Tetranychus neocaledonicus* (vegetable mite)

10.1.1. Hazard identification

Scientific name: *Tetranychus neocaledonicus* André
Synonyms or changes in taxonomy or combination: *Tetranychus cucurbitae, Eotetranychus neocaledonicus, Tetranychus equatorius*
Taxonomic position: Acari: Tetranychidae
Common names: vegetable mite, Mexican spider mite
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: ESNZ 1977; Manson 1987; Ramsey 1980; PPIN (18/4/2007); Zhang *et al*. 2002

10.1.2. Biology

Adult *Tetranychus neocaledonicus* are usually about 0.5mm in size and carmine red in colour (Martin and Mau, 1991).

Fertilized females overwinter on secondary hosts (weed species), and with the onset of warmer weather they start to breed rapidly and move to cultivated hosts, usually cucurbits (Jeppson *et al.* 1975). Eggs are usually laid on the underside of leaves (commonly along the mid-vein) in webbing. Newly hatched larvae have a short quiescent period then moult to the first of two nymphal stages (Kambrekar and Nandihalli, 2003). The life cycle can take as little as 10 days in optimal conditions (Jeppson *et al.* 1975) (Table 12). Mating can take place immediately after the females emerge. This species is also parthenogenic (Shaw and Devroy 1995). A female *T. neocaledonicus* can lay up to 90 eggs during her lifetime (Jeppson *et al.* 1975).

The overall optimal temperature for development of *T. neocaledonicus* is 30˚C. At temperatures over 20˚C development is faster but mortality at all life stages increased. The mite could not survive at temperatures beyond 37˚C (Pande and Sharma 1986) and displayed preference for conditions of low (45-50%) relative humidity (Pillai and Jolly 1986).

Diapause in tetranychids is thought to be facultative and controlled by temperature, photoperiod and nutrition (Jeppson *et al.* 1975). Immature stages of *T. urticae* that were exposed to diapause-inducing conditions then went into diapause (Parr and Hussey 1966). This is very likely to apply to other phytophagous mite species that overwinter in the adult stage (Jeppson *et al*. 1975), such as *T. neocaledonicus.*

Some tetranychid mites lay two kinds of eggs. One kind hatches soon after laying, the other kind are diapausing eggs, laid when changing weather or host plant conditions mean the mite has to adjust to survival stages (Jeppson *et al*. 1975).

There have been numerous reports of diapausing females withstanding very low temperatures. An extreme example in the literature is from Bondarenko (1958a, cited in Jeppson *et al.* 1975) who found 85-90% of tetranychid mites in outdoor sheds survived temperatures of -27˚C but died at -32˚C.
Pande and Yadava (1976) indicate the thick webbing produced by *Tetranychus* spp. they surveyed (including *T. neocaledonicus*) protects these mites from temperature extremes (in Rajasthan, India this is 40˚C in summer to -3˚C in winter).

Pande and Reddy (1985) observed that host plants affect fecundity and life cycle duration. The highest mean fecundity (54.8 fertilised eggs/female) was on pumpkin, *Cucurbita moschata*, with a complete life cycle in females taking 13.5 days. On *Luffa acutangula* (ridge gourds) the life cycle was 15.4 days and on *Lagenaria siceraria* (bottle gourds) it took 16.1 days. As an adult the female may live about 19 days (Martin and Mau 1991).

Up to 32 generations of *T. neocaledonicus* per year can occur under ideal conditions (Jeppson *et al.* 1975).

Table 12 Duration in days for each life stage of *Tetranychus neocaledonicus* under laboratory conditions on aubergine (temperatures not given) (based on Kambrekar and Nandihalli 2003 and Martin and Mau 1991).

Life stage	Duration (in days)
Egg	3.5-4.0
Larva	1.5-2.5
Protonymph	1.0-2.0
Deutonymph	1.0-1.5
Adult	F:19.0, M:14.0
Total life cycle (egg to adult emergence)*	7.0-10.0

* the whole life cycle can take 12-23 days depending on temperature (Martin and Mau 1991)

Tetranychid mites have various methods of dispersal to other plant hosts. They may crawl, disperse aerially (carried on air currents by silk threads) or disperse accidently (ie. via farm machinery) (Helle and Sabelis 1985). Most *Tetranychus* species are not known to balloon but will position themselves on the plant so that they can be caught by the wind. This usually occurs in high density populations with food shortage (Jeppson *et al* 1975).

10.1.3. Hosts

T. neocaledonicus will attack the leaves, twigs and fruits of *Citrus* species. These mites commonly attack ripe fruit rather than green fruit (Martin and Mau 1991).
T. neocaledonicus attacks over 110 different plant species comprising flowers, fruits, vegetable and field crops throughout the subtropical and tropical regions of the world. *Solanum melongena* (aubergine) is the major host. Other hosts include; *Abelmoschus esculentus* (okra); *Arachis hypogaea* (groundnut); *Carica papaya* (papaya); *Cocos nucifera* (coconut); *Cucumis sativus* (cucumber); *Cucurbita*; *Eucalyptus*; *Lactuca sativa* (lettuce); *Leucaena*; *Luffa acutangula* (angled luffa); *Luffa aegyptiaca* (loofah); *Mangifera* sp. (mango); *Manihot esculenta* (cassava); *Morus* (mulberrytree); *Musa* (banana); *Phaseolus vulgaris* (common bean); *Prunus persica* (peach); *Solanum tuberosum* (potato); *Trifolium* sp.(clover); *Vigna unguiculata* (cowpea). Chrysanthemum, hibiscus, roses and various ornamentals are also hosts (CPC 2007; Jeppson *et al*. 1975; Martin and Mau 1991).

10.1.4. Distribution

This mite has a wide distribution throughout subtropical and tropical areas that include Asia, Africa, USA, Central and South America, Australia, American Samoa, Fiji, New Caledonia, Papua New Guinea, Samoa (Bolland *et al.* 1998; CPC 2007; Jeppson *et al*. 1975; CSIRO 2004; Martin and Mau 1991)

10.1.5. Hazard identification conclusion

Given that *Tetranychus neocaledonicus*

- is not known to be present in New Zealand;
- is present in Samoa;
- and is reported to occur in association with *Citrus* fruit;

Tetranychus neocaledonicus is considered a potential hazard on this pathway.

10.2. Risk assessment

10.2.1. Entry assessment

Mites are small and can shelter under the calyx of *Citrus* fruit (Gould and McGuire 2000). Adult *T. neocaledonicus* can live up to about 19 days so would easily survive the time from harvest in Samoa to distribution in New Zealand (approximately 24-48 hours when freighted by air).

Mites have frequently been intercepted on *Citrus* fruit at the New Zealand border. At least 259 of the 1473 consignments of *Citrus* arriving in New Zealand from January 2005 to June 2006 were infested with mite species of varying life stages (MAF unpublished data). Although *T. neocaledonicus* is reported to be associated with *Citrus* fruit this is not its preferred host. Therefore the likelihood of *T. neocaledonicus* entering New Zealand on fresh *Citrus* fruit is medium.

10.2.2. Exposure assessment

The most likely route for exposure will be by peel or poor quality fruit discarded on compost or into the environment. This species is mobile and may crawl onto other hosts, or climb a plant to be carried by the wind. As clover is a host for this species, and it grows on most pasture, wastelands and lawns, the likelihood of exposure is considered to be high.

10.2.3. Establishment assessment

The available information indicates *T. neocaledonicus* is markedly affected by temperature, humidity and food, showing it to be sensitive to changes in any of these factors (Pande and Sharma 1986; Pillai and Jolly 1986; Pande and Reddy 1985). This typically manifests as reduced fecundity, higher mortality at particular life stages or slower development.

The overall optimal temperature for development of *T. neocaledonicus* is 30˚C (Pande and Sharma 1986). There is no information on the lower thermal threshold for *T. neocaledonicus* and this study didn't test below 20˚C. However Pande and Yadava (1976) report results of a survey carried out in Rajasthan, India, where summer temperatures rise to 40˚C and winter temperatures fall to -3˚C. This infers *T. neocaledonicus* can survive these low temperatures. The subtropical congener *T. evansi* was shown to have a developmental range of 10˚C to more than 36˚C (Bonato 2004). As the biology of *T. evansi* as described by Jeppson *et al.* (1975) is very similar to *T. neocaledonicus*, it is considered that this lower developmental threshold may be similar for *T. neocaledonicus*. Females can enter diapause in adverse conditions so it is highly likely this species could survive in New Zealand.

Therefore, considering the likely temperature tolerances, the ability to enter diapause and that the species is also able to reproduce parthenogenetically *T. neocaledonicus* could establish in New Zealand, but mostly in warm regions. As the conditions in New Zealand are not optimal it is unlikely there would be the rapid population increases that can occur in hotter climates. The likelihood of establishment is considered to be medium.

10.2.4. Consequence assessment

10.2.4.1 Economic impact

Damage, in the form of chlorosis, can be caused to the leaves, twigs and fruit of host plants (Martin and Mau 1991). Leaf drop is also common, as mites suck the plant sap causing wilting, drying and eventually dropping of the leaf (Jeppson *et al.* 1975; Smith *et al.* 1997). Growth, flowering and fruit yield is also adversely affected by mite damage to host plants (Helle and Sabelis 1985; Jeppson *et al.* 1975). Infestations would affect agricultural, forestry, horticultural and nursery sectors. Conditions in New Zealand are not optimal for development of heavy infestations. Therefore the economic consequences of establishment are considered to be medium.

10.2.4.2 Environmental impact

T. neocaledonicus could potentially find hosts in the Myrtaceae which is represented by a few New Zealand natives including *Leptospermum, Metrosideros* and *Lophomyrtus* species. As it is a polyphagous species it is likely to find a number of native New Zealand species palatable. *T. neocaledonicus* is not likely to find conditions favourable to rapid population growth so it is uncertain the degree of impact establishment of this mite would have.

10.2.4.3 Human health and social impact

There are numerous reports of respiratory allergy due to exposure to *Tetranychus urticae* (Acari: Tetranychidae), in particular in horticulture and farm workers (e.g. Astarita *et al*. 2001; Kronqvist *et al*. 2005). No evidence appears to exist to indicate that similar impacts on human health are caused by *T. neocaledonicus*. In addition, *T. urticae* is not only extremely widespread throughout New Zealand, but is also known to infest a very wide range of hosts (Zhang *et al*. 2002). As a result, even if *T. neocaledonicus* was capable of causing respiratory allergy in humans, it would be unlikely to cause any additional impact on human health in view of the existing exposure to *T. urticae*, therefore the human health consequences are considered negligible.

10.2.5. Risk estimate

The likelihood of entry of *T. neocaledonicus* is medium, exposure is high and establishment is medium. The consequences of establishment are medium.
The risk estimate for *T. neocaledonicus* is non negligible therefore this organism is classified as a hazard in this commodity and risk managemnet measures can be justified.

10.3. Risk management

10.3.1. Options

There are a number of points on the import pathway where effective measures could be applied to reduce the likelihood of *T. neocaledonicus* arriving in New Zealand.

10.3.1.1 Post harvest culling, washing, waxing and visual inspection

The post harvest washing of fruit followed by visual inspection is a supplementary measure to be implemented in conjunction with the chosen disinfestation treatment to reduce pest numbers in fruit for export.

Citrus fruit harvested for export to New Zealand should be free from any scabbing, holes, cracks or damage to the skin, free from any abnormal discoloration and pests or pathogens. Mite damage, especially when extensive is detectable and the fruit should be discarded. Although the mite is very small, visual inspection may detect it, as it is a bright carmine red colour. However, red-green colourblind individuals may be less effective in detecting these mites on green fruit, and the mite is able to shelter under the fruit calyx thus escaping detection.

Washing may remove some mites from the fruit surfaces, but may not remove those under the calyx. Surfactants may assist in removing mites from under the calyx. Waxing is more likely to repell or kill some mites remaining on the fruit (please refer to section 5.3). However there are no efficacy data specific to mites with regard to waxing therefore residual risk is uncertain.

10.3.1.2 High temperature forced air

There are no specific efficacy data for the disinfestation of mites from *Citrus* fruit by HTFA. Waddell *et al.* (1993) found it took 10.9 hours at 45˚C to achieve 99% mortality of *Tetranychus urticae* (a particulary difficult mite to kill as it is very hardy) using "hot air", although the method they employed is not comparable to HTFA. *T. neocaledonicus* is reported to not survive at temperatures beyond 37˚C (Pande and Sharma 1986) and displayed preference for conditions of low (45-50%) relative humidity (Pillai and Jolly 1986).
HTFA treatment takes about 4-6 hours to get the air temperature a degree or two higher than the required (47.2˚C) core temperature of the fruit for fruit fly disinfestation, therefore HTFA at 47.2˚C for 20 minutes is likely to kill *T. neocaledonicus* on the fruit surface with a low likelihood of survivors.

For *Citrus* except lemons and limes: high temperature forced air treatment raising the internal temperature of the commodity from ambient temperature to 47.2˚C for a minimum of 20 minutes with the total treatment time being at least 4 hours or longer.
(**NB**. This is an approved treatment by the USDA-PPQ; however they note that of all citrus tested to date, grapefruit has shown the highest tolerance for this treatment and specific cultivars should be tested to determine their tolerance to HTFA at this time/temperature regime.)

Please refer to Section 5.5.9 and 5.5.10 for detail of issues surrounding HTFA

10.3.1.3 Hot water immersion

As discussed in Section 5.6, Gould and McGuire (2000) found hot water immersion for 20 minutes at 49˚C killed all arthropods on limes, including mites found externally and under the calyx. It is likely HWI at 49˚C for 20 minutes will be effective against *Tetranychus neocaledonicus* as it is reported not to survive temperatures above 37˚C (Pande and Sharma 1986) The tolerance of *Citrus* other than limes for this treatment is uncertain.

10.3.1.4 Cold disinfestation

There are no efficacy data for disinfestation of mites by cold treatment. Given that it seems this mite may be able to tolerate low temperatures for an extended period of time this treatment may not be suitable, resulting in high levels of residual risk.

10.3.1.5 Visual inspection at the border

The life stages of *T. neocaledonicus* are very small (the adults are about 0.5mm). Although the adult is brightly coloured, because adults and nymphs can seek shelter under the calyx they may be difficult to detect by visual inspection of the consignment on arrival in New Zealand. If the mite is in low frequencies this will also reduce the likelihood of detection.

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11. Whitefly

11.1. Hemiptera: Aleyrodidae

Aleurodicus dispersus Russell-spiralling whitefly
Parabemisia myricae Kuwana- Japanese bayberry whitefly
Paraleyrodes bondari Peracchi-whitefly

The six species of whitefly considered in this document are associated with *Citrus* species (Mound and Halsey 1978). Only three species are known to be associated with *Citrus* fruit. Where populations reach high numbers it is possible for whitefly not usually associated with fruit to infest fruit (pers. obs.). Therefore it would be worthwhile identifying any whitefly found on *Citrus* fruit to see if they are of the species listed in Appendix 1 thus removing the uncertainty around association. This is particularly important regarding *Bemisia tabaci* biotype B 'Nauru', which is not present in New Zealand and can potentially vector viruses not present in New Zealand.

11.1.1. Introduction

Whiteflies are small, sap-sucking insects related to aphids, scale and mealybugs. There are 6 lifestages: egg, crawler, 2 nymphal stages, pupa and then the adult. The adults resemble tiny moths and congregate on the undersides of leaves. They fly readily if disturbed. The nymphal stages are sessile, fixed by their mouthparts to the leaves. Both adults and nymphs produce honeydew. Whiteflies also produce wax which starts in small amounts with the crawler once it settles to feed, then more obviously from nymphs, pupae and adults (Smith *et al*. 1997; Gerling 1990). Whiteflies are usually pests of agricultural or horticultural crops because they can vector viruses and secrete honeydew which provides a growing medium for fungi.

Aleurodicus dispersus is not known to be present in New Zealand (PPIN 1/2/2008) and is present in Samoa (de Barro *et al*. 1997). It is also recorded from Portugal, Spain, Africa India, Taiwan, Southeast Asia, Central and South America, Florida, Hawaii, Australia and some Pacific Islands (CPC 2008).
A. dispersus is known to lay eggs on fruit. Mated females produce offspring of both sexes and unmated females produce only males (CPC 2008). Population growth can be rapid. The species is highly polyphagous and hosts include: *Citrus* spp., *Prunus* spp., coconut, avocado, guava, *Capsicum*, melons, tomatoes lettuce, sweet potato and ornamentals (CPC 2008)

Paraleyrodes bondari is not known to be present in New Zealand (PPIN 1/2/2008; USDA whitefly 1/2/2008) and is present in Samoa (de Barro *et al*. 1997). It is also recorded from Hawaii, Taiwan, California, Florida, Belize, Brazil, Honduras, Venezuela, Madeira Islands, Mauritius Islands, Reunion Island (USDA whitefly 1/2/2008).
P. bondari is native to Brazil and has spread into the Pacific. It is associated with leaves and fruit (Walker 2007). Hosts include *Citrus* spp, coconut, vanilla, banana, guava, and ornamentals (Walker 2007). NOTE: Very little information in English has been found on the biology of this whitefly. Until there is clarification a precautionary approach is taken and *P. bondari* has been included as a potential hazard in this document

A full assessment is presented on *Parabemisia myricae.* It is expected that any measures that are considered for *P. myricae* will also effectively cover the other whitefly included in this analysis.

11.2. *Parabemisia myricae* (Japanese bayberry whitefly)

11.2.1. Hazard identification

Scientific name: *Parabemisia myricae* Kuwana
Synonyms or changes in taxonomy or combination: *Bemisia myricae*
Organism type: insect
Taxonomic position: Hemiptera: Aleyrodidae
Common name: Japanese bayberry whitefly
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: ESNZ 1977: Spiller and Wise 1982; PPIN (30/5/2007); Scott and Emberson 1999
Pathogens vectored: Citrus chlorotic dwarf virus (Korkmaz *et al.* 1995).

11.2.2. Biology

P. myricae adults are whitish-yellow to dusty grey-lavender in colour with opaque wings. They are 0.92-1.42mm long. Larvae are translucent, white to yellowish, difficult to see until they reach the pupal stage which is 0.89-0.97mm long.

P. myricae reproduces by parthenogenesis and males are rare (Rose *et al.* 1981 in: Smith *et al.* 1992). Eggs are laid on leaf margins or upper surfaces of young leaves (Walker and Aitken 1985), fruit and green wood (Smith *et al.* 1992). There are four instars prior to adulthood. First instars or crawlers are mobile and move to the lower leaf surface settling to feed. Subsequent pre-adult stages are sessile, being fixed to the leaf by their mouthparts. Depending on environmental conditions the development time from egg to adult varies from 22-80 days, with development slowest at 15˚C and fastest at 30˚C. Mortality rates increase at higher temperatures and low humidity (RH 40%), but are lower at moderate temperatures and high humidity (25˚C and RH 90%) (Walker and Aitken, 1985; Orphanides, 1991; Uygun *et al*.,1993).

In Cyprus under field conditions Orphanides (1991) observed that *P. myricae* could have up to 9 generations per year on *Citrus*, and this species overwintered in an early larval stage.

P. myricae larvae produce honeydew which attracts sooty moulds and ants to the host plants. The larvae have a waxy exterior that reduces their susceptibility to chemical sprays (CPC 2007).

11.2.3. Role as vector

P. myricae can vector citrus chlorotic dwarf virus (Korkmaz *et al.* 1995), but it is not known if this particular virus (regulated in New Zealand) is present in Samoa.

11.2.4. Hosts

Primarily a pest of *Citrus*, *P. myricae* is also recorded from *Cinnamomum camphora* (camphor laurel), Cucurbitaceae (cucurbits), *Diospyros kaki* (persimmon), *Eriobotrya japonica* (loquat), *Morus alba* (mora), *Pyrus* (pears), *Camellia sinensis* (tea), *Coffea* (coffee), *Ficus carica* (fig), *Gardenia jasminoides* (cape jasmine), *Lycopersicon esculentum* (tomato), *Murraya koenigii* (curry leaf tree), *Myristica fragrans* (nutmeg), *Persea americana* (avocado), *Prunus avium* (sweet cherry), *Prunus domestica* (plum), *Prunus persica* (peach), *Prunus salicina* (Japanese plum), *Psidium guajava* (guava), *Betula* (birches), *Hibiscus* (rosemallows), *Persea*, *Rhododendron* (Azalea), *Salix* (willow), *Vitex* (CPC 2007)

11.2.5. Distribution

P. myricae has a scattered distribution through Asia, Africa and Europe. It is also found in California, Florida, Hawaii, Venezuela, Papua New Guinea (Smith *et al* 1997b; CPC 2007) and Samoa (de Barro 1997).

11.2.6. Hazard identification conclusion

Given that *Parabemisia myricae, Aleurodicus dispersus* and *Paraleyrodes bondari*

- are not known to be present in New Zealand;
- are present in Samoa;
- are associated with *Citrus* fruit;
- and *P. myricae* vectors a regulated virus that is not present in New Zealand;

Parabemisia myricae, *Aleurodicus dispersus* and *Paraleyrodes bondari* are considered potential hazards for the purpose of this risk analysis.

11.3. Risk assessment

11.3.1. Entry assessment

The eggs and nymphs of whitefly are very small and difficult to detect.
Although young leaves are preferred, both eggs and nymphs of *P. myricae* are occasionally found on *Citrus* fruit. *P. myricae* adults tend to fly at dawn and dusk (Meyerdirk and Moreno 1984) and it is unlikely adults disturbed at harvest might resettle on picked fruit.

Eggs of *Aleurodicus dispersus* are sometimes laid on fruit (CPC 2008), so it is likely nymphs will also be found there. Adult *Aleurodicus dispersus* are active in the morning (Waterhouse and Norris 1989), which tends to be the time of harvest, so it is unlikely adults will enter on fruit.

Paraleyrodes bondari is expected to behave similarly by laying eggs occasionally on fruit and therefore presence of nymphs will also be occasional. Behaviour of the adult is uncertain.
The likelihood of entry of eggs and nymphs of *Parabemisia myricae*, *Aleurodicus dispersus* and *Paraleyrodes bondari* is considered to be low but non negligible.

11.3.2. Exposure assessment

Most whitefly actively disperse as crawlers and flying adults. Crawlers usually move a few millimetres from their hatch site (Gerling 1990), but can be caught by air currents and then carried some distance. Adult whiteflies can disperse over distances of several kilometres by air currents (Costa 1975, in: Gerling 1990). There are sufficient hosts for *Parabemisia myricae, Aleurodicus dispersus* and *Paraleyrodes bondari* in urban or rural areas. The likelihood of exposure is considered to be medium.

11.3.3. Establishment assessment

It is uncertain what the lowest temperature threshold is for development of *P. myricae*. A degree-day model used by Walker and Aitken (1993) in California adopted the figure of 12.8˚C. Uygun *et al*. (1993) showed that *P. myricae* would complete development at 15˚C and the optimal temperature for development is 25˚C in high humidity. Therefore it is likely *P. myricae* could establish in northern North Island (above 38˚S) with small localised populations surviving the winter.

In Taiwan the estimated temperature thresholds for development of *Aleurodicus dispersus* vary from 4.6˚C for eggs to 9.8˚C for 3rd and 4th instars, and adult survival is reduced at temperatures below 5˚C (Wen *et al.* 1994). The adults are active at 12-32˚C and the mean fecundity (28 eggs/female) is highest at 25˚C (Cherry 1979). Below 10˚C there is extreme mortality of *A. dispersus* in Florida which limits its northward spread (Cherry 1979).

It is uncertain what the temperature thresholds are for *Paraleyrodes bondari* development. Given that its distribution is largely tropical to subtropical it is assumed it would survive in the north of the North Island, with small isolated populations overwintering in warm microclimates.

The likelihood of establishment for *P. myricae, Aleurodicus dispersus and Paraleyrodes bondari* is considered to be medium.

11.3.4. Consequence assessment

11.3.4.1 Economic impact

Whiteflies usually feed on the undersides of leaves, tapping into the phloem thus causing direct damage to host plant by nutrient removal leading to leaf wilt and drop. Whiteflies produce honeydew which favours the development of sooty mould. This results in a loss of plant vigour through reduced ability to photosynthesize, unsightly appearance and loss of market value for produce. Honeydew secretion encourages ant attendance which can disrupt the work of natural enemy biocontrols in IPM programmes. Introduction of new viruses to the horticultural sector would reduce crop yields and affect export volumes. Costs associated with control of the vectors would impact adversely upon the horticultural and nursery sectors, and control of whitefly is complex and difficult, with resistance to pesticides commonly observed.

Crops likely to be affected include *Citrus*, stonefruit, pipfruit, tomatoes, avocado, persimmons, cucurbits, and a number of ornamentals like birches, camelias and azaleas and roses.

The economic consequences of establishment of these whiteflies are considered to be high.

11.3.4.2 Environmental impact

It is uncertain what the impact would be on native plants in New Zealand. However, as there are numerous exotic species that are natural hosts to *P. myricae, A. dispersus* and *Paraleyrodes bondari* it is considered the environmental impact from establishment would be low but non negligible.

11.3.4.3 Human health and social impact

These species are not known to be of any significance to human health. The impact on domestic gardeners through loss of yield and cost and difficulty of control is uncertain but non negligible.

11.3.5. Risk estimation

The likelihood of *Parabemisia myricae, Aleurodicus dispersus* and *Paraleyrodes bondari* entering the country is low, being exposed to suitable hosts and establishing is medium. If they were to establish the consequences would be medium to high. The risk estimation for

Parabemisia myricae, Aleurodicus dispersus and *Paraleyrodes bondari* is non negligible therefore these organisms are classified as hazards in this commodity and risk management measures can be justified.

11.4. Risk management

11.4.1. Options

There are a number of points on the import pathway where effective measures could be applied to reduce the likelihood of *P. myricae, A. dispersus and Paraleyrodes bondari* arriving in New Zealand.

11.4.1.1 In field sanitation

In field sanitation by removal of alternative host species such as weeds in the *Citrus* orchards will assist in reducing pest populations.

11.4.1.2 Post harvest culling, washing, waxing and visual inspection

Citrus fruit harvested for export to New Zealand should be free from any scabbing, holes, cracks or damage to the skin, free from any abnormal discoloration and pests or pathogens. Damaged or infested fruit should be discarded.

Whitefly eggs and nymphs are very small and may not be easily detected during visual inspection.

Washing using brushes and submerging the fruit in water is likely to remove most whitefly eggs, nymphs or pupae from the fruit. Waxing is likely to repell or kill some whitefly remaining on the fruit (please refer to section 5.3). There are no efficacy data specific to this organism with regard to washing and waxing therefore it is uncertain what proportion of whitefly would survive this treatment.

11.4.1.3 High temperature forced air

There are no efficacy data on disinfestation of whitefly on *Citrus* by HTFA. However, a vapour heat treatment by Hansen *et al.* (1992) killed aphids on tropical cut flowers after 1 hour at 46.6˚C or 2 hours at 45˚C. Therefore it is anticipated that HTFA at 47.2˚C for a minimum of 20 minutes will be effective against a similar, small soft-bodied insect

For *Citrus* except lemons and limes: high temperature forced air treatment raising the internal temperature of the commodity from ambient temperature to 47.2˚C for a minimum of 20 minutes with the total treatment time being at least 4 hours or longer.
(**NB**. This is an approved treatment by the USDA-PPQ; however they note that of all citrus tested to date, grapefruit has shown the highest tolerance for this treatment and specific cultivars should be tested to determine their tolerance to HTFA at this time/temperature regime.)

Please refer to Section 5.5.9 and 5.5.10 for detail of issues surrounding HTFA.

11.4.1.4 Hot water immersion

HWI at 49˚C for 20 minutes is effective against a number of external arthropod pests on limes (Gould and McGuire, 2000) as discussed in section 5.5 therefore may be effective against whitefly. The tolerance of *Citrus* other than limes for HWI is uncertain.

11.4.1.5 Cold disinfestation

There are no efficacy data for whitefly disinfestation by cold treatment. *A. dispersus* eggs have an estimated thermal threshold of 4.6˚C and for other lifestages this threshold is higher (Wen *et al*.1994). There is no threshold given for *P. myricae* but Orphanides (1991) noted this species overwinters in Cyprus as an early larval stage. Winters in Cyprus are reported to be mild with mean daily temperatures between 10˚C (on the central plain) and 3˚C (the higher parts of Troodos mountains) (Cyprus Meteorological Service 2008).
Therefore it could be anticipated that these very small, soft-bodied, sub-tropical or tropical invertebrates might not survive 2 weeks at a constant low temperature below 3˚C.
Cold disinfestation of *Citrus* fruit is currently:
13 days at 0˚C or below or
16 days at 1˚C + or – 0.6˚C
There is no supporting literature to suggest limes may be treated by cold disinfestation without damage to the fruit.
Please refer to Section 5.7 for further information on cold disinfestation.

11.4.1.6 Visual inspection at the border

The eggs and nymphs of whitefly are very small, and the adults are less than 1.5 mm, therefore detection by visual inspection of the consignment upon arrival in New Zealand would be difficult, especially if there are low densities of either pest.

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12. Mealybugs

12.1. Hemiptera: Coccoidea: Pseudococcidae

Mealybugs represent one family of hemipterans, the Pseudococcidae, of the superfamily Coccoidea. Mealybugs are so named for the white mealy wax covering they usually have over their bodies. They are sap sucking insects and secrete honeydew (Williams and Watson, 1990).

Six species have been identified as potential hazards. They are:
Ferrisia virgata Cockerell
Planococcus citri Risso
Planococcus minor Maskell
Pseudococcus cryptus Hempel
Dysmicoccus brevipes (Cockerell)
Dysmicoccus neobrevipes (Beardsley)
All are known to be associated with *Citrus* (Scalenet 2007)

12.2. *Ferrisia virgata* (guava/striped mealybug)

12.2.1. Hazard identification

Scientific name: *Ferrisia virgata* Cockerell
Synonyms or changes in taxonomy or combination: *Dactylopius segregatus*, *Dactylopius virgatus, Dactylopius virgatus farinosus, Dactylopius virgatus humilis*, *Dactylopius ceriferus, Dactylopius talini,*
Dactylopius dasylirii, Dactylopius setosus, Pseudococcus virgatus,
Dactylopius magnolicida, *Pseudococcus magnolicida, Pseudococcus virgatus farinosus, Pseudococcus dasylirii, Pseudococcus segregatus,Pseudococcus virgatus humilis*,
Dactylopius virgatus madagascariensis, Pseudococcus marchali, Pseudococcus virgatus madagascariensis,Pseudococcus bicaudatus, Ferrisia virgata, Ferrisiana virgata,
Heliococcus malvastrus, Ferrisiana setosus, Ferrisia neovirgata,
Dactylopius cerciferus (ScaleNet 2007)
Common name: grey mealybug**,** guava mealybug, striped mealybug (ScaleNet 2007)
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: ESNZ 1977: Spiller and Wise 1982; PPIN (12/6/2007); Scott and Emberson 1999, Cox 1987, ScaleNet 2007.
Pathogens vectored: cocoa swollen shoot virus and cocoa Trinidad virus (CPC 2007), plus a badnavirus (Bhat *et al.* 2003)

12.2.2. Biology

Adult females of *F.virgata* are oval, 5mm long, grey-yellow with two long dark dorsal stripes seen through their waxy coating. They have glassy wax threads about 4-4.5mm long projecting from their dorsum (Williams and Watson 1988)

Ferrisia virgata is now recognised as a species complex (Gullen, 2003) and has been confused with *F. malvastra*, particularly in India where both species occur. *F. virgata* and *F. malvastra* are morphologically similar until examined microscopically. Thus many of the early records of this species need verification. Granara de Willink (1991) and Williams (1996) both separated or synonymised species from the complex, clarifying the taxonomy.

Ferrisia virgata is biparental, whereas reproduction in *F. malvastra* is parthenogenetic. "*F.virgata*" females lay 109-185 eggs in their lifetime, in some cases up to 500, into an ovisac beneath their bodies (Schmutterer, 1969: in CPC 2007). In India several overlapping generations a year occur (Nayer *et al.* 1976), while three generations have been observed in Saudi Arabia (Ammar *et al.* 1979).

In a laboratory experiment conducted in Iraq, Awadallah *et al*. (1979) observed the duration of the female *F. virgata* nymphal stage averaged 43.2 days at 28.9°C and 92.6 days at 16.6°C while in males it averaged 25.4 days at 25-26.5°C. The total life span of females, from egg stage to end of adult stage averaged 76.2-154.6 days as opposed to 19-47 days in males.

The adult female overwinters in cracks and junctions of trunks and large branches and on fallen leaves (Ammar *et al.* 1979).
F.virgata is feeds on shoots, leaves and fruit and can get under the calyx of fruit (Schreiner 2000). It sucks the sap causing withering, leaf and fruit drop (CPC 2007).

12.2.3. Role as vector

In other countries *F. virgata* is known to transmit certain viruses including a badnavirus (Bhat *et al*. 2003) which shows a positive serological relationship with Banana streak virus (BSV) and Sugarcane bacilliform virus (ScBV). Banana Streak badnavirus is present in Samoa (PIPLD 3/8/2007), however, based on currently available information, this virus affects family Musaceae only (Plant Viruses Online 2007). As there does not appear to be detailed information on *F.virgata* being associated with specific viruses in Samoa that are regulated in New Zealand it will not be considered further as a potential vector.

12.2.4. Hosts

F. virgata is a highly polyphagous mealybug, known from some 150 plant species from 68 families. *Citrus* is one of its many hosts. It is recorded on *Citrus* species in Kiribati and Papua New Guinea and on guava in Samoa (Williams and Watson 1990).
Some of the main hosts are:
Abelmoschus esculentus (okra), *Acalypha* (copperleaf), *Anacardium occidentale* (cashew nut), *Ananas comosus* (pineapple), *Annona*, *Arachis hypogaea* (groundnut), *Cajanus cajan* (pigeon pea), *Carica papaya* (papaw), *Citrus*, *Coccoloba uvifera* (seaside grape), *Cocos nucifera* (coconut), *Codiaeum variegatum* (croton), *Coffea* (coffee), *Colocasia esculenta* (taro), *Corchorus* (jutes), *Cucurbita maxima* (giant pumpkin), *Cucurbita pepo* (ornamental gourd), *Dracaena*, *Elaeis guineensis* (African oil palm), *Ficus*, *Gossypium* (cotton), *Hibiscus* (rosemallows), *Ipomoea batatas* (sweet potato), *Leucaena leucocephala* (leucaena), *Litchi chinensis* (lichi), *Lycopersicon esculentum* (tomato), *Malpighia glabra* (acerola), *Mangifera indica* (mango), *Manihot esculenta* (cassava), *Manilkara*, *Musa* (banana), *Nicotiana tabacum* (tobacco), *Persea americana* (avocado), *Phaseolus* (beans), *Phoenix dactylifera* (date-palm), *Piper betle* (betel pepper), *Piper nigrum* (black pepper), *Psidium guajava* (guava), *Punica granatum* (pomegranate), *Saccharum officinarum* (sugarcane), *Solanum melongena* (aubergine), *Solanum nigrum* (black nightshade), *Theobroma cacao* (cocoa), *Vigna unguiculata* (cowpea), *Vitis vinifera* (grapevine), *Zea mays* (maize), *Zingiber officinale* (ginger) (CPC 2007)

12.2.5. Distribution

F.virgata has spread throughout the tropics but also subtropical and temperate regions. It can be found in Asia, Africa, Saudi Arabia, USA, Central and South America. It is present in

Australia, Belau, Cook Islands, Caroline Islands, Fiji, French Polynesia, Kiribati, Marshall Islands, New Caledonia, Northern Mariana Islands, Papua New Guinea, Samoa, Soloman Islands, Tonga, Tuvalu, Johnston Island, Wake Island, Vanuatu, Wallis and Futuna (CPC, 2007; Williams and Watson, 1988)

12.2.6. Hazard identification conclusion

Given that *Ferrisia virgata*:

- is not known to be present in New Zealand;
- is present in Samoa; and
- is associated with *Citrus* fruit;

F. virgata is considered a potential hazard in this risk analysis.

12.3. *Planococcus citri* (citrus mealybug)

12.3.1. Hazard identification

Scientific name: *Planococcus citri* (Risso)
Synonyms or changes in taxonomy or combination: *Coccus citri, Coccus tuliparum, Dactylopius alaterni, Dactylopius brevispinus*, *Dactylopius ceratoniae, Dactylopius citri, Dactylopius cyperi*, *Dactylopius destructor*, *Dactylopius robiniae, Dactylopius secretus, Dorthesia citri*, *Lecanium phyllococcus, Phenacoccus spiniferus*, *Planococcoides cubanensis, Planococcus citricus*, *Planococcus cubanensis*, *Planococcus cucurbitae*, *Pseudococcus brevispinus, Pseudococcus citri, Pseudococcus citricoleorum, Pseudococcus citri phenacocciformis, Pseudococcus citri var. phenacocciformis, Pseudococcus alaterni, Pseudococcus ceratoniae, Pseudococcus citri coleorum, Pseudococcus cyperi, Pseudococcus robiniae, Pseudococcus tuliparum* (ScaleNet 2007)
Common name: citrus mealybug
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: ESNZ 1977: Spiller and Wise 1982; Scott and Emberson 1999, Cox 1987
NB: This species was discovered on *Cassia fistula* (Caesalpiniaceae) during routine surveillance in Auckland on 12 April 2007. Mealybugs and egg masses were found in leaf axils. It was identified on 1 May 2007 and validated on 16 May 2007. It is now under official control and is still considered as a potential hazard in this risk assessment (PPIN 5/6/2007).
Pathogens vectored: cocoa swollen shoot virus (CPC 2007), grapevine leafroll associated virus 3 (Cabaleiro and Segura 1997), banana streak virus and cucumber mosaic streak virus (Su HongJi *et al.* 1997), *Dioscorea alata* bacilliform virus (DaBV) and *Schefflera* ringspot badnavirus (Lockhart *et al*. 1996).

Planococcus species are not easily distinguishable from one another, especially in the immature stages. A level of complexity is added with variable morphological characters in some species, as these can change depending on environmental conditions (such as temperature) and host plants (Cox 1983, 1989). *Planococcus citri* and *P. minor* have been taxonomically confused and routinely misidentified as adults are similar in appearance and share similar hosts and geographic range (Williams 1985, Cox 1989, Williams and Granara de Willink 1992, Ben-Dov 1994). Adults (females) can be identified based upon close examination of morphological characters by a taxonomist. Cox (1981, 1985, 1989) has clarified the descriptions and taxonomy of closely related mealybug species. Electrophoretic and serological techniques have been used to help distinguish between closely related species,

though much of this work has been focused on *P. citri* (Rotundo and Tremblay 1980, Williams 1985).

12.3.2. Biology

Adult female are orange-pink and covered in a powdery white wax, being oval, 1.6-3.2mm long and 1.0-2.0mm wide (Cox 1987). The male has a single pair of wings and no mouthparts (CPC 2007)

P.citri is oviparous, producing eggs two weeks after fertilisation into a fluffy posterior ovisac. Egg numbers vary: 150-200 (Cote-d'Ivoire), 20-250 (Ghana), 300 (on cocoa in Trinidad) and up to 500 (on *citrus* in California). Incubation is 2-10 days (Le Pelley 1968). Females have 3 instars before adulthood. Duration of the nymphal stages vary from 16 days in Trinidad and 32-38 days in Cote d'Ivoire and Ghana (Entwhistle 1972).

In Australia 300-600 eggs are laid in 1-2 weeks, hatching in about 1 week. In Queensland and the Northern Territory there are at least 6 generations per year whereas in South Australia and Victoria there are about 3-4 generations per year. In late spring young *P. citri* move onto *Citrus* fruit settling under the calyx or between touching fruit. They can be found in the navel of oranges from late December (Smith *et al.* 1997).

Experiments by Arai (1996) concluded the lower developmental threshold temperatures and thermal constants of *P. citri* raised on *citrus* were 7.7˚C and 401 DD (degree days) during the nymphal stage and 8.0˚C and 378 DD during the preovipositional period.
On coffee leaves under laboratory conditions females lived (egg hatch to adult death) about 115 days and males only 27 days (Martin and Mau 2007).

P. citri feeds on fruit, leaves and shoots (Meyerdirk *et al.* 1981).

12.3.3. Role as vector

From the information currently available, the viruses known to be associated with *P.citri* are either not present in Samoa, or are present in New Zealand (Mossop and Fry 1984; Pearson *et al*. 2006; PIPLD 2007), therefore the role of *P.citri* as a vector will not be considered further in this risk assessment.

12.3.4. Hosts

Citrus species, particularly *C. paradisi* and *C. sinensis*, are the preferred plant hosts of *Planococcus citri*. It is recorded from *C. grandis* in Samoa (Williams and Watson 1988).
P. citri is also recorded from *Albizia falcataria*, *Ananas comosus* (pineapple), *Annona*, *Annona muricata* (soursop), *Annona squamosa* (sugarapple), *Brassica oleracea* var. *capitata*, *Cajanus cajan* (pigeon pea), *Carica papaya* (papaw), *Ceiba pentandra, Citrus limon, C. paradisi, C. sinensis, Codiaeum variegatum* (croton), *Coffea* (coffee), *Coleus*, *Cucurbita maxima*, *C. pepo*, *Cyrtosperma chamissonis*, *Dioscorea* (yam), *Eugenia*, *Gardenia* sp., *Gossypium* (cotton), *Inocarpus* sp., *Ipomoea batata*, *Leucaena glauca, Lycopersicon esculentum* (tomato), *Macadamia integrifolia* (macadamia), *Mangifera indica* (mango), *Manihot esculenta* (cassava), *Morinda umbellata* var. *forsteri*, *Musa* (banana), *Nicotiana tabacum* (tobacco), *Ocimum* sp., *O. basilicum, Persea americana* (avocado), *Psidium guajava* (guava), *Pueraria thunbergiana, Rhus* sp., *Saccharum officinarum* (sugarcane), *Solanum* (nightshade), *Solanum tuberosum* (potato), *S. verbascifolium* var.*auriculatum*, *Theobroma*

cacao (cocoa), *Vitis vinifera* (grapevine), *Xanthium strumarium* (common cocklebur) (CPC 2007, Williams and Watson 1988).

In the Auckland Domain glasshouse *P. citri* is recorded from:
Aglaonema sp., *Dieffenbachia* sp., *Dizygotheca elegantissima, Heliconia rostrata, Hoya* sp., *Philodendron panduraeforme, Strobilanthus dyeriana* and *Synsepalum dulcificum* (PPIN 2007)

12.3.5. Distribution

P. citri occurs almost worldwide, although it seems to be absent from Canada and some Pacific Islands. CABI/EPPO 1999 note it occurs in greenhouses in southern Europe, Northern America and Southern Australia. It is present in Belau, Cook Is., Federated States of Micronesia, Fiji, French Polynesia, Guam, Marshall Is., Niue, Papua New Guinea, Samoa, and Tonga (CPC 2007)

12.3.6. Hazard identification conclusion

Given that *Planococcus citri*

- is not known to be present in New Zealand outside of the containment area in Auckland Domain Glasshouse;
- is under official control in New Zealand (PPIN 12/6/2007);
- is present in Samoa; and
- is associated with *Citrus* fruit;

P. citri is considered a potential hazard in this risk assessment.

12.4. *Planococcus minor* (Pacific mealybug)

12.4.1. Hazard identification

Scientific name: *Planococcus minor* (Maskell)
Synonyms or changes in taxonomy or combination: *Dactylopius calceolariae minor, Planococcus minor*, *Planococcus pacificus*, *Planococcus psidii, Pseudococcus calceolariae minor* (ScaleNet 2007)
Common names: pacific mealybug, passionvine mealybug
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: ESNZ 1977: Spiller and Wise 1982; PPIN (12/6/2007); Scott and Emberson 1999, Cox 1987

12.4.2. Biology

P. minor is very similar in appearance to *P. citri*, and distinction usually requires the expertise of a taxonomist. The adult female is oval, 1.3-3.2mm long and 0.8-1.9mm wide.

In India the female can produce a minimum of 230-310 eggs during winter, when temperatures are between 16-21˚C. The eggs will hatch after about 14 days. Female nymphs complete development in 29-36 days. Life cycle is between 28-45 days depending on time of year. The optimum temperature range for development appears to be 25-31˚C. *P. minor* can complete 10 generations in a year (Sahoo *et al.* 1999)

It feeds on fruit, stems, leaves and shoots during any growth stage and post harvest (MAF unpublished)

12.4.3. Hosts

A full host list for *P.minor* in Samoa is given in Williams and Watson (1988). *P. minor* is highly polyphagous, and is recorded from more than 250 host plants in nearly 80 families (Venette and Davis 2004). In Samoa this species has been recorded from *Citrus aurantifolia, C. grandis, C. limon, C. paradisi, C. reticulata, C. sinensis* and a vast number of other plant species (Williams and Watson 1988). The list of hosts for *P. minor* includes:
Apium graveolens, Araliaceae, Asteraceae, *Avicennia* sp., *Brassica* sp., *Broussonetia papyrifera, Camelia sinensis, Capsicum annuum, Capsicum frutescens, Colocasia esculenta* (taro), *Corynocarpus* sp., *Cucumis* sp., *Cyperus rotundis, Euphorbia* sp., *Hibiscus* sp., *Ipomoea* sp., *Ipomoea batata, Lycopersicum esculentum, Macadamia tetraphylla, Mangifera indica* (mango), *Musa* (banana), *Ocimum basilicum,* Orchidaceae, *Passiflora* sp., *Persea americana, Psidium guajava, Rosa chinensis, Saccharum officinarum, Schefflera* sp., *Solanum melongena, Solanum tuberosum* (potato), *Sophora tomentosa, Vitis vinifera, Zea mays* (Williams and Watson, 1990).
Theobroma cacao (cocoa), *Citrus deliciosa* (mediterranean mandarin), *Coffea* (coffee), *Ziziphus* (CPC, 2007)

12.4.4. Distribution

A pest of temperate, subtropical and tropical regions *P. minor* occurs in parts of Southeast Asia, Central America, Argentina and Brazil. It is widespread in the Pacific, being found in Australia, American Samoa, Cook Islands, Fiji, French Polynesia, Irian Jaya, Kiribati, New Caledonia, Niue, Papua New Guinea, Soloman Islands, Samoa, Tokelau, Tonga and Vanuatu (ScaleNet 2007; Williams and Watson 1990).

12.4.5. Hazard identification conclusion

Given that *Planococcus minor*

- is not known to be present in New Zealand;
- is present in Samoa; and
- is associated with *Citrus* fruit;

P. minor is considered a potential hazard in this risk analysis

12.5. *Pseudococcus cryptus* (citriculus / cryptic mealybug)

12.5.1. Hazard identification

Scientific name: *Pseudococcus cryptus* Hempel
Synonyms or changes in taxonomy or combination: *Pseudococcus citriculus, Pseudococcus mandarinus, Pseudococcus spathoglottidis* (ScaleNet 2008)
Common names: citriculus mealybug, cryptic mealybug
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: ESNZ 1977: Spiller and Wise 1982; PPIN (12/1/2008); Scott and Emberson 1999

12.5.2. Biology

Female *Pseudococcus cryptus* can be up to 3.15mm long, broadly oval and covered in a white mealy wax. Pseudococcid females go through three nymphal instars and males through four before adulthood (Gullen 2000)

There is little information available on the biology of *P. cryptus,* however it is understood to be similar to *Planococcus citri*.

In an experiment by Arai (1996) *P. citriculus* (*P. cryptus*) were raised on citrus leaves to determine the lower developmental thresholds and thermal constants for each nymphal stage. In the entire nymphal stage this was 11.7˚C and 338 DD (degree days).

The main dispersal stage is the crawler although movement is relatively minimal. Crawlers can be carried between plants and sites by wind, and all life cycle stages can be transported on plant material.

12.5.3. Hosts

Pseudococcus cryptus is a polyphagous species but is commonly known from *Citrus* and coconut. In Israel it is especially common on *Citrus* and will attack all parts of the plant. Concealed fruit is heavily attacked by *P. cryptus* with sooty moulds developing on the honeydew that is produced (Avidov and Harpaz 1969, In: Williams and Watson 1988).
In Samoa it has been recorded from:
Artocarpus altilis, A. incisa, Calophyllum inophyllum, Citrus aurantiifolia, C. aurantium, C. grandis, C. limon, C. reticulata, C. sinensis, Cocos nucifera, Coffea liberica leaves, *Crinum asiaticum, Dillenia indica, Elaeis guineensis, Erythrina* sp., 'filimoto', *Gardenia* sp., *Hevea brasiliensis, Mangifera indica, Musa* sp., *Pandanus* sp., *P. upoluensis, Passiflora foetida, Persea americana, Piper methysticum,* 'Poumuli', *Psidium guajava* (Williams and Watson 1988). A list of the families containing host plants can be found on ScaleNet.

12.5.4. Distribution

P. cryptus is known from southern and South East Asia, the Middle East, Hawaii and South America, American Samoa and Samoa (Williams and Watson 1988).

12.5.5. Hazard identification conclusion

Given that *Pseudococcus cryptus*

- is not known to be present in New Zealand;
- is present in Samoa; and
- is associated with *Citrus* fruit;

P. cryptus is considered a potential hazard in this risk analysis

12.6. *Dysmicoccus brevipes* (pineapple mealybug)

12.6.1. Hazard identification

Scientific name: *Dysmicoccus brevipes* (Cockerell)
Synonyms or changes in taxonomy or combination: *Dactylopius* (*Pseudococcus*) *ananassae*, *Dactylopius brevipes, Dysmicoccus brevipes, Pseudococcus brevipes*;

Pseudococcus cannae, *Pseudococcus defluiteri*,*Pseudococcus longirostralis, Pseudococcus missionum, Pseudococcus palauensis*, *Pseudococcus pseudobrevipes* (ScaleNet 2008)
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: Not present in New Zealand (not recorded in ESNZ 1977: Spiller and Wise 1982; PPIN 2008; Scott and Emberson 1999; ScaleNet 2008). An adult *Dysmicoccus brevipes* was found in a plum orchard in Auckland in November 1997, but a subsequent survey in 1998 did not detect the Pseudococcid. This suggests that it either failed to establish or that populations are currently below detectable levels on host crops (Richmond & Crowley 1998) No further records have been collected of the mealybug in New Zealand since 1997 therefore this organism is considered in this risk analysis.

12.6.2. Biology

D. brevipes is a broadly oval to rotund species pinkish in colour, growing to 3mm long and covered in waxy filaments. The legs are well developed (Williams and Watson 1988; Mau and Martin-Kessing 1992).

Reproduction can be either parthenogenetic or sexual. Females have 3 nymphal instars, reaching maturity in about 24 days. Males have 2 nymphal, a prepupal and a pupal stage/s, also maturing at 24 days. Females are ovoviviparous (eggs hatch within the body, then live young are born) birthing 19-137 larvae over about 9 days. These crawlers have flattened bodies with long hairs that aid their dispersal by wind (Mau and Martin-Kessing 1992). The adult female will live for about 17-49 days (her entire life span averages 95 days) and males 1-3 days. Thermal thresholds for first and second instar and pupal life stages were 12.1 ºC, 13.5 ºC and 12.8 ºC respectively (Colen *et al.* 2000).
D. brevipes produces copious amounts of honeydew which attracts ants who feed on it. In Hawaii three ant species are closely associated with this mealybug: *Pheidole megacephala*, *Iridomyrmex humilis* and *Solenopsis geminata (*Mau and Martin-Kessing 1992).

12.6.3. Hosts

On plants other than pineapple infestations of *D. brevipes* can occur on the foliage, stems and fruit (CPC 2008). It has been intercepted at the New Zealand border on various fresh produce including oranges. This species is highly polyphagous and is recorded from more than 100 genera in 53 families including :
Anacardium occidentale (cashew nut), *Ananas comosus* (pineapple), *Annona muricata* (soursop), *Annona squamosa* (sugarapple), *Apium graveolens* (celery), *Arachis hypogaea* (groundnut), *Brassica rapa subsp. chinensis* (Chinese cabbage), *Canna indica* (Queensland arrowroot), *Capsicum* (peppers), *Casuarina equisetifolia* (casuarina), *Citrus*, *Cocos nucifera* (coconut), *Coffea arabica* (arabica coffee), *Colocasia esculenta* (taro), *Cucumis sativus* (cucumber), *Cucurbita* (pumpkin), *Daucus carota* (carrot), *Elaeis guineensis* (African oil palm), *Ficus*, *Gossypium* (cotton), *Hibiscus* (rosemallows), *Ipomoea batatas* (sweet potato), *Malus domestica* (apple), *Mangifera indica* (mango), *Manihot esculenta* (cassava), *Medicago sativa* (lucerne), *Musa* (banana), Orchids, *Persea americana* (avocado), *Phoenix dactylifera* (date-palm), *Piper betle* (betel pepper), *Poaceae* (grasses), *Psidium guajava* (guava), *Saccharum officinarum* (sugarcane), *Solanum tuberosum* (potato), *Sorghum halepense* (Johnson grass), *Theobroma cacao* (cocoa), *Trifolium pratense* (purple clover), *Trifolium repens* (white clover), *Zea mays* (maize), *Zingiber officinale* (ginger) (CPC 2008).

12.6.4. Distribution

D. brevipes is found worldwide in tropical and subtropical zones. In Oceania it is found in American Samoa, Australia, Belau, Caroline Is., Cook Is., Fiji, French Polynesia, Guam, Irian

Jaya, Kiribati, Marshall Is., New Caledonia, Niue, Northern Mariana Is., Papua New Guinea, Samoa, Solomon Is., Tokelau, Tonga, Tuvalu, and Vanuatu (Williams and Watson 1988; Ben-Dov 1994).

12.6.5. Hazard identification conclusion

Given that *D. brevipes*:

- is not known to be present in New Zealand;
- is present in Samoa; and
- is associated with *Citrus* fruit;

D. brevipes is considered a potential hazard in this risk analysis.

12.7. *Dysmicoccus neobrevipes* (gray pineapple mealybug)

12.7.1. Hazard identification

Scientific name: *Dysmicoccus neobrevipes* (Beardsley)
Synonyms or changes in taxonomy or combination: none
Common names: gray pineapple mealybug
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: ESNZ 1977: Spiller and Wise 1982; PPIN (12/1/2008); Scott and Emberson 1999; ScaleNet 2008.

12.7.2. Biology

D. neobrevipes is a broadly oval species up to 3.5mm long with well developed legs. Greyish wax tufts and filaments cover the entire body (Williams and Watson 1988; Martin-Kessing and Mau 1992)

The biology is very similar to *D. brevipes*. The female is ovoviviparous, and will birth about 350 larvae, (though some produce as many as 1000) over 30 days. The crawlers have flattened bodies with long hairs which help in their dispersal by wind.The adult female will live about 48-72 days and adult males only 2-7 days (Martin-Kessing and Mau 1992). *D. neobrevipes* produces copius amounts of honeydew and is also attended by the three ant species that attend *D. brevipes* (Martin-Kessing and Mau 1992).

12.7.3. Hosts

D. neobrevipes is a highly polyphagous species and occurs on the leaves, stems, aerial roots, flower and fruit clusters of host plants (Martin-Kessing and Mau 1992). It has been intercepted at the New Zealand border on various fruit and vegetable produce including *Citrus* fruit (oranges and limes).
Host plants include:
Acacia (wattles), *Agave*, *Aglaonema*, *Alpinia*, *Anagallis arvensis* (scarlet pimpernel), *Ananas comosus* (pineapple), *Annona*, *Arachis*, *Artocarpus* (breadfruit trees), *Barringtonia*, *Cajanus*, *Citrus*, *Clerodendrum* (Fragrant clerodendron), *Coccoloba* (sea grape), *Codiaeum* (ornamental croton), *Coffea* (coffee), *Cucurbita maxima* (giant pumpkin), *Gossypium* (cotton), *Heliconia*, *Lycopersicon esculentum* (tomato), *Musa* (banana), *Opuntia* (Pricklypear), *Pandanus* (screw-pine), *Phaseolus* (beans), *Philodendron*, *Polianthes*, *Punica*, *Samanea*, *Solanum melongena* (aubergine), *Tectona*, *Theobroma*, *Thespesia*, *Vigna unguiculata* (cowpea), *Wrightia arborea* (lanete), *Yucca* (CPC 2008).

12.7.4. Distribution

This species is found in Hawaii, American Samoa, Cook Is., Kiribati, Samoa, Fiji, Jamaica, Malaysia, Mexico, Micronesia, Philippines, Thailand and Taiwan (CPC 2008, Martin-Kessing and Mau 1992; Williams and Watson 1988).

12.7.5. Hazard identification conclusion

Given that *D. neobrevipes*

- is not known to be present in New Zealand;
- is present in Samoa; and
- is associated with *Citrus* fruit;

D. neobrevipes is considered a potential hazard in this risk analysis.

12.8. Risk assessment for *Ferrisia virgata, Planococcus citri, P. minor, Pseudococcus cryptus, Dysmicoccus brevipes, D. neobrevipes*

12.8.1. Entry assessment

Ferrisia virgata, Planococcus citri, P. minor, Pseudococcus cryptus, Dysmicoccus brevipes and *D. neobrevipes* are likely to be associated with fresh *Citrus* fruit at the time of harvest as both nymphs and adults attack fruit, shoots and leaves. The life cycles for all six species range between 19-155 days, easily encompassing the transit time from Samoa to New Zealand. Mealybugs attach to their hosts very firmly and often when populations are at low densities they will be found under the calyx and the peduncle of the fruit (Meyerdirk 1981; Schreiner 2000). The likelihood of *F. virgata, Planococcus citri, P. minor, Pseudococcus cryptus, Dysmicoccus brevipes* or *D. neobrevipes* entering the country on the pathway is considered to be medium.

12.8.2. Exposure assessment

Mealybug crawlers can actively disperse to other hosts by their own means, but can also be wind dispersed. Barrass *et al*. (1994) found *Pseudococcus longispinus* crawlers and second instars on sticky traps 10m from a citrus orchard and in New Zealand a HortResearch trial found crawlers 15m from their research vineyard. Once airborne they have the potential to be carried long distances (Lo *et al*.2006).

Many of the host plants of these mealybugs (including *Citrus*, sweet potato, taro, tomato, guava, grapes, avocado, beans, maize, eggplant, cucurbits and *Lucerne*) are grown in New Zealand, with some occurring more commonly in northern North Island (e.g. guava and *Citrus*). Disposal of fruit within an urban or rural environment will provide a means of exposure to a suitable host for any of these six mealybugs. Crawlers are more likely to find new hosts than adult mealybugs, and this is thought to be more likely in a domestic environment (garden or compost) than along a roadside (MAF unpublished draft 1994).

Given the highly polyphagous nature and reasonable mobility of all six species the likelihood of exposure is considered to be medium.

12.8.3. Establishment assessment

Climate may be a limiting factor for *F. virgata, P. minor, D. brevipes and D. neobrevipes* establishing in many parts of New Zealand as these species are largely found in tropical and subtropical climates, surviving at an optimal temperature for growth and development of about 25°C. There are no data for lower thresholds for development for *F. virgata* and *P. minor* but both extend their lifespans at cooler temperatures e.g. 16.6°C (Awadallah 1979). It is likely these 4 species could establish in the northern North Island. Greenhouse conditions are likely to enable the establishment of a permanent population of *F. virgata, P. minor, D. brevipes* and *D. neobrevipes* in other areas of New Zealand

Planococcus citri and *Pseudococcus cryptus* have a greater cold tolerance, with lower developmental threshold temperatures around 7-8°C and 11-12°C respectively (Arai 1996). This would allow establishment of populations of *Planococcus citri* in the north of the North Island, and possibly the Poverty Bay/Hawkes Bay region of the East Coast, that could survive throughout the winter. *Pseudococcus cryptus* may be limited to the north of the North Island.

The likelihood of *F. virgata*, *Planococcus citri*, *P. minor*, *D. brevipes, D. neobrevipes* and *Pseudococcus cryptus* establishing in New Zealand is considered medium.

12.8.4. Consequence assessment

12.8.4.1 Economic impact

Hosts of economic importance in New Zealand include *Citrus*, avocado, grapes, asparagus, olive, tomato, eggplant, potato, *Phaseolus* (beans), sweet potatoes, cucurbits and *Lucerne* (MAF, 2001).

Infestations of *F. virgata, Planococcus citri and P.minor* are clustered around the terminal shoots, leaves and fruit, sucking the sap which results in yellowing, withering and drying of plants and shedding of leaves and fruit. *D. brevipes* and *D. neobrevipes* also infest the same plant parts. *Pseudococcus cryptus* will attack and damage fruit. The foliage and fruit also become covered with large quantities of sticky honeydew which serves as a medium for the growth of black sooty moulds. The sooty moulds and waxy deposits result in a reduction of photosynthetic area, causing loss of plant vigour, fruit yield and in severe cases death. Ornamental plants and produce can lose their market value (CPC 2007).
The economic consequences of *F. virgata, P. citri, P. minor, Pseudococcus crytpus, D. brevipes* or *D. neobrevipes* establishing are medium.

12.8.4.2 Environmental impact

There are existing records of New Zealand native plants becoming hosts for introduced cosmopolitan mealybug species, such as the vine pest *Pseudococcus calceolariae* which has been recorded from *Sophora microphylla* (kowhai), *Dodonaea viscosa* (akeake), *Coprosma australis (C. grandifolia)* and *Nestegis lanceolata* (maire) (Beever et al, 2007).
Two plant species attacked by the *F. virgata* overseas are *Piper betel* and *Piper nigrum*. The family Piperaceae is represented by a very common native species *Macropiper excelsus* which is widespread in coastal and lowland areas of New Zealand. There is the potential for *F. virgata* to attack this plant as an alternative host. *P. minor* is known from *Corynocarpus* sp, *Schefflera* sp., *Solanum* sp., *Sophora* sp. and Orchidaceae, all of which are represented in New Zealand by indigenous species.

As the ability to find suitable hosts is not a limiting factor for any of these six honeydew secreting mealybugs, it is considered they may have an undesirable impact on the native flora. In addition other pests such as *Vespula* wasps are attracted to the honeydew, which may encourage an undesirable increase in wasp populations.

The environmental consequences of *F. virgata, P. citri, P. minor* and *Pseudococcus crytpus* establishing are medium.

12.8.4.3 Human health impact

There is no evidence that *F. virgata, P. minor, D. brevipes* and *D. neobrevipes* are of any significance to human health. However, Cipolla *et al*. (1997) observed sensitization to *P. citri* on laboratory workers, indicating that this species is potentially allergenic to humans. Therefore, *P. citri* may be of some significance, although probably minor, to human health.

Vespula wasps are attracted to honeydew excreted by some insects, and high numbers of wasps in recreational, urban or other areas may adversely impact on health (painful stings or allergy to stings) and social activities. Therefore *F. virgata, Planococcus citri*, *P. minor, Pseudococcus cryptus, D. brevipes* or *D. neobrevipes* may indirectly have some impact on human activities.

12.8.5. Risk estimation

The likelihood of entry, exposure, establishment and consequences is medium for *F. virgata*, *Planococcus citri*, *P. minor, Pseudococcus cryptus, Dysmicoccus brevipes* or *D. neobrevipes.* The risk estimate is non negligible therefore these six organisms are classified as hazards in this commodity and risk management measures can be justified.

12.9. Risk management of *Ferrisia virgata, Planococcus citri, P. minor, Pseudococcus cryptus, Dysmicoccus brevipes, D. neobrevipes*

12.9.1. Options

There are a number of points on the import pathway where effective measures could be applied to reduce the likelihood of *F. virgata*, *Planococcus citri*, *P. minor, Pseudococcus cryptus, Dysmicoccus brevipes* or *D. neobrevipes* arriving in New Zealand.

12.9.1.1 Post harvest culling, washing, waxing and visual inspection

The post harvest washing of fruit followed by visual inspection is a supplementary measure to be implemented in conjunction with the chosen disinfestation treatment to reduce pest numbers in fruit for export.

Citrus fruit harvested for export to New Zealand should be free from any scabbing, holes, cracks or damage to the skin, free from any abnormal discoloration and pests or pathogens. Therefore any damaged or infested fruit should be discarded.

Visual inspection is likely to detect adults but may not pick up nymphs especially if they are under the calyx. As mealybugs tend to fix themselves firmly to their hosts it is unlikely they will be easily removed by washing, unless they are seen and actively scrubbed off. Surfactant in the water increases the efficacy (Hansen *et al.* 2006). Waxing on limes has been shown to

kill 30% to 94% of the mealybugs tested, (Gould and McGuire 2000), depending on the coating and method (in section 5.3).

12.9.1.2 High temperature forced air

There are no specific efficacy data for the disinfestation of mealybugs on *Citrus* by HTFA. Dentener *et al.* (1996) found forced hot air temperatures at 48-50˚C for about 4 hours (including a 2 hour warm-up period) were required to kill 99% of *Epiphyas postvitana* (lightbrown applemoth) and *Pseudococcus longispinus* (longtailed mealybug) on persimmons. Vapour heat treatment of tropical cut flowers killed mealybugs (including *Planococcus citri*) after 1 hour at 46.6˚C or 2 hours at 45˚C (Hansen *et al.* 1992). HTFA is used at a lower humidity level, and the duration of the entire treatment (from ambient heat to lethal temperature then a brief cooling period) is around 6 hours.
It is anticipated that HTFA at 47.2˚C for 20 minutes would be similarly effective against mealybugs as in the Dentener *et al.* (1996) trials, but it is uncertain what degree of residual risk there would be.

For *Citrus* except lemons and limes: high temperature forced air treatment raising the internal temperature of the commodity from ambient temperature to 47.2˚C for a minimum of 20 minutes with the total treatment time being at least 4 hours or longer.
(**NB**. This is an approved treatment by the USDA-PPQ; however they note that of all citrus tested to date, grapefruit has shown the highest tolerance for this treatment and specific cultivars should be tested to determine their tolerance to HTFA at this time/temperature regime.)

Please refer to Section 5.5.9 and 5.5.10 for detail of issues surrounding HTFA.

12.9.1.3 Hot water immersion

Gould and McGuire (2000) found mealybugs on limes were killed after a hot water immersion at 49˚C for 20 minutes, as discussed in section 5.5. The ED = 99.7706% which is the estimated mortality of this treatment on a population of mealybugs at 95%CL (as per Couey and Chew 1986). The tolerance of *Citrus* other than limes for this treatment is uncertain.

12.9.1.4 Cold disinfestation

There are no efficacy data for disinfestation of mealybugs from *Citrus* by cold treatment. There is uncertainty around the efficacy of this treatment for mealybugs, given their protective wax coating.

12.9.1.5 Visual inspection at the border

The adults of all six species are 3-5mm in size therefore may be detected by visual inspection of the consignment on arrival in New Zealand. The nymphal stages are much smaller and any lifestage that seeks shelter under the fruit calyx are not likely to be detected. Low frequency of occurrence will reduce the likelihood of detection.

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13. Scale Insects

There are 13 species of scale insects considered to be potential hazards which are discussed in this risk analysis. These are sap sucking insects from the Hemiptera superfamily Coccoidea (Williams and Watson 1988). These organisms have been grouped here by family. The first 12 species belong to the armoured scale family Diaspididae, and 1 species belongs to the soft scale family Coccidae. Given the number of scales to consider, the approach taken is to give an overview of each family and use one potential hazard species from each family to provide more detail. Each species is known to be associated with *Citrus*. Where there is some uncertainty regarding association with fruit this is noted in the risk assessment.

A list of host species for each scale insect is shown in Appendix 3.

13.1. Hemiptera: Diaspididae – the armoured scales

Table 13 Diaspidids considered potential hazards in this risk analysis and plant part they are associated with

Species	Common name	Plant part	reference
Aonidiella inornata McKenzie	papaya red scale	fruit, leaves	Watson 2005
Aspidiotus destructor Signoret	coconut scale	Leaf, bark, fruit	Dekle 1976; Martin-Kessing and Mau 1992
Chrysomphalus aonidum Linnaeus	Florida red scale	Leaf, bark, fruit	Dekle 1976; Smith *et al*. 1997
Chrysomphalus dictyospermi Morgan	Dictyospermum scale	Leaf, bark, fruit	Dekle 1976; Smith *et al*. 1997
Howardia biclavis (Comstock)	burrowing scale	Bark, leaf, fruit	Dekle 1976
Ischnaspis longirostris (Signoret)	black thread scale	Leaf, bark, fruit	Dekle 1976
Lepidosaphes gloverii Packard	Glover scale	Bark, leaf, fruit	Smith *et al*. 1997
Parlatoria cinerea Hadden in Doane and Hadden	apple parlatoria	Bark, leaf, fruit	Watson 2005; Culik *et al*. 2007
Parlatoria pergandii Comstock	chaff/oyster scale	Bark, leaf, fruit	Smith *et al*. 1997
Pinnaspis strachani Cooley	hibiscus snow scale	Bark, leaf, fruit	Tenbrick and Hara 2007; Dekle 1976
Pseudaulacaspis pentagona (Targioni Tozzetti)	white peach scale	Bark, leaf, fruit	Dekle 1976; Williams and Watson 1988
Unaspis citri Comstock	citrus snow scale	Fbark, leaf, fruit	Dekle 1976 Smith *et al*. 1997

13.1.1. Introduction

All female diaspidids considered in this risk assessment produce a fibrous scale that is partly waxy secretions and partly the dorsal exuviae of the previous instars. In most instances the exuviae is obvious, being slightly darker than the rest of the scale cover. The male also secretes a similar but smaller scale (incorporating his exuviae), remaining protected underneath it until he becomes a winged adult. Adult females are always sessile, dispersing only during the first instar or "crawler" stage when they have functional legs, or when picked up by the wind or an animal (Williams and Watson 1988). Air currents can carry scale insects several tens of kilometres away (Greathead 1990).

Once a suitable feeding site is found they insert their mouthparts and remain on the particular host. The diaspidids in this assessment reproduce sexually except for *I. longirostris* and *H. biclavis* which are both parthenogenetic. Although reproduction is usually sexual in *Chrysomphalus dictyospermi*, parthenogenetic populations have been noted in the USA (Brown 1965). Diaspidids are either oviparous (lay eggs), ovoviviparous (eggs hatch within the body, then live young are born) or viviparous (birth live young). The diaspidids in this assessment vary in fecundity from 20-50 eggs per female to 200 per female (Watson 2005). All have between 3-4 generations per year or more, sometimes overlapping. Female and male diaspidids have 3 and 5 instars, respectively (Williams and Watson, 1988). The adult male is mobile and has no functional mouthparts, and one pair of wings, although some species are wingless (Williams and Watson, 1988).

Members of the Diaspididae do not excrete honey dew so are not associated with sooty mould and are rarely attended by ants (Watson 2005). However during feeding they are thought to

inject toxins into plant tissues, damaging fruit and causing leaf drop. Heavy infestations can lead to the death of the host (Smith *et al.* 1997).

Most diaspidids suffer increased mortality in heavy rain and reach high population levels in dry weather (CPC 2007).

13.2. *Pseudaulacaspis pentagona* (white peach scale)

13.2.1. Hazard identification

Scientific name: *Pseudaulacaspis pentagona* (TargioniTozzetti)
Synonyms or changes in taxonomy or combination or changes in combination or taxonomy: *Aspidiotus lanatus*, *A. vitiensis*, *A. pentagona*, *A. pentagona rubra*, *A. pentagona auranticolor*, *Chionaspis prunicola*, *Diaspis amygdali* var. *rubra*, *D. amygdali*, *D. auranticolor*, *D. geranii*, *D. lanata*, *D. lanatus*, *D. patelliformis*, *D. pentagona*, *D. rubra*, *Epidiaspis vitiensis*, *Howardia prunicola*, *Pseudaulacaspis amygdali*, *P. prunicola*, *Sasakiaspis pentagona*
Diaspis pentagona, (ScaleNet 2008).
Common names: white peach scale, mulberry scale
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: PPIN (11/2/2008); Scott and Emberson 1999; Charles and Henderson 2002; ScaleNet 2008

13.2.2. Biology

The female scale is subcircular, greyish-white, with reddish-brown marginal exuviae and measures 2.0-2.5mm long. The male is elongate, white, flat and about 0.7mm long with a 1.4mm wingspan (van Duyn and Murphy 1971; Williams and Watson 1988)

About two weeks after mating the female scale will begin laying eggs, continuing for 8-9 days. The eggs are deposited on the surface of the host plant. When she completes oviposition the female dies. The first eggs are orange and give rise to females, the following eggs are white and give rise to males. Usually around 100 eggs are laid (van Duyn and Murphy 1971). Eggs hatch 3-4 days after being laid in Florida (van Duyn and Murphy 1971), but can be 7-14 days in Virginia (Bobb *et al*. 1973). The female crawlers will move about on the plant for up to 12 hours before settling to feed. The males remain near their mother, and tend to shelter under her armour (van Duyn and Murphy 1971; Bobb et al 1973).

Females undergo 2 moults and males 5 moults before sexual maturity. The males live only one day after reaching maturity but can usually mate with several females before dying. Two to four generations per year are usual and fertilised females will overwinter in the USA, China and Japan (Bobb *et al.* 1973; Stimmel 1982; Jiang 1985; Takeda 2004).

Takeda's research (2004) indicates reproductive diapause in overwintering females switches off at a mean temperature of 10.5˚C and increasing daylength. At 11 – 15˚C Ball (1980) recorded *P. pentagona* taking a minimum of 110 days to complete a generation and 40 days at about 26˚C. At 13˚C it will take about 50 days before females begin to oviposit after maturing, but only 16 days at 26˚C (Ball 1980).

13.2.3. Hosts

P. pentagona is a highly polyphagous and destructive species. It attacks wood, leaves and fruit (Williams and Watson 1988). ScaleNet (2008) lists over 300 hosts in 78 plant families, eg: Brassicaceae, Cucurbitaceae, Fabaceae, Fagaceae, Lauraceae, Myrtaceae, Oleaceae, Orchidaceae, Rubiaceae, Solanaceae. Hosts from Rutaceae include *Citrus aurantium*, *C. maxima* and *C. reticulata.*
P. pentagona is recorded in Samoa on *Morinda citrifolia* (Williams and Watson 1988).

13.2.4. Distribution

Pseudaulacaspis pentagona is a cosmopolitan species. It is recorded in Asia, Africa, Europe, and the Americas. In the Pacific it is found in Australia, Belau, Caroline Islands, Fiji, Guam, New Caledonia, Norfolk Is., Northern Mariana Is., Papua New Guinea, Samoa, Solomon Is., Tonga, Vanuatu, Wallis and Futuna (CPC 2008; Williams and Watson 1988).

13.2.5. Hazard identification conclusion

Given that the diaspidid scale insects listed in section 13.1:

- are not known to be present in New Zealand;
- are present in Samoa;
- are associated with *Citrus* fruit;

they are considered potential hazards in this risk analysis.

13.3. Hemiptera: Coccidae - the soft scales

13.3.1. Introduction

There is one Coccid considered in this risk analysis:
Coccus viridis Green

The coccids are often referred to as soft scales, although some of the more than 1000 species will produce a heavy sclerotization at maturity. Others remain 'naked' throughout life, some produce a dense sticky wax or enclose themselves in a felted ovisac (Williams and Watson, 1990). Young females retain their legs and antennae, and may move if their position becomes unfavourable. They are wingless and once mature they usually remain sessile. Females lay eggs or birth live young. Males typically have one pair of wings (Mau and Martin-Kessing, 2007). Most soft scales secrete honeydew which provides a growth medium for sooty moulds (Smith *et al.* 1997) and attracts ants.

13.4. *Coccus viridis* (Soft green scale)

13.4.1. Hazard identification

Aetiologic agent: *Coccus viridis* Green
Synonyms or changes in taxonomy or combination: *Eulecanium viridis; Lecanium viridis*
Common name: Soft green scale
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: ESNZ 1977: Spiller and Wise 1982; PPIN 2007; Scott and Emberson 1999; CPC 2007

13.4.2. Biology

The adult female is not strongly chitinised, is pale green and often translucent. She is elongate, 2.5-3.3mm and slightly convex to flat. Presence of males has not been recorded (Williams and Watson 1990).

Reproduction is parthenogenetic. Up to 500 eggs are laid under the female, hatching within a few hours. The larvae remain under the female for a few days then disperse to the undersides of leaves, the tips of shoots and fruit. As crawlers they are capable of moving 1m in 45 minutes (Keuchenius 1915). In Florida they will pass through three larval instars before becoming adults, taking about 50-70 days to reach maturity. The adults are sessile (Fredrick 1943). Su and Lin (1986) reared *C. viridis* on *Citrus* seedlings at 25˚C. Development took 32 days and the adult lifespan was 67 days.

C. viridis produces honeydew and Frederick (1943) noted 5 different species of ants attending this scale.

13.4.3. Hosts

Coccus viridis has a broad host range and is a pest on *Citrus* species. All stages of *C. viridis* were observed by Frederick (1943) on immature oranges and immature and mature limes. In Samoa it has been found on: *C. aurantiifolia, C. limon, C. grandis, C. paradisi, C. reticulata* and *C. sinensis* (Williams and Watson, 1990). It feeds on leaves, tips of shoots and fruits (Dekle and Fasulo 2005; Smith *et al*. 1997). The host list for *C. viridis* is shown in Appendix 3.

13.4.4. Distribution

Coccus viridis is widespread through Asia, Africa, Central and South America. It is found in Florida, Mexico, Australia, American Samoa, Belau, Federated States of Micronesia, Fiji, French Polynesia, Guam, Kiribati, New Caledonia, Niue, Northern Mariana Is., Papua New Guinea, Samoa, Tonga, and Vanuatu (CPC 2007; Williams and Watson 1990).

13.4.5. Hazard identification conclusion

Given that *Coccus viridis*

- is not known to be present in New Zealand;
- is recorded from Samoa;
- and has a known association with *Citrus* fruit;

C. viridis is considered a potential hazard for the purpose of this risk analysis.

13.5. Risk assessment for armoured and soft scale

13.5.1. Entry assessment

There have been approximately 81 interceptions of scale insects (eg: *Chrysomphalus dictyospermi, Parlatoria cinerea, Lepidosaphes sp., Aonidiella sp*) on imported limes inspected at the border over the period 2003-2006 (MAF unpubl. 2007)
Other diaspidids and coccids have been intercepted on various *Citrus* species in this time period (MAF unpubl. 2007)
Scale insects are small and often inconspicuous, usually living around the sepal or under the calyx of the fruit from flowering onwards-eg: *Parlatoria pergandii* will usually be found near or under the calyx (Smith *et al.* 1997) (Biosecurity Australia, 2006). Eggs, crawlers and adult

scale insects on fruit would survive the transit time to New Zealand from Samoa (approx. 4 hrs by air freight).

Therefore it is considered the likelihood of entry for all the scale species is considered to be high.

13.5.2. Exposure assessment

The requisites for exposure of scale infested citrus fruit to suitable hosts will be the lifestage of the scale, the environmental conditions and the proximity to potential hosts. A recently mated female or parthenogenetic scale about to lay or already laying eggs could survive in warm, dry or slightly humid conditions allowing the eggs to hatch. Newly hatched crawlers have the greater likelihood of exposure, but are also susceptible to desiccation. Although they actively disperse only over very short distances, scale insects may disperse over several kilometres by wind (Greathead, 1990). In the urban and rural environments near the point of arrival in New Zealand there will be suitable hosts for the scale species considered in this risk analysis.

Infested fruit or peel may be discarded on the roadside, in reserves or open composts. However crawlers are likely to suffer high mortality, therefore the likelihood of exposure is considered to be low but non negligible.

13.5.3. Establishment assessment

The scale insects considered in this risk analysis have a subtropical and tropical range. Those that are also found in temperature regions are usually found in greenhouses or under glass.

For most of these scale the optimal temperature range for development is between 22-38˚C with a relative humidity between 50-75% (Andrade and Busoli, 2004; Salama, 1970; Bruwer 1998; Arias-Reveon and Browning 1995; Su and Lin, 1986). *Aspidiotus destructor* females have a development threshold of 10.5˚C and males 8.7˚C (Zhou *et al.* 1993). *A. destructor* can produce 3 generations annually in China, overwintering on *Actinidia* (Zhou *et al.* 1993). *Unaspis citri* has an estimated developmental threshold of 12˚C (Arias-Reveon and Browning, 1995) and *Chrysomphalus aonidum* 10.6˚C (Klein 1937). *Chrysomphalus dictyospermi* completes its entire lifecycle in 91 days at 18ºC and 71 days at 25 ºC (Cabido-Garcia 1949). In Turkey *Chrysomphalus dictyospermi* overwinters as first or second instar nymphs (Tuncyurek and Oncuer 1974) and in Italy as young adults (Vigianni and Iannaconne 1972).

Table 14 Monthly mean temperatures (˚C) for the warmest (February) and coldest (July) months (based on NIWA data for 1971-2000)

City	February			July		
	Mean daily minimum	Monthly mean	Mean daily maximum	Mean daily minimum	Monthly mean	Mean daily maximum
Kaitaia	15.6	20.0	24.5	8.7	12.2	15.6
Whangarei	15.7	20.0	24.2	7.2	11.2	15.1
Auckland	15.8	19.8	23.7	7.1	10.8	14.5
Tauranga	14.7	19.2	23.8	5.2	9.7	14.3
Gisborne	13.6	18.9	24.2	4.6	9.3	14.1
Napier	14.5	19.3	24.1	4.6	9.3	14.1
Nelson	12.9	17.7	22.4	1.6	7.0	12.4

Mean monthly relative humidity in the above areas range from 73.2 to 88.7%, which is similar to Samoa (average 80% RH). *Citrus* fruit coming from Samoa is likely to arrive in Auckland during the summer months.

Some exotic scale species such as *Ceroplastes destructor* and *Lepidosaphes beckii* have established in New Zealand despite their tropical/subtropical distribution (Scalenet 2007; Henderson 2001).

Given that *Aspidiotus destructor, Chrysomphalus dictyospermi, and Pseudaulacaspis pentagona* overwinter in cold climates the likelihood that these three species could establish in the northern parts of the North Island, on the East Coast or the northern part of the South Island, and elsewhere in protected environments such as greenhouses or glasshouses, is high.

There is evidence that *Chrysomphalus aonidum* females can survive temperatures down to freezing point before death occurs (Mathis 1947). Numerous authors have reported the fact that freezing temperatures markedly reduce *C. aonidum* populations (Thompson & Griffiths 1949). Given the development thresholds of *C. aonidum*, and *Unaspis citri*, these two species are also likely to establish in the northern parts of the North Island, around the Bay of Plenty, the East Coast, and elsewhere in protected environments such as greenhouses or glasshouses.

Lepidosaphes gloveri, Parlatoria cinerea and *Parlatoria pergandii,* are likely to survive the summer months in favourable microclimates of the North Island and may suffer population reductions over the winter.
Coccus viridis is more likely to be restricted to establishment in the far north or under glasshouse conditions.

Although a tropical species *Ischnaspis longirostris* has established in cool temperate countries (eg: Ireland, Denmark, Sweden, Northern USA) under glasshouse conditions. *Howardia biclavis* also established in temperate climes under the same conditions (Watson 2005). These two species could establish in the far north or anywhere under glasshouse conditions.

There is insufficient information on *Aonidiella inornata* and *Pinnaspis strachani*, but both are recorded from tropical areas. It is more likely these two species could survive the summer in the far north, and are unlikely to survive the winter unless under glasshouse conditions

Therefore the likelihood of establishment for these 13 scale insects is considered to vary from low to high.

13.5.4. Consequence assessment

13.5.4.1 Economic impact

Apart from ornamentals, the crop species most likely to be affected by the establishment of any of these scale insects include kiwi fruit, *Citrus*, avocado, peach, pears, pine trees, eucalyptus, apple, capsicums, tomatoes, brassicas, olives, *Cucumis* sp. and grapes.
All 13 species of scale considered in this analysis are polyphagous and some highly polyphagous (eg: *C. dictyospermi* has hosts belonging to 73 plant families, *A. destructor* has hosts belonging to 75 genera in 44 plant families and *P. pentagona* has over 300 hosts in 78 plant families).

Fruit are affected by feeding damage from diaspidids and coccids and production of honeydew by *Coccus viridis* allows sooty mould development which decreases tree vigour and health. Fruit appearance is affected by sooty mould either reducing the fruit quality or volume available for sale thereby incurring financial loss from export and domestic markets. Severe infestations of diaspidids can form heavy crusts, causing branches or trees to die (CPC 2008). *P. pentagona* is the subject of quarantine regulations in many countries and establishment in New Zealand would cause disruption of access to some markets (eg: Western Australia).

Scale insects, especially diaspidids are difficult to control once established due to their protective covering and control measures incur costs to industry.

The economic consequences across forestry, horticulture and nursery sectors is likely to be high.

13.5.4.2 Environmental impact

It is likely most of these scale insects will find exotic hosts within their usual host range as many exotic plants are already present in New Zealand. However 4 of the 28 exotic Diaspidids that have established in New Zealand have also found endemic hosts in native forest (Charles and Henderson 2002). These authors comment that the polyphagous nature of scale insects should not be underestimated. Overseas, both *Chrysomphalus* species have been recorded on *Dodonaea vicosa*. *C. dictyospermi* and *P. strachani* have been recorded on orchids (Williams and Watson 1990; CPC 2007).

Many New Zealand native plants are used for amenity and domestic plantings in this country and this increases the availability of natives and a conditioning to them as potential host species. As scale insects often disperse by wind as crawlers, in time it can be expected some will eventually establish in native bush reserve areas within or close to urban areas. The honeydew secreting species such as *C. viridis* are likely to attract *Vespula* wasps, (Beggs 2001) which are nuisance species that disrupt outdoor activities. The limiting factor in this spread is likely to be a combination of wet and cold habitats.
Therefore the likelihood of unwanted environmental consequences is considered to be high.

13.5.4.3 Human health impact

Scale insects are not known to directly impact on human health. However honeydew excreting species can indirectly affect people by attracting nuisance species such as wasps and ants, whose stings and bites can cause severe reactions in people allergic to them.

13.5.5. Risk estimation

The likelihood of scale insects entering the country is high, the likelihood of exposure is low and the likelihood of establishment varies from low to high depending on the species. If they were to establish then the consequences would be high. The risk estimation for all 13 scale insects considered in this risk analysis is non negligible. Therefore these organisms are classified as hazards in this commodity and risk management measures can be justified.

13.6. Risk management of armoured and soft scale

13.6.1. Options

There are a number of points on the import pathway where effective measures could be applied to reduce the likelihood of scale insects arriving in New Zealand.

13.6.1.1 Post harvest culling, washing, waxing and visual inspection

Citrus fruit harvested for export to New Zealand should be free from any scabbing, holes, cracks or damage to the skin, free from any abnormal discoloration and pests or pathogens. Damaged or infested fruit should be discarded.

Visual inspection may detect sessile adults, crawlers under calyxes are unlikely to be seen. Washing is unlikely to remove adult scale insects as they are usually firmly fixed by their mouthparts, requiring active brushing to dislodge them. It was noted that the stylets remain imbedded in the fruit and sap oozed from the wound encouraging pathogen entry (Giliomee and Swanepoel 1979).

Surfactants in the washing water have been shown to increase efficacy of washing (Hansen *et al.* 2006). Waxing may assist in repelling or killing scale insects (in section 5.3). However it is considered that these measures will not be sufficient on their own, and should be supplemented by another treatment

13.6.1.2 High temperature forced air

There are no specific efficacy data for the disinfestation of scale insects on *Citrus* by HTFA. Hansen *et al.* (1992) found vapour heat treatment of tropical cut flowers at 46.6˚C for 1 hour or 45˚C for 2 hours killed nymphs and adults of soft and armoured scale insects.

It is anticipated high temperature forced air treatment raising the core temperature of the commodity from ambient temperature to 47.2˚C for 20 minutes with the total treatment time being at least 4 hours or longer would kill scale insects, with a low level of survivors (**NB**. This is an approved treatment by the USDA-PPQ; however they note that of all citrus tested to date, grapefruit has shown the highest tolerance for this treatment and specific cultivars should be tested to determine their tolerance to HTFA at this time/temperature regime.)

Please refer to Section 5.5.9 and 5.5.10 for detail of the issues surrounding HTFA.

13.6.1.3 Hot water immersion

Gould and McGuire (2000) found mealybugs on limes were killed after a hot water immersion at 49˚C for 20 minutes. This treatment was considered a suitable method of disinfestation. The tolerance of *Citrus* other than limes for this treatment is uncertain.

Mealybugs have a waxy coating similar to that of scale insects so it is assumed measures for mealybugs may be effective for scale insects. However the degree of residual risk is uncertain.

13.6.1.4 Cold disinfestation

Given diaspidid and coccid scale have been intercepted alive at the New Zealand border after cold treatment (eg. *P. pentagona* on kiwifruit- QuanCargo database) and diaspidids also survived 20-66 days at 4˚C (Blank *et al*. 1990) it seems this is not an efficacious treatment for scale insects.

13.6.1.5 Visual inspection at the border

The crawler stages of scale insects are very small and can seek shelter under the fruit calyx therefore may escape detection by visual inspection of the consignment on arrival in New Zealand. The adult, sessile scale insects may be more visible but may not be detected if they are in low densities.

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14. Other Hemiptera

14.1. *Leptoglossus gonagra* (squash bug)

14.1.1. Hazard identification

Scientific name: *Leptoglossus gonagra* (Fabricius)
Synonyms or changes in taxonomy or combination: *Fabrictilis australis, Leptoglossus australis, Theognis gonagra*
Organism type: insect
Taxonomic position: Hemiptera: Coreidae
Common names: squash bug, leaf-footed bug, coreid bug, citreon bug, passionvine bug
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: ESNZ 1977: Spiller and Wise 1982; PPIN (14/7/2007); Scott and Emberson 1999.

14.1.2. Biology

Eggs are laid in a row on the stem or leaf midvein of the larval host plant, which is often a cucurbit species or weed species. *L. gonagra* eggs laid on *Cucurbita pepo* kept at room temperature hatched in 5-12 days (Amaral and Storti 1976). There were 5 nymphal stages that averaged 3.6, 13.9, 10.4, 11.2 and 15.4 days respectively. Adults are alate, about 15mm long, and mid-brown with some orange markings laterally and ventrally. *L.gonagra* becomes sexually mature at 4-11 days after the final moult with a preoviposition period for females of about 10-40 days. Females laid up to 23 batches of eggs and up to a total of 169 eggs in their lifetime. Adult males live up to 70 days and females up to 77 days (Amaral and Storti 1976). The congener, *L. phyllopus* is multivoltine (Mead 2007) so the same is likely to apply to *L. gonagra*.

In Florida *L. gonagra* frequently breeds in decayed fruits of the citron melon *Citrullus lanatus* [*C. vulgaris*] that grows in citrus orchards. The shells harbour the nymphs and adults in late summer and early autumn. Populations of the different lifestages build up on citron melons, weeds in the citrus orchards and adjacent fields of watermelon. As the host plants dry out only the adults move to the *Citrus* trees and attack the fruits, causing serious losses by October-November (Fasulo and Stansly 2004). The *L. gonagra* adults pierce the *Citrus* fruit and suck juice from the vesicles (Albrigo and Bullock 1977), which often leads to premature colour break and fruit drop, as well as creating favourable conditions for a variety of fungal diseases and insects. Fasulo and Stansly (2004) note that adults tend to aggregate and are most active in flight in the heat of the day.

14.1.3. Hosts

The *Citrus* fruit most commonly affected are satsumas, tangerines and early and midseason varieties of oranges. Grapefruit and Valencia oranges seldom attract *L. gonagra*, probably due to the rind thickness (Thompson 1940; Fasulo and Stansly 2004). The list of host plants for *L. gonagra* include:
Arachis hypogaea (groundnut), *Bixa orellana* (annatto), *Carica papaya, Citrullus lanatus, Citrus* (tangerines, oranges and grapefruit), *Cleome spinosa*, *Cocos nucifera* (coconut), *Coffea* (coffee), *Crotalaria* spp., Cucurbitaceae (cucurbits), *Cucumis sativus*, *Dioscorea* (yam), *Helianthus annus*, *Ipomoea batatas* (sweet potato), *Litchi chinensis*, *Luffa aegyptiaca* (loofah), *Manihot esculenta* (cassava), *Momordica charantia*, *Oryza sativa* (rice), *Passiflora* (passionflower), *Phaseolus* (beans), *Psidium grandiflorum*, *Psidium guajava* (guava), *Punica granatum*, *Schinus terebinthefolia, Sechium edule, Sicyos* sp., *Solanum* sp., *Theobroma cacao*

(cocoa), *Typha domingensis* (CPC 2007; Amaral and Storti 1976; FloridaEnvironments 2007; Waterhouse 1993; Fasulo and Stansly 2004)

14.1.4. Distribution

L. gonagra has a subtropical and tropical distribution. It is found in southern USA, Asia, Africa and parts of Central and South America. It is present in Australia, American Samoa, Belau, Federated States of Micronesia, Fiji, French Polynesia, Guam, New Caledonia, Northern Mariana Islands, Papua New Guinea, Samoa, Soloman Islands, Tonga, Vanuatu, Wallis and Futuna (CPC 2007; Waterhouse 1997)

14.1.5. Hazard identification conclusion

Given that *Leptoglossus gonagra*:

- is not known to be present in New Zealand;
- is present in Samoa;
- and the adults feed on *Citrus* fruit;

Leptoglossus gonagra is considered a potential hazard in this risk analysis.

14.2. Risk assessment

14.2.1. Entry assessment

It is highly unlikely eggs or immature stages of *L. gonagra* would enter New Zealand on *Citrus*, as they rely on totally different host plants.
The adults aggregate to feed and are highly mobile during the heat of the day. It is likely that this species would be disturbed from feeding during the harvesting, and adults could re-settle to feed on harvested fruit. *L. gonagra* would survive the period from harvesting in Samoa to distribution in New Zealand, feeding on *Citrus* fruit.
The likelihood of entry is considered to be very low but non negligible.

14.2.2. Exposure assessment

L. gonagra are winged, but it is not known how far they are able to fly. However, the congener *L. phyllopus* is noted in Florida to fly great distances from its initial host thistles to orange groves (Hubbard 1885: in Mead 2007) so it is assumed the same could apply to *L. gonagra*.

Because the species is assumed to be an active flier, it is more likely to disperse from the site where *Citrus* fruit is unpacked rather than being carried home by the consumer. If a gravid female entered, in order to lay eggs she would need to search for suitable hosts; e.g.: cucurbit leaves, weeds – such as *Solanum americanum* (Amaral and Storti 1976) – or rotting watermelons. Cowley *et al*. (1993) quote information from MAF stating that approximately one in 20 properties in Auckland and Northland had cucurbits growing. Some retail outlets are situated quite close to domestic gardens and weed species are readily available so it is considered likely that *L. gonagra* adults would find suitable host plants.
The likelihood of exposure is considered to be high.

14.2.3. Establishment assessment

Despite the absence of data on *L. gonagra* temperature requirements, given its current distribution localised populations could establish in the north of the North Island. The limiting factor however, would be the combination of wet and cold winter conditions.
The likelihood of establishment is considered to be low but non negligible.

14.2.4. Consequence assessment

14.2.4.1 Economic impact

This species is generally considered a minor pest species of *Citrus* on its own, but in Florida is part of a citrus pest species complex that includes its congenor *L. phyllopus* and the stink bug *Nezara viridula*. Periodically numbers of all three species swell sufficiently to cause major losses of crops within a few weeks (Fasulo and Stansly 2004). In conjunction with *Nezara viridula* (present in New Zealand) it is considered that localised outbreaks would be costly and highly inconvenient to horticulturists in the northern North Island. Affected crops are likely to be cucurbits, *Citrus*, beans, kumara, tomatoes, potatoes and passionfruit.

The economic consequences of establishment of *Leptoglossus gonagra* is considered to be low but non negligible.

14.2.4.2 Environmental impact

Native flora species in New Zealand most likely to be susceptible to attack from *L. gonagra* would be *Solanum aviculare* (poroporo) although the fruits might not be large enough or juicy enough for the adults. Native Rutaceae may not be susceptible to the adults as the fruits are about 5mm in diameter and are dry (Allan, 1982), and larvae are likely to prefer more juicy leaf types. It is uncertain what other species may be palatable to *L. gonagra*.

The environmental consequences of establishment of *L. gonagra* is uncertain, but is likely to be very low.

14.2.4.3 Human health impact

There is no evidence that *L. gonagra* is of any significance to human health.

14.2.5. Risk estimation

The likelihood of *L. gonagra* entering the country is low, being exposed to suitable hosts is high and establishing is low. The consequences of establishment is low but non negligible. The risk estimation is non negligible therefore this species is classified as a hazard in this commodity and risk management measures can be justified.

14.3. Risk management

14.3.1. Options

There are a number of points on the import pathway where effective measures could be applied to reduce the likelihood of *L. gonagra* arriving in New Zealand.

14.3.1.1 In field sanitation

In-field control of *L. gonagra* can be assisted by removal or mowing of suitable egg and larval hosts such as bitter gourd *Momordica charantia*, leguminous weed species, thistles and other succulent weeds from within and around *Citrus* orchards (Albrigo and Bullock 1977). This can reduce the incidence of the pest. Control in a commercial Florida *Citrus* grove was achieved by shaking the pest from *Citrus* trees in the cool of the morning into pans of oil (Thompson 1940)

14.3.1.2 Post harvest culling, washing, waxing and visual inspection

The post harvest washing of fruit followed by visual inspection is a supplementary measure to be implemented in conjunction with the chosen disinfestation treatment to reduce pest numbers in fruit for export. *Citrus* fruit harvested for export to New Zealand should be free from any scabbing, holes, cracks or damage to the skin, free from any abnormal discoloration and pests or pathogens. Damaged or infested fruit should be discarded. It is expected that *L. gonagra* would be detected by visual inspection prior to export as the bug is of a reasonable size. Washing by submerging the fruit is most likely to remove the bug and waxing could assist in repelling it.

14.3.1.3 High temperature forced air

There are no specific efficacy data for the disinfestation of *L. gonagra* on *Citrus* fruit by HTFA. It is anticipated this treatment may kill some bugs, however it is uncertain what proportion would die and if this proportion would be considered suitable for biosecurity purposes.

For *Citrus* except lemons and limes: high temperature forced air treatment raising the internal temperature of the commodity from ambient temperature to 47.2˚C for a minimum of 20 minutes with the total treatment time being at least 4 hours or longer.
(**NB**. This is an approved treatment by the USDA-PPQ; however they note that of all *Citrus* tested to date, grapefruit has shown the highest tolerance for this treatment and specific cultivars should be tested to determine their tolerance to HTFA at this time/temperature regime.)

Please refer to Section 5.5.9 and 5.5.10 for detail of the issues around HTFA.

14.3.1.4 Hot water immersion

There are no efficacy data for the disinfestation of *Citrus* of *L. gonagra* by HWI.
However it is assumed that HWI at 49˚C for 20 minutes would cause the bug to leave the fruit. Limes are proven to tolerate this treatment (Gould and McGuire 2000) but the tolerance of other *Citrus* is uncertain.

14.3.1.5 Cold disinfestation

There are no efficacy data for the disinfestation of *Citrus* of *L. gonagra* by cold disinfestation. The distribution of this insect suggests it is used to tropical and subtropical temperatures. Therefore it seems unlikely it would survive a very low temperature continuous over 2 weeks. However the degree of residual risk is uncertain.

Cold disinfestation of *Citrus* fruit is currently:
13 days at 0˚C or below or

16 days at 1˚C + or – 0.6˚C
There is no supporting literature to suggest limes may be treated by cold disinfestation without damage to the fruit.
Please refer to Section 5.7 for further information on cold disinfestation.

14.3.1.6 Visual inspection at the border

A *Leptoglossus gonagra* adult is about 15mm in size, therefore it is anticipated that visual inspection of the consignment on arrival in New Zealand could detect *L. gonagra* individuals. However, low frequency of occurrence reduces the likelihood of detection.

14.4. References

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15. Ants

15.1. Hymenoptera: Formicidae

15.1.1. Introduction

Two ant species are identified as potential hazards. These are:
Anoplolepis gracilipes Smith -yellow crazy ant
Paratrechina longicornis Latreille -crazy ant

Both species are considered "hitch-hiker" or "tramp" species, with opportunistic associations with commodities. The most likely association they will have with *Citrus* is tending honeydew-excreting homoptera such as aphids, scale insects and mealybugs.

15.2. *Anoplolepis gracilipes* (yellow crazy ant)

15.2.1. Hazard identification

Scientific name: *Anoplolepis gracilipes* Smith
Synonyms or changes in taxonomy or combination: originally *Formica gracilipes* Smith
Common name: yellow crazy ant
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: ESNZ 1977: Spiller and Wise 1982; PPIN (8/12/2004); Scott and Emberson 1999
Comment: Hitchhiker species

15.2.2. Biology

Workers have a yellow body and greenish-brown gaster, are about 4mm in length with very long legs and antennae.

Queens lay about 700 eggs/year. The lifecycle is estimated to take 76-84 days at 20-22˚C (Fluker and Beardsley 1970). Eggs take 18-20 days to hatch and larvae 16-20 days to develop. Worker pupae develop over about 20 days whereas queen pupae need 30-34 days. Workers live for about 6 months and queens for several years (Abbott *et al*. 2005). Reproductive brood can occur throughout the year but are usually produced just prior to the 'rainy season' in subtropical/tropical climates. Alate males and females are known, but it is unclear if they start new colonies. Colony budding off appears to be the main form of dispersal (O'Dowd 2004). Colonies readily migrate if disturbed (Passera 1994).

The colonies are polygyne (multi-queened) with an average of 4000 individuals in a nest. Nests can be in a variety of locations such as cracks and crevices in the ground, leaf litter, tree hollows, or urban buildings and debris. In New Guinea nests of *A. gracilipes* were recorded in the crowns of coconut palms where they fed on honeydew excretions from scale insects and palm flower nectar (O'Dowd 2004).

This species is omnivorous. Besides nectar and honeydew food items include grains, seeds, vegetation, decaying matter, arthropods and small animals. Foraging occurs both day and night, mostly at temperatures between 21-35˚C. Foragers subdue and kill prey by spraying formic acid (eg: landcrabs on Christmas Is) (O'Dowd 2004).

A. gracilipes is primarily a species of lowland tropical rainforest with a preference for moist habitats (Veeresh 1987). It is capable of invading both disturbed and undisturbed habitats including tropical urban areas, savannah, rainforest, woodland, grassland and plantations (O'Dowd 2004)

This species was observed tending aphids on *Citrus* in Samoa (pers. obs).

15.2.3. Hosts

A hitchhiker species is 'an organism that has an opportunistic association with a commodity or item with which it has no biological host relationship' (M. Newfield pers.comm. 2007). CPC (2007) lists the following species as 'hosts' of *A. gracilipes*. However, as *A. gracilipes* is a hitchhiker species it has no direct association with a particular plant species and will occur to a greater or lesser degree with various plant species.
A. gracilipes is associated with cocoa, *Coffea* (coffee) and *Mangifera indica* (mango) (CPC 2007).
A variety of agricultural systems have been successfully colonised by *A. gracilipes* including *Citrus,* cinnamon and coffee crops and coconut plantations. It will frequently nest at the base or even in the crown of crop plants (O'Dowd (2004).

15.2.4. Distribution

A. gracilipes is thought to have originated in either Asia or Africa. It is recorded from most countries in Asia; also Southeast Asia, East Africa, Brazil, Chile, Mexico, some Caribbean islands, Australia (Northern Territory); and most of the Pacific islands including Samoa (Abbott et al; O'Dowd 2004; Wetterer and Vargo 2003)

15.3. *Paratrechina longicornis* (crazy ant)

15.3.1. Hazard identification

Scientific name: *Paratrechina longicornis* Latreille
Synonyms or changes in taxonomy or combination: originally *Formica longicornis* Latreille; *Paratrechina currens* Motschoulsky, *Formica gracilescens* Nylander, *Formica vagans* Jerdon, *Prenolepis longicornis* (Latreille)
Common name: crazy ant, longhorned ant,
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: ESNZ 1977: Spiller and Wise 1982; PPIN (8/12/2004); Scott and Emberson 1999
Comment: Hitchhiker species

15.3.2. Biology

Workers are dark brown to almost black with a faint bluish iridescence, about 2.3-3mm long with very long legs and antennae.

The colonies are polygyne, with up to about 40 queens and 2000 workers in a nest. Queens do not appear to have mating flights. On warm, humid nights males will gather at nest entrances and await a queen. It is thought mating occurs at the nest entrance in such groupings (Trager 1984). New nests are usually formed by budding off from an established colony. Nests can be in dry or moist environments, in the sand (even submersed at high tide on beaches), on the ground in trash, wood, mulch, occcasionally in tree holes. In buildings they will nest in wall spaces and under stored items. The nests can be temporary and Trager (1984) says this highly

mobile species will move if disturbed. *P. longicornis* is highly adaptable and appears to prefer disturbed habitats particularly the vicinity and interior of human dwellings (Harris and Abbott 2005).

This species is opportunistically omnivorous, feeding on live and dead insects and larger animals, honeydew, fruits, seeds and househod foods. They will forage long distances from the nest – up to 25m (Jaffe 1993).
P. longicornis has been observed tending the brown citrus aphid *Toxoptera citricida* (Michaud and Browning 1999).

15.3.3. Hazard identification conclusion

Given that *Anoplolepis gracilipes* and *Paratrechina longicornis*

- are not known to be present in New Zealand;
- are recorded as present in Samoa (Wetterer and Vargo 2003);
- are associated with *Citrus*;
- have been previously intercepted on produce from the Pacific Islands;
- and are potentially harmful to humans and animals because of spraying formic acid (*A. gracilipes*);

Anoplolepis gracilipes and *Paratrechina longicornis* are considered potential hazards in this risk analysis.

15.4. Risk assessment for *Anoplolepis gracilipes and Paratrechina longicornis,*

15.4.1. Entry assessment

As hitchhiker species *A. gracilipes* and *P. longicornis* can be associated with any part of the fresh produce import pathway. Although commonly found in disturbed areas such as crop fields and orchards, they are urban pests also, so may be found nesting in or near buildings. Ants could be incidentally exported with *Citrus.* Both ant species (queens, small colonies or just workers) have been intercepted at the New Zealand border, frequently on fresh produce from the Pacific as well as empty sea containers and timber (Abbott *et al*. 2005; Harris and Abbott 2005).

Although it would be unlikely whole nests could be moved with fresh *Citrus* fruit, it is possible individual ants or small groups could find their way into the cartons prior to export, from within or around the packing house or storage areas.

Both species of ant have survived the shipping time of 6-8 days in the past (Abbott *et al*. 2005; Harris and Abbott 2005) therefore they will survive the flight time from Samoa to Auckland (about 4 hours) or shipping time of about 7 days.

It is considered the likelihood of entry for *Anoplolepis gracilipes* and *Paratrechina longicornis* is high.

15.4.2. Exposure assessment

Initially any ants arriving in produce are likely to move from the point where the boxes are opened because of the disturbance. They will move to an area where they can find shelter and food. Their mobility increases the likelihood of exposure.
Dispersal would most likely occur by human mediated movement.

It is considered the likelihood of exposure for *Anoplolepis gracilipes* and *Paratrechina longicornis* is medium.

15.4.3. Establishment assessment

Workers on their own cannot begin a colony as they are sterile.
A. gracilipes and P. longicornis have successfully spread and established outside of their native range and are well established in the Pacific. A single mated queen is sufficient to start a population if she arrives with enough fat reserves to locate a nest site and rear the first workers. The time of year is important as establishment is less likely in winter although a suitable microclimate (inside a building or glasshouse) could allow this.

Climate matching showed New Zealand has a low degree of similarity with sites where *A. gracilipes* has established. *A. gracilipes* is not as closely associated with buildings as is *P. longicornis*. It is a tropical/subtropical species and it may survive in hot microclimates in the far north of the North Island. However is is more likely New Zealand is too cold for establishment of *A. gracilipes* (Abbott *et al*. 2005).

In 2004 a nest of *P. longicornis* was found and destroyed in Wellington (Harris and Abbott 2005). *P. longicornis* is a disturbance specialist and will readily nest in disturbed environments, in or near buildings. It is likely to move into heated buildings if it finds the outdoors too cool (Harris and Abbott 2005; Nickerson and Barbara 2007).

The likelihood of establishment for *A. gracilipes* is low but non negligible.
The likelihood of establishment for *P. longicornis* is high.

15.4.4. Consequence assessment

15.3.4.1 Economic impacts

A. gracilipes and *P. longicornis* are likely to be a nuisance in horticulture by tending and protecting honeydew secreting homoptera. *A. gracilipes* can be destructive by removing roots around plants (Abbot *et al.* 2005). Where abundant *A. gracilipes* has been known to to prey upon newborn newborn pigs, chickens, cats, rats, dogs and rabbits, and irritate by spraying formic acid (Haines *et al*. 1994).

As climate is a limiting factor *A. gracilipes* is unlikely to reach densities that would cause significant economic impacts. *P. longicornis* is likely to have a greater range and reach higher numbers, although also not likely to cause significant economic impact. However surveillance and response programmes are very costly.

The economic consequences of establishment of *A. gracilipes* and *P. longicornis* are considered to be medium and are therefore non-negligible.

15.3.4.2 Environmental impact

A. gracilipes, should it establish in hot microclimates could have a significant impact on indigenous fauna such as native land snails (see Abbott *et al.* 2005; Andersen 2000).
P. longicornis prefers disturbed environments so is not likely to establish in native habitats. In optimal climates this species is not ecologically dominant (Harris and Abbott 2005).

The environmental consequences of establishment of *A. gracilipes* are considered to be high.
The environmental consequences of establishment of *P. longicornis* are considered to be low but non negligible.

15.3.4.3 Human health and social impact

In the Seychelles, in high densities, *A. gracilipes* is a serious household pest, a nuisance in public buildings and food processing establishments and a medical problem by entering open wounds, ears, eyes and noses (Abbott *et al*. 2005).
A. gracilipes has been known to cause formic acid burns on people, resulting in scarring (K. Abbott pers obs.: In Abbott *et al*. 2005).
P. longicornis is a pest in urban areas where it can become abundant indoors. *P. longicornis* may also transmit diseases. In three Brazilian hospitals it was the second most common species recorded and at least 20% of the foragers carried pathogenic bacteria (Fowler *et al*. 1993).
It is more frequently is known for being a nuisance in domestic situations when abundant.

As climate is likely to have a moderating effect on establishment and spread of *A. gracilipes* and *P. longicornis*, the health or social consequences of entry and establishment is considered medium.

15.4.5. Risk estimation

The likelihood of *Anoplolepis gracilipes* and *Paratrechina longicornis* entering the country is high, exposure is medium and establishment low to high depending on the species. The consequences are low to high depending on the species. The risk estimate is non negligible therefore these two species of ant are classified as hazards in this commodity and risk management measures can be justified.

15.5. Risk management of *Anoplolepis gracilipes* and *Paratrechina longicornis*,

15.5.1. Options

15.4.1.1 Monitoring

Currently Atele Packing house applies an insecticidal spray (Icon) weekly to the perimeter of the treatment area/packing house. This practise is successful and should continue.

15.4.1.2 Post harvest culling, washing, waxing and visual inspection

Pre-export storage could be monitored with ant bait stations.
Citrus fruit harvested for export to New Zealand should be free from any scabbing, holes, cracks or damage to the skin, free from any abnormal discoloration and pests or pathogens. Damaged or infested fruit should be discarded. Ants may be detected by pre-export visual inspection because of their rapid movement in warm temperatures. Washing by submerging the fruit is likely to remove most ants. Waxing may add to the overall efficacy of treatment by repelling ants (see section 5.3).

15.4.1.3 High temperature forced air

There are no specific efficacy data for the disinfestation of *A. gracilipes* or *P. longicornis* on *Citrus* fruit by HTFA.
Francke *et al.* (1985) looked at the heat tolerance of four species of fire ants.
Ninety-five percent of *S. geminata* acclimated to 32˚C and 22˚C, then exposed for one hour to high temperature died at 43.2˚C and 43.9˚C respectively. It is assumed that *A. gracilipes* and *P. longicornis* might respond similarly.

HTFA takes a few hours to move from ambient temperature to the internal fruit temperature of 47.2˚C. The air temperature is likely to be a couple of degrees higher.
It is therefore anticipated that HTFA at 47.2˚C for a minimum of 20 minutes may kill a large proportion of ants although the degree of residual risk is uncertain.

For *Citrus* except lemons and limes: high temperature forced air treatment raising the internal temperature of the commodity from ambient temperature to 47.2˚C for a minimum of 20 minutes with the total treatment time being at least 4 hours or longer.
(**NB**. This is an approved treatment by the USDA-PPQ; however they note that of all citrus tested to date, grapefruit has shown the highest tolerance for this treatment and specific cultivars should be tested to determine their tolerance to HTFA at this time/temperature regime.)

Please refer to Section 5.5.9 and 5.5.10 for detail of the issues around HTFA.

15.4.1.4 Hot water immersion

Hara *et al.* (1996) found that HWI at 49˚C for 12-15 minutes eliminated more than 95% of ants, aphids and mealybugs on red ginger flowers.
This treatment is suitable for limes (Gould and McGuire 2000) but the tolerance of other *Citrus* is uncertain at 12-15 minutes or if conducted for the 20 minutes Gould and McGuire (2000) used.

15.4.1.5 Cold disinfestation

There are no efficacy data for cold disinfestation of ants from *Citrus.* As these three ant species are tropical/subtropical species requiring warm temperatures or protection from weather (eg: inside buildings) cold disinfestation may cause mortality. However it is uncertain what level of residual risk there will be.

Cold disinfestation of *Citrus* fruit is currently:
13 days at 0˚C or below or
16 days at 1˚C + or – 0.6˚C
There is no supporting literature to suggest limes may be treated by cold disinfestation without damage to the fruit.
Please refer to Section 5.7 for further information on cold disinfestation.

15.4.1.6 Visual inspection at the border

A. gracilipes and *P. longicornis* are small but very mobile. The optimal foraging temperature for both species is about 21-25˚C and *Paratrechina* spp.tend to forage at night. MAF Quarantine officers reported that detection of ants on vehicles is very weather dependent (Toy and Glassey 2006). In warm temperatures ants are likely to be detected by their movement, but cool or cold weather is more likely to inhibit movement and therefore detection.
The efficacy of detection by visual inspection of the consignment on arrival in New Zealand is uncertain. Ants detected in consignments should be identified to provide information around commodity associations and distribution.

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16. Fungi

16.1. Glossary of terms for fungi

(OED Online 2007; Kirk *et al*. 2001) (Modified by S. R. Pennycook 2008)
Ascospores: sexual reproductive spores that develop inside an ascus

Ascus: The swollen sac-like cell at the end of the branches of the hyphæ in ascomycetous fungi and lichens, in which the sexual reproductive spores develop. Asci sit within a structure called an *ascocarp* or *ascoma* (pl. *ascomata*).

Conidia: An asexual reproductive body (spore) occurring in certain fungi.

Haustorium: a special hyphal branch, especially one within a living cell of the host, for the absorption of food.

Heterothallic: (of a fungus) having an incompatibility system by which only genetically different strains can undergo nuclear fusion during sexual reproduction.

Mycelium: the vegetative tissue of a fungus typically consisting of a network of fine filaments (*hyphae*).

Pseudothecium: a 'flask-shaped' structure containing ascospores (a type of ascoma; other types include perithecium, apothecium, cleistothecium)

Sclerotia: these are vegetative resting states of some fungi that store nourishment and present as aggregations of densely packed mycelial hyphae.

Sporangium: A receptacle containing spores; a spore-case or capsule (pl. *sporangia*).

Zoospores: A spore having the power of spontaneous movement, occurring in certain Algæ, Fungi (e.g. *Phytophthora*), and Protozoa; a motile spore.

Sooty moulds and mildews

The species under consideration are:
Capnodium citri (sooty mould)
Meliola citricola (sooty blotch/black mildew)
Phaeosaccardinula javanica (sooty mould)

16.2. *Capnodium citri* (sooty mould)

16.2.1. Hazard identification

Scientific name: *Capnodium citri* Berk. and Desm. (1849)
Synonyms or changes in taxonomy or combination: *Meliola citri* (Briosi and Pass.) Sacc. (1882); *Capnodium salicinum* Mont. (1849)
Taxonomic position: Dothideomycetes: Meliolales: Meliolaceae
Common name: sooty mould
New Zealand Status: not known to be present in New Zealand
Sources that do not record presence: PPIN (29/10/2007); Pennycook 1989-(*C. salicinum* is listed but not *C. citri*- see NOTE below); NZFungi (29/10/2007)-ambiguous

NOTE:
The fungus recorded from Samoa is *Capnodium citri*.
Capnodium citri and *Capnodium salicinum* are listed as synonyms by Index Fungorum. However, these names are unreliable indicators of the actual biological species involved. *Capnodium citri* is a name of dubious application that has been applied to a wide spectrum of sooty mould species on *Citrus* (Reynolds 1999). Similarly, the name *C. salicinum* has been loosely applied to sooty moulds of varied but uncertain identity.
Sooty mould has been widely recorded on *Citrus* in New Zealand since at least 1925 (Cunningham 1925, as *Capnodium citricolum*; and as *Capnodium salicinum* -NZFungi 2007). It is likely that sooty mould on *Citrus* involves similar species in both Samoa and New Zealand, but as this is not yet confirmed it remains as a potential hazard in this risk analysis.

16.2.2. Disease cycle and epidemiology

Capnodium citri is a black, superficial fungus that will grow on leaves, stems and fruit, after *Citrus* have become infested with honeydew-excreting insects such as mealybugs, aphids or soft scale. The fungal mass is usually heavier on the upper surfaces rather than undersides of leaves. *C. citri* does not penetrate the plant tissue but can affect the plants ability to photosynthesise, thereby affecting host growth and fruit development. Sooty mould can also delay fruit colouring (Whiteside 2000).
Spores or fragments of sooty molds are wind dispersed to honeydew excretions where new colonies of sooty mould develop (Baker *et al*. 2002).

Control of this fungus is mainly through controlling the honeydew-excreting insects, and is usually only done when fruit yield or quality is potentially affected. Petroleum spray oils can loosen the mould allowing wind and rain to remove the growth and may also control some of the honeydew-excreting insects (Whiteside 2000).

16.2.3. Hosts

In Samoa, *C. citri* has been recorded on *Citrus aurantiifolia* and *C. sinensis* (Dingley *et al.* 1981). Other hosts include: *Citrullis vulgaris*, *Citrus* x *tangelo*, *C.* x *paradisi*, *C. aurantium*,

C. delicosa, C. grandis, C. latifolia, C. limon, C. maxima, C. medica, C. meyeri, C. microcarpa, C. nobilis, C. reticulata, C. unshiu, Coffea arabica, Gardenia jasminoides, Ilex glabra, Mangifera indica, Persea americana, Phillyrea latifolia, Psidium pomiferum (Farr *et al*. 2007).

16.2.4. Distribution

Capnodium citri is found in India, China, Hong Kong, Vietnam (Whittle 1992), Italy (Grasso and Polizzi 1988), parts of North, Central and South America (Farr *et al.* 2007); Fiji (Dingley *et al.* 1981); Samoa (Dingley *et al*. 1981; J. Wright, 19/10/2007 pers. comm.).

16.2.5. Hazard identification conclusion

Given that:

- *Capnodium citri* is not known to be present in New Zealand;
- is present in Samoa;
- and is associated with *Citrus* fruit;

Capnodium citri is considered a potential hazard for the purpose of this risk analysis.

16.3. *Meliola citricola* (sooty blotch)

16.3.1. Hazard identification

Scientific name: *Meliola citricola* Syd. and P. Syd. (1917)
Synonyms or changes in taxonomy or combination: not given
Taxonomic position: Dothideomycetes: Meliolales: Meliolaceae
Common names: black mildew, black mould, sooty blotch
New Zealand Status: not known to be present in New Zealand
Sources that do not record presence: PPIN (29/10/2007); NZFungi (29/10/2007); Pennycook 1989

16.3.2. Disease cycle and epidemiology

Meliola citricola is often mistaken for a sooty mould and has been found in association with *Capnodium citri* (Minter 2006). However, the development is not dependent on honeydew excretions from invertebrates as is usual for sooty moulds (Whittle 1992).

Colonies begin from a single ascospore. The fungus is largely superficial but a fine haustoria penetrates each infected epidermal cell. The fungus colonises both upper and lower surfaces of leaves. Symptoms are usually only seen on mature leaves and fruit because colony growth is slow. Transmission is by ascospores, possibly wind-dispersed during humid weather (Minter 2006). Ascospores of *M. citricola* require young leaves for penetration and infection (Ecoport 2008).
The Meliolaceae are adapted to long wet seasons and heavy night dews in the dry season with preference for warm, densely shaded areas (Saenz and Taylor 1999).

It is not a strong parasite and economic loss is usually related to the unsightly appearance of the black fungal growth on the fruit. Like sooty moulds, severe infections may affect the photosynthesis ability of plants and reduce fruit yields. Control of *Meliola citricola* is readily achievable by petroleum based oil sprays (Minter 2006).

16.3.3. Hosts

In Samoa, *M. citri* has been found on *C. aurantiifolia, C. aurantium*, and *C. sinensis* (Dingley *et al.* 1981). It has also been recorded on *C. decumana, C. suhuiensis, Citrus* x *Citrofortunella mitis* (Minter 2006), *C.* x *paradisi*, *C. grandis, C. limon, C. maxima, C. medica, C. microcarpa, C. reticulata* and *C. nobilis* (Farr *et al.* 2007).

16.3.4. Distribution

Meliola citricola is found in Brunei, Cambodia, China, India, Indonesia, Malaysia, Papua New Guinea, Philippines, Singapore, Sri Lanka, Thailand, Vietnam, Fiji, New Caledonia, Samoa, Solomon Is. and Vanuatu (Dingley *et al.* 1981; SBML 2007; Minter 2006).

16.3.5. Hazard identification conclusion

Given that:

- *Meliola citricola* is not known to be present in New Zealand;
- is present in Samoa;
- and is associated with *Citrus* fruit;

Meliola citricola is considered a potential hazard for the purpose of this risk analysis.

16.4. *Phaeosaccardinula javanica* (sooty mould)

16.4.1. Hazard identification

Scientific name: *Phaeosaccardinula javanica* (Zimm.) Yamam. 1940
Synonyms or changes in taxonomy or combination: *Chaetothyrium javanicum* (Zimm.) Boedijn 1931
Taxonomic position: Ascomycota: Ascomycetes: Dothideales: Chaetothyriaceae
Common name: sooty mould
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: Pennycook 1989; PPIN 2006; NZFungi (29/10/2007)

16.4.2. Disease cycle and epidemiology

The fungus is found on leaves, fruits and stems, appearing as a superficial black growth, which does not penetrate the tissues (AFFA 2002). It is predominantly associated with leaves (Eriksson and Yue 1985).

16.4.3. Hosts

In Samoa, it has been recorded on *Citrus maxima* (Dingley *et al.* 1981). Some economically important hosts include: *Acacia* spp., *Camellia sinensis*, *Citrus* spp., *Coffea arabica*, *Coffea robusta*, *Eleaocarpus serratus*, *Euphoria longana*, *Ficus* spp., *Litchi chinensis*, *Mangifera indica*, *Miscanthus japonicus*, *Psidium guajava*, *Quercus glauca*, *Schefflera octophylla*, *Vitis shifunensis* (Farr *et al.* 2007).

16.4.4. Distribution

It is found in Taiwan (Chen *et al.* 2002), China (Tai 1979), Samoa (Dingley *et al.* 1981) and India (Ramakrishnan and Pillay 1962).

16.4.5. Hazard identification conclusion

Given that:

- *Phaeosaccardinula javanica* is not known to be present in New Zealand;
- is present in Samoa;
- and is associated with *Citrus* fruit;

Phaeosaccardinula javanica is considered a potential hazard in this risk analysis.

16.5. Risk assessment for *Capnodium citri, Meliola citricola, Phaeosaccardinula javanica*

16.5.1. Entry assessment

As *Capnodium citri* and *Phaeosaccardinula javanica* are highly visible, superficial fungi it is expected that fruit with sooty moulds would be detected at harvest and during the handling at packing and not be exported to New Zealand. However it is possible a very new infection may not be visible. The latter is predominantly associated with leaves and is a tropical fungi that would be unlikely to establish in New Zealand.
Therefore the likelihood of entry of *C. citri*, and *P. javanica* is very low, but non negligible.

Meliola citricola will penetrate the epidermis of the fruit. A light infection may not be detected prior to export as growth to a symptom stage is slow. However the fungus requires young leaves to begin development (Ecoport 2008) and it could be assumed the same applies to fruit. The likelihood of this fungus entering is considered to be very low but non negligible.

16.5.2. Exposure assessment

There is little information about how these fungi would survive after fruit or peel disposal to the environment. Dormant mycelium or spores on fruit may survive and develop in warm, humid conditions. Dispersal would most likely occur by rain splash or wind.
It appears that *M. citricola* is specific to *Citrus* species, although most records of this fungus are on a smooth skinned cultivar of *Citrus reticulata* (Whittle 1992).
Capnodium citri and *P. javanica* have a broader host range so there is more likelihood of exposure to a new host. However, it is assumed there would be very low frequency of occurrence on imported fruit, and there is uncertainty around the ability of spore survival.

Therefore the likelihood of exposure for all three species of fungus is considered to be low.

16.5.3. Establishment assessment

Based on its current distribution it could be assumed that *C. citri* could establish in New Zealand, particularly in the north of the North Island.
M. citricola and *P. javanica* are tropical fungi but could survive in the far north of the North Island, or under glasshouse conditions.

The likelihood of establishment for *C. citri* is considered to be medium.
The likelihood of establishment for *M. citricola* and *P. javanica* is considered to be very low but non negligible.

16.5.4. Consequence assessment

16.5.4.1. Economic impacts

Establishment of these three species of fungi would affect *Citrus* species, avocado, grapes and some ornamentals like *Camellia* and holly. The appearance of these fungi on produce reduces saleability. Severe infections may affect the photosynthesis ability of plants and reduce fruit yields. As the horticultural industry is likely to be controlling for mildews and other fungi these particular three fungi may not have an accumulative effect.
The economic consequence of establishment is considered to be low

16.5.4.2. Environmental impacts

It is uncertain if these three fungi could infect Rutaceae other than *Citrus*. *P.javanica* has been recorded on plants in genera that are represented in the indigenous flora. However temperature may be a limiting factor in the development of this fungus. The environmental consequences of establishment of these three fungi is uncertain, but non negligible.

16.5.4.3. Human health and social impacts

There is no evidence to suggest there is likely to be a health impact from the establishment of *C. citri, M. citricola* and /or *P. javanica.*

16.5.5. Risk estimation

The likelihood of entry, exposure, establishment and consequences is low to medium for *Capnodium citri, Meliola citricola and Phaeosaccardinula javanica*. The risk estimate is non-negligible therefore these organisms are classified as hazards in this commodity and risk management measures can be justified.

16.6. Risk management

16.6.1. Options

There are a number of points on the import pathway where effective measures could be applied to reduce the likelihood of *C. citri, M. citricola and P. javanica* arriving in New Zealand. Control of fungal diseases usually relies heavily on preventative spray programmes, and fastidious orchard sanitation.

16.6.1.1. In-field sanitation

Pruning to open up the crowns to more light, and ensuring other infected species are not in close quarters to *Citrus* would assist in reducing the likelihood of infection. This would be part of a systems approach to management of the risk.

16.6.1.2. Spray programmes

The control of honeydew-excreting invertebrates will aid in controlling for the two sooty moulds, *C. citri* and *P. javanica*. This can be done with horticultural oil sprays and will loosen the moulds helping them to be weathered away. Control of *M. citricola* is readily achievable

by petroleum based oil sprays (Minter 2006) This would be part of a systems approach to management of the risk.

16.6.1.3. Post harvest culling, washing, waxing and visual inspection

Citrus fruit harvested for export to New Zealand should be free from any scabbing, holes, cracks or damage to the skin, free from any abnormal discoloration and pests or pathogens. Damaged and infected fruit should be discarded.
Thorough washing of all *Citrus* by submersion in chlorinated water (section 5.2.4) and brushing is likely to ensure removal of any non-visible mould or mildew spores.
Waxing may reduce spore viablity (see section 17.6.1.3)

However washing will not remove any *M. citricola* haustoria that have penetrated the epidermal cells. The haustoria are feeding hyphae and are very unlikely to be a site of regrowth or infection transmission.
Given that *M. citricola* requires young leaves to infect, and it could be assumed the same applies to fruit, it is likely *M. citricola* will have developed visible symptoms by time of harvest and should be culled out prior to export.
Therefore it is assumed that this measure (16.6.1.3) combined with in-field sanitation and a oil spray programme will result in very little residual risk for all three species.

16.6.1.4. Visual inspection at the border

Mature growths of these three fungi are likely to be detected.

16.7. References

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17. Other Fungi

The species under consideration are:
Corticium koleroga (web blight)
Elsinoe australis (sweet orange scab)
Mycosphaerella citri (greasy spot)
Phytophthora palmivora (brown rot)

17.1. *Corticium koleroga* (thread blight)

17.1.1. Hazard identification

Scientific name: *Corticium koleroga* (Cooke) Höhn. 1910
Synonyms or changes in taxonomy or combination: *Botryobasidium koleroga* (Cooke) Venkatar. (1949), *Ceratobasidium noxium* (Donk) P. Roberts (1999), *Hypochnus koleroga* F. Stevens and J.G. Hall*Koleroga noxia* Donk (1958), *Pellicularia koleroga* Cooke (1876).
Taxonomic position: Basidiomycetes: Corticales: Cortiaceae
Common name: thread blight, web blight
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: Pennycook 1989; PPIN (24/7/2007); NZFungi (24/7/2007)
Note: The records found in the SBML database (2007) have this note attached: "this is a confused name; the type specimen is a mixture of the vegetative hyphae of a resupinate basidiomycete and the conidia of a deuteromycete. Reports probably refer to various species of *Botryobasidium, Ceratobasidium* and *Thanatephorus.*"
This could mean there are several different entities with this name, some of which have been reported from more temperate-tolerant host species (e.g.: *Euonymus japonica, Ficus carica, Malus* sp., *Nyssa sylvatica, Pyrus* sp.) and some which have been recorded from more tropics-tolerant host species. The fungus-host records show the distribution of the fungus in the USA as being largely humid subtropical (e.g.: Louisiana, Florida, South Carolina), but also contains records from latitudes the same as Northland, New Zealand.

This document refers to *Corticium koleroga*, given the organism recorded as *Corticium koleroga* is present in Samoa (J. Wright, 19/10/2007 pers. comm.).

17.1.2. Disease cycle and epidemiology

Corticium koleroga attacks twigs, fruit and leaves of *Citrus* trees (Timmer 2000).
Rhizomorphs form and cover the tissue which may die if heavily invaded.
Small black sclerotia often form on the rhizomorphs and basidiospores may form on the wefts of mycelium on host tissue (Timmer 2000).

On apple trees, basidiospores form on newly infected leaves in summer and are probably disseminated by air currents, thus initiating new infections on nearby trees. Sclerotia and rhizomorphs can grow superficially on fruit and sclerotia perpetuate the fungus from season to season (Hartman 1991).

Studies in Samoa of the congener *Corticium salmonicolor* on cocoa showed rainfall triggered basidiospore release within 20 minutes and this continued for up to 13.5 hours after the rain stopped (Schneider-Christians *et al.* 1986). Basidiospores have a variable optimum temperature for germination of 18-32˚C (Mordue and Gibson, 1976). A seasonal pattern to the

life cycle was noted with increases in new infections during the rainy season (summer months) (Schneider-Christians *et al*. 1986).

On *Hevea* (rubber trees), the optimum temperature for growth of *C. salmonicolor* was 28˚C, with minimum and maximum temperatures of 5˚C and 40˚C (Shamsuri *et al*. 1997).

The mycelium *of C. koleroga* is white when actively growing but becomes dark brown with age (Timmer 2000). Benchimol *et al.* (2001) were able to reproduce the white-thread blight symptoms under greenhouse conditions one week after using a PDA plug inoculation on the underside of young leaves left in a dew chamber for 48 hours (*Azadirachta indica* - neem, *Khaya ivorensis* - African mahogany, *Musa* cv. yangambi - banana, *Cocos nucifera* - coconut and *Ixora coccinea* - ornamental Ixora). There is no information available about the stage of *Citrus* fruit development that is susceptible to *Corticium koleroga*.

Thread blight can become severe in tropical areas with high rainfall and may be controlled with copper fungicides; however it is seldom severe enough to require treatment (Timmer 2000). In Samoa, it is mostly found on coffee, and prefers dark, humid conditions (J. Wright, 19/10/2007 pers. comm.).

17.1.3. Hosts

Cajanus cajan (pigeon pea), *Citrus*, *Coffea* (coffee), Cucurbitaceae (cucurbits), *Mangifera indica* (mango), *Malus domestica* (apple), *Melia azedarach* (Chinaberry) (CPC 2007), and *Azadirachta indica* (neem), *Khaya ivorensis* (African mahogany), *Musa* cv. *yangambi* (banana), *Cocos nucifera* (coconut) and *Ixora coccinea* (ornamental Ixora) (Benchimol *et al*. 2001). The SBML database (2007) has records of this fungus on members of more than 33 different plant families including: Aceraceae, Asteraceae, Buxaceae, Cupressaceae, Ericaceae, Euphorbiaceae, Fabaceae, Lauraceae, Moraceae, Myrtaceae, Oleaceae, Piperaceae, Pittosporaceae, Rosaceae, Rubiaceae, Rutaceae (*Citrus aurantium, C. reticulata, C. sinensis*), Solanaceae, Theaceae and Ulmaceae.

17.1.4. Distribution

This fungus has a limited distribution in the southern USA, and is found in American Samoa (CPC 2007). It is listed on the Pacific Islands Pest List database (accessed 2007) as occurring in the Fiji Islands; Federated States of Micronesia (FSM); New Caledonia; Samoa and Vanuatu.

17.1.5. Hazard identification conclusion

Given that:

- *Corticium koleroga* is not known to be present in New Zealand;
- is present in Samoa;
- is associated with *Citrus* fruit;

Corticium koleroga is considered a potential hazard in this risk analysis.

17.2. Risk assessment

17.2.1. Entry assessment

Infected fruit may not necessarily show signs of disease caused by *Corticium koleroga* which means this fungus could enter undetected (Benchimol *et al.* 2001). However, it is known mostly from coffee in Samoa (J. Wright, 19/10/2007 pers. comm.) so there may not be a high rate of occurrence on *Citrus* fruit coming from Samoa.

The likelihood of entry is considered to be medium.

17.2.2. Exposure assessment

The time from harvest in Samoa to distribution in New Zealand is likely to be about 48 hours. It is possible fruit may begin to show signs and symptoms of thread blight whilst on sale or after purchase by individuals. There are two possibilities at this point. Firstly, the retailer may realise the problem and dispose of the fruit, which is likely to be taken to the local rubbish dump. Secondly, the consumer may discard the fruit *en route* or at home. *En route* disposal could be a public waste container or littering the urban or rural roadside. Home disposal would include domestic rubbish or open compost. *C. koleroga* is very polyphagous so there are likely to be suitable hosts within range of exposed infected fruit. Assuming the life cycle of *C. koleroga* is similar to *C. salmonicolor* then basidiospores could be air dispersed after rain or overhead watering.

The likelihood of exposure is considered to be medium.

17.2.3. Establishment assessment

Corticium koleroga tends to have a tropical and subtropical distribution. If this fungus established it is likely it would be restricted to warmer, humid, shadier areas within the north of the North Island. The congener *C. salmonicolor* is recorded from the Coromandel, Auckland and Northland in New Zealand (NZFungi 2008).

The likelihood of establishment is considered to be low but non negligible.

17.2.4. Consequence assessment

17.2.4.1 Economic impact

C. koleroga is known to infect apples and members of the Myrtaceae. However pipfruit is not grown commercially in areas where the climate is likely to be most conducive to *C. koleroga* (eg: Northland).
Citrus is commercially grown in Northland. There is little information regarding the infection process of *C. koleroga* in *Citrus* fruit and this could be because it is not perceived as economically important. Timmer (2000) states *C. koleroga* infection on *Citrus* fruit is seldom severe enough to require treatment. However this species is polyphagous and other crops such as avocado, tamarillo and kumera may be susceptible.

The economic consequences of establishment are considered to be medium.

17.2.4.2 Environmental impact

C. koleroga is a highly polyphagous fungus, with hosts in families that are represented in New Zealand by various indigenous species. Some of these are categorised as 'in decline' through to "nationally critical" (e.g.: Rubiaceae: *Coprosma walli, C. obconica*; Asteraceae: *Olearia gardneri*; Pittosporaceae: *Pittosporum obcordatum, P. turneri*; Fabaceae: *Clianthus maximus, Carmichaelia muritai*; Euphorbiaceae: *E. glauca*) and many others are common in suburban reserve areas and used in amenity or domestic plantings. Should *C. koleroga* establish, it is most likely it will initially be in urban areas of the northern North Island, but in time may spread into rural or wilderness areas of the North.

The environmental consequences of establishment are considered to be medium.

17.2.5.1 Human health and social impact

There is no information to suggest there is likely to be a health or social impact from the establishment of *Corticium koleroga.*

17.2.5. Risk estimation

The likelihood of entry, exposure, establishment and consequences is low to medium for *Corticium koleroga*. The risk estimate is non-negligible therefore this organism is classified as a hazard in this commodity and risk management measures can be justified.

17.3. Risk management

17.3.1. Options

There are a number of points on the import pathway where effective measures could be applied to reduce the likelihood of *C. koleroga* arriving in New Zealand. Control of fungal diseases usually relies heavily on preventative spray programmes, and fastidious orchard sanitation.

17.3.1.1 In-field sanitation

C. koleroga is found mainly on coffee in Samoa (J. Wright, pers. comm. 2007) and in dark, humid areas. Pruning to open up the crowns to more light, and ensuring other infected species are not in close quarters to *Citrus* would assist in reducing the likelihood of infection.

The soil surface under *Citrus* trees should be kept free of weeds and debris, and the trunk bark should be free of injury to avoid entry points for pathogens. Fallen fruits, leaves and infected material needs to be removed to reduce the infection cycle or avoid reinfection, and buried no less than 30cm deep, or burned.

17.3.1.2 Spray programmes

Corticium koleroga can be controlled by copper fungicides (Timmer 2000)

17.3.1.3 Post harvest culling, washing, waxing and visual inspection

The post-harvest washing of fruit followed by visual inspection is a supplementary measure to be implemented in conjunction with the chosen disinfestation treatment to reduce pathogens on fruit for export. *Citrus* fruit harvested for export to New Zealand should be free from any

scabbing, holes, cracks or damage to the skin, free from any abnormal discoloration and pests or pathogens. Damaged fruit should be discarded.
C. koleroga is not likely to be removed by washing.
It is expected fruit with sclerotia will be detected during harvesting and handling and be rejected prior to export. However, recently infected fruit may not show any visible sign.

17.4.1.4 High temperature forced air

There are no efficacy data on disinfesting *Citrus* of fungi by HTFA treatment

17.3.1.5 Visual inspection at the border

Recent infections (less than 1 week old) of *C. koleroga* are unlikely to be detected by visual inspection on arrival in New Zealand, resulting in a moderate to high level of residual risk.

17.4. *Elsinoë australis* (sweet orange scab)

17.4.1. Hazard identification

Scientific name: *Elsinoë australis* Bitanc. and Jenkins 1936
Anamorph: *Sphaceloma australis* Bitanc. and Jenkins 1936
Synonyms or changes in taxonomy or combination: none given
Taxonomic position: Dothideomycetes: Myriangiales: Elsinoaceae
Common name: sweet orange scab
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: Pennycook 1989; PPIN (24/7/2007); NZFungi (24/7/2007)

17.4.2. Disease cycle and epidemiology

Elsinoë australis could be confused with its congener *Elsinoë fawcettii*. They both cause scab diseases of *Citrus*. However, *E. australis* primarily attacks the fruit whereas *E. fawcettii* infects both the leaves and fruit (Timmer 2000).

E. australis forms lesions that are slightly raised pustules of plant tissue and fungus on the surface of the fruit. Inoculum for new infections consists of conidia, and possibly ascospores from these lesions. It is the young tissues that are attacked (Sivanesan and Critchett 1974), when fruit are less than 20mm diameter (Smith *et al*. 1992).

Lesions formed by *E. australis* on oranges and tangerines tend to be flatter than those caused by *E. fawcettii*, but because scab symptoms vary with cultivar and tissue age it is difficult to distinguish between the two diseases by symptoms alone. The anamorphs of *E. fawcettii* and *E. australis* are almost identical but the conidia of *E. fawcettii* on the scab lesions are spindle shaped and those of *E. australis* are not. In addition the ascospores of *E. australis* are larger than those of *E. fawcettii* (Timmer 2000). The teleomorphs (*E. fawcettii* and *E. australis*) have only been reported from Brazil, whereas other records are of the anamorphs (*Sphaceloma fawcettii*, *S. australis*).

Germination of conidia and infection are possible in the presence of moisture from dew or fog, and do not require rainfall. A wet period of 1-2 hr will allow conidia to form and 2-3 hr is needed for conidial infection. *E. australis* can grow at constant temperatures from 9.5 to

35°C. The optimal temperature is near 26°C with best growth between 24.5°C and 29°C (Bitancourt and Jenkins 1937). Fruits are susceptible to infection for 6-8 weeks after petal fall (Timmer 2000).

Lesions on fruits remaining on the tree provide the inoculum for the next season. Timmer (2000) says it is uncertain how this fungus survives through periods of no fruit and perhaps the sexual stage plays a greater role in the survival and dispersal of it. Dissemination is mostly by wind-borne rain and conidia can be airborne for short distances.

E. australis will persist in areas where suitable conditions of temperature and rainfall or high humidity prevail (wet subtropics and cooler tropics). Elsewhere, it occurs when fruit set coincides with spells of relatively warm, humid weather. Local conditions such as damp, low-lying areas and dense, shaded citrus groves will also favour its survival.

This disease can be controlled by copper fungicide applications at petal fall and again as fruit develops (Timmer 2000).

It is worth noting that scab diseases can be confused with other diseases such as bacterial canker (*Xanthomonas campestris* pv. *citri*) and melanose (*Diaporthe citri*) or with injuries caused by various agents (Smith *et al.* 1992; Timmer 2000).

17.4.3. Hosts

Citrus reticulata (mandarin), *C. sinensis* (navel orange), *C. limon* (lemon), *C. unshiu* (satsuma), *Fortunella margarita* (oval kumquat) (CPC 2007), lime, tangerine, grapefruit and *Citrus hystrix* (pointed leaf papeda) (Sivanesan and Critchett 1974).

17.4.4. Distribution

E. australis is found in South America, Cook Islands, Fiji, Niue and Samoa (CPC 2007).

17.4.5. Hazard identification conclusion

Given that:

- *Elsinoë australis* is not known to be present in New Zealand;
- is present in Samoa;
- and can be carried on *Citrus* fruit;

Elsinoë australis is considered to be a potential hazard organism in this risk analysis.

17.5. Risk assessment

17.5.1. Entry assessment

As fruit are infected when young they can become misshapen and will sometimes drop prematurely. In harvested fruit the lesions should be visible and therefore the fruit should be excluded from export. It is possible fruit could be overlooked during harvesting and handling as on occasion the lesions might be small or could be confused with wind scarring (Timmer 2000).

The likelihood of entry is considered to be low but not negligible.

17.5.2. Exposure assessment

As sweet orange scab is specific to *Citrus* species, infected fruit would need to be disposed of in close proximity to *Citrus* trees. The lesions on the discarded fruit would then need to be wet for 1-2 hours to allow for conidial development, with a further 2-3 hours of moisture to allow for infection to develop. Based on a study by Whiteside (1975), the estimated spread rate for *E. australis* in Florida *Citrus* groves would be no more than 100-300m per year (PPQ-USDA 6/8/2007).
The likelihood of exposure is considered to be low but non negligible.

17.5.3. Establishment assessment

The environmental requirements for *E. australis* development indicate it could establish in the north of the North Island, Bay of Plenty and the Gisborne/Hawkes Bay region wherever there is *Citrus* growing. Although the temperature range it can grow in is broad (9.5°C-35°C) the optimal temperature is near 26°C (Bitancourt and Jenkins 1937). Addtionally *E. australis* has not been recorded as established in temperate climates (CPC 2007). Therefore the likelihood of establishment is considered to be medium.

17.5.4. Consequence assessment

17.5.4.1 Economic impact

Culling diseased fruit increases the costs of handling and reduces the volumes available for domestic sale or export. Countries free of *E. australis* that New Zealand exports *Citrus* to would most likely impose trade restrictions.
New Zealand has *Elsinoë fawcettii* and any current control of this disease on *Citrus* will also control *E. australis*, although different *Citrus* species or cultivars may be affected.
The economic consequences of establishment are considered to be non- neglible.

17.5.4.2 Environmental impact

As this fungus is specific to *Citrus* species it is unlikely to have any impact on native species in New Zealand.
The environmental consequences of establishment are considered to be negligible.

17.5.4.3 Human health and social impact

There is no information suggesting *Elsinoë australis* has health or social impacts.

17.5.5. Risk estimation

The likelihood of entry, exposure, establishment and consequences are low to medium for *Elsinoë australis*. The risk estimate is non-negligible therefore this organism is classified as a hazard in this commodity and risk management measures can be justified.

17.6. Risk management

17.6.1. Options

There are a number of points on the import pathway where effective measures could be applied to reduce the likelihood of the fungi arriving in New Zealand. Control of fungal

diseases usually relies heavily on timing of preventative spray programmes, and fastidious orchard sanitation.

17.6.1.1 In-field sanitation

In-field sanitation is extremely important in the control of fungi.
Infected leaves and fruit on tree should be removed and the tree pruned to open the canopy to light and air.

17.6.1.2 Spray programmes

Young fruit and leaves are susceptible to infection. Where there is a lot of inoculum carryover from the previous year copper fungicides before the spring flush, again at petal fall and a third spray to protect fruit will help control the disease.

17.6.1.3 Post harvest culling, washing, waxing and visual inspection

The post-harvest washing of fruit followed by visual inspection is a supplementary measure to be implemented in conjunction with the chosen disinfestation treatment to reduce pathogens on fruit for export. *Citrus* fruit harvested for export to New Zealand should be free from any scabbing, holes, cracks or damage to the skin, free from any abnormal discoloration and pests or pathogens. Damaged fruit should be discarded.
"Routine packing house treatments used to control Citrus Black Spot (*Guignardia citricarpa*) such as chlorine dip, warm water bath, or chemical tank dip (1000 µg ml-1 guazatine, 503 µg ml-1 imazalil sulphate, 500 µg ml-1 2,4-D sodium salt) and combinations of these treatments (Korf et al., 2001a), should be effective in reducing the viability of the *Elsinoë australis*. In addition, wax treatments that further reduce the viability of CBS conidia (Korf et al., 2001a; Seberry et al., 1967) should also reduce the viability of *Elsinoë australis* conidia" (PPQ-USDA 6/8/2007). These measures in combination with in-field sanitation and a regular spray programme should significantly reduce the residual risk to very low levels.

17.6.1.4 High temperature forced air

There are no efficacy data on disinfesting *Citrus* of fungi by HTFA treatment.

17.6.1.5 Visual inspection at the border

Lesions on fruit should be visible and therefore detectable. This is more likely in small consignments. However, the likelihood of finding one infected fruit amongst several hundred kilos of uninfected fruit would be small.

17.7. *Mycosphaerella citri* (greasy spot rind blotch)

17.7.1. Hazard identification

Scientific name: *Mycosphaerella citri* Whiteside (1972)
Anamorph: *Stenella citri-grisea* (F.E. Fisher) Sivan. (1984)
Synonyms or changes in taxonomy or combination: *Cercospora citri-grisea* F.E. Fisher (1961)
Taxonomic position: Ascomycetes: Mycosphaerellales: Mycosphaerellaceae
Common name: greasy spot
New Zealand Status: not known to be present in New Zealand
Sources that do not record presence: PPIN (29/10/2007); NZFungi (29/10/2007); Pennycook (1989).

17.7.2. Disease cycle and epidemiology

The main effect of this disease is premature defoliation, resulting in reduced yields and fruit size. It also produces greasy spot rind blotch on *Citrus* fruit (Timmer and Gottswald 2000). Symptoms on fruit appear 3-6 months after infection, presenting first as pinkish then brown-black necrotic specks between the oil glands on the fruit rind. The symptoms of greasy spot rind can be confused with injury caused by rust mites (Timmer and Gottswald 2000). *Or is it Gottwald??*

M. citri overwinters in fallen leaves under *Citrus* trees. Pseudothecia are formed in the decomposing leaves and after a period of wetting and drying they release ascospores which are the primary source of inoculum for the disease. The ascospores germinate producing hyphae that penetrate the leaf surface and fruit rinds (Hidalgo *et al.* 1997; Timmer and Gottswald 2000). Air-borne ascospores from fallen leaves are thought to be the most important infection source (Sivanesan and Holliday 1976)

Prolonged and repeated periods of high humidity (near 100%) combined with warm temperatures (25-30˚C) are required for hyphal infections via stomatal penetration (Hidalgo *et al.* 1997). Dry weather delays development of pseudothecia and prevents the release of ascospores. Thus, in high-temperature and high-rainfall areas, such as is found in the Caribbean and Central America, the cycle continues the whole year with infection occurring at any time (Timmer and Gottswald 2000).

Control of the disease is mostly by copper or strobilurin sprays. Benomyl was effective when first used but this fungus is reported to have developed resistance to it (Timmer and Gottswald 2000). Spring growth can be protected anytime before the onset of the rainy season or up to 3 weeks thereafter. Summer growth should be protected 3-4 weeks after emergence. In Florida a single spray per month from June to August (their summer) is used (Mondal and Timmer 2005).

17.7.3. Hosts

M. citri affects *C.* x *paradisi* (grapefruit), *C. limon* (lemons), early *C. sinensis* varieties (oranges) and *C. paradisi* x *C. reticulata* tangelos most severely, and is less severe on late oranges and tangerines (Timmer and Gottwald 2000). *C. reticulata* (mandarins) seem to be more tolerant of greasy spot. Other genera in the Rutaceae are also attacked by *M. citri* (Timmer and Gottswald 2000) and it is also known to infect *Acacia mangium, Musa* sp., *Aeglopsis* sp., *Fortunella*, *Murraya* and *Poncirus* (Pretorius *et al.* 2003 in: Crous *et al.* 2004).

17.7.4. Distribution

M. citri occurs in Florida, Texas, Caribbean, Central America, South America and Japan, Thailand, Taiwan, Hong Kong, Australia (Timmer and Gottswald 2000; Crous *et al.* 2004; CPC 2007) and Samoa (J. Wright pers. comm. 2007).

17.7.5. Hazard identification conclusion

Given that

- *Mycosphaerella citri* is not known to be present in New Zealand;
- is present in Samoa;
- is associated with *Citrus* fruit;
- and has a latent period between infection and symptom expression of 3-6 months on fruit;

Mycosphaerella citri is therefore considered a potential hazard for the purposes of this risk analysis.

17.8. Risk assessment

17.8.1. Entry assessment

Not all infected fruit can be expected to be detected due to the latency period between infection and symptom expression. Therefore the likelihood of entry for *Mycosphaerella citri* is considered high.

17.8.2. Exposure assessment

Citrus fruit does not pose a risk of transmitting *Mycosphaerella citri* even if it is infected, as the fungus does not sporulate on fruit. Therefore the likelihood of exposure of *Mycosphaerella citri* on fresh *Citrus* from Samoa is considered negligible and this species shall not be considered further in this risk analysis.

17.9. *Phytophthora palmivora* (brown rot)

17.9.1. Hazard identification

Scientific name: *Phytophthora palmivora* (E.J. Butler) E.J. Butler 1919
Synonyms or changes in taxonomy or combination: *Phytophthora palmivora* var. *palmivora* (E.J. Butler) E.J. Butler 1919[1918] Phytophthora arecae (L.C. Coleman) Pethybr (1913); Phytophthora cactorum var. arecae (L.C. Coleman) Sacc. & Trotter, (1912); Phytophthora faberi Maubl., (1909); Phytophthora heveae A.W. Thomps., (1929); Phytophthora omnivora var. arecae L.C. Coleman, (1910); Phytophthora palmivora var. heveae (A.W. Thomps.) Orellana, (1959); Phytophthora palmivora var. theobromae (L.C. Coleman) Orellana, (1959); Phytophthora theobromae L.C. Coleman (1910); Pythium palmivorum E.J. Butler, (1907)
Taxonomic position: Oomycetes: Pythiales: Pythiaceae
Common name: brown rot
New Zealand Status: Not known to be present in New Zealand
Sources that do not record presence: Pennycook 1989; PPIN (24/7/2007); NZFungi (24/7/2007)

17.9.2. Disease cycle and epidemiology

P. palmivora causes brown rot of *Citrus* fruit. *C. limon, C. aurantiifolia, C. sinensis* and *C. paradisi* are very susceptible to this fungus (Graham and Menge 2000).

Phytophthora palmivora is heterothallic, having an incompatibility system by which only genetically different strains can undergo nuclear fusion during sexual reproduction. There are two mating types of *P. palmivora* (A^1 and A^2), and both are found in many areas of the world (Zentmyer 1988). *P. palmivora* requires high moisture and high temperatures for development.

Low populations can persist in the soil. Fallen fruit "attract" *P. palmivora* from the soil and sporulation is profuse under moist conditions. Sporangia can be dispersed at least 0.5m into the tree by rain splash. Fruits approaching maturity are infected by the sporangia and zoospores this way. Secondary infections are then caused by sporangia spread through the tree by splashing water, windblown rain and, more rarely, invertebrates such as snails and ants (Graham and Menge 2000; Taylor and Griffin 1981). Timmer *et al.* (2000) state rain drops would be sufficient to propel small sporangium- filled droplets into the air where they could be carried some distance by wind. Most infected fruit soon abscise but harvested fruit may not show symptoms until after they have been held in storage for a few days. Brown rot presents with a light brown discoloration initially, then a delicate white mycelium forms, accompanied by a distinctive pungent, rancid odour (Graham and Menge 2000).

Soil populations are maintained by repeated infections of the fibrous roots and *P. palmivora* can persist in unfavourable conditions for some time as chlamydospores (Graham and Menge 2000).

Erwin and Ribeiro (1996) state the minimum temperature for growth is 11˚C, and the optimum is 27.5 to 30˚C, the maximum is near 35˚C. Timmer *et al.* (2000) conducted an experiment on oranges in Florida. They showed the optimal temperature range for infection and disease development was between 27 and 30˚C and the optimal temperature for sporangium production on the fruit surface was 24˚C. Although inhibiting disease development, temperatures ranging from 10-22˚C would not prevent sporangium formation.

Therefore sporangia are likely to be dispersed by rain with lesions developing when temperatures increased. Even at optimal temperatures sporangia development is slow on fruit, taking up to 72 hours (Timmer *et al*. 2000). In tropical areas with frequent rainfall and temperatures between 20-30˚C *P. palmivora* produces sporangia rapidly and has a short regeneration time (Erwin and Ribeiro 1996).
In Florida epidemics have occurred when temperatures were from 20-30˚C and fruit wetness duration was greater than 12 hours. These events usually occurred during the Florida summer when fruit was beginning to mature and followed several consecutive rain events (Timmer *et al*. 2000).
Control is largely by strict orchard sanitation, the use of systemic fungicides and copper fungicides (Graham and Menge 2000).

17.9.3. Hosts

In Samoa *P. palmivora* is recorded from *Cocos nucifera* (coconut) (Dingley *et al*. 1981) and *Artocarpus altilis* (breadfruit) Gerlach and Salevao (1984; in Erwin and Ribeiro 1996). *P. palmivora* infects more than 200 species of economic, ornamental, shade and hedge plants including the following:
Anacardium occidentale (cashew nut), *Ananas comosus* (pineapple), *Annona*, *Antirrhinum majus*, *Areca catechu* (betelnut palm), *Areca lutescens*, *Artocarpus altilis* (breadfruit), *Capsicum annuum*, *Cattleya* sp., *Carica papaya* (papaw), *Citrus* sp., *C. limon, C. aurantiifolia, C. sinensis, Citrus x paradisi* (grapefruit), *Colocasia* sp., *Crotalaria* sp., *Cymbidium* sp., *Dendrobium* sp., *Dianthus caryophyllus*, *Dieffenbachia* sp., *Durio zibethinus* (durian), *Elaeis guineensis* (African oil palm), *Ficus carica* (fig), *Gossypium hirsutum* (Bourbon cotton), *Grevillea* sp., *Hedera* sp., *Hevea brasiliensis* (rubber), *Hibiscus* sp., *Howea* sp., *Lavandula* sp., *Lycopersicon esculentum*, *Macadamia integrifolia*, *Magnolia grandiflora*, *Manihot esculenta* (cassava), *Mangifera indica*, *Manilkara zapota* (sapodilla), *Myristica fragrans* (nutmeg), *Paphiopedilum* sp., *Persea americana*, *Petunia violacea, Phalaenopsis* sp., *Phaseolus* sp., *Philodendron* sp., *Piper nigrum* (black pepper), *Rhopalostylis baueri*, *Solanum tuberosum, Syzygium paniculatum, Theobroma cacao* (cocoa) (CPC 2007; Graham and Menge 2000; Farr *et al*. 2007-partial list).

17.9.4. Distribution

P. palmivora is typically found in tropical and subtropical countries with high rainfall. It is present throughout Asia, parts of Europe, Africa, southern North America, Central and South America. It is found in Australia, is widespread in American Samoa, Fiji, French Polynesia, New Caledonia, Northern Mariana Islands, Papua New Guinea, Samoa, Solomon Islands, Tonga and Vanuatu. (CPC 2007).

17.9.5. Hazard identification conclusion

Given that:

- *Phytophthora palmivora* is not known to be present in New Zealand;
- is present in Samoa;
- is associated with *Citrus* fruit;
- and may not be readily detectable;

Phytophthora palmivora is considered to be a potential hazard in this risk analysis.

17.10. Risk assessment

17.10.1. Entry assessment

Infected fruit may not necessarily show signs of disease caused by *Phytophthora palmivora* for several days, which means this fungus could enter undetected. The likelihood of entry of *P. palmivora* is considered to be high.

17.10.2. Exposure assessment

The time from harvest in Samoa to distribution in New Zealand is likely to be about 48 hours. It is possible fruit may begin to show signs of brown rot whilst on sale or after purchase by individuals. There are three possibilities at this point. The retailer may realise the problem and dispose of the fruit which is likely to be taken to the local rubbish dump. It is uncertain if the fruit would remain exposed or be buried, or if there would be suitable host species close enough to a rubbish dump to become infected.

The purchaser may discard the fruit en route or at home. En route disposal could be a public waste container or littering the urban or rural roadside. Home disposal would include domestic rubbish or open compost. It is possible *P. palmivora* might not develop fully if temperatures are less than 22˚C but open composts may provide a suitable microclimate allowing a good incubation environment for *P. palmivora*. The fungus could survive as chlamydospores, until conditions were suitable for development, whereupon "rain droplets would be sufficient to propel small sporangium-bearing droplets into the air where they could be carried some distance by the wind" (Timmer *et al*. 2000).
The likelihood of exposure of *P. palmivora* is considered to be medium.

17.10.3. Establishment assessment

It is unclear if *P. palmivora* dies or becomes dormant at temperatures below 10-11˚C.
If *P. palmivora* dies below 10˚C it is unlikely to establish in New Zealand.
If *P. palmivora* becomes dormant under 10-11˚C there is a medium likelihood of it establishing in New Zealand, particularly the north of the North Island.

However, disease development occurs at higher temperatures (27-30˚C-Erwin and Ribeiro 1996, Timmer *et al*. 2000), and sporangia can take up to 72 hours to develop on *Citrus* at optimal temperatures (Timmer *et al*. 2000). The mean monthly minimum and maximum temperatures (in the period 1971-2000) for Kaitaia (35˚.08'S, 173˚.17'E) in February was 15.6˚C and 24.5˚C respectively. In the North Island it is unusual to have several days at temperatures of 27˚C or greater, and night temperatures would be considerably less so there is a very low likelihood of *P. palmivora* developing pathogenicity in New Zealand.
The likelihood of establishment is considered to be medium with a low likelihood of disease development.

17.10.4. Consequence assessment

17.10.4.1 Economic impact

The New Zealand *Citrus* industry produces fruit for domestic and export markets. Other produce susceptible to *P. palmivora* include tomato, avocado, macadamia and potatoes. As it seems unlikely that *P. palmivora* could become pathogenic in New Zealand the economic consequences is considered to be low but non negligible.

17.10.4.2 Environmental impact

P. palmivora is a highly polyphagous fungus, with hosts in families that are also represented in New Zealand by various indigenous species. Some of these are in decline to nationally critical status (e.g.: Orchidaceace) and many others are common in suburban reserve areas and used in amenity or domestic plantings. If *P. palmivora* established, it is most likely it will initially be in urban areas of the northern North Island. It is uncertain the degree to which it would spread and therefore it is uncertain what the environmental consequences would be.

17.10.4.3 Human health and social impact

There does not appear to be any information suggesting *P. palmivora* has any adverse affect on human health.

17.10.5. Risk estimation

The likelihood of entry of *Phytophthora palmivora* is high, exposure is medium and establishment is medium. The consequences of establishment are low but non negligible. The risk estimate is non negligible therefore this organism is classified as a hazard in this commodity and risk management measures can be justified.

17.11. Risk management

17.11.1. Options

There are a number of points on the import pathway where effective measures could be applied to reduce the likelihood of the fungi arriving in New Zealand. Control of fungal diseases usually relies heavily on timing of preventative spray programmes, and fastidious orchard sanitation.

17.11.1.1 In-field sanitation

In-field sanitation is extremely important in the control of fungi such as *Phytophthora*. The soil surface under *Citrus* trees should be kept free of weeds and debris, and the trunk bark should be free of injury to avoid entry points for pathogens (Graham and Menge 2000). Good drainage is important to avoid pathogen build-up (Graham and Menge 2000).
Fallen fruits, leaves and any infected material needs to be removed to reduce the infection cycle or avoid reinfection, and buried no less than 30cm deep, or burned.

17.11.1.2 Spray programmes

A spray programme is more effective when in combination with in-field sanitation. Copper fungicides are usually effective when applied before the rainy season. Post-harvest fungicidal treatments commonly used in packhouses are not effective in controlling brown rot, but fosetyl-A when applied to the canopy 12 weeks prior to infection will control the disease after harvest (Graham and Menge 2000).

17.11.1.3 Post harvest culling, washing, waxing and visual inspection

The post-harvest washing of fruit followed by visual inspection is a supplementary measure to be implemented in conjunction with the chosen disinfestation treatment to reduce pathogens on fruit for export. *Citrus* fruit harvested for export to New Zealand should be free from any

scabbing, holes, cracks or damage to the skin, free from any abnormal discoloration and pests or pathogens. Damaged fruit should be discarded.

17.11.1.4 High temperature forced air

There are no efficacy data on disinfesting *Citrus* of fungi by HTFA treatment.

17.11.1.5 Hot water immersion

Although papaya in Hawaii undergo HWI for control of *Phytophthora* spp. (Aragaki *et al*. 1981) this doesn't appear to be routine for *Citrus* spp. There are also limitations regarding the efficacy of this treatment (see section 5.6).
It is likely HWI will contribute to reducing the risk of *Phytophthora palmivora* entering New Zealand on *Citrus* fruit from Samoa, but is best used in conjunction with in-field control for greater effectiveness. Couey (1989) states that fungicides are most effective when applied at high temperatures, so it is possible to combine the two treatments. However this should not be seen as an alternative to in-field control but as a supplement to it.
Aragaki *et al*. (1981) used a treatment of 48˚C for 20 minutes on papaya. There is uncertainty if *Citrus* other than limes (Gould and McGuire 2000) can tolerate this time/temperature regime.

17.11.1.6 Visual inspection at the border

Recent infections of *P. palmivora* are unlikely to be detected by visual inspection on arrival in New Zealand.

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18. Research Priorities

There is a paucity of information on the efficacy of the available risk mitigation options in managing the biosecurity hazards associated with *Citrus* fruit. This chapter identifies research priorities. This will enable us to validate the assumptions made in the risk analysis.

- Washing
  This is a simple and affordable treatment. Comparisons are needed between washing fruit under a running tap; washing and brushing under running water; submersing in chlorinated water for a set time; submersing and brushing.
  Efficacy needs to be tested for mealybugs, whitefly, aphids, thrips, mites, ants and bugs.

- HTFA and cold disinfestation
  Most of the information available deals with the use of these treatments for fruit fly disinfestation. There appears to be no information on mites, mealybugs, scale insects, thrips, aphids and whitefly. Data on the proportion of organisms in these groups that survive these treatments are required.

- Produce disposal
  Scientific information regarding the disposal of bought fresh produce in New Zealand is required to determine the likelihood of associated pests being able to move from the commodity to another host.

Appendix 1 List of organisms considered in this analysis

All organisms thought to be associated with *Citrus* in Samoa are listed in the table below. Potential hazards are identified as those organisms that are not present in New Zealand, are potential vectors, are under official control and have evidence of association with *Citrus* fruit. A risk assessment is undertaken for organisms identified as potential hazards (Chapters 7-17). Potential hazards that are assessed as having a non negligible risk are considered to be hazards.

Organisms not considered to be potential hazards are listed in Appendix 2, with a technical justification and references for their non-hazard status in this document. These species are listed in the same order that is used in the table below.

Invertebrates

Phylum: Class: Order	Scientific name (Family)	Common name	Presence in NZ	Association with *Citrus* fruit	Presence in Samoa	Vector?	Unwanted or controlled?	Potential hazard?	Hazards
Arthropoda: Arachnida: Acari	*Phyllocoptruta oleivora* (Eriophyidae)	Citrus rust mite	Y (Manson 1984)	Y: Smith *et al*. 1997	Waterhouse 1997	N	N	N (App 2)	N
	Polyphagotarsonemus latus (Tarsonemidae)	Broad mite	Y (Manson 1983)	Y: Smith *et* al. 1997	Waterhouse 1997	N	N	N (App 2)	N
	Tetranychus neocaledonicus (Tetranychidae)	Mexican spider mite	N	Y: Martin and Mau 1991	Bolland *et al*.1998	N	Y	Y (Chap14)	Y
Arthropoda: Insecta: Coleoptera	*Elytroteinus subtruncatus* (Curculionidae)	Fijian ginger weevil	N	Y: Miller 1923	Gerlach 1988	N	Y	N (App 2)	N
Arthropoda: Insecta: Diptera	*Atherigona orientalis* (Muscidae)	Muscid fly	N	N: Al-Janabi *et al*. 1983	Pont 1992	n/a	n/a	N (App2)	N
	Bactrocera kirki (Tephritidae)	Fruit fly	N	Y: Heimoana *et al.* 1996	Heimoana *et al.* 1996	N	Y	Y (Chap 7)	Y
	Bactrocera xanthodes (Tephritidae)	Fruit fly	N	Y: Heimoana *et al.* 1996	Heimoana *et al.* 1996	N	Y	Y (Chap 7)	Y
Arthropoda: Insecta: Hemiptera	*Aleurodicus dispersus* (Aleyrodidae)	Spiralling whitefly	N	Y: CPC 2007	De Barro *et al*. 1997	Y viruses	Y	Y (Chap 11)	Y
	Aonidiella aurantii (Diaspididae)	California red scale	Y (Charles and Henderson 2002)	Y: Smith *et al.* 1997	Williams and Watson 1988	N	N	N (App 2)	N
	Aonidiella inornata (Diaspididae)	Papaya red scale	N	Y: Watson 2005	Williams and Watson 1988	N	Y	Y (Chap 13)	Y
	Aphis craccivora (Aphididae)	Bean aphid	Y (Teulon *et al.* 2004)	N: CPC 2007	Waterhouse 1997	Y viruses	N	N (App 2)	N
	Aphis gossypii (Aphididae)	Cotton aphid	Y (Teulon *et al.* 2004)	N: Smith *et al.* 1997	Waterhouse 1997	Y viruses	Y	N (App 2)	N
	Aspidiotus destructor (Diaspididae)	Coconut scale	N	Y: Martin-Kessing and Mau 2007	Williams and Watson 1988	N	Y	Y (Chap 13)	Y
	Bemisia tabaci biotype B 'Nauru' (Aleyrodidae)	Tabacco whitefly	N	N: De Barro *et al*. 1997	De Barro *et al*. 1997	Y viruses	Y	N (App 2)	N

Phylum: Class: Order	Scientific name (Family)	Common name	Presence in NZ	Association with *Citrus* fruit	Presence in Samoa	Vector?	Unwanted or controlled?	Potential hazard?	Hazards
	Ceroplastes rubens (Coccidae)	Red wax scale	N	N: Smith *et al.* 1997	Williams and Watson 1988	N	Y	N (App 2)	N
	Chrysomphalus aonidum (Diaspididae)	Florida red scale	N	Y: Smith *et al.* 1997	Williams and Watson 1988	N	Y	Y (Chap 13)	Y
	Chrysomphalus dictyospermi (Diaspididae)	Dictyospermum scale	N	Y: Smith *et al.* 1997	Williams and Watson 1988	N	Y	Y (Chap 13)	Y
Arthropoda: Insecta: Hemiptera	*Coccus capparidis* (Coccidae)	Capparis soft scale	N	N:	Williams and Watson 1988	N	Y	N (App 2)	N
	Coccus hesperidum (Coccidae)	Brown soft scale	Y (Hodgson and Henderson 2000)	Y: Smith *et al.* 1997	Williams and Watson 1988	N	N	N (App 2)	N
	Coccus viridis (Coccidae)	Soft green scale	N	Y: Smith *et al.* 1997	Williams and Watson 1988	N	Y	Y (Chap 13)	Y
	Dialeurodes citrifolii (Aleyrodidae)	Cloudy winged whitefly	N	N	De Barro *et al*. 1997	N	Y	N (App 2)	N
	Duplaspidiotus claviger (Diaspididae)	Camellia mining scale	N	N: Dekle 1976	Williams and Watson 1988	N	Y	N (App 2)	N
	Dysmicoccus brevipes (Pseudococcidae)	Pineapple mealybug	N	Y	Williams and Watson 1988	N	Y	Y (Chap 12)	Y
	Dysmicoccus neobrevipes (Pseudococcidae)	Annona mealybug	N	Y	Williams and Watson 1988	N	Y	Y (Chap 12)	Y
	Dysmicoccus nesophilus (Pseudococcidae)		N	N	Williams and Watson 1988	N	Y	N (App 2)	N
	Eucalymnatus tessallatus (Coccid)	Palm scale	N	N	Williams and Watson 1988	N	Y	N (App 2)	N
	Fiorinia fiorina (Diaspidiae)	Avocado scale	N	N: Gill 1997	Williams and Watson 1988	N	N	N (App 2)	N
	Ferrisia virgata (Pseudococcidae)	Striped mealybug	N	Y: Schreiner 2000	Williams and Watson 1988	Y viruses	Y	Y (Chap 12)	Y
	Hemiberlesia lataniae (Diaspididae)	Latania scale	Y (Blank *et al.* 1993)	Y: Dekle 1976	Williams and Watson 1988	N	N	N (App 2)	N
	Hemiberlesia palmae (Diaspididae)	Tropical palm scale	N	N: Dekle 1976	Williams and Watson 1988	N	Y	N (App 2)	N
	Howardia biclavis (Diaspididae)	Mining scale	N	Y: Dekle 1976	Williams and Watson 1988	N	Y	Y (Chap 13)	Y
	Icerya seychellarum Maskell (Magorodidae)	Seychelles scale	N	N	Williams and Watson 1988	N	Y	N (App 2)	N
	Ischnaspis longirostris (Diaspididae)	Black thread scale	N	Y: Dekle 1976	Williams and Watson 1988	N	Y	Y (Chap 13)	Y
	Lepidosaphes beckii (Diaspididae)	Purple scale	Y (Charles and Henderson 2002)	Y: Smith *et al.* 1997	Williams and Watson 1988	N	N	N (App 2)	N
	Lepidosaphes gloverii (Diaspididae)	Glover scale	N	Y: Smith *et al.* 1997	Williams and Watson 1988	N	Y	Y (Chap 13)	Y
	Leptoglossus gonagra (Coreidae)	Coreid bug	N	Y: Albrigo and Bullock 1977	Waterhouse 1997	Y yeast	Y	Y (Chap 14)	Y

Phylum: Class: Order	Scientific name (Family)	Common name	Presence in NZ	Association with *Citrus* fruit	Presence in Samoa	Vector?	Unwanted or controlled?	Potential hazard?	Hazards
	Lopholeucaspis cockerelli (Diaspididae)	Cockerell scale	N	N: Dekle 1976	Williams and Watson 1988	N	Y	N (App 2)	N
Arthropoda: Insecta: Hemiptera	*Kilifia acuminata* (Coccid)	Acuminate scale	N	N	Williams and Watson 1988	N	Y	N (App 2)	N
	Milviscutulus mangiferae (Coccid)	Mango sheild scale	N	N	Williams and Watson 1988	N	Y	N (App 2)	N
	Morganella longispina (Diaspididae)	Plumose scale	N	N	Williams and Watson 1988	N	Y	N (App 2)	N
	Myzus persicae [Aphididae]	Green peach aphid	Y (Teulon *et al.* 2004)	N: CPC 2007	Waterhouse 1997	Y viruses	N	N (App 2)	N
	Nezara viridula (Pentatomidae)	Green vegetable bug	Y (Clunie 2004)	Y: Fasulo and Stansly 2004	Waterhouse 1997	Y yeast	N	N (App 2)	N
	Orchamoplatus mammaeferus (Aleyrodidae)	Croton whitefly	N	N	De Barro *et al*. 1997	N	Y	N (App 2)	N
	Parabemesia myricae (Aleyrodidae)	Japanese bayberry whitefly	N	Y: Smith *et al.* 1997	De Barro *et al*. 1997	Y viruses	N	Y (Chap 11)	Y
	Paraleyrodes bondari (Aleyrodidae)	whitefly	N	uncertain	De Barro *et al*. 1997	uncertain	N	Y (Chap 11)	Y
	Parasaissetia nigra (Coccidae)	Nigra scale	Y (Hodgson and Henderson 2000)	Y: Smith *et al.* 1997 (fruit stalk)	Williams and Watson 1988	N	N	N (App 2)	N
	Parlatoria cinerea (Diaspididae)	Apple parlatoria	N	Y: Culik *et al.* 2007	Williams and Watson 1988	N	Y	Y (Chap 13)	Y
	Parlatoria pergandii (Diaspididae)	Chaff / oyster scale	N	Y: Smith *et al.* 1997	Williams and Watson 1988	N	Y	Y (Chap 13)	Y
	Pinnaspis strachani (Diaspididae)	Hibiscus snow scale	N	Y: Tenbrick and Hara 2007	Williams and Watson 1988	N	Y	Y (Chap 13)	Y
	Planococcus citri (Pseudococcidae)	Citrus mealybug	N	Y: Smith *et al.* 1997	Williams and Watson 1988	Y viruses	Y	Y (Chap 12)	Y
	Planococcus minor (Pseudococcidae)	Passionvine mealybug	N	Y: Williams and Watson, 1990	Williams and Watson 1988	N	Y	Y (Chap 12)	Y
	Pseudococcus cryptus (Pseudococcidae)	Cryptic mealybug	N	Y: Avidov and Harpaz 1969	Williams and Watson 1988	N	N	Y (Chap 12)	Y
	Pseudaulacaspis pentagona (Diaspididae)	Peach scale	N	Y: Williams and Watson 1988	Williams and Watson 1988	N	N	Y (Chap 13)	Y
	Saissetia coffeae (Coccidae)	Hemispherical scale	Y (Henderson 2001)	Y: Smith *et al.* 1997 (fruit stalk)	Williams and Watson 1988	N	N	N (App 2)	N
	Saissetia oleae (Coccidae)	Black olive scale	Y (Henderson 2001)	Y: Smith *et al.* 1997	Williams and Watson 1988	N	N	N (App 2)	N
	Toxoptera aurantii	Camellia aphid	Y (Teulon *et al.* 2004)	N: Smith *et al.* 1997	Waterhouse 1997	Y viruses	N	N (App 2)	N
	Toxoptera citricida	Black citrus aphid	Y (Teulon *et al.* 2004)	N: Smith *et al.* 1997	Waterhouse 1997	Y viruses	N	N (App 2)	N
Arthropoda: Insecta: Hemiptera	*Unaspis citri* (Diaspididae)	Citrus snow scale	N	Y: Smith *et al.* 1997	Williams and Watson 1988	N	Y	Y (Chap 13)	Y

Phylum: Class: Order	Scientific name (Family)	Common name	Presence in NZ	Association with *Citrus* fruit	Presence in Samoa	Vector?	Unwanted or controlled?	Potential hazard?	Hazards
Arthropoda: Insecta: Hymenoptera	*Anoplolepis gracilipes* (Formicidae)	Yellow crazy ant	N	hitch-hiker	Wetterer and Vargo 2003	N	Y	Y (Chap 15)	Y
	Paratrechina longicornis (Formicidae)	Crazy ant	N	hitch-hiker	Wetterer and Vargo 2003	N	Y	Y (Chap 15)	Y
	Pheidole megacephala (Formicidae)	Bigheaded ant	Y (Don and Harris 2007)	hitch-hiker	Wetterer and Vargo 2003	n/a	n/a	N (App 2)	N
	Solenopsis geminata (Formicidae)	Tropical fire ant	N	hitch-hiker	Wetterer and Vargo 2003	N	Y	Y (Chap 15)	Y
Arthropoda: Insecta: Lepidoptera	*Eudocima fullonia* (Noctuidae)	Fruit-piercing moth	N	Y: Smith *et al.* 1997	CPC 2007	N	Y	Y (Chap 8)	N
	Helicoverpa armigera (Noctuidae)	Tomato fruitworm	Y (Clunie 2004)	Y: Smith *et al.* 1997	CPC 2007	N	N	N (App 2)	N
	Phyllocnistis citrella (Gracillariidae)	Citrus leafminer	N	Y: Heppner 1995	CPC 2007	N	Y	Y (Chap 8)	N
	Prays citri (Yponomeutidae)	Citrus flower moth	N	Y: Ibrahim and Shahateh 1984	CPC 2007	N	Y	Y (Chap 8)	Y
	Tiracola plagiata (Noctuidae)	Banana fruit caterpillar	N	Y: Smith *et al.* 1997	CPC2007	N	Y	Y (Chap 8)	N
Arthropoda: Insecta: Thysanoptera	*Thrips hawaiiensis* (Thripidae)	Hawaiian flower thrips	N	Y: Chiu *et al.* 1991	CPC 2007	N	Y	Y (Chap 9)	Y
	Thrips palmi (Thripidae)	Palm thrips	N	Y: Sakimura *et al.* 1986	CPC 2007	Y viruses	Y	Y (Chap 9)	Y
Mollusca: Gastropoda: Pulmonata	*Achatina fulica* (Achatinidae)	Giant East African snail	N	hitch-hiker	CPC 2007	n/a	n/a	N (App 2)	N

Fungi

Phylum: Class: Order	Scientific name [Anamorph]	Common name	Presence in NZ	Association with *Citrus* fruit	Presence in Samoa	Vector?	Unwanted or controlled?	Potential hazard?	Hazards
Ascomycota: Ascomycetes: Pleosporales	*Alternaria alternata*	Black stalk rot	Y (Pennycook 1989)	Y Timmer *et al.* 2000	Gerlach 1988	N	N	N (App 2)	N
Ascomycota: Ascomycetes: Pleosporales	*Alternaria citri*		Y (NZ Fungi 2007)	Y NZ Fungi 2007	Dingley *et al.* 1981	N	N	N (App 2)	N
Basidiomycota: Basidiomycetes: Polyporales	*Athelia rolfsii* [*Sclerotium rolfsii*]	Rolf's disease	Y (Pennycook 1989)	Y CPC 2007	Reynolds 1975	N	N	N (App 2)	N
Ascomycota: Ascomycetes: Dothideales	*Botryosphaeria rhodina* [*Lasiodiplodia theobromae*]	Gummosis	Y (Pennycook 1989)	Y Timmer *et al.* 2000	Gerlach 1988	N	N	N (App 2)	N
Ascomycota: Dothideomycetes: Meliolales	*Capnodium citri*	Sooty mould	uncertain	Y Whiteside 2000	Dingley *et al.* 1981	N	Y	Y (Chap 16)	Y
Basidiomycota: Basidiomycetes: Ceratobasidiales	*Corticium koleroga*	Web blight	N	Y:Timmer 2000	J. Wright pers. comm. 2007	N	Y	Y (Chap 17)	Y
Ascomycota: Leotiomycetes: Heliotales	*Cryptosporiopsis citri*		Y(NZ Fungi 2007)	N J. Wright pers. comm. 2007	J. Wright pers. comm. 2007	N	N	N (App 2)	N
Ascomycota: Sordariomycetes: Diaporthales	*Diaporthe citri* [*Phomopsis citri*]	Melanose/stem end rot	Y (NZ Fungi 2007)	Y Timmer 2000	Dingley *et al.* 1981	N	N	N (App 2)	N
Ascomycota: Sordariomycetes: Diaporthales	*Diaporthe medusaea*		Y (NZ Fungi 2007)	Y NZ Fungi 2007	NZ Fungi 2008	N	N	N (App 2)	N
Ascomycota: Dothideomycetes: Myriangiales	*Elsinoë australis* [*Sphaceloma australis*]	Sweet orange scab	N	Y Timmer 2000	J. Wright pers. comm. 2007	N	Y	Y (Chap 17)	Y
Ascomycota: Dothideomycetes: Myriangiales	*Elsinoë fawcettii* [*Sphaceloma fawcettii*]	Verrucosis / Citrus scab	Y (NZ Fungi 2007)	Y Timmer 2000	Dingley *et al.* 1981	N	N	N (App 2)	N
Ascomycota: Ascomycetes: Incertae sedis	*Glomerella cingulata* [*Colletotrichum gloeosporioides*]	anthracnose	Y (Laundon 1972)	Y Timmer *et al.* 2000	Carlos and Misipati 1992	N	N	N (App 2)	N
Ascomycota: Dothideomycetes: Meliolales	*Meliola citricola*	Sooty blotch	N	Y Minter 2006	Dingley *et al.* 1981	N	Y	Y (Chap 16)	Y
Ascomycota: Ascomycetes: Mycosphaerellales	*Mycosphaerella citri* [*Stenella citri-grisea*]	Greasy spot	N	Y Timmer and Gottwald 2000	J. Wright pers. comm. 2007	N	Y	Y (Chap 17)	N
Ascomycota: Ascomycetes: Hypocreales	*Nectria haematococca* [*Fusarium solani*]	Fusarium fruit rot	Y (Pennycook 1989)	Y Farr et al. 1989	Gerlach 1988	N	N	N (App 2)	N
Ascomycota: Chaetothyriomycetes: Chaetothyriales	*Phaeosaccardinula javanica*	Sooty mould	N	Y Dingley et al. 1981	Dingley *et al.* 1981	N	Y	Y (Chap 16)	Y
Oomycota: Oomycetes: Pythiales	*Phytophthora nicotianae*	Buckeye rot	Y (Pennycook 1989)	Y Timmer *et al.* 2000	Dumbleton 1954	N	N	N (App 2)	N
Oomycota: Oomycetes: Pythiales	*Phytophthora palmivora*	Black rot	N	Y Graham and Menge 2000	Dingley *et al.* 1981	N	Y	Y (Chap 17)	Y
Ascomycota: Zygomycetes: Mucorales	*Rhizopus stolonifer*	Rhizopus soft rot	Y (Pennycook 1989)	Y Adisa and Obinyereokwu 1988	Gerlach 1988	N	N	N (App 2)	N
Adcomycota : Ascomycetes:Helotiales	*Sclerotinia sclerotiorum*	Cottony rot	Y (Pennycook 1989)	Y Timmer *et al.* 2000	Gerlach 1988	N	N	N (App 2)	N
Chlorophyta: Ulvophyceae: Trentepohliales	*Cephaleuros virescens*	Algal leaf spot	Y (Pennycook 1989)	Y Timmer *et al.* 2000	Gerlach 1988	N	N	N (App 2)	N

Appendix 2 Species not considered to be potential hazards in this risk analysis

Species listed below were not considered to be potential hazards in this risk analysis because they meet one or more of the following criteria:

- the organism/disease has no recorded association with *Citrus* fruit; and
- the organism/disease is already present in New Zealand; and
- the organism/disease is not under official control; and
- there is no evidence that the arrival (and subsequent establishment) of the organism/disease in New Zealand would lead to any significant increase in the existing exposure; and
- the organism/disease would not introduce new pathogens/diseases/strains into New Zealand.

Invertebrates

Acari:

Phyllocoptruta oleivora (Ashmead) (Acarina: Eriophyidae) -citrus rust mite

This mite was first recorded from a residence in Auckland in 1975. A subsequent survey of neighbouring areas found it to be quite common on lemons, oranges mandarins and grapefruit (Manson 1984).

Polyphagotarsonemus latus (Banks) (Acari: Tarsonemidae) -broad mite

As this mite is already present in New Zealand, and is not under official control, it is not considered further in this risk assessment.

Manson (1983) recorded this mite from *Beta vulgaris*, *Cyclamen* sp., *Feijoa sellowiana* and *Solanum muricatum* in New Zealand.

Coleoptera:

Elytroteinus subtruncatus Fairmaire (Coleoptera: Curculionidae) - Fijian ginger weevil This genus is flightless, dwelling in forest litter. Larvae live and feed in decaying vegetable matter on the forest floor. The adults graze on non-phanerogamic vegetation close to the ground. The larval stage will burrow into the root, corm or tuber of the host plant. The subsequent feeding results in wilt and loss of vigour of the host.

In Hawaii it was first found in white ginger roots (*Hedychium coronarium*) and subsequently has been reported on avocado seed, bird of paradise tubers (*Strelitzia reginae*), cycad trunk, lemons, Marrattia fern, sugarcane, taro roots, and ti cuttings (*Cordyline terminalis*) (Mau and Martin 1992). In Fiji it is recorded as damaging *Begonia*, boring down the centres of the main stems near the plant base resulting in dieback (Simmonds 1928).

Mau and Martin (1992) state this weevil infested lemon by boring into the pulp at the base of the stalk and pupating there. This possibly pertains to the record published by Miller in 1923 in which 2 consignments of lemons arrived in New Zealand from the Cook Islands, with larvae of *E. subtruncatus* in them. This reference reappears in the literature a few times (Swezey 1924; Simmonds 1928; Lever 1940; Fakalata 1981), but it does not seem to have been substantiated by further new accounts of such an association. Guillermo Kuschel (pers. comm to F.Velvin, MAF 2004) considers the likelihood association with *Citrus* fruit remote due to the ground dwelling nature of this species. *E. subtruncatus* will therefore not be considered further in this risk analysis.

Diptera:
Atherigona orientalis Schiner (Diptera: Muscidae) pepper fruit fly
A. orientalis belongs to the subgenus *Acritochaeta*, which are known to mostly be saprophagous and/or facultatively carnivorous flies. It is considered unlikely to be associated with fresh *Citrus* fruit given its habit of association with rotting vegetation and decaying fruit (Al-Janabi *et al*.,1983; Pont 1992). Pont (1992) undertook an extensive review of the distribution and host records of this species and has made an association with *Citrus*. These data were then used by Cahill (1992) in a CLIMEX model to ascertain the likelihood of *A. orientalis* establishing in New Zealand, concluding the climate of New Zealand was unsuitable for this tropical species, the limiting factor being the relatively cold temperatures. Therefore, based on the rather low likelihood of association with the fresh fruit pathway, and the apparent lack of suitable climate in New Zealand *A. orientalis* is not considered to be a potential hazard in this risk analysis.

Hemiptera:
Aonidiella aurantii Maskell (Coccoidea: Diaspididae) - California red scale
California red scale this species has established in New Zealand where *Citrus* is grown, mostly in the warmer areas of the North Island and the northern part of the South Island. It is usually a minor pest for well managed orchards (Charles and Henderson 2002).

Aphis craccivora Koch (Hemiptera: Apididae)- cowpea aphid
This aphid prefers legumes and feeds at the growing tips of plants. Although *Citrus* is listed as a minor host by CPC (2008) *A. craccivora* is not recorded as associated with *Citrus* fruit. This aphid is present in New Zealand and in Samoa (CPC 2008; PPIN 2008; Waterhouse 1997). This aphid has been intercepted on oranges in 2005 (MAF 2007). However this aphid is not known to transmit regulated *Citrus* viruses known to be present in Samoa and absent from New Zealand (Mossop and Fry 1984; Pearson *et al*. 2006; BORIC 2008).

Aphis gossypii Glover (Hemiptera: Aphidiae)- cotton aphid
This aphid is present in Samoa and in New Zealand (CPC 2007; Waterhouse 1997; PPIN 2007). It can vector of a number of viruses. *A. gossypii* infests the young shoots of *Citrus* but more commonly attacks cucurbits, cotton and ornamentals (Smith *et al*. 1997).

Bemisia tabaci **type B 'Nauru'** Gennadius (Hemiptera: Aleurodidae)- cotton whitefly, sweetpotato whitefly.
Bemisia tabaci is a highly polyphagous pest worldwide, known to vector up to 111 important plant viruses. *B. tabaci* comprises 24 different biotypes, A through to T. (Scott *et al*. 2007). *Bemisia tabaci* is present in New Zealand, possibly as biotype 'B' (de Barro *et al*.1997) and as biotype 'Q' (Scott *et al*. 2007). The species recorded from Samoa is *B. tabaci* biotype B 'Nauru' (de Barro *et al*. 1997), a new biotype also found in Taiwan, American Samoa, Fiji, Federated states of Micronesia, Guam, Kiribati, Marshall Is., Nauru, Niue, Northern Mariana Is., Tonga and Tuvalu. However information has not been found clarifying an association with *Citrus* fruit therefore this organism is not considered as a hazard on this pathway.

Ceroplastes rubens Maskell (Coccoidea: Coccidae)- red wax scale
A highly polyphagous species, *Ceroplastes rubens* has been recorded on *C. aurantiifolia* and *C. limon* in Samoa (Williams and Watson 1990). It is not known to be present in New Zealand (PPIN 2007; ScaleNet 2007). It infests the leaves of *Citrus* (Smith *et al*. 1997).

Coccus capparidis Green (Coccoidea: Coccidae) - capparis soft scale
This scale is not known to be present in New Zealand (ScaleNet 2008; PPIN 2008; Hodgson and Henderson 2000). It is present in Samoa and has been recorded from *C. sinensis* (Williams and Watson 1990). It infests the undersides of the leaves (Ben-Dov 1980).

Coccus hesperidum Linnaeus (Coccoidea: Coccidae) - brown soft scale
This scale insect is widespread throughout New Zealand (PPIN 2006; Hodgson and Henderson 2000; Scott and Emberson 1999). It is associated with the veins found on stems, leaves and green twigs of its host plants (Copland and Ibrahim 1985).

Dialeurodes citrifolii Morgan (Hemiptera: Aleurodidae)- cloudywinged whitefly
D. citrifolii is present in Samoa (Martin 1987) and is not known to be present in New Zealand (PPIN 2008).
This whitefly almost exclusively colonises the underside of host plant leaves. Severe infestations can cause leaf and fruit fall. CPC (2007) consider this species should be regarded as a quarantine pest in all tropical and subtropical citrus-growing areas where it is currently not present. However there does not appear to be evidence of association with *Citrus* fruit.

Duplaspidiotus claviger (Cockerell) (Coccoidea: Diaspididae)- camellia mining scale
This scale insect is recorded from *C. limon* and *C. sinensis* in Samoa (Williams and Watson 1988). It mines the twigs and stems of its hosts, almost becoming completely covered by the plant epidermis (ScaleNet 2008; Dekle 1976).

Dysmicoccus nesophilus Williams and Watson (Coccoidea: Pseudococcidae)- mealybug
This mealybug is present in Samoa (Williams and Watson 1988) and is not known to be present in New Zealand (PPIN 2008). *Citrus* is one of many host plants for this mealybug *D. nesophilus* has been intercepted a number of times at the New Zealand border on fresh produce. However there is no interception record of it on *Citrus* fruit.

Eucalymnatus tessallatus (Signoret) (Coccoidea: Coccidae)- tessellated scale
This soft scale is primarily a leaf-infesting scale (Dekle 1999). It is parthenogenetic and ovoviviparous. Although it is a polyphagous scale, it prefers palms (Gill 1988). *Citrus* is a host however it appears the fruit are not. It is present in Samoa (Williams and Watson 1990; ScaleNet 2008) and is not known to be present in New Zealand (PPIN 2008)

Fiorinia fioriniae (Targioni Tozzetti) (Coccoidea: Diaspididae)– avocado scale
It is present in Samoa (Williams and Watson 1988; ScaleNet 2008) and is not known to be present in New Zealand (Charles and Henderson 2002). This scale is found on the underside of leaves (Gill 1997).

Hemiberlesia lataniae Signoret (Coccoidea: Diaspididae) - latania scale
This scale is a pest of kiwifruit in New Zealand (Blank *et al.* 1993) and is relatively widespread. In California it occasionally is found on *Citrus* fruit (Gill 1997).

Hemiberlesia palmae (Cockerell) (Coccoidea: Diaspididae)- tropical palm scale
This polyphagous scale occurs on the leaves of its host (Ferris 1938a). It has been recorded from *C. limon* (Williams and Watson 1988) but is not recorded on fruit. This species is present in Samoa (Williams and Watson 1988) but is not known to be present in New Zealand (ScaleNet 2008; Charles and Henderson 2002).

Icerya seychellarum Westwood (Coccoidea: Margarodidae)- seychelles scale
This large scale insect is present in Samoa (Waterhouse 1997). It is not known to be present in New Zealand (Morales 1991). It is recorded from *Citrus* leaves (Ben-Dov 2005) and in Samoa from *C. limon*, *C. grandis* and *C. sinensis* (Williams and Watson 1988).

Kilifia acuminata (Signoret) (Coccoidea: Coccida)- acuminate scale
This soft scale is not known to be present in New Zealand. It is present in Samoa (Williams and Watson 1990). *Citrus* is a host and it appears the scale infests leaves. In Egypt on mango it is recorded as causing great damage to the leaves by feeding on the sap and producing large amounts of honeydew (Al-Sayied 2006).

Lepidosaphes beckii Newman (Coccoidea: Diaspididae) - purple scale
Internationally known as a pest of *Citrus* this species is found in the North Island and the northern parts of the South Island. According to Charles and Henderson (2002) it is infrequently found and not considered a pest here.

Lopholeucaspis cockerelli (Grandpré and Charmoy) (Coccoidea: Diaspididae)- Cockerell scale.
Not known to be present in New Zealand (Charles and Henderson 2002), and is present in Samoa (Williams and Watson 1988).
Although *Citrus* is a host (ScaleNet 2008) this species is usually found on stems and leaves (Dekle 1976)

Milviscutulus mangiferae (Green) (Coccoidea: Coccidae)-mango sheild scale
This scale is polyphagous with hosts in over 39 plant families, including Rutaceae (*Citrus* spp.) (ScaleNet 2008). It is recorded from Samoa (Williams and Watson 1990) and is not known to be present in New Zealand (ScaleNet 2008). There do not appear to be records of association with *Citrus* fruit. Those records that do state the material examined are leaves, eg: from mango leaves in Australia (Grimshaw and Donaldson 2007).

Morganella longispina (Morgan) (Coccoidea: Diaspididae)– plumose scale
M. longispina occurs on the bark of its host plants (Ferris 1938a).

Myzus persicae Sulzer (Hemiptera: Apididae)- green peach aphid
This aphid is present in New Zealand (BORIC), and is also recorded from Samoa (Waterhouse 1997). It is a highly polyphagous species able to vector more than 100 viruses. This aphid feeds on the leaves of its host, mostly along the midvein and not the fruit. There has been an interception of a live adult in a consignment of oranges in 2005 (MAF 2007). However this aphid is not known to transmit regulated *Citrus* viruses known to be present in Samoa and absent from New Zealand (Mossop and Fry 1984; Pearson *et al*. 2006; BORIC 2008).

Nezara viridula Linnaeus (Hemiptera: Pentomidae) -green vegetable bug
This is an introduced species now common throughout New Zealand (Clunie 2004).
This species is recorded vectoring the fungus *Nematospora coryli* on *Citrus* (Shivas 2007). The yeast survives in the adult insect throughout the insects life. However only yeast cells near the mouthparts are transmitted, and nymphs and newly emerged adults must feed on a source of *N. coryli* after each moult before they can transmit it (Kulik and Sinclair 1993). *N. coryli* is not known to be present in New Zealand (NZFungi 8/2/2008, PPIN 8/2/2008; Pennycook 1989; CPC 2008) and is not recorded as present in Samoa (CPC 2008; Shivas *et al*. 2005; Dingley *et al*. 1981).

Orchamoplatus mammaeferus Quaintance and Baker (Hemiptera: Aleurodidae)- croton whitefly
This whitefly has been recorded from croton in Samoa and is largely not considered a pest (Waterhouse 1997). There are records of it from *C. aurantiifolia*, *C. medica*, *C. paradisi* and *C. sinensis* (Mound and Halsey 1978) but there is no information regarding association with fruit.

Parasaissetia nigra Nietner (Coccoidea: Coccidae) - nigra scale
This scale insect has a scattered distribution throughout New Zealand and is a minor pest on the exotic plants it has been found on including *Citrus, Daphne, Feijoa sellowiana, Ilex, Iris germanica* and *Prunus armeniaca* (Hodgson and Henderson 2000).

Sassetia coffeae Walker (Coccoidea: Coccidae) -hemispherical scale
An exotic (adventive) species, first recorded here in 1879. Hemispherical scale is an important pest of ornamentals and potted plants, especially ferns. It is recorded on 18 exotic plants and 14 native plants here, and has been found inside native forest. Its range is throughout the North Island and most of the South Island (Henderson 2001) This species is also a major pest on *Citrus* fruit.

Saissetia oleae Olivier (Coccoidea: Coccidae) – black olive scale
This species is exotic (adventive), first recorded here in 1885. Olive scale is an important citrus pest, particularly in Gisborne. It is recorded on 20 exotic plants and 23 native plants here, and can be a problem in gardens. Its range is from the Kermadec and Three Kings Islands, throughout the North Island and most of the South Island (Henderson 2001).

Toxoptera aurantii Boyer de Fonscolombe (Hemiptera: Apididae)- black citrus aphid
This aphid is present in New Zealand (PPIN 2008). It feeds on the leaves and growing tips of *Citrus* (Smith *et al*.1997). Although this aphid was intercepted alive on oranges in 2004 (MAF 2007), it is not known to transmit regulated *Citrus* viruses that are known to be present in Samoa and absent from New Zealand (Mossop and Fry 1984; Pearson *et al*. 2006; BORIC 2008).

Toxoptera citricida (Kirkcaldy) (Hemiptera: Apididae)- brown citrus aphid
T. citricida is present in New Zealand (PPIN 2008). It feeds on the leaves and growing tips of *Citrus* (Smith *et al*.1997).

Hymenoptera:
Pheidole megacephala Fabricius (Hymenoptera: Formicidae) - bigheaded ant
Pheidole megacephala is a notorious tramp species, is almost certainly of African origin, but probably arrived here via Australia or the Pacific region, rather than directly. The first record of establishment in New Zealand, dated 10 February 1942, appears to be from a chocolate factory in Auckland. It had been intercepted a few years earlier, and has since been intercepted at ports on a regular basis. It currently appears to be restricted to coastal suburbs of Auckland, although it is likely that coastal areas north of Auckland would also be suitable (Don and Harris 2007).

Lepidoptera:
Helicoverpa armigera Hübner (Lepidoptera: Noctuidae) -tomato fruitworm
This species is introduced from the tropics. It is a pest of tomato, corn and other crops. It is found in the lowlands of New Zealand in gardens and on farms (Clunie 2004).

Pulmonata:
Achatina fulica Bowdich (Gastropoda: Achatinidae) -Giant East African snail
A. fulica has a preference for decayed vegetation and animal matter, lichen, algae and fungi. There is no current evidence of a direct association between this species and *Citrus* fruit, although CPC (2007) state that the bark of *Citrus* trees is subject to attack. Typically this species is known as a hitchhiker pest, and the literature does not establish an association between the pest and the pathway, so it is not considered a hazard in this risk analysis. However, should information emerge (eg: evidence of interceptions on this pathway or information from overseas), then this assessment would need to be reconsidered.

Fungi and other micro-organisms
Alternaria alternata (Fr.) Keissl. (Ascomycetes: Pleosporales) - black stalk rot
This fungus is widespread in New Zealand and has multiple hosts (PPIN 2006; NZFungi 2007).

Alternaria citri Ellis and N. Pierce (1902) Hyphomycete
This species is recorded from *Citrus* in Auckland, New Zealand, and also in Samoa (NZ Fungi 2007).

Athelia rolfsii (Curzi) C.C Tu and Kimbr. (Basidiomycota: Polyporales: Atheliaceae) [Anamorph: *Sclerotium rolfsii* Sacc.] -Rolfs disease
An exotic species recorded and widespread in New Zealand (Pennycook 1989), this fungus infects more than 500 species of monocotyledonous and dicotyledonous plants, but is especially severe on legumes, solanaceous crops, cucurbits and other vegetables grown in rotation with beans (Hall, 1991). It causes leaf blight, stem canker, damping off, crown and root rot (Farr *et al.* 2007)

Botryosphaeria rhodina (Berk. & M.A.Curtis) Arx (Ascomycetes: Dothideales: Botryosphaeriaceae) [Anamorph: *Lasiodiplodia theobromae* (Pat.) Griffon and Maubl.] - stem end rot
An exotic saprophytic species recorded in New Zealand (Pennycook 1989). This species causes stem end rot on citrus fruit, usually post harvest (Timmer *et al.* 2000).

Cryptosporiopsis citri P.R.Johnst.and Full.(1988) Coelomycete
This fungus occurs on *Citrus* leaves, not the fruit (J. Wright pers. comm.2007). Present in NZ, found on *C. limon* (NZ Fungi 2007). In Samoa it is recorded from orange, lime and lemon (NZ Fungi 2007).

Diaporthe citri FA Wolf (1926) (Ascomycetes: Diaporthales: Valsaceae) [Anamorph: *Phomopsis citri* H.S. Fawc. 1912]
Diaporther citri causes melanose and stem-end rot in *Citrus* fruit (Whiteside 2000). It is present and widespread in New Zealand (NZ Fungi 2007). In Samoa it is recorded from grapefruit, orange, lime, lemon and pomelo (Dingley *et al*. 1981).

Diaporthe medusaea Nitschke (1870) (Ascomycetes: Diaporthales: Valsaceae)
This fungus has been recorded from *Ceratonia siliqua* (carob) in New Zealand, and in Samoa recorded from grapefruit, mandarin, tangerine, clementine, lime and pomelo (NZ Fungi 2007).

Elsinoë fawcettii Bitanc. and Jenkins (Ascomycetes: Myriangiales: Elsinoaceae) [Anamorph: *Sphaceloma fawcettii* Jenkins] verrucosis, citrus scab

This species is widespread in New Zealand (NZ Fungi 2007) and causes citrus scab, which produces warty areas on fruit and leaves (Timmer *et al.* 2000).

Glomerella cingulata (Stoneman) Spauld and H. Schrenk (Sordariomycetidae: Glomerellaceae) [Anamorph: *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc] - anthracnose
This fungus is widespread throughout New Zealand (Launden 1972), found mainly on exotic plants (e.g. *Citrus* spp.; *Malus x domestica*) but also on several native plants (e.g. *Beilschmeidia* spp., *Coprosma* spp, *Pseudopanax chatamicus* and *Tecomanthe speciosa*) (NZFungi 2006).

Nectria haematococca Berk and Broome (Ascomycetes: Hypocreales: Nectriaceae) [Syn. *Haematonectria haematococca* (Berk. & Broome) Samuels & Nirenberg] - Fusarium fruit rot
The name *Nectria haematococca* as used sensu lato refers to a complex of species, rather than a single taxon. Anamorphic states belong to Fusarium Section Martiella and it is as the anamorph that these fungi are normally encountered in plant pathology. Anamorphs of *N. haematococca* have a very wide host range, affecting more than 65 families. *F. solani sensu lato* is found universally in soil and causes damping-off, foot rot and stem canker diseases of almost any plant (CPC 2007). It is present and widespread in New Zealand (NZ Fungi 2007).

Phytophthora nicotianae Breda de Haan (Oomycetes: Pythiales: Pythiaceae) - buckeye rot
Citrus, tomato and tobacco are major hosts of this fungus (CPC 2007). It is a soil borne pathogen and is found in New Zealand (NZ Fungi 2007).

Rhizopus stolonifer (Ehrenb.) Vuill. (Zygomycetes: Mucorales: Mucoraceae) -rhizopus soft rot
This fungus causes soft rot of fruits and vegetables including *Citrus* (Tashiro *et al.* 2002). Present and widespread in New Zealand (NZ Fungi 2007)

Sclerotinia sclerotiorum (Lib.) de Bary (Ascomycetes: Helotiales: Sclerotiniaceae) -cottony rot
This is a highly polyphagous fungus, with a wide host range including *Citrus*. It causes Sclerotinia twig blight and cottony rot (Timmer *et al.* 2000). It is present in New Zealand (NZ Fungi 2007)

Cephaleuros virescens Kunze (Alga: Trentepohliales: Trentepohliaceae) - algal leaf spot
This alga is widespread on leaves of both native and introduced species in New Zealand (PPIN 2007) including *Melicytus ramiflorus*, *Metrosideros kermadecensis, Griselinia littoralis*, *Passiflora edulis*, *Banksia serrata, Eucalyptus* spp. and *Callicoma serratifolia*. (22 NZ hosts listed in Pennycook, Plant Diseases Recorded in New Zealand, vol. 3, 1989)

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Appendix 3 Scale insect host list (CPC 2007/ScaleNet 2008)

Please note that this list may not be the full and comprehensive host list for each scale

Plant Species	*Aon_ino*	*Asp_des*	*Chr_aon*	*Chr_dic*	*Coc_vir*	*How_bic*	*Isc_lon*	*Lep_glo*	*Par_cin*	*Par_per*	*Pse_pen*	*Pin_str*	*Una_cit*
Abutilon hybridum												•	
Acacia				•			•				•	•	
Acalypha													
Acer											•		
Acer palmatum				•									
Actinidia		•									•		
Agave				•			•						
Agave americana												•	
Aglaonema													
Albizia													
Albizia julibrissin				•									
Aleurites		•											
Aleurites moluccana												•	
Allamanda	•	•				•					•		
Allamanda carthatica						•					•		
Alocasia macrorrhiza								•					
Aloe				•			•						
Alpinia		•											
Alpinia purpurata					•							•	
Alstonia scholaris													
Anacardium occidentale												•	
Ananas comosus													•
Annona		•		•		•	•		•				
Annona muricata		•				•	•					•	•
Annona reticulate						•	•					•	
Anthurium							•						
Anthurium andreanum													
Aralia											•		
Araucaria angustifolia				•									
Ardisia													
Areca				•			•						
Areca catechu	•												
Arecaceae												•	
Artemesia						•							
Artocarpus				•	•								

Plant Species	*Aon_ino*	*Asp_des*	*Chr_aon*	*Chr_dic*	*Coc_vir*	*How_bic*	*Isc_lon*	*Lep_glo*	*Par_cin*	*Par_per*	*Pse_pen*	*Pin_str*	*Una_cit*
Artocarpus altilis	•	•										•	
Artocarpus catechu													
Artocarpus heterophyllus												•	•
Artocarpus integer													
Asclepius											•		
Asparagus officinalis			•	•			•					•	
Asparagus setaceus										•			
Asplenium													
Asplenium nidus												•	
Astronia	•												
Asystasia											•		
Averrhoa carambola													
Bambusa vulgaris				•									
Barringtonia	•											•	
Bauhinia						•					•	•	
Begonia						•							
Bignonia						•					•		
Bischofia	•												
Bixa						•							
Bixa orellana													
Blechnum													
Bougainvillaea									•				
Brahea							•						
Brassica		•									•		
Broussonetia papyrifera											•		
Buddleia						•					•		
Bursera						•							
Buxus microphylla													
Cactaceae				•									
Caesalpina pulcherrima													
Cajanus cajan						•					•	•	
Callicarpa											•		
Callistemmon													
Calophyllum						•					•		
Camellia		•		•		•							
Camellia sinensis		•	•		•								
Campnosperma brevipetiola	•												
Cananga odorata												•	
Canna indica												•	
Capsicum		•									•		•

Plant Species	*Aon_ino*	*Asp_des*	*Chr_aon*	*Chr_dic*	*Coc_vir*	*How_bic*	*Isc_lon*	*Lep_glo*	*Par_cin*	*Par_per*	*Pse_pen*	*Pin_str*	*Una_cit*
Capsicum annuum											•	•	
Capsicum frutescens												•	
Carica papaya	•	•	•	•		•							
Carissa						•		•					
Cassia	•	•				•					•		
Cassytha filiformis												•	
Castanea						•							
Casuarina	•					•							
Ceiba pentandra		•											
Celosia argentea													
Celtis											•		
Ceratonia siliqua				•									
Chrysanthemum					•								
Chrysophyllum cainito						•							
Cinnamomum verum		•	•	•									
Citharexylum quadrangulare													
Citrus		•	•		•		•	•	•	•	•	•	•
Citrus aurantiifolia			•	•		•			•	•	•	•	•
Citrus aurantium				•			•		•				•
Citrus delicosia					•								
Citrus limon			•		•	•			•	•		•	•
Citrus maxima			•	•					•	•	•	•	•
Citrus reticulata	•				•				•	•	•		•
Citrus sinensis			•	•	•		•		•	•		•	•
Citrus unshiu				•			•		•				
Citrus x paradisi	•		•	•					•	•		•	•
Clerodendrum													
Coccoloba uvifera												•	
Cocos nucifera	•	•	•	•			•				•	•	•
Codiaeum variegatum								•					
Coffea					•	•	•						
Coffea Arabica					•								
Colocasia esculenta				•								•	
Convolvulus													
Coprosma													
Cordyline	•						•						
Cordyline fruticosa												•	
Cotinus						•							
Crataegus				•									
Crotolaria												•	

Plant Species	*Aon_ino*	*Asp_des*	*Chr_aon*	*Chr_dic*	*Coc_vir*	*How_bic*	*Isc_lon*	*Lep_glo*	*Par_cin*	*Par_per*	*Pse_pen*	*Pin_str*	*Una_cit*
Croton						•							
Cucumis		•											
Cucurbita maxima												•	
Cupressus macrocarpa				•									
Cycas	•			•									
Cydonia						•					•		
Cycas revoluta												•	
Cymbidium				•									
Cyperus							•						
Cypripedium				•									
Cytisus													
Daphne													
Datura metel												•	
Dendrobium				•									
Derris elliptica													
Dictyosperma				•									
Dioscorea		•											
Dioscorea alata												•	
Dioscorea bulbifera												•	
Diospyros				•			•				•		
Diospyros kaki											•	•	
Dizygotheca elegantissima													
Dodonaea viscose						•						•	
Dracaena			•	•			•				•		
Dracaena marginata													
Elaeis guineensis		•		•			•					•	
Elettaria cardamomum	•												
Epipremnum pinnatum												•	
Eriobotrya japonica													
Erythrina subumbrans												•	
Erythrina				•				•			•	•	
Eucalyptus				•								•	
Eucalyptus deglupta		•											
Eugenia		•		•			•				•		
Euonymus						•		•			•		
Eupatorium						•							
Euphorbia	•	•				•						•	
Euphorbia regisjubae				•									
Excoecaria agollocha												•	
Fagraea cambageana	•												

Plant Species	*Aon_ino*	*Asp_des*	*Chr_aon*	*Chr_dic*	*Coc_vir*	*How_bic*	*Isc_lon*	*Lep_glo*	*Par_cin*	*Par_per*	*Pse_pen*	*Pin_str*	*Una_cit*
Fatsia japonica													
Feijoa													
Feijoa sellowiana													
Ficus		•		•		•	•				•	•	
Ficus carica		•										•	
Fitchia												•	
Fortunella								•					•
Fraxinus				•							•		
Garcinia													
Gardenia									•				
Gerbera													
Gmelina arborea												•	
Gossypium			•				•				•	•	
Gossypium hirsutum												•	
Grevillea				•									
Grevillia robusta													
Grewia									•				
Hedera				•									
Hedera helix													
Hedyotis ocutangulus													
Helianthus													
Heliconia							•					•	
Hernandia ovigera												•	
Hernandia peltata												•	
Hevea brasiliensis		•											
Hibiscus		•				•					•		•
Hibiscus manihot												•	
Hibiscus syriacus				•								•	
Howea				•			•						
Howea forsteriana				•									
Ilex													
Illicium													
Inocarpus fagifer							•			•		•	
Ipomoea batatas													
Ixora					•		•						
Jasminum	•	•					•		•				
Justicia adhatoda												•	
Lactuca sativa													
Laportea												•	
Latania				•			•						

Plant Species	*Aon_ino*	*Asp_des*	*Chr_aon*	*Chr_dic*	*Coc_vir*	*How_bic*	*Isc_lon*	*Lep_glo*	*Par_cin*	*Par_per*	*Pse_pen*	*Pin_str*	*Una_cit*
Lauraceae			•										
Laurus				•									
Laurus nobilis													
Leucaena leucocephala												•	
Ligustrum				•		•					•		
Lindera													
Litchi chinensis													
Lycopersicon esculentum		•										•	
Macadamia tetraphylla				•									
Magnolia							•						
Malaviscus arboreus												•	
Malus				•		•			•		•		
Malus domestica			•							•			
Malus sylvestris													
Mangifera indica	•	•	•	•	•	•	•	•	•			•	
Manihot				•									
Manihot esculenta					•							•	
Manilkara zapota					•		•						
Melia									•				
Maranta												•	
Melaleuca	•												
Metrosideros						•							
Mimosa pudica												•	
Monstera							•						
Monstera delicosa				•									
Morinda citrifolia											•	•	
Morus				•							•		
Morus alba													
Musa	•	•	•	•			•						•
Musa x paradisiaca			•									•	
Myristica fragrans		•		•									
Nandina domestica													
Nephelium													
Nephrolepis exaltata													
Nerium	•			•	•	•	•		•			•	
Nypa fruticans	•											•	
Ochrosia	•												
Ocimum												•	
Olea				•		•							
Opuntia cochinellifera				•									

Plant Species	*Aon_ino*	*Asp_des*	*Chr_aon*	*Chr_dic*	*Coc_vir*	*How_bic*	*Isc_lon*	*Lep_glo*	*Par_cin*	*Par_per*	*Pse_pen*	*Pin_str*	*Una_cit*
Orchidaceae												•	
Pandanus	•	•									•	•	
Pandanus graminifolia				•									
Passiflora		•				•					•		
Passiflora coerulea				•									
Passiflora edulis													
Pedilanthus												•	
Pelargonium				•							•		
Persea americanus		•		•								•	
Persea thunbergii													
Phaseolus													
Phaseolus vulgaris												•	
Philodendron													
Phoenix dactilifera		•	•	•			•						
Phormium)				•									
Physalis		•											
Pimenta dioica													
Pinus			•	•									
Pinus caribbea													
Pinus thunbergii													
Piper	•	•				•	•				•		
Piper nigrum		•											
Pistacia				•									
Pittosporum				•									
Platanocephalus	•												
Platanus				•							•		
Plumeria	•	•		•							•		
Plumeria rubra var. acutifolia					•							•	
Polygonum	•												
Polyscias quilfoylei													
Poncirus								•					
Poncirus trifoliate													•
Populus				•									
Prunus				•		•	•			•	•	•	
Prunus domestica										•			
Prunus mume													
Prunus persica		•											
Psidium guajava		•		•	•	•	•				•		•
Punica				•									
Punica granatum													

Plant Species	*Aon_ino*	*Asp_des*	*Chr_aon*	*Chr_dic*	*Coc_vir*	*How_bic*	*Isc_lon*	*Lep_glo*	*Par_cin*	*Par_per*	*Pse_pen*	*Pin_str*	*Una_cit*
Pyrus				•		•							
Pyrus communis													
Quercus				•									
Raphanus		•											
Rhamnus				•									
Rhizophora	•	•										•	
Rhododendron													
Rhus											•		
Ricinus communis												•	
Rosa				•					•				
Roystonea				•									
Rubus													
Ruscus				•									
Ruta				•									
Saccharum officinarum		•											
Salix				•							•		
Samanea saman													
Schefflera												•	
Schefflera actinophylla													
Schinus						•					•		
Senna occidentalis												•	
Sida				•							•		
Smilax									•				
Solanum		•				•					•		
Solanum melongena				•								•	
Solanum torvum												•	
Sophora				•								•	
Spartium junceum													
Spiraea													
Spondias purpurea		•		•									
Stachytarpheta						•						•	
Strelitzia				•								•	
Syzygium													
Syzygium aromaticum		•											
Syzygium cumini													
Syzygium malaccense				•									
Tamarindus indica		•		•									
Tamarix													
Taxus baccata				•									
Tectona grandis													
Terminalia catappa						•						•	

Plant Species	*Aon_ino*	*Asp_des*	*Chr_aon*	*Chr_dic*	*Coc_vir*	*How_bic*	*Isc_lon*	*Lep_glo*	*Par_cin*	*Par_per*	*Pse_pen*	*Pin_str*	*Una_cit*
Ternstroemia													
Theobroma cacao		•			•								
Thevetia peruviana													
Thuja occidentalis				•									
Tillandsia usneoides													•
Tournefortia										•	•	•	
Urena lobata												•	
Vanilla planifolia				•									
Vigna unguiculata		•											
Vitis vinifera	•	•		•					•		•	•	
Xanthosoma saggitifolium		•		•									
Yucca													
Zingiber officinale		•		•								•	
Zinnia													