Import Risk Analysis:

Litchi chinensis (Litchi) fresh fruit from Taiwan

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Biosecurity New Zealand
Ministry of Agriculture and Forestry
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New Zealand

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Policy and Risk
Biosecurity New Zealand

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Approved for general release

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Glossary of Definitions and Abbreviations

AFFA	Australian Government Department of Agriculture Fisheries and Forestry
AQIS	Australian Quarantine and Inspection Service
BAPHIQ	Bureau of Animal and Plant Health Inspection and Quarantine (Taiwan)
CPC	Crop Protection Compendium. Internet Database
Endemic	Plants or animals indigenous to a specified area.
Establishment	The point where a contaminating organism has a viable population on hosts or host material in New Zealand such that it could potentially spread in the future.
Exposure	The point where a contaminating organism becomes associated with a host in New Zealand in a manner that allows the organism to complete a normal life cycle.
Exotic	Organism belonging to another country
Hitch-hiker pest	a species that is sometimes associated with a commodity but does not feed on the commodity or specifically depend on that commodity in some other way
Indigenous	Plant or animal born or produced naturally in a region.
Introduced	Organism not originally from the country it is found in, introduced there by humans.
IHS	Import Health Standard
IRA	Import risk analysis
MAF	Ministry of Agriculture and Forestry. New Zealand
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.
Vector	Usually a pest organism such as a mite or insect that transmits a viral or other pathogenic agent between host plants

1. Executive Summary

Taiwan has requested access for the export of fresh litchi fruit to New Zealand. There is currently no import health standard (IHS) issued for litchi fruit from Taiwan. This import risk analysis examines the biosecurity risks posed by the importation of this fruit. Fruit is sourced from farms where farmers follow advised measures for the production of exported fruits combining best quality and pest control programs (Plant Protection Manual for Major Pest Controls). There is a specific focus on control of downy blight and litchi fruit borer (BAPHIQ 2006).

Litchi chinensis is a member of the Sapindaceae family and is native to Southern China, Northern Vietnam and Malaysia. It is an important fruit industry in Taiwan. The total cultivation area and annual production in Taiwan are 12,150 hectares and 82,107 tons respectively (BAPHIQ 2006). With a subtropical oceanic climate Taiwan has warm and mild weather all year round with annual average temperatures between 21-26ºC. The most common pests and pathogens affecting litchi orchards in Taiwan are *Phellinus noxius* (brown root rot), *Kerria lacca* (lac insect), *Ceroplastes ceriferus* (Indian white wax scale) and most importantly *Conopomorpha sinensis* (litchi fruit borer) (BAPHIQ 2006).

Pests and pathogens are grouped according to their biology and members of the same genus are considered within one pest risk assessment. The groups include Tephritid fruit flies, Bugs (Hemiptera), Moths, Scales, Mealybugs, Mites, Fungi and Witches' Broom. A total of 116 pests and pathogens were researched for the assessment of which 20 were further considered in the risk analysis. Twelve were considered risk hazards and management options for these species are discussed and reviewed. Species were assessed on the likelihood of entry, exposure and establishment within New Zealand and the potential consequences they might cause to the economy, the environment and human health. Ninety six were not considered potential hazards because there was no supporting literature or evidence for their association with the commodity.

Many species of insects and mites reviewed occur principally in tropical latitudes and can have a narrow band of temperature tolerance for growth and development. Under current climatic conditions in New Zealand the possibility of establishment of these "tropical" pests here is considered very low. Treatment measures including vapour heat treatment or cold disinfestations and visual inspection recommended for high risk hazards will mitigate the low risk of potential entry of these organisms. The risk analysis concluded there was a non-negligible risk for organisms listed in Table 1 and that phytosanitary measures were justified. Based on efficacy data and biology of the organisms it is recommended that either vapour heat treatment at ≥ 46.5 ºC or greater for a minimum of 20 minutes or cold disinfestations at 0-1 ºC for 13 days be used to reduce the risk to New Zealand of pests and pathogens likely to be associated with litchi fruit to an acceptable level.

Table 1. Pest species, and recommended treatment measures based on efficacy data and biology

Species	Pest Group	Cold Disinfestation Treatment	Vapour Heat Treatment
Bactrocera cucurbitae	Tephritid fruit fly	0-1ºC or below for 13 days	≥ 46.5 ºC for a minimum of 20 minutes
Bactrocera dorsalis	Tephritid fruit fly	0-1ºC or below for 13 days	≥ 46.5 ºC for a minimum of 20 minutes
Kerria lacca	Homoptera (lac insect)		≥ 46.5 ºC for a minimum of 20 minutes
Ceroplastes pseudoceriferus & C. rubens	Homoptera (scales)		≥ 46.5 ºC for a minimum of 20 minutes
Ischnaspis longirostris	Homoptera (scale)		≥ 46.5 ºC for a minimum of 20 minutes
Ferrisia virgata	Homoptera (mealybug)		≥ 46.5 ºC for a minimum of 20 minutes
Adoxophyes orana	Lepidoptera (moth)	0-1ºC or below for 13 days	
Cryptophlebia ombrodelta	Lepidoptera (moth)	0-1ºC or below for 13 days	
Lymantria dispar, L. mathura & L. xylina	Lepidoptera (moths)		≥ 46.5 ºC for a minimum of 20 minutes

2. Risk Analysis Background and Process

2.1 Background

There is no import health standard for fresh litchi fruit from Taiwan. But import health standards do exist for litchi fruit from New Caledonia (MAF 2000) and from Thailand (MAF 2005). This import risk analysis uses newly developed and implemented procedures and methodology which will be the primary platform for development of an import health standard for fresh litchi fruit from Taiwan. The document will also be used as a reference for future IRAs on species in the Sapindaceae.

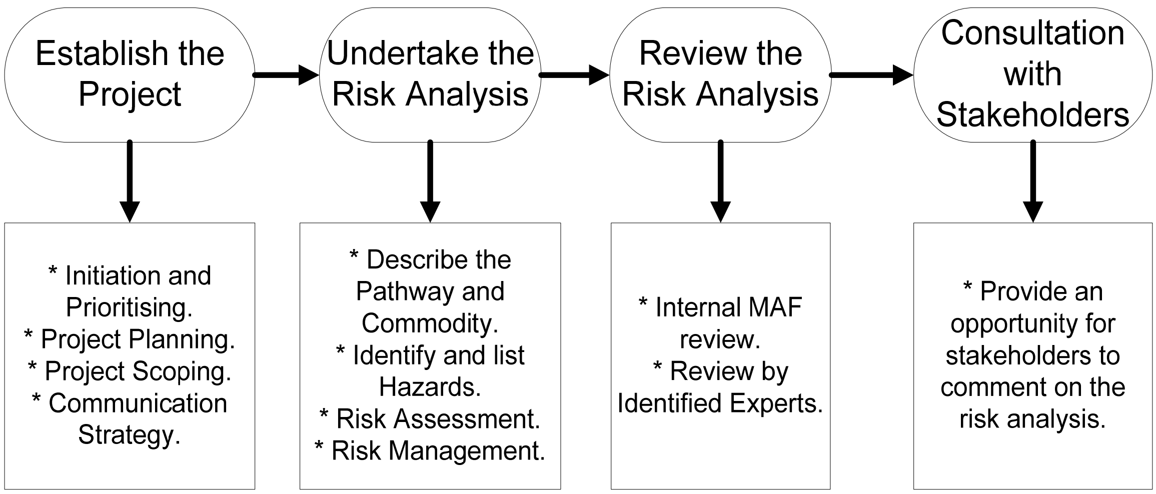
2.2 Scope of the Risk Analysis

The scope of this risk analysis is the potential hazard organisms or diseases associated with fresh fruit of *Litchi chinensis* imported from Taiwan. Risk in this context is defined as the likelihood of the occurrence and the likely magnitude of the consequences of an adverse event. For the purposes of this analysis "fresh fruit" means the fruit complete with skin, flesh and seed, without attached stems or leaves. A small portion of pannicle is exempt from this definition as often removing this part would 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 (Version 1 12 April 2006) which is available on the Ministry of Agriculture and Forestry website (www.maf.govt.nz).
The risk analysis process leading to the final risk analysis document is summarised in Figure 1.1 below:

Figure 1: A summary of the Biosecurity New Zealand risk analysis development process



The "Establishing the Project" phase is an internal project management process undertaken with Biosecurity New Zealand for all risk analysis projects and as such is not described further here.

2.4 Commodity and Pathway Description

The first step in the risk analysis process is to describe the 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.

2.5 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 unwanted 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 that don't feed on it or specifically depend on that commodity in some other way are also included in the analysis. This is because the potential for economic environmental and human health consequences can outweigh the low likelihood of the organism being associated with the commodity.

2.6 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.
A risk assessment consists of four inter-related steps:

- assessment of likelihood of entry;
- assessment of likelihood of exposure and establishment;
- assessment of consequences;
- risk estimation.

In this risk analysis hazards have been grouped to avoid unnecessary duplication of effort in the assessment stage of the project. Where there is more than one species in a genus for example, the most common or potentially damaging species is researched and analysed in detail and used as an example to cover major biological traits within the group. Any specific differences between congeners are highlighted in individual analyses.

2.7 Assessment of Uncertainties

The purpose of this section is to summarise the uncertainties and assumptions identified during the preceding hazard identification and risk assessment stages. An analysis of these uncertainties and assumptions can then be completed to identify which are critical to the outcomes of the risk analysis. Critical uncertainties or assumptions are considered for further research with the aim of reducing uncertainty or removing the assumption.

Where there is significant uncertainty in the estimated risk, a precautionary approach to managing risk may be adopted. In these circumstances the measures should be consistent with other measures where equivalent uncertainties exist and be reviewed as soon as additional information becomes available.

2.8 Analysis of Measures to Mitigate Biosecurity Risks

Risk management in the context of risk analysis is the process of deciding measures to effectively manage the risks posed by the hazard(s) associated with the commodity or organisms under consideration. It is not acceptable to identify a range of measures that might reduce the risks. There must be a reasoned relationship between the measures chosen and the risk assessment so that the results of the risk assessment support the measure(s).

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:

2.9 Risk Evaluation

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

2.10 Option Evaluation

a) Identify possible options, including measures identified by international standard setting bodies, where they are available.

b) Evaluate the likelihood of the entry, exposure, establishment or spread of the hazard according to the option(s) that might be applied.

Select an appropriate option or combination of options that will achieve a likelihood of entry, exposure, establishment or spread that reduces the risk to an acceptable level.

The result of outlining the risk management options will be either that no measures are identified which are considered appropriate, or the selection of one or more management options that have been found to lower the risk associated with the hazard(s) to an acceptable level. These management options form the basis of regulations or requirements specified with an import health standard.

2.11 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 are not adopted the rationale must be fully explained and documented.

Once a risk analysis has been peer reviewed and the critiques addressed, the risk analysis is then published and released for public consultation. The period for public consultation is usually six weeks from the date of publication.

All submissions received from stakeholders are analysed and compiled into a review. Either a document will be developed containing the results of the review or recommended modifications to the risk analysis itself will be edited to comply with the modifications.

3. Import Risk Analysis

The following chapter provides information on the commodity and pathway that is relevant to the analysis of biosecurity risks and common to all organisms or diseases potentially associated with the pathway and commodity. Organism or disease-specific information is provided in subsequent chapters.

3.1 Commodity Description

Litchi chinensis is a member of the Family Sapindaceae, which includes other edible plants like the mamoncillo (*Melicoccus bijugatus*) and the longan (*Dimocarpus longan*). Two of its main synonyms are *Dimocarpus litchi* and *Nephelium litchi*. It is an evergreen species growing 9-30 metres high and equally as wide with pinnate 12.5-20cm long leaves having 4 to 8 alternate, elliptic-oblong to lanceolate, abruptly pointed leaflets (Morton 1987).

The flowers are inconspicuous, borne on terminal clusters in a thyrse and emerge anytime from late December to April in the northern hemisphere (ARC 2006). The trees bear three flower types on the same tree: male, female and bisexual, the ratio varying with cultivar and season (ARC 2006). The flowers require transfer of pollen by insects, and the honeybee is the most important pollinator.

The fruits hang in loose pendent clusters of 3 to 50, and are round or oval. The leathery skin ranges from yellowish to pinkish, or red and fruit must be allowed to ripen on the tree (Mossler & Nesheim 2002). This skin is flexible and easily peeled when fresh. The aril is a fleshy, translucent white to greyish or pinkish, usually separating easily from the seed. The flavour is subacid and distinctive. The seed is variable in form and size, and shrunken in some fruits due to faulty pollination, holding only partially developed seeds. Such fruits are prized because of the greater proportion of flesh (Morton 1987).

The litchi is native to low elevations of the provinces of Kwangtung and Fukien in southern China, where it flourishes along rivers and near the coast. It thrives best in regions without heavy frosts, with cool and dry conditions in winter, and hot, wet conditions in summer. Cold tolerance of the litchi is intermediate between that of the sweet orange on one hand and mango and avocado on the other (Morton 1987).

The cultivated litchi originated in the region between southern China, northern Vietnam and Malaysia. Wild trees grow in elevated and low rain forests; in some parts of southern China litchi is one of the main forest species. The spread of litchi to other countries in the past 400 years has been slow, due to the exacting climatic requirements and the short life of its seed. Within South-East Asia northern Thailand produces litchi in quantity and there is one valley in Bali where the crop is grown commercially. Elsewhere in South-East Asia the trees usually fail to flower, although in Thailand a lowland type litchi bears fruit (CPC 2006).

Litchis do not ripen off the tree and are picked as close to full maturity as possible. Maturity is judged by a particular shape, skin colour, skin texture and flavour of each cultivar. A maturity index based on sugar/acid ratio has been developed in Australia (Menzel *et al.* 1988). Most fruit can be picked from a tree within 1 week and from a single cultivar in an orchard within 3 weeks. Most growers plant a range of cultivars to spread the picking workload.

In Taiwan fruit develop between April and September (Hwang & Hsieh 1989). They would most likely be exported into New Zealand during the winter months and early spring (June to

September). In most parts of Asia, bunched panicles of fruit are marketed. Standard grades for detached fruits have been developed in Australia (Menzel *et al.* 1988).

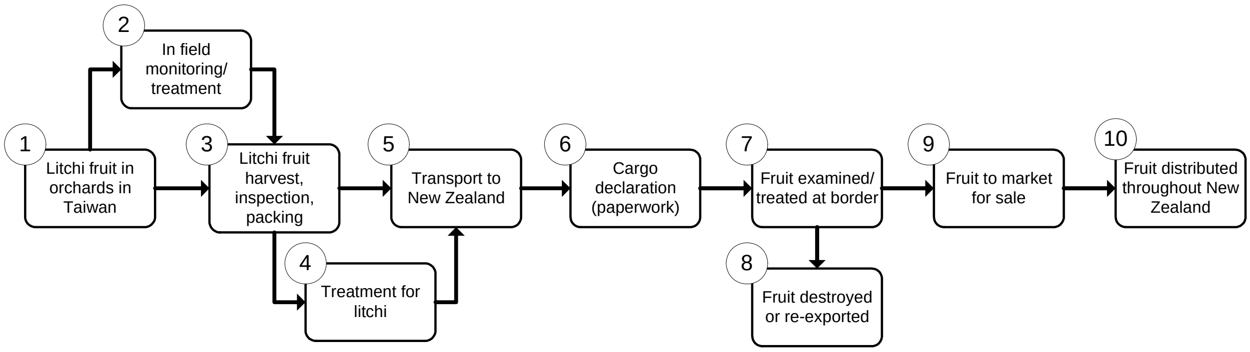
Litchis do not reproduce well from seed, and the best varieties with high flesh quantity and small seed are often abortive. Litchi seeds remain viable only 4 to 5 days, and seedling trees will not bear until they are 5 to 12, or even 25 years old (Morton 1987). For these reasons seeds are planted mostly for selection and breeding purposes or for rootstock. The fruit can be stored at temperatures below zero for a year, non-frozen temperatures for 30 days and ambient temperatures for 7-10 days (Zhang *et al.* 1998). Fruits are delicate, and with high water and sugar contents, they become spoiled through rotting when exposed to high temperatures. Browning of the peel occurs rapidly at warm temperatures and low relative humidity (FAO 2004).

Many pest species mentioned in this report are found not only on litchi but on its close relative longan (*Dimocarpus longan*). These species include *Bactrocera dorsalis*, *Coccus viridis*, *Nezara antennata*, *Pulvinaria psidii*, *Tessaratoma papillosa*, *Adoxophyes orana*, *Conopomorpha sinensis*, *Deudorix epijarbas*, *Phytophthora palmivora* and longan witches broom disease. Where relevant longan is mentioned if it is a major host of a particular pest or pathogenic agent. This may indicate a potential likelihood of host switching to native Sapindaceae if it enters New Zealand.

3.2 Description of the Proposed Import Pathway

For the purpose of this risk analysis, litchi fruit (fruits in their skins with or without a small portion of stem attached) are presumed to be from anywhere in Taiwan. The Taiwanese government predicts that exports of litchi fruit to New Zealand will be in the range of 60,000-100,000 kgs annually. To comply with existing New Zealand import requirements for fresh fruit, the commodity would need to be prepared for export to New Zealand by ensuring certain pests (fruit flies etc.) are not associated with the product. Fruit would then be sea or air freighted to New Zealand where it will go to a holding facility before being distributed to supermarkets, fruit and vegetable markets and shops for consumption.

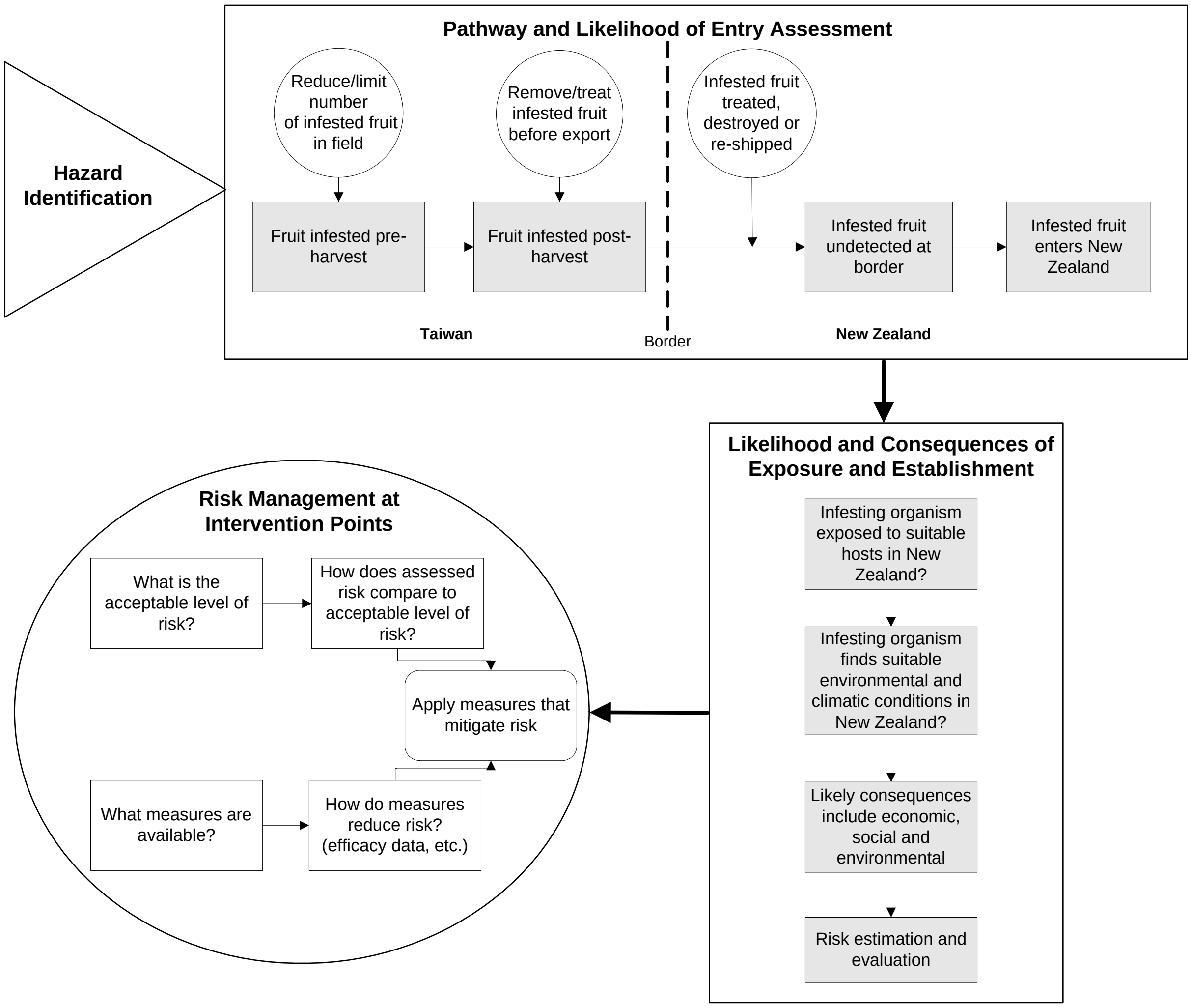
Figure 2: Linear Pathway Diagram



1. Litchi fruit in Taiwan are growing in an orchard, either as a single crop or beside other fruit trees.
2. Monitoring of fruit fly and other pests is undertaken, with appropriate controls applied.
3. Litchi are harvested, inspected and the best quality fruit washed, pre-treated and packed in boxes.
4. Post harvest disinfestations including Vapour Heat Treatment or Cold Disinfestation are undertaken either before or during transport of the fruit to New Zealand.
5. Transport to New Zealand is by air or sea.
6. Each shipment must be accompanied by the appropriate certification, e.g. a phytosanitary certificate attesting to the identity of the fruit, any treatments completed, or other information required to help mitigate risks.
7. Fruit is examined at the border to ensure compliance
8. Any fruit not complying with New Zealand's biosecurity requirements (e.g. found harbouring pest organisms) are either treated, re-shipped or destroyed.
9. Fruit are stored before being distributed to market for sale.
10. Supermarkets and fruit shops stock litchis and they are bought by consumers within the local area they are sold in.

Figure 3. Synthesis of Figures 1 & 2

Synthesis of figures 1 & 2 indicating how the risk analysis process is applied at the pathway level.



3.3 Taiwan – Climate and Geography

Taiwan is located 200 km from the southeast China mainland. It is on the border of the eastern Pacific Ocean and in the west of the Taiwan Strait. The island of Taiwan extends from 119 E to 124 E in longitude and 21 N to 25 N in latitude, and its total area is about 36,006 km^2 with two thirds of this consisting of mountains or hill country. Taiwan is 377 km long north to south and 142 km east to west at its widest point. Its coastal length is about 1,140 km. The land over 100 m above sea level makes up about two-thirds of the total area, and arable land makes up about one-fourth (GIO 2002).

It possesses thickly forested mountains, deep valleys and rapid rivers. Agriculture is predominantly undertaken on the remaining 26 percent consisting of flatter plains land, with approximately 866,000 hectares in cultivation. All aspects of horticulture can be found in Taiwan: arboriculture, fruit growing, flower culture, vegetable production, seedling production and mushroom production (ISHS 2006). There are many kinds of fruit, from tropical to deciduous, cultivated, including citrus fruits, banana, mango, grape, pear, wax apple, papaya, pineapple, peach, and litchi. Subtropical fruit such as litchis are grown in mid to southern Taiwan. Deciduous fruit is grown on the hills and mountainous land (ISHS 2006).

Taiwan has a subtropical oceanic climate. The weather is warm and mild all year round with annual average temperatures between 21.7-25.5 °C. Average yearly precipitation ranges from 1,700-3,200 mm and average hours of daylight are 1,163-2,008 hrs for northern to southern Taiwan. The island receives occasional snowfall on higher mountains in the winter. Frost and snow appear only at high elevations in the Chungyang Range. The highest peak Yu Shan is 3,997 m high (ISHS 2006).

During winter, northern Taiwan experiences the northeast monsoon, which brings heavy rain from October to March. The north is somewhat less wet in summer, when southern Taiwan receives heavy precipitation from the southwest monsoon. Typhoons occur between June and October but they do not have a long-term impact on the island. Summers are hot and humid, with an average temperature of 28°C (82°F). Winter lasts from December until February and is mild, with an average January temperature of 18°C (64°F). Most areas of Taiwan are well suited to horticulture for most of the year (ISHS 2006).

3.4 Taiwan – Pest Control Programme for Litchi

The largest project for integrated pest management of economically important fruits is the programme for the control of fruit fly. One hundred and seventy townships and cities across Taiwan were covered for the control with 120 hectares of fruit orchard plantations in the programme. Monitoring and trapping for fruit fly includes the use of poisonous fiber boards (4.5 x 4.5 x 0.9cm) containing a mixture of 5 percent naled and 95 percent methyl eugenol as lure hung on trees to attract and then kill fruit flies. Four pieces of board were used for each hectare in non peak times and 6 pieces of board per hectare at higher peak density. The lure remained effective for two months and therefore at least 4-6 changes were necessary annually. Baits are renewed bi-monthly. According to data collected from 2005, the population density of fruit flies on average was 70/trap/10 days. The average infestation rate was 3 percent or lower during the growing season (BAPHIQ 2006).

Further information regarding pest type and incidence, as well as control of fruit fly pests in Taiwanese litchi orchards can be found in sections 3.4, 3.5 and 3.6. This fruit fly control programme needs to be verified. However, it is assumed for the purposes of this risk analysis that only fruit fly treatment is applied to the commodity before it enters New Zealand. Steam heat or cold disinfestations treatments are currently used (See section 3.6).

3.5 Taiwan – Production and Pre-export Handling of Commodity

There is little information regarding these aspects of the pathway, it is assumed quality assurance systems are in place to reduce the likelihood of fruit being infested with pest and pathogenic agents before export to New Zealand. After harvesting, all stalks and leaves will be removed from the litchis before cleaning, sorting and putting them into baskets. The fruit will then undergo a pre-cooling treatment prior to carrying out the in transit cold treatment during sea transportation. The temperature will not be higher than the designated temperature for cold treatment (BAPHIQ 2006). Farmers follow advised measures for the production of exported fruits combining best quality and pest control programs together (Plant Protection Manual for major pest controls). There is a specific focus on control of downy blight and litchi fruit borer (BAPHIQ 2006).

3.6 Treatment Schedules for Taiwanese Litchis to Other Countries

Currently Taiwan BAPHIQ has treatment schedules for fresh litchi fruit exported to Japan, the USA and Korea. These are outlined below.

1. Litchi exported to Japan: The fruits are steamed and maintained at 46.2°C for 20 mins, sprayed with cold water, transferred into cold water tank, cooled to 2°C or lower within 6 hours, and stored for 42 hours before packing. The treatments are under the supervision of Taiwanese plant quarantine officers and Japanese quarantine officers.

2. Litchi exported to USA: The pulp temperature is pre-cooled to 1°C or lower before packing. The quarantine inspection is performed by Taiwanese plant quarantine officers who are certified by the USDA. The fruits are stored for 15 days with the pulp temperature at 1°C or lower (or stored for 18 days at 1.3°C or lower).

3. Litchi exported to Korea: The fruits are steamed and maintained at 46.2°C for 20 min, sprayed with cold water and transferred into a cold water tank, cooled to 2°C or lower within 6 hours, and stored for 42 hours before packing. The treatments are under the supervision of Taiwanese plant quarantine officers and Korean quarantine officers.

3.7 International Transportation of Commodity

Depending on the method of treatment used to remove pests and pathogens the fruit can take two routes into the country.

3.7.1 Sea Freighted

Several shipping lines were researched using information from The New Zealand Shipping Gazette (January 13 No. 1/07) to identify the possible time the commodity would be in transit from Taiwan to New Zealand.

- The Maersk Line has ships departing from Keelung in the north of Taiwan which reach Auckland, New Zealand in 12-13 days.
- Cosco (New Zealand) Ltd has ships departing from Keelung to reach Auckland in 15-16 days.

The ships pass through the tropics and are therefore subject to higher temperatures than air freighted produce. Humidity is also likely to be high. Containers are refrigerated in transit, to a temperature of between 3-13°C. Sometimes cold treatment of fruit requiring cooler temperatures (between 0-1°C) is carried out during ship transportation.

3.7.2 Air Freighted

There are direct flights from Taipei in Taiwan to Auckland with Eva Air with a flight time of 11 hours. Flights from Kaoshiung to Auckland are via Taipei. The transit time would not be more than 24 hours.

Temperatures in the hold of the plane are likely to be average to cold. The length of time in transit is considerably shorter than on the shipping pathway and cold storage is not available or required. Humidity is also likely to be much lower. Often heat treated commodities are transported by air.

3.8 Movement and Distribution of Commodity within 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. Because of its expense it is more likely that it will be sent straight to supermarket chains and shops.

Two scenarios around the disposal of litchi fruit waste material are possible. In the first scenario because it is a luxury item there could be less likelihood of whole damaged fruits being discarded as waste because of expense. In scenario two other people less concerned with cost may be more likely to discard damaged fruit. 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. It is assumed that a smaller percentage of litchi fruit will be discarded than other fruit types. There is no quantitative value available for this assumption.

3.9 Fruit Fly Surveillance in New Zealand

Part of the system approach to ensuring border biosecurity fully mitigates the risk of unwanted organisms arriving in New Zealand is the current fruit fly surveillance programme which has been operating since 1989 and is designed as an early warning system.

It also provides proof 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. 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 2006).

3.10 New Zealand Climate – General

New Zealand has a maritime climate which varies from warm subtropical in the far north to cool temperate in the far south, with severe alpine conditions in the mountainous areas. Mountain chains extending the length of New Zealand's South Island provide a barrier for the prevailing westerly winds, dividing the country into two separate climatic regions. The West Coast of the South Island is the wettest, whereas the area to the east of the mountains, just over 100 km away, is the driest (NIWA 2006).

Most parts of the country get between 600 and 1600 mm of rainfall annually, with a dry period during the summer. At four locations on the west coast of the South Island (Westport, Hokitika, Mt Cook and Milford Sound) mean annual rainfall was between 2200mm and 6800mm for the period 1971-2000 (NIWA 2006).Over the northern and central areas of New Zealand more rain falls in winter than summer, whereas for much of southern New Zealand, winter is the season of least rainfall.

Mean annual temperatures range from 10°C in the south to 16°C in the north. The coldest month is usually July and the warmest month is usually January or February. Generally there is little variation between summer and winter temperatures, although inland and to the east of the ranges the variation is greater (up to 14°C). Temperatures also drop about 0.7°C for every 100 m of altitude (NIWA 2006).

Sunshine hours are relatively high in places sheltered from the west and most of New Zealand would have at least 2000 hours annually. Most snow falls in the mountain areas. Snow rarely falls at the coast of the North Island and west of the South Island, although the east and south coasts of the South Island may experience some snow in winter. Frosts can occur anywhere, and usually form on cold nights with clear skies and little wind (NIWA 2006).

3.11 Northern New Zealand

The northern part of New Zealand is the most climatically suitable for the establishment of new pests and pathogens coming from a tropical/subtropical country such as Taiwan. The area includes Kaitaia, Kerikeri, Whangarei, Auckland – the largest city in New Zealand and Tauranga. The latter two cities both contain large active ports. Kerikeri is a well known orcharding town with many varieties of citrus fruit grown there. This is a sub-tropical climate zone, with warm humid summers and mild winters. Typical summer day time maximum air temperatures range from 22°C to 26°C, but seldom exceed 30°C. Winter day time maximum air temperatures range from 12°C to 17°C.

Annual sunshine hours average about 2000 per year in many areas, with Tauranga for example, experiencing at least 2200 hours. 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 most 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 2006).

Auckland has the highest rate of naturalised plants of any city in the country. The prime reasons for the high numbers of plant species are considered to be a 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. It is more likely that glasshouses would be suitable sites for pest and pathogen establishment in northern New Zealand, but this factor is not considered within the scope of this risk analysis.

3.12 Potential Sapindaceae Hosts in New Zealand

Currently there are approximately 15 litchi trees in cultivation in New Zealand, predominantly in Kaitaia in the far north of Northland district and one tree in Kaipara south of Auckland (David Austen, Alan Booth & John Prince pers. comm. 2007). Appropriate conditions for the growth and development of successfully fruiting trees in New Zealand include high temperatures in summer, light frosts in winter and constant moisture for the roots (David Austen pers. comm. 2007). These conditions are met in small areas in Northland and Bay of Plenty. Because of the negligible number and isolated locations of specimens, and their restricted ability to set seed these individuals are seen as a very low risk in providing host material for pests and pathogens associated with litchis imported from Taiwan.

Several specimens of *Dimocarpus longan* are cultivated, again in negligible numbers in localised areas (John Prince pers. comm. 2007).

Litchi chinensis is a member of the Sapindaceae, and it is possible that some of its associated pests and pathogens could potentially utilise native New Zealand Sapindaceae as hosts if they were to establish here. Other native plants that could be impacted are discussed in each individual risk analysis. There are two species of the family in New Zealand: *Alectryon excelsus* (titoki) including the Three Kings Islands *A. excelsus* subspecies *grandis*, and *Dodonaea viscosa* (akeake). Both are native but *A. excelsus* is endemic and *D. viscosa* widely distributed throughout the world.

Titoki occurs in the North and South Islands from Te Paki in the far northern North Island to Banks Peninsula south of Christchurch in South Island. It is a widespread coastal to lowland forest tree, often favouring well drained, fertile, alluvial soils along river banks and associated terraces (Salmon 1999). The large fruits are bird dispersed so titoki trees often occur as sparse components of most lowland forest types, throughout the North Island (NZPCN 2005). *Alectryon excelsus* subsp. *grandis* is an allopatric Three Kings Islands endemic (NZPCN 2005) and is unlikely to be found on the mainland except in collections.

An endemic specialist gracillariid moth *Conopomorpha cyanospila* lives exclusively on titoki, its larvae entering young *Alectryon* fruit through circular holes drilled in the capsule and seed walls (Sullivan *et al.* 1995). They tunnel into the contents, mainly the embryo with very large cotyledons, and kill the seeds. As *A. excelsus* fruits heavily at irregular intervals there may be a long adult life period (Sullivan *et al.* 1995). This moth has three congeners in Taiwan, *C. cramerella*, *C. litchiella* and *C. sinensis*, of which the latter is a severe pest of litchi fruit and exhibits a similar feeding ecology.

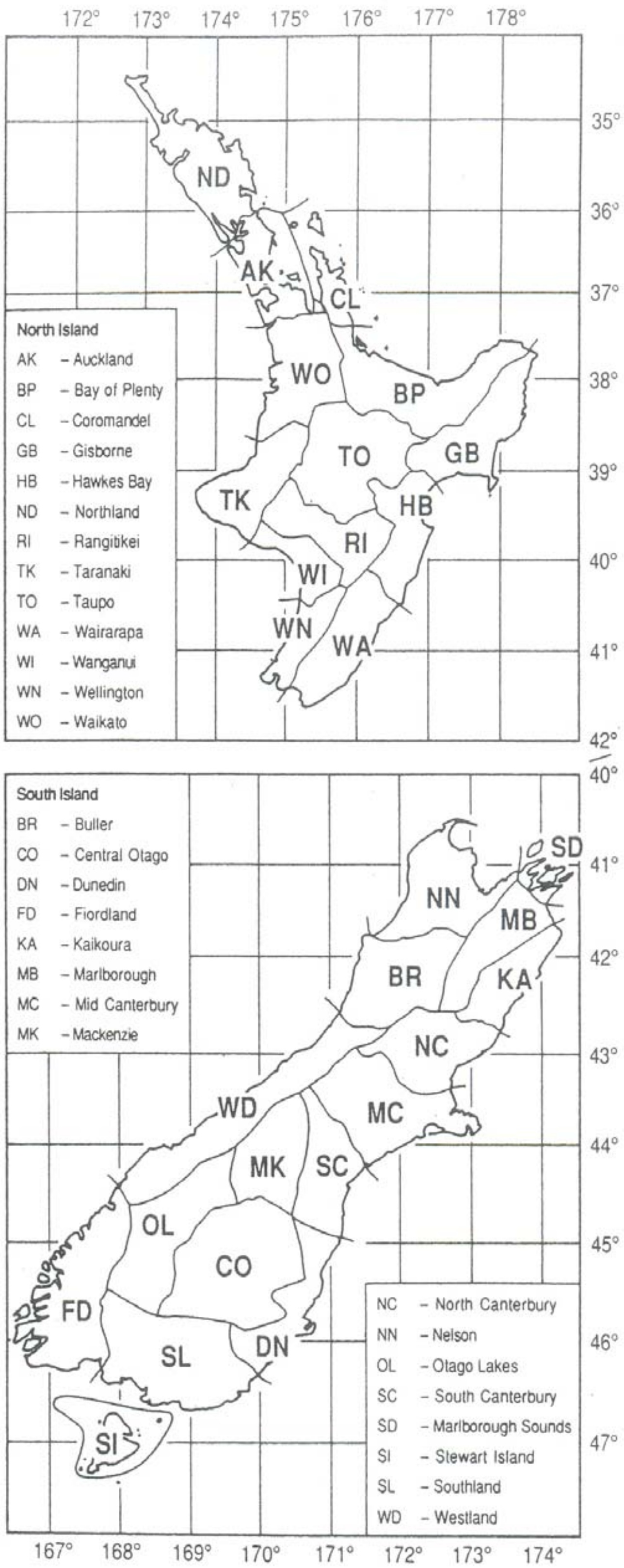
Akeake (*D. viscosa*) is an erect shrub or small tree found in exposed coastal situations, lowland scrub and forests from sea level to 550 metres. Its synonyms include *Dodonaea angustifolia, D. eriocarpa, D. sandwicensis, D. scottsbergii* and *Dodonaea spathulata* (Stevens *et al.* 1999). *D. viscosa* flowers from September to January and it is dioecious. It is moderately frost tolerant, and is highly wind, salt and drought tolerant (TRC 2002). *D. viscosa* can be affected by a yellowing disease distinguished by chlorotic witches' brooms in Hawaii (Borth *et al.* 1995). A relatively small number of plants are infected in Hawaii but this disease is spreading and can be found on all the major islands (Borth *et al.* 1995). In Taiwan longan witch's broom is a serious pathogen of litchi and longan fruit and although the relationship between these two pathogenic agents is unknown there is potential for a witches broom to affect native Sapindaceae given the right conditions i.e. higher temperatures and relatively high humidity.

3.13 Locality Naming Conventions

The system for recording specimen localities of insects (Crosby *et al.* 1976, 1998) has been used in this document to indicate places where exposure and establishment of hazardous organisms could occur (Figure 4). The places referred to and their two-letter abbreviations are listed. North Island: AK, Auckland; BP, Bay of Plenty; CL, Coromandel; GB, Gisborne; HB, Hawkes Bay; ND, Northland; RI, Rangitikei; TK, Taranaki; TO, Taupo; WA, Wairarapa; WI, Wanganui; WN, Wellington; WO, Waikato. South Island: MC, Mid Canterbury; NN, Nelson; SD, Marlborough Sounds. The Crosby system continues as a well established approach used by most New Zealand entomological and fungal collections, museums, and publication series. It has the advantages of allowing distributional information to be uniformly recorded and easily compared (Larivière & Larochelle 2004).

Figure 4: Crosby Codes of New Zealand.

A map reproduced from the fauna of New Zealand series showing all Crosby codes for New Zealand.


172° 173° 174° 175° 176° 177° 178°
35° 36° 37° 38° 39° 40° 41° 42°
ND
AK
CL
WO
BP
TO
GB
TK
HB
RI
WI
WN
WA
North Island
AK – Auckland
BP – Bay of Plenty
CL – Coromandel
GB – Gisborne
HB – Hawkes Bay
ND – Northland
RI – Rangitikei
TK – Taranaki
TO – Taupo
WA – Wairarapa
WI – Wanganui
WN – Wellington
WO – Waikato
40° 41° 42° 43° 44° 45° 46° 47°
South Island
BR – Buller
CO – Central Otago
DN – Dunedin
FD – Fiordland
KA – Kaikoura
MB – Marlborough
MC – Mid Canterbury
MK – Mackenzie
SD
NN
MB
BR
KA
NC
WD
MC
MK
SC
OL
CO
FD
SL
DN
SI
NC – North Canterbury
NN – Nelson
OL – Otago Lakes
SC – South Canterbury
SD – Marlborough Sounds
SI – Stewart Island
SL – Southland
WD – Westland
167° 168° 169° 170° 171° 172° 173° 174°

4. Hazard Identification

Chapter 4 outlines the potential hazards associated with litchi fruit in Taiwan, and considers some of the major risk characteristics of the commodity and its hazards.

An initial hazard list was made of all pests and pathogens associated with *Litchi chinensis* and found in Taiwan. The Australian Government Department of Agriculture Fisheries and Forestry (AFFA) list for pests of litchi from Taiwan was used as its basis (AFFA 2004), with various species added or excluded after considerations of association. This original list was later refined to include only those organisms directly associated with litchi fruit and found to be present in Taiwan. Some hitch-hiker pests are included in the pest analyses where entry and establishment of a species into the country would cause potential economic, environmental or health consequences. Appendix 1 is a list of those organisms assessed and discarded as likely hazards based on biology, and lack of association with the commodity. Appendix 2 contains a list of all potential hazards and Chapter 5 contains individual pest risk assessments and recommend measures where required.

4.1 Potential Hazard Groups

Pests and pathogens can be grouped in two main ways regarding their association with the commodity. Under their taxonomic category, i.e. Lepidoptera, Coleoptera, Acari, Fungi etc, or within the trophic role they play in their association, and what structures or part of the fruit they attack, e.g. surface feeder, seed feeder, pathogen. In this risk analysis hazard organisms are grouped according to their general taxonomic category. Where a genus contains more than one species, information on all species is contained within one pest risk assessment. If organisms that are hitch hikers or vectors this is noted in the individual pest risk assessment. The following categories are used in Chapter 5:

Tephritid Fruit flies	Mites	
Bugs (Hemiptera)	Mealybugs	Fungi
Moths	Scales	Witches' Broom

4.2 Pests and Pathogens of Litchi in Taiwan

The most common pests and pathogens affecting litchi orchards in Taiwan are shown in Tables 2 and 3 below. Brown root rot (*Phellinus noxius*), lac insect (*Kerria lacca*) and the Indian white wax scale (*Ceroplastes ceriferus*) are the three most common pest and pathogenic agents throughout the year, but the litchi fruit borer (*Conopomorpha sinensis*) is the most severe.

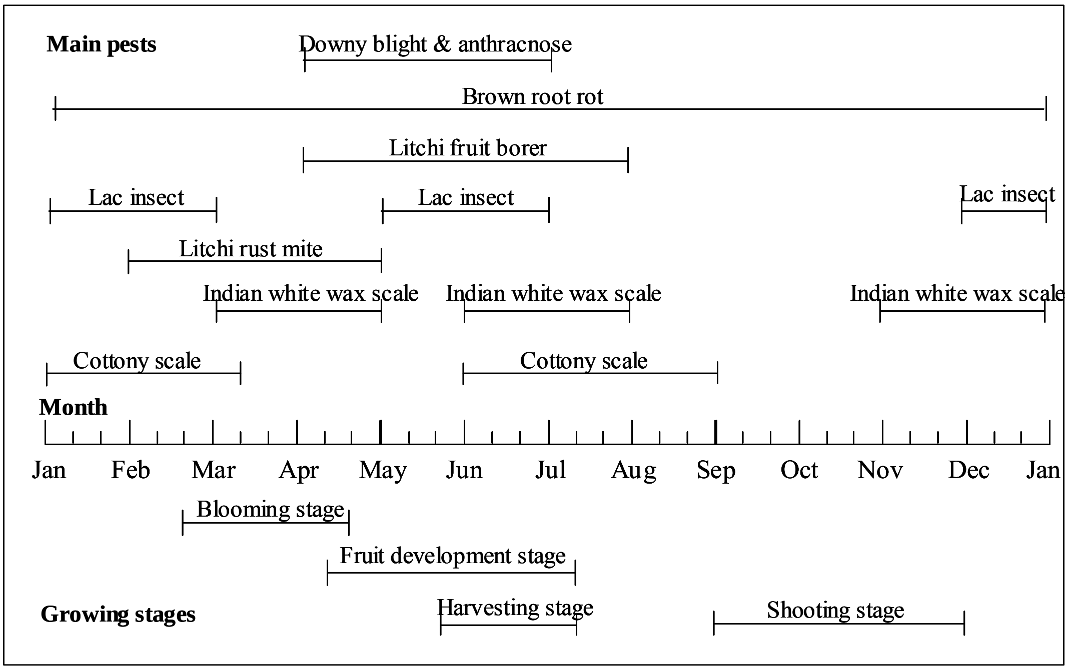
Table 2. Major Diseases and Pests of Litchi in Taiwan (BAPHIQ 2006)

Common name	Scientific name	Severity*
Disease		
Anthracnose	*Colletotrichum gloeosporiodies*	+
Brown root rot	*Phellinus noxius*	++
Downy blight	*Peronophythora litchii*	+
Pest		
Coffee leopard moth	*Zeuzera coffeae*	+
Cottony scale	*Chloropulvinaria psidii*	++
Indian white wax scale	*Ceroplastes ceriferus*	+
Lac insect	*Kerria lacca*	+
Litchi fruit borer	*Conopomorpha sinensis*	+++
Litchi rust mite	*Eriophyes litchii*	+

(*: Severity of pests and diseases: +++:severe; ++:moderate; +:slight)

Of the pest species listed above, *Ceroplastes ceriferus*, *Conopomorpha sinensis*, *Kerria lacca*, *Peronophythora litchii* and *Phellinus noxius* are considered further in the risk analysis.

Table 3. Chronology of Major Pests on Litchi in Taiwan (BAPHIQ 2006)



The majority of infestations occur between February and July, during the blooming, fruit development and harvesting stages of fruit production. The fruit development and harvesting stages are the most likely time in the production cycle for pests and pathogenic agents to infest the commodity and therefore increase the likelihood of these agents arriving in New Zealand. The shooting stage appears relatively unaffected by pests and pathogenic agents.

4.3 Organism Interceptions on Litchi Fruit from Existing Pathways

Volumes of fruit and figures for organisms associated with fruit, recorded as interceptions from New Caledonia and Thailand are discussed. This allows an understanding of the potential risk organisms that may be associated with the pathway. There are significant limitations in the interception data available however which cannot be taken to indicate true contamination rate. These data cannot be used to quantify interceptions of exotic organisms, and are only useful as an indication of types of hazards likely to be associated with the pathway.

Between 2001 and August 2006 a total of 116795 kgs of fresh litchi fruit were imported into New Zealand from existing pathways as commercial consignments (QuanCargo Database 2006). The size of consignment ranged from 250 kg to 18840 kgs. From this volume there were 9 inspections. These interceptions were part of the visual inspection regime for imported fresh produce where 600 units (a unit is a piece of fruit in this instance) are randomly chosen and inspected on arrival in New Zealand for pests or pathogens. The identifications are listed below. The numerical value is the number of times each pest category was found.
Diptera: 1
Tephritidae: 1
Drosophila sp.: 2
Pseudococcidae: 2
Not identified: 3

Three of the intercepted organisms were unable to be identified. Four of the organisms were found non-viable i.e. dead on arrival, 2 organisms were alive and 3 consignments were fumigated as remedial treatment for the removal of pest organisms. Five of the 6 interceptions identified were done this year (QuanCargo Database 2006). This reflects the higher volume of litchis entering the country in recent years. The data suggest there was a 0.007 percent rate of pest organisms arriving and being detected within the 600 unit sample on the pathway during the 6 year period. This is likely to be an underestimate of the total number of pests arriving with each consignment. With an increase in volume to 60 tonnes per year (60,000 kgs) it is assumed this rate could increase to 0.5 percent over the next 10 years.

Although this data cannot be extrapolated to predict likely pest interception numbers for litchi fruit from Taiwan it does reveal the type and quantity of risk associated with a similar pathway where similar treatment types have been used.

4.4 Other Risk Characteristics of the Commodity

Although many pests dealt with in this risk analysis have adequate information for assessment, we can not predict future or present risks that currently escape detection for a variety of reasons.

4.4.1 Unlisted Pests

These include pests that are not yet identified. With a trend towards decreasing use of chemical products in agriculture and further reliance on Integrated Pest Management strategies it is assumed that new pests will enter the system at some time in the future. Prolonged use of large doses of pesticides and fertilisers can lead to previously non pest species becoming economically important through resistance to pest treatments. Any of these types of organism could initially appear in very small numbers associated with the commodity, and may not be identified as hazards before their impacts become noticeable.

4.4.2 Symptomless Micro-organisms

Pests such as microbes and fungi infect fruit before transit and may not produce symptoms making them apparent only when they reach a suitable climate to sporulate or reproduce. Many fungi can infect fruit after arrival making it difficult to distinguish the origin of saprobes and pathogens without adequate identification. Consumers tend to throw away moulded fruit rather than take it to a diagnostic laboratory so there is little data on post entry appearance of “invisible organisms”.

4.5 Assumptions and Uncertainties

The assessment of uncertainties and assumptions for each organism often covers similar areas of information or lack of information, with key factors or variables being relevant across different organism groups. The following sections (4.5-4.8) outline these considerations. The assumptions and uncertainties are covered in these sections rather than individually in each pest risk assessment.

4.6 Assumptions and Uncertainties Around Hazard Biology

- For some species such as the Gypsy moth (*Lymantria dispar*) much information exists about a particular strain (European strain), but less information is available on other strains (Asian strain) or congeners. The overall characteristics for the genera are considered in such cases and it is noted in the text where only laboratory information (that may be difficult to extrapolate to field conditions) exists. For example *Lymantria dispar* is a well known hitch-hiker species, and has been associated with *Litchi chinensis*. Currently there are no data demonstrating this association between this hitch-hiker pest and the pathway. Interception data rather than biological information would be required to clarify this issue.

- The biology of insects that have been reared in the laboratory for several generations is often different to wild counterparts established in greenhouses or in field conditions (Mangan & 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 & 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.

4.7 Assumptions and Uncertainties Around the Inspection of Produce

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 commodity.

The 600 sample inspection requirement to achieve a 95 percent level of confidence that the maximum pest level will not be exceeded 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 random distribution of pests within the consignment some pests will not be detected if they are present outside the 600 unit sample;
- 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.

4.8 Assumption Around Transit Time of Fruit on the Air Pathway

An assumption is made around the time the fruit takes to get from the field in Taiwan to New Zealand ready for wholesale if it is transported by aircarrier. It is assumed that picking and packing of fruit will take up to one day, that transport of the commodity to the airport could take up to one day, and then transit to New Zealand and into distribution areas could also take up to one day. In total it is assumed that transport of litchis from Taiwan by air will take at least 3 days to reach New Zealand.

4.9 Assumption Around *Litchi chinensis* Grown in New Zealand

Discussion with the main growers (David Austen, Alan Booth & John Prince pers. comm. June-July 2007) suggests fewer than 15 litchi trees reported to fruit are grown in New Zealand. There are likely to be less than 40 trees in total cultivated here. Appropriate conditions for the growth and development of successfully fruiting trees include high temperatures in summer, light frosts in winter and constant moisture for the roots (David Austen pers. comm. July 2007). These conditions are met in a small number of areas in Northland and Bay of Plenty. Only one variety (Brewster 3) sets fruit unassisted and with any regularity.

It is assumed from the small number of isolated specimens, their slow growth in New Zealand and restricted ability to grow mature fruit set seed, that they would present a minimal risk of providing host material to potential pests and pathogens imported on litchi from Taiwan. Should more trees be planted in future or cultivated for commercial purposes this assumption will need to be reviewed.

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5. Review of Management Options

5.1 Introduction

The following chapter reviews management options of organisms that may be considered an unacceptable risk when associated with litchi fruit imported from Taiwan. These management options can be either generic measures for a broad range of hazard organisms or specific measures that are targeted towards a few key hazard species.

5.2 Post Harvest and Production Measures

There is little information regarding these aspects of the pathway, it is assumed quality assurance systems are in place to reduce the likelihood of fruit being infested with pest and pathogenic agents before export to New Zealand. After harvesting, all stalks and leaves will be removed from the litchis before cleaning, sorting and putting them into baskets. The fruit will then undergo a pre-cooling treatment prior to carrying out the in transit cold treatment during sea transportation. The temperature will not be higher than the designated temperature for cold treatment (BAPHIQ 2006). Farmers follow advised measures for the production of exported fruits combining best quality and pest control programs together (Plant Protection Manual for major pest controls). There is a specific focus on control of downy blight and litchi fruit borer (BAPHIQ 2006).

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 considered as 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).

Inspection as a biosecurity measure in a systems approach can be used 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 or foliage damage in the case of cut flowers or nursery stock;
- symptoms of treatment such as damage to goods;
- the use of indicators during treatment such as live organisms or colour indicators.

5.4 Specific Management Options – Vapour Heat Treatment & Cold Disinfestations

Applied treatments require the affected insect life stages receive a lethal treatment inducing very high mortality while the plant tissue is affected as little as possible (Shannon 1994 in Mangan & Hallman 1997). This must come at a reasonable cost and minimally encumber the marketing system (Mangan & Hallman 1997). According to a review by Mangan & Hallman (1997) the most frequently used temperature ranges for the two most commonly applied treatments, is between 0-3°C for Cold disinfestations and 43-49°C for Vapour heat treatment. Temperatures above 3 and below 43ºC might not kill all insects associated with the commodity and temperatures below 0 and above 49 ºC may harm the commodity and render it unsalable.

Although all stages of the pest life cycle are targeted with disinfestations measures there is evidence to show that the response of some life stages such as insect eggs to physical treatments varies with age (Corcoran 1993). Johnson and Wofford (1991) found that age was a significant factor in the response of two pyralid moths to cold applied as a disinfestation treatment. In the case of tephritid fruit flies, susceptibility to cold in eggs of *Anastrepha suspensa* (Loew) decreased with age (Benschoter & Witherell 1984) and Moss and Jang (1991) reported that mortality of Mediterranean fruit fly eggs subjected to hot water immersion was also dependent on age. Heard and other researchers (1991) found that age was a factor in the response of *B. tryoni* eggs to hot water immersion. Litchi fruits are known to be very susceptible to postharvest decay (Coates *et al.* 1994; Zhuang *et al.* 1998) and cold treatment may not be as efficacious against fungi as it is against arthropods.

Because of the inherent difficulties in assessing these treatments it is important that a systems approach to managing biosecurity risk be encompassed by both the country of export origin and the country importing the commodity. Information including interception records and any slippage monitored via ongoing surveillance programmes are important feedback data that influence the iterative nature of biosecurity decisions around the risk analysis and import health standard process.

5.5 Vapour Heat Treatment

In Vapour heat treatment the fruit are heated in humid air, about 95 % relative humidity to temperatures lethal to fruit flies but non-injurious to the fruit (Jacobi *et al.* 1993). Vapour heat (VHT) differs from high temperature, forced air in that moisture accumulates on the surface of the fruit. The water droplets transfer heat more efficiently than air, allowing the fruit to heat quickly, but there may also be increased physical injury to the fruit. Varietal and maturity differences in fruit heat sensitivity, as well as the capacity for long term storage have to be considered when researching into refining VHT for commercial application (Jacobi *et al.* 1993).

Heat has fungicidal as well as insecticidal action, but heat regimes that are optimal for insect control may not be optimal for disease control, in some cases they may even be detrimental. But high temperature manipulation before storage may have beneficial effects on the commodity treated, including slowing the ripening of climacteric fruit and vegetables, enhancing sweetness by increasing the amount of sugars or decreasing acidity, and prevention of storage disorders such as superficial scald on apples or chilling injury on subtropical fruits (Lurie 1998). Litchi fruit are non-climacteric and do not continue to ripen after harvest (Joubert 1986) producing relatively low levels of ethylene (<2.8µL kg^{-1} h^{-1}) after harvest, in comparison with climacteric fruits (Chen *et al.* 1986).

A pre shipping heat treatment can allow for low temperature disinfestations of commodities such as citrus, by improving the resistance of fruit to chilling injury generally incurred during this treatment (Lurie & Klein 2000).

Litchis are less tolerant of heat treatments for quarantine control of insect pests. Immersion in water at 60°C for 10 mins caused the pericarp to brown (Underhill & Critchley 1993). Vapour heat treatment to a core temperature of 45°C for 42 mins was less damaging as part of an Australian treatment against the Queensland fruit fly (Jacobi *et al.* 1993). Hawaii has also proposed an alternative heat treatment using immersion in water at 49°C for 20 minutes, followed by hydrocooling (Federal Register 1997).

There is no specific research into the efficacy of vapour heat treatment measures against insect pests in litchi fruit from Taiwan so efficacy data for the control of fruit fly in mango, bitter gourd and netted melon is used as a proxy. Kuo *et al.* (1987) heated mango fruit pulp at 46.5°C with fixed fluctuation in heat ranged between 46.4 +- 0.4°C for 30 minutes. The table below indicates the amount of time at which the 46.5°C was applied where 1 or fewer individuals of either eggs or larvae survived vapour heat treatment. Below these times more than one individual survived.

Developmental Stage	B. dorsalis	B. cucurbitae
Eggs	138 mins (1 survived)	138 mins (0 survived)
1^{st} and 2^{nd} instar larvae	143 mins (1 survived)	133 mins (0 survived)
3^{rd} instar larvae	133 mins (0 survived)	133 mins (0 survived)

It is apparent that *B. dorsalis* is more heat resistant for longer than *B. cucurbitae*.

Sunagawa *et al.* (1988) tested a vapour heat treatment against *B. cucurbitae* on bitter gourd fruit. The treatment applied a core temperature of 45°C for 30 minutes against 35,964 fly eggs (the most resistant life stage) within the fruit. Survival was measured by pupae recovery. As no survivors were recorded over three replicates, the treatment achieved an efficacy rate of $TE_{99.9956}$.
In another study using netted melon Iwata *et al.* (1990) tested a VHT against *B. cucurbitae* applying a core temperature of 45°C for 30 minutes against 68,428 one day old fly eggs within the fruit. Survival was also measured by pupae recovery. No survivors were recorded over four replicates, so the treatment achieved an efficacy rate of $TE_{99.9956}$.

There is no efficacy data for the heat treatment of surface pests such as scales and mealybugs on litchi fruit. Experiments carried out on removing surface pests from cut flowers in Hawaii (Hansen *et al.* 1992) determined efficacy of vapour heat treatment for scales, mealybugs, thrips and aphids after 2 hours at 45.2°C. It is suggested that this temperature and timeframe will kill all adult and nymphal stages of these groups and would therefore be an appropriate treatment to remove these organisms from litchi fruit.

The biological characteristics of a particular organism suggest its susceptibility to vapour heat treatment. These are covered in individual pest risk assessments. Based on the previous treatment efficacy data (Kuo *et al.* 1987; Sunagawa *et al.* 1988; Iwata *et al.* 1990) the risk of *B. cucurbitae* being mitigated against is by means of vapour heat from ambient temperature to a temperature of up to 46.5°C for 20 minutes.

5.6 Cold Disinfestation

In general, litchis have a short storage life under ambient conditions. Desiccation with the accompanying loss of red colour and development of browning can occur rapidly after harvest 9<72h) (Nip 1988). Browning renders the fruit hard to vend, therefore prolonging the shelf life could be commercially advantageous. Lowering the storage temperature is proven to extend the shelf life (Follett & Sanxter 2003). Cold treatments may be more appropriate for litchis than heat treatment however they require more time to complete (Paull 1994).

Problems with cold treatment have arisen from the occurrence of extraordinarily cold resistant life stages (Moffit & Albano 1972 in Dowdy 2002) or cold habituation (Meats 1976; Czajka & Lee 1990) in certain taxa (Jacas & Del Rio 2002). Cold damage can occur during treatment and preconditioning of fruit to lower temperatures, and the use of plastic wrapping, and plant growth regulators have been researched to prevent these side effects (McDonald *et al.* 1988; Miller *et al.* 1990; Yokohama *et al.* 1999).

Cold temperatures combined with storage in vented plastic bags that maintain humidity (Campbell 1994) showed that air conditioning these fruit by placing them at 5°C prior to 1°C storage reduced cell membrane permeability and peroxidase activity in the pericarp. Such pre-treatment did tend to retain the colour of Mauritius fruit but improvement was slight (McGuire 1997). Although pre-cooling may be an effective means of preserving fruit life under storage conditions there is no data to suggest that this additional measure increases the likelihood of killing pest organisms. Cold treatment can be applied during transportation to markets in refrigerated trucks or marine containers, whereas heat treatment imposes an additional postharvest step and could require construction of new facilities.

Literature looking at cold treatment for the elimination of *Bactrocera dorsalis* and *Conopomorpha sinensis* in litchi fruit indicated that at temperatures of 1°C or less all 2nd and 3rd instar larvae of *B. dorsalis* and all larvae of *C. sinensis* were dead after 12 and 14 days respectively (Lin *et al.* 1987; Su *et al.* 1993). While there is no independantly published efficacy data for experiments on cold treatment in litchi, in longan Liang *et al.* (1999) showed that at temperatures of 1°C all 2nd and 3rd instar larvae of *B. dorsalis* were dead after 13 days. Two replicates of 34,502 and 1 of 32,219 individuals of 2nd and 3rd instar larvae were tested in total. Longan is a similar size and shape to litchi fruit and results can be extrapolated from one species to the other. The recommended cold treatment to mitigate the risk of infestation by *Bactrocera* fruit flies and *Conopomorpha sinensis* for litchi fruit is as follows:

Fruit pulp temperature °C	**Exposure Period (consecutive days)**
0-1°C	13

5.7 Assessment of Residual Risk

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

a) 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
b) the level of risk posed by the hazard(s) was determined accurately in the risk analysis.

The remaining risk while being acceptable may still result in what could be interpreted as failures in risk management. Residual risk information in this case would be interception data from the litchi consignments coming into New Zealand from Taiwan. To effectively manage the risks of the majority of hazard organisms excluding fruit flies, phytosanitary measures would need to ensure that with 95 percent confidence not more than 0.5 percent of the units in any given consignment of fresh litchi fruit were infested with live organisms when given a biosecurity clearance into New Zealand. For fruit flies 0 units in any given consignment of litchi fruit would be the acceptable level. As this data has yet to be collected there can be no assessment of residual risk until this data eventuates. Also managing hitchhiker species is difficult because infestation appears random but it is most likely not random, there is merely a lack of interception information to base assumptions on.

While there are already two established pathways for fresh litchi fruit coming into New Zealand, data cannot be extrapolated to predict any possible level of slippage or efficacy of treatments acquired via interceptions. 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.

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6. Potential Hazard Organisms: Risk Analyses

Tephritid Fruit flies

6.1 *Bactrocera cucurbitae* (Melon Fly)

6.1.1 Hazard Identification

Aetiological agent: *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae)

Synonyms: Dacus cucurbitae, Dacus yayeyamanus, Chaetodacus cucurbitae, Strumeta cucurbitae, Zeugodacus cucurbitae

New Zealand Status: Not known to be present in New Zealand (not recorded in Scott & Emberson 1999; PPIN 2006; NZBugs 2006)

6.1.2 Biology

Melon fly belongs to the subgenus *Zeugodacus* a well defined group of about 70 species. Members of this subgenus have a strong preference for plants in the Cucurbitaceae, often attacking and developing in flowers as well as the fruit (White & Elson-Harris 1992). There are 3 larval instars which develop inside the fruit, a pupal stage which develops underground in soil at a depth of between 1-15cm (Khan *et al.* 1993) and an adult stage with several generations produced per year depending on environmental factors. In China, Yang (1991) recorded 4-5 generations annually.

Density and infestation rate of *B. cucurbitae* was compared in pawpaw (papaya) fruits on the ground and on trees in orchards in Hawaii (Liquido 1991). There was a significant relation between density of adult fruit flies in the orchard and larval density in fallen fruits, but not between adults and larval density in tree fruits. These results suggest that fruits left on the ground serve as a major breeding site, and thus as a reservoir of resident fly populations in pawpaw growing areas of Hawaii (Liquido 1991).

Emerging adults need to feed on nectar and protein to mature. Without protein in their diet female *B. cucurbitae* failed to oviposit during a study done in India (Kaur & Srivastava 1995), but adults lived longer on this diet (113 days) than those fed on a diet containing all components (101.6 days).

Duration of each life stage is dependent on environmental factors, with estimates for egg, larval, pupal, and adult longevity between 26 hours-5.1 days, 4.2-16.3 days, 6.5-39 days and 15.0-222 days respectively (Kumar & Agarwal 2005; Vargas *et al.* 1997; Koul & Bhagat 1994; Khan *et al.* 1993; Samalo *et al.* 1991; Vargas & Carey 1990; Liu & Lee 1987; Shivarkar & Dumbre 1985). These times are humidity and temperature dependent, and the whole life cycle can be completed in two and a half weeks under ideal conditions (ATTRA 2005). There are usually high egg and larval survival rates with the greatest mortality in the pupal stage (Vargas & Carey 1990). Wild females may reach maturity 20 days after emergence (Wong *et al.* 1986). Between 1973-1978 *B. cucurbitae* was intercepted at the New Zealand border in a cucurbit from India and larvae and eggs were reared to adults in laboratory conditions where they survived for more than two weeks (Keall 1981).

Vargas *et al*. (1997) found that the highest net reproductive rates for three species of fruit fly including *B. cucurbitae* occurred at 24°C. The highest rates of population increase for all species were observed at 29°C. The temperature threshold for cold exposure of larvae and eggs was assessed in studies in China (Yang *et al.* 1994) where it was found that no eggs or larvae survived exposure to constant temperatures of 2-3°C for longer than 7 days. Pupal development was studied in field and lab conditions in Taiwan (Liu & Lee 1987) and it was found that the duration of the pupal stage was 8 and 39 days at 30 and 14°C respectively. The lower developmental temperature thresholds for pupal development at constant temperature in the laboratory and fluctuating temperatures in a screenhouse were 9.98 and 9.75°C respectively (Liu & Lee 1987) in research conducted in China. Koidsumi (1938) 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.

B. cucurbitae are strong fliers and very mobile. Where host plants are sparse or the environment is unfavourable and during sterile release programmes, melon fly readily travels 30-50 km (Kawai *et al.* 1978). Fletcher (1989) observed that where host plants are available, melon fly usually only moves about 200m. The maximum recorded distance is 265km, which included travel over water (Waterhouse 1993). In the Mariana Islands, melon fly has flown to and re-infested Rota Island from Guam (Mitchell 1980) about 60km away.

The density of *B. cucurbitae* has been found at its highest in habitats where fruit trees and vegetables were mosaically cultivated or cucurbits and vegetables were commercially grown in one part of the area. The seasonal abundance of the tephritid coincided with the harvest of their host in China (Chen *et al.* 1995). In central Taiwan, it was found that populations of *Bactrocera cucurbitae* in fields of bitter gourds were closely correlated with fruit production, increasing from June, reaching a peak in July-August and then declining (Fang & Chang 1987). In another study of the population dynamics of *B. cucurbitae* in southern Taiwan (Wen 1985) on a variety of fruit crops there appeared to be two population peaks of the fly in August-October and May-June.

Some suggestions for environmental factors influencing these peak occurrences have been temperature and rainfall (Fang & Chang 1984). Wind is another major factor that can influence dispersal ability, with Vargas *et al* (1989) reporting 3-8 times higher capture rates of *B. cucurbitae* males on the leeward side than on the windward side of Kauai island in Hawaii.

6.1.3 Hosts

Preferred hosts include *Cucumis melo* (melon), *Cucurbita maxima* (giant pumpkin), *Cucurbita pepo* (ornamental gourd), and *Trichosanthes cucumerina var. anguinea* (snakegourd) (CPC 2006).

Other hosts are *Abelmoschus moschatus*, *Artocarpus heterophyllus* (jackfruit), *Benincasa hispida* (wax gourd), *Carica papaya* (papaw), *Citrullus colocynthis* (colocynth), *Citrullus lanatus* (watermelon), *Citrus maxima* (pummelo), *Citrus sinensis* (navel orange), *Cucumis auguria* (gerkin), *Cucumis sativus* (cucumber), *Cucurbita moschata* (pumpkin), *Cydonia oblonga* (quince), *Cyphomandra betacea* (tree tomato), *Ficus carica* (fig), *Lagenaria siceraria* (bottle gourd) and *Litchi chinensis* (Wen 1985), *Luffa acutangula* (angled luffa), *Luffa aegyptiaca* (loofah), *Lycopersicon esculentum* (tomato), *Mangifera indica* (mango), *Manilkara zapota* (sapodilla), *Momordica balsamina* (common balsam apple), *Momordica charantia* (bitter gourd), *Passiflora*, *Passiflora edulis* (passionfruit), *Persea americana* (avocado), *Phaseolus vulgaris* (common bean), *Prunus persica* (peach), *Psidium guajava* (guava), *Sechium edule*, *Sesbania grandiflora* (agati), *Syzygium samarangense* (water apple), *Trichosanthes cucumerina*, *Vigna unguiculata* (cowpea) and *Ziziphus jujuba* (common jujube) (CPC 2006).

Wild hosts include *Citrus hystrix* and members of the *Cucurbitaceae* (CPC 2006).

6.1.4 Distribution

Melon fly is thought to have originated in tropical Asia, and became known to science after its establishment in Hawaii in 1895 (White & Elson-Harris 1992), and occurs in large populations throughout Asia and Hawaii. It is found in China, Hong Kong, Japan (Ryukyu Islands), Laos, Malaysia, Taiwan, Thailand, Vietnam, and Mariana Islands (Rota) in Asia (CAB 2003, MAF 1994).

It does not occur in Europe, or Australia, was previously eradicated from California and has been intercepted on various fresh fruit and vegetables at the New Zealand border (PPIN 2007; Keall 1981).

6.1.5 Hazard Identification Conclusion

The melon fly is an internationally recognised pest on a wide range of host plants. Many of its known hosts are common horticultural and garden species grown throughout New Zealand. It should be able to establish and cause unwanted consequences in many parts of New Zealand. With its high fecundity and mobility it is considered a potential hazard on fresh litchi fruit from Taiwan.

6.1.6 Risk Assessment

6.1.6.1 Entry Assessment

Melon fruit fly is a major, well established pest on many fruit species in Taiwan including litchi. The life cycle of the fly means the larval life stage will be in the nearly mature fruits at the time of harvest. The eggs hatch in 26 hrs to 5 days and the larvae burrow into the fruit to feed for 4 to 16 days. Therefore eggs laid in a litchi fruit just prior to harvest would be expected to survive export to New Zealand as either eggs or larvae given that transport time to New Zealand is likely to be no more than 16 days. The fly pupates in soil and the adults require a protein source to reproduce, so it is unlikely these stages would survive or reproduce during transit time on the shipping pathway. Air travel is much shorter and all life stages could potentially survive and enter the country.

The shipping pathway is temporally long reducing the likelihood of entry of adult and pupal life stages into New Zealand. The likelihood of entry of larvae on the shipping pathway and all life stages on the air pathway which is temporally shorter is high and therefore non-negligible.

6.1.6.2 Exposure Assessment

Exposure requires reproduction, and that requires eggs and larvae developing to adults after entry. Adult longevity (15-222 days) is likely to enhance the likelihood of adult flies finding a mate. There would be no shortage of host plants available all year round. Fruit left on the ground serve as a major breeding site and reservoir population for fruit fly overseas (Liquido 1991). In particular *Malus* spp. (apple), *Prunus armeniaca* (apricot), *Persea americana* (avocado), *Phaseolus vulgaris* (beans), *Capsicum annuum* (capsicum), *Citrus* spp. (citrus), *Cucumis sativus* cucumber, *Solanum melongena* (eggplant), *Feijoa sellowiana* (feijoa), *Ficus carica* (fig), *Psidium guajava* (guava), *Cucumis*, *Cucurbita*, *Luffa* & *Marah* spp. (gourds), *Eriobotrya japonica* (loquat), *Cucurbita pepo* (marrow, zucchini), members of the Cucurbitaceae (melons), *Carica papaya* (pawpaw), *Prunus persica* (peach), *Pyrus* spp. (pear), *Cajanus cajan* (pigeon pea), *Cucurbita pepo* (pumpkin), *Cucurbita* spp (squash), *Lycopersicon esculentum* (tomato), and *Citrullus lanatus* watermelon (MAF, 1994).

The young fruit of zucchini have soft skin and are highly favoured hosts (Lee 1972), so zucchini can be expected to be heavily infested. Other hosts of relevance include *Brassica oleraceae* (broccoli, cabbage), *Averrhoa carambola* (carambola) *Sechium edule* (choko), *Vitis vinifera* (grape), *Passiflora edulis* passionfruit and various flowers (e.g. Leguminosae, Cucurbitaceae and *Sesbania grandiflora*) (MAF 1994).

It is likely that exposure will be higher when waste fruit is discarded in a domestic compost heap and suitable hosts are grown in the same area.

6.1.6.3 Establishment Assessment

High summer temperatures are not expected to limit spread of melon fly in New Zealand as mean monthly temperatures would not rise above the temperatures regularly experienced elsewhere in its range (Anon 1983). New Zealand regions most at risk from the establishment of permanent populations would be those where mean temperatures do not fall below 12°C and mean monthly rainfall is around 100-150mm. Using the Crosby *et al.* (1976) locality definitions and climate data of Gerlach (1974) and Anon (1983), these criteria are satisfied in parts of ND, AK, CL, WO, BP, GB, TK, NN, and small parts of HB, RI, WI and MC (Crosby *et al.* 1998 See Figure 2 Chapter 3).

It is likely that lower winter temperatures would limit the extent of establishment as *B. cucurbitae* is currently only found in tropical areas. The Auckland climate is suitable for development of *B. cucurbitae* throughout much of the year (MAF 1996). Parasitism by wasps, predation by ants, other invertebrates, some birds and fungal diseases would be expected to reduce numbers in its natural environment. Some elements of the natural enemy fauna may not exist in New Zealand and initially levels of predation parasitism and disease are likely to be low.

The most likely months for importing litchi fruit from Taiwan are between June and September. It is unlikely that *B. cucurbitae* would be able to establish in areas of New Zealand that may have suitable summer temperatures but do not have suitable establishment temperatures over the trading months (June to September).

It is highly likely that Melon fly would be exposed to suitable hosts in many parts of New Zealand and that climatic conditions would facilitate its establishment particularly in Auckland and the upper North Island. Such factors are considered non-negligible.

6.1.7 Consequence Assessment

6.1.7.1 Economic impact

Detection of a fruit fly in the surveillance programme would need to be reported internationally and an expected result would be reduced market access for New Zealand host material to markets free from *B. cucurbitae*. Once established fruit fly infestation causes fruit to ripen and drop early (Bateman & Sonleitner 1967) hence the reduction in harvest for infested crops would be significant. Postharvest disinfestation costs depend on the type of treatment used (MAF 1996).

Field studies carried out at various sites in central Taiwan on the injuriousness and seasonal occurrence of *B. cucurbitae* on different fruit and vegetable crops found that population density was highest on bitter gourd, followed by litchi, loquat and grape and pear in that order. Peak numbers were generally reached in November and temperature and rainfall were thought to be important factors in population regulation (Fang & Chang 1984).

In Australia, apples and citrus fruit undergo a cold treatment for fruit fly at a cost (1996 figures) of approximately A$200/tonne. Avocados are treated with hot forced air costing approximately A$125/tonne, and stone fruit cucurbits and tomatoes are treated with a dimethoate dip which costs approximately A$100/tonne (MAF 1996). It is assumed that similar treatments would be acceptable for New Zealand produce in the event of fruit fly infestation. These costs include transport to a central treatment station, equipment maintenance and chemical use, plus initial setup costs (MAF 1996).

Percentage losses from the export markets for apples and squash would be greater than for other hosts (MAF 1996) as a high proportion of these crops are exported. In 2004 the market value of total apples exported was NZ$485,222,000 and for squash in the same year NZ$53,488,000. That amounts to a potential combined loss (assuming countries do not accept area freedom assurances for areas not infested with the fruit fly) of NZ$538,710,000 worth of annual export value should *B. cucurbitae* establish here and reduce trade with our trading partners.

Based on past experience it is likely that most of New Zealand's major trading partners would take a more reasonable approach and limit trade only from areas where the fly has established. Area free status would be necessary to resume trade in areas without the fly. The likely loss in export value then would be proportionately less. Treatment options other than area freedom assurance (disinfestation of fruit) would be significantly more expensive.

6.1.7.2 Environmental

There are two plant genera: *Passiflora* and *Syzygium* attacked by Melon fly represented in the native flora. *Passiflora tetranda* and *Syzygium maire,* both endemic species are found in lowland forest throughout the North Island and parts of the South Island. *Passiflora* was traditionally used by Maori people as a food source. There is a possibility that if *B. cucurbitae* became established it could invade native forest areas adjacent to horticultural land and use these species as hosts. The extent and impact of *B. cucurbitae* on these species is unknown but is assumed to be similar to other non-native hosts that melon fly has colonised.

6.1.7.3 Human Health

There is some evidence implicating *Bactrocera cucurbitae* as the causative agent of gastrointestinal myiasis (pseudomyiasis) in humans in Pakistan, acquired via the ingestion of contaminated fruit. Experimental infection of human volunteers ingesting live larvae, led to the excretion in faeces of only dead larvae, prompting Khan and Khan (1984) to conclude that *B. cucurbitae* "cannot be considered as a cause of enteric myiasis in man". Identification of larvae in other studies from stools of human patients suffering from enteric myiasis culminated in the isolation of *B. cucurbitae* (Khan & Khan 1987), and one study showed it was the most commonly involved species in the infection (Khan 1987). The manner in which the larvae were ingested in earlier studies (Khan & Khan 1984) might have consequently influenced the results.

The Mediterranean fruit fly (*Ceratitis capitata*) is capable of transmitting human pathogens from faeces to intact fruit (Sela *et al.* 2005). Fruit flies must feed on protein in order to develop eggs (Sela *et al.* 2005), and faecal material can also be among the sources sought by *B. cucurbitae*. Therefore, it is theoretically possible that the latter species could potentially play a role in the transmission of human pathogens to fruit.

Although there seems to be a potential theoretical low risk that *Bactrocera cucurbitae* would cause adverse effects to human health following its establishment in New Zealand, it is unlikely the conditions required to facilitate this health risk would be found here. These include farm or domesticated animals in close proximity to human living areas and low levels of hygiene.

Consequences of the exposure and establishment of B. cucurbitae in New Zealand are high and therefore non-negligible.

6.1.8 Risk Estimation

The likelihood of entry is high (section ***6.1.2.2***), leading to either the interception of an adult fruit fly in a surveillance trap or the establishment of a population in Auckland or other climatically suitable areas. The likelihood of exposure is low to moderate (section ***6.1.2.3***), establishment is low to moderate (section ***6.1.2.4***), but the consequences of establishment are high (section ***6.1.2.5***). As a result the risk estimate for *B. cucurbitae* associated with litchi fresh fruit imported from Taiwan is non-negligible.

6.1.9 Risk Management

6.1.9.1 Risk Evaluation

Since the risk estimate for *B. cucurbitae* associated with litchi fresh fruit imported from Taiwan is non-negligible, phytosanitary measures will need to be employed to effectively manage the risks to reduce them to an acceptable level.

6.1.9.2 Option Evaluation

6.1.9.3 Risk Management Objective

To prevent entry and establishment of *B. cucurbitae* into New Zealand

6.1.9.4 Options Available

There are a number of points on the import pathway at which effective measures could be applied to reduce the likelihood of live life stages being intercepted at the border, surveillance detection or the establishment of *B. cucurbitae* to an acceptable level. Pest management systems in the orchards, screening measures and visual inspection should be considered in conjunction with the chosen disinfestation treatment to reduce pest numbers in fruit for export.

4) Vapour Heat treatment or Cold Disinfestation treatment.
In accordance with the risk management objective the treatment must kill all life stages of *B. cucurbitae* in the fruit before it is dispersed in New Zealand. Efficacy data for experiments on cold treatment in longan (Liang *et al.* 1999) showed that at temperatures of 1°C all 2nd and 3rd instar larvae of *B. dorsalis* were dead after 13 days. Longan is a similar size and shape to litchi fruit and results can be extrapolated from one species to the other. In an older study in Taiwan (Lin *et al.* 1987) results indicated oriental fruit fly could be completely killed in litchi fruit at 0-1°C after exposure for 12 days. The USDA treatment manual recommends temperatures of 0.99°C for 17 days or 1.38°C for 20 days (USDA 2006 See Chapter 5 for detailed discussion). After analysis of several studies it was determined that 1ºC or below for 13 days will be sufficient to kill any larvae or eggs in litchi fruit.

Based on the treatment efficacy data for bitter melon, gourd and mangoes (Kuo *et al.* 1987; Sunagawa *et al.* 1988; Iwata *et al.* 1990 See Section 5.4 & 5.5) litchis should be heated by means of vapour heat from ambient temperature to a temperature of at least 46.5°C. The litchis must be held at ≥ 46.5°C for a minimum of 20 minutes (see Section 5.4 & 5.5 for detailed discussion).

6.1.9.5 Recommended Management Options

Pest management systems in the orchards, screening measures and pre export visual inspection should be implemented in conjunction with the recommended disinfestations treatment.

a) Cold disinfestations treatment: 0-1ºC or below for 13 days.
or
a). Vapour heat treatment: ≥ 46.5 ºC for a minimum of 20 minutes.

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6.2 *Bactrocera dorsalis* (Oriental Fruit Fly)

6.2.1 Hazard Identification

Aetiological agent: *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae)

Synonyms: *Chaetodacus dorsalis, Chaetodacus ferrugineus dorsalis, Dacus dorsalis, Dacus ferrugineus, Strumeta dorsalis, Chaetodacus ferrugineus okinawanus*

New Zealand Status: Not known to be present in New Zealand (not recorded in Scott & Emberson 1999; MAF Country Freedom Report *Bactrocera dorsalis* 1999; PPIN 2006)

6.2.2 Biology

Oriental fruit fly, *Bactrocera dorsalis* (*sensu stricto*) is part of a species complex (the *B.* (*B.*) *dorsalis* complex) within the subgenus *Bactrocera*. Drew (1991) noted evidence of a number of closely related species infesting commercial fruit in south east Asia, and Drew and Handcock (1994) recognised and redescribed *Bactrocera dorsalis* (*s.s.*) along with another 52 species in this complex from the Asian region. In the western and southern parts of its geographic range information on *B. dorsalis* may be unreliable because of misidentifications (White & Elson-Harris 1992), as may be information from the Asian region prior to 1994.

B. dorsalis has a similar life cycle and biology to its congener *B. cucurbitae*. Reproduction is biparental with a lek mating system (Shelley 2001) and the sex ratio is approximately 1:1 (Binay & Agarwal 2005; Shimada *et al.* 1979). Pupation occurs in the soil under the host plant, with larvae jumping up to 70cm to search for available sites (Chu & Chen 1985). Five generations were recorded per year in Yunnan, in southwestern China (Shen *et al.* 1997). Females have been recorded ovipositing up to 132.3+/-7.31 eggs in guava, attracted by the wounds in the fruits caused by mechanical injury (Yuan *et al.* 2005) but egg numbers deposited can vary from 1-132 (Yuan *et al.* 2005; Chua 1994). Female territoriality accounts in some part for oviposition success with larger females tending to better defend oviposition sites as observed in Hawaii in field studies on mango trees (Shelly 1999).

Emerging adults need to feed on nectar and protein to mature and reproduce, and like *B. tryoni* it is thought the main protein source is from ‘fruit fly type’ bacteria that adults culture on leaf surfaces. In laboratory studies conducted in Bangladesh it was found that larval diets without protein sources significantly lowered the weight of resulting pupae (Mahfuza *et al.* 1999).

Duration of each life stage is dependant on environmental factors, with estimates for egg, larval, pupal and male and female adult longevity between 3.3-6.76, 8.29-92, 6.07-41, 51 days, 73-123 respectively and total life span ranging from 48.43-123 days (Binjay & Agarwal 2005; Vargas & Carey 1990; Liu & Lee 1986; Liu *et al.* 1985; Ibrahim & Gudom 1978). In laboratory observations of fruit fly on grapes in Taiwan it took 11.7 days for eggs to hatch, complete larval development and pupate (Chu & Tung 1996).

In studies conducted in China on the influence of temperature on the development of *B. dorsalis* it was found that the development of preadults ranged from 30.4 days at 19°C to 17.4 days at 36°C. Females laid the most eggs (1581 eggs) at 22°C and the fewest (9 eggs) at 36°C. The population doubled in 7.3 days at 34°C and doubled at a much slower rate of 130.7 days at 36°C (Yang *et al.* 1994). In India populations of *B. dorsalis* were highest when the temperature was between 25 and 38°C (Agarwal *et al.* 1995).

In the south western region of Kunming (China) field observations of the fly on the high plateau revealed *B. dorsalis* could withstand 13°C as a daily temperature average but no flies were recorded in any of the four study years at a daily temperature colder than 10°C (Ye & Liu 2005). The fly only occurs seasonally, and the area is re-colonised each year by migrating flies from several southern regions (Shi *et al.* 2005). Shi *et al*. (2005) suggest that because of haplotype similarities found in populations of *B. dorsalis* in Yunnan Province, separated by >300km, the fly might be engaging in long range dispersal, most probably taking advantage of prevailing air currents.

B. dorsalis is a strong flier and is highly mobile, re-establishing onto Lambay Island 12 km off the south west coast of Taiwan after an eradication attempt on the fly there. The main reason for re-infestation was the transportation of infested fruit between the two localities, but several marked males were recaptured on Lambay Island indicating the tephritid can migrate long distances (Chu & Chiu 1989).

Garbage could also be a potential pathway with drift from Taiwan to Lambay occurring within 12 hours. It was found that infested guava fruits immersed in marine water for 48h still produced 70 percent of tested larvae successfully emerging as adults (Chu & Chiu 1989). In studies on foraging behaviour *B. dorsalis* was recorded moving up to 600m between areas of food and non-food plants in field experiments in Taiwan (Chiu 1983) where observations showed that bamboo stands were the most preferred sites for resting.

A monitoring system for populations of *Bactrocera dorsalis* has been in place since August 1994 in Taiwan. North Taiwan showed lower densities of the fly, with 1994-1996 data revealing an annual decrease during winter and a peak from June to September (Hwang *et al.* 1997). The peak period coincided with the mature periods of fruiting trees in 1994-1995 (Zhang *et al.* 1995).

6.2.3 Hosts

B. dorsalis attacks over 300 cultivated and wild fruits (Mau & Matin, 1992). Host records for *B. dorsalis* in Taiwan vary from 89 hosts in 32 plant families to 150 plants in 38 families (Cheng & Lee 1991, 1993). It does not attack cucurbit crops such as cucumber and squash as readily as *B. cucurbitae*.

Hosts also include: *Aegle marmelos* (golden apple), *Anacardium occidentale* (cashew nut), *Annona* spp*.*, *Areca catechu* (betelnut palm), *Artocarpus* spp., *Averrhoa carambola* (carambola), *Capsicum annuum* (bell pepper), *Carica papaya* (papaw), *Chrysophyllum cainito* (caimito), *Citrus* spp., *Coffea arabica* (arabica coffee), *Cucumis melo* (melon), *Cucumis sativus* (cucumber), *Dimocarpus longan* (longan tree), *Diospyros kaki* (persimmon), *Ficus racemosa* (cluster tree), *Flacourtia indica*, *Litchi chinensis* (Ho *et al.* 2003), *Malpighia glabra* (acerola), *Malus domestica* (apple), *Mangifera foetida* (bachang), *Mangifera indica* (mango), *Manilkara zapota* (sapodilla), *Mimusops elengi* (Spanish cherry), *Momordica charantia* (bitter gourd), *Muntingia calabura* (Jamaica cherry), *Musa* (banana), *Nephelium lappaceum* (rambutan), *Persea americana* (avocado), *Prunus* spp. *Psidium guajava* (guava), *Punica granatum* (pomegranate), *Pyrus communis* (European pear), *Spondias purpurea*, *Syzygium* spp. *Terminalia catappa* (Singapore almond), *Ziziphus jujuba* (common jujube), and *Ziziphus mauritiana* (jujube) (CPC 2006).

6.2.4 Pest distribution

B. dorsalis was originally described from Taiwan, and occurs in dense populations in Asia and Hawaii. Its distribution range includes Pakistan and India to southern Japan, Indonesia to

Micronesia, the Mariana Islands and Hawaii. Recent outbreaks have occurred in California and Florida (Mau & Matin, 1992).

6.2.5 Hazard Identification Conclusion

B. dorsalis is an internationally recognised pest on a wide range of host plants. Many of its known hosts are common horticultural and garden species grown throughout New Zealand. It also has potential to impact some native species. It is likely to have spread through international trade and should be able to establish and cause unwanted consequences in many parts of New Zealand. With its high fecundity and mobility it is considered a potential hazard on fresh litchi fruit from Taiwan.

6.2.6 Risk Assessment

6.2.6.1 Entry Assessment

Oriental fruit fly is a major, well established pest on many fruit species in Taiwan including litchi. In recent years, suppression techniques such as release of sterile males, lures to target male flies and poison bait targeting emerging flies from the pupa stage have seen a reduction in the numbers of this fruit fly affecting crops in Taiwan (Creamer 2004).

The life cycle of the fly means that larval life stages will be in the nearly mature fruits at the time of harvest. The eggs can hatch in a day given optimal conditions and the larvae burrow into the fruit to feed for 8 to 92 days. Therefore eggs laid in a litchi fruit just prior to harvest and larvae feeding in fruit would be expected to survive export to New Zealand given that transport time is likely to be no more than 16 days. The fly pupates in soil and the adults require a protein source to reproduce, so it is unlikely these stages would survive or reproduce during transit time on the shipping pathway. Air travel is much shorter and all life stages could potentially survive and enter the country.

The shipping pathway is temporally long reducing the likelihood of entry of adult and pupal life stages into New Zealand. The likelihood of entry of larvae on the shipping pathway and all life stages on the air pathway which is temporally shorter is high and therefore non-negligible.

6.2.6.2 Exposure Assessment

Eggs and larvae entering the country will have to mature to adulthood to be able to reproduce. Adult longevity is likely to enhance the likelihood of adult flies finding a mate. There would be no shortage of host plants available all year round.
Hosts of relevance to New Zealand include: Apple, apricot, avocado, banana, capsicum, carambola, choko, citrus, *Eugenia* spp, feijoa, fig, grape, guava, litchi, loquat, mango, passionfruit, pawpaw, peach, pear, persimmon, plum, tomato, various flowers (e.g. *Sesbania grandiflora*: Leguminosae, and Orchidacea) and watermelon (MAF 1994; White & Elson-Harris 1992).

It is likely that exposure will be higher when waste fruit is discarded in a domestic compost heap and suitable hosts are grown in the same area.

6.2.6.3 Establishment Assessment

New Zealand regions most at risk from the establishment of permanent populations would be those where mean temperatures do not fall below 12°C and mean monthly rainfall is around 100-150mm. Using the Crosby *et al.* (1976) locality definitions and climate data of Gerlach (1974) and Anon (1983), these criteria are satisfied in parts of ND, AK, CL, WO, BP, GB, TK, NN, and small parts of HB, RI, WI and MC (Crosby *et al.* 1998. See Figure 2 Chapter 3).

Lower winter temperatures would likely limit its establishment since *B. dorsalis* is known to be established only in tropical areas currently. It is highly likely that Oriental fruit fly would be exposed to suitable hosts in many parts of New Zealand and that climatic conditions in Auckland and the upper north island could facilitate its establishment here especially during warmer months.

Parasitism by wasps, predation by ants, other invertebrates, some birds and fungal diseases would be expected to reduce numbers in its natural environment. Some elements of the natural enemy fauna may not exist in New Zealand and initially levels of predation parasitism and disease are likely to be low.

It is highly likely that B. dorsalis would be exposed to suitable hosts in many parts of New Zealand and that climatic conditions would facilitate its establishment particularly in Auckland and the upper North Island. Such factors are considered non-negligible.

6.2.7 Consequence Assessment

6.2.7.1 Economic

Detection of a fruit fly in the surveillance programme would need to be reported internationally and would be expected to result in reduced market access for New Zealand host material to markets free from *B. dorsalis*.

Damage to crops occurs from oviposition in fruit and soft tissues or vegetative parts of certain plants, feeding by the larvae and decomposition of plant tissue by invading secondary micro organisms. Once established, fruit fly infestation causes fruit to ripen and drop early (Bateman & Sonleitner 1967) hence the reduction in harvest for infested crops would be significant.

Postharvest disinfestation costs would be necessary and depend on the type of treatment used (MAF 1996). In Australia, apples and citrus fruit undergo a cold treatment for fruit fly at a cost (1996 figures) of approximately A$200/tonne. Avocados are treated with hot forced air costing approximately A$125/tonne, and stone fruit cucurbits and tomatoes are treated with a dimethoate dip which costs approximately A$100/tonne (MAF 1996). It is assumed that similar treatments would be necessary for New Zealand produce in the event of fruit fly infestation. These costs include transport to a central treatment station, equipment maintenance and chemical use, plus initial setup costs (MAF 1996).

Figures can be extrapolated for *B. dorsalis* from the economic impact of *B. cucurbitae*. In 2004 the market value of total apples exported was NZ$485,222,000 and for squash in the same year NZ$53,488,000. That amounts to a potential combined loss (assuming countries do not accept area freedom assurances for areas not infested with the fruit fly) of NZ$538,710,000 worth of annual export value should *B. dorsalis* establish here and prevent all trade with our biggest trading partners. Based on past experience it is likely that most of New Zealand's major trading partners would take a more reasonable approach and limit trade from areas only considered to provide a suitable climate for establishment of *B. dorsalis*. The likely loss in export value would be proportionately less. Treatment options other than providing area freedom assurance (i.e. disinfestation of fruit) would be significantly more expensive.

6.2.7.2 Environmental

Overseas at least six species of *Syzygium* are attacked by *B. dorsalis*. The native tree species *Syzygium maire* could potentially become an alternative host for the fruit fly if it established near native lowland forest in which the tree species predominantly occurs. The likelihood of the fruit fly contacting and establishing on native hosts is less than the likelihood of it infesting fruit and vegetable crops, or orchards.

6.2.7.3 Human Health

According to Khan and Khan (1981), *Bactrocera dorsalis* is a common causative agent of pseudomyiasis in humans in Pakistan. Following ingestion of infested fruit, the authors reported that patients experience a variety of symptoms such as "nausea, headaches, bowel irritation and sometimes vomiting before expulsion of living larvae with the faeces".

Khan and Khan (1986) experimentally infected human volunteers via ingestion of live larvae, which were all excreted dead in the faeces, leading the authors to the conclusion that *B. dorsalis* does not cause pseudomyiasis in humans. However, it seems very likely that the methodology used in Khan and Khan's (1986) experiments resulted in misleading conclusions. Subsequent studies from the same authors, again recorded *B. dorsalis* from human stools as one of the main causative agents of pseudomyiasis in Pakistan (Khan 1987; Khan & Khan 1987, 1992). The link between the fruit fly and this human health issue has not been proved unequivocally, therefore, it is considered a low potential theoretical risk. It is unlikely the conditions required to facilitate this health risk would be found in New Zealand. These include farm or domesticated animals in close proximity to human living areas and low levels of hygiene.

Consequences of the exposure and establishment of B. dorsalis in New Zealand are very high and hence non-negligible.

6.2.8 Risk Estimation

The likelihood of entry is very high (section ***6.2.6.1***), leading to either the interception of an adult fruit fly in a surveillance trap or the establishment of a population in Auckland or other climatically suitable areas. Likelihood of exposure is low to moderate (section ***6.2.6.2***), establishment is low to moderate (section ***6.2.6.3***), and the consequences of establishment are moderate to high (section ***6.2.7***). As a result the risk estimate for *B. dorsalis* associated with litchi fresh fruit imported from Taiwan is non-negligible.

6.2.9 Risk Management

6.2.9.1 Risk Evaluation

Since the risk estimate for *B. dorsalis* associated with litchi fresh fruit imported from Taiwan is non-negligible, phytosanitary measures will need to be employed to effectively manage the risks to reduce them to an acceptable level. Currently the latter means that no viable fruit fly individuals can be associated with the commodity.

6.2.9.2 Option Evaluation

6.2.9.3 Risk Management Objective

To prevent entry and establishment of *B. dorsalis* into New Zealand.

6.2.9.4 Options Available

There are a number of points on the import pathway at which effective measures could be applied to reduce the likelihood of live life stages being intercepted at the border, surveillance detection or the establishment of *B. dorsalis* to an acceptable level. Pest management systems in the orchards, screening measures and visual inspection should be viewed as complementary options that need to be implemented in conjunction with the chosen disinfestation treatment to reduce pest numbers in fruit for export.

4) Vapour Heat treatment or Cold Disinfestation treatment.
In accordance with the risk management objective the treatment must kill all life stages of *B. dorsalis* in the fruit before it is dispersed in New Zealand. See Section ***6.1.9.4*** in *B. cucurbitae* assessment for more detail.

6.2.9.5 Recommended Management Options

Pest management systems in the orchards, screening measures and pre export visual inspection should be implemented in conjunction with the recommended disinfestations treatment.

a) Cold disinfestations treatment: 0-1ºC or below for 13 days.
or
b) Vapour heat treatment: ≥ 46.5 ºC for a minimum of 20 minutes.

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Hemiptera (Bugs)

6.3 *Aphis gossypii* (Cotton/Melon Aphid)

6.3.1 Hazard Identification

Aetiological agent: *Aphis gossypii* Glover (Homoptera: Aphididae)

Synonyms: *Aphis bauhiniae, Aphis circezandis, Aphis citri, Aphis citrulli, Aphis cucumeris, Aphis cucurbiti, Aphis lilicola, Aphis minuta, Aphis monardae, Aphis parvus, Aphis tectonae, Cerosipha gossypii, Doralina frangulae Doralina gossypii, Doralis frangulae, Doralis gossypii, Toxoptera leonuri*

New Zealand Status: *A. gossypii* is known to be present in New Zealand (Spiller & Wise 1982; Charles 1998; Scott & Emberson 1999; Teulon *et al.* 2004,). Papaya ringspot virus is not present in New Zealand (PPIN 2006; Pearson *et al.* 2006)

6.3.2 Biology

The taxonomic status of *Aphis gossypii* is complicated, being distinguished from the *Aphis frangulae* group in Europe by the absence of sexual reproduction (Komazaki 1993). Its reproduction in Europe is mostly asexual with either alate or apterous (winged or wingless) females. Nutritional stress and crowding are the two proposed determining factors as triggers for alate production (CPC 2006). In East Asia, Japan and China, however, it has an holocyclic (sexual) life-cycle in addition to an anholocyclic (asexually reproducing) one (Zhang & Zhong 1990). The anholocyclic cycle involves a migration from a winter host to a summer host in the spring and a return to a winter host in the autumn for laying eggs (CPC 2006) with parthenogenetic overwintering populations reported from Japan (Inaizumi 1980).

It is not known if any populations require special overwintering hosts or if sexual forms occur in New Zealand (Martin & Cameron 2003).

In Japan *A. gossypii* first appears on citrus in the spring, its early appearance is explained by the fact that the aphid has a wide range of overwintering hosts other than citrus, such as vegetables and weeds, on which it overwinters parthenogenetically. The role of those *A. gossypii* populations that overwinter on citrus in spring infestations, may be comparatively slight, because the invasion from other hosts begins earlier than the appearance of alates of the citrus overwintering population (Komazaki 1993). The aphids develop on young shoots, so their numbers also depend on the number of new shoots (Komazaki 1981).

A. gossypii is considered a serious pest of litchi in Vietnam (Chomchalow 2004). While there is no direct evidence for association with the fruit it could be a hitch hiker species.

Development times vary depending on environmental factors particularly temperature, with estimates for immature and adult stages between 3.81-20.70 days and 8.56-20 days respectively and total longevity estimated between 6.8-26 days (Zamani *et al.* 2006; Satar *et al.* 2005; Kim & Kim 2004; Kim *et al.* 2004; Michelotto *et al.* 2003; Mogeni & Rezwani 1998). On average the duration of the adult reproductive period is about 15, and the post reproductive period 5 days (Capinera 2005).

Fecundity of females has been recorded in laboratory situations to range from 5.8-61.8 nymphs per female (Kim & Kim 2004; Karim *et al.* 1999) with the production of 2.8 nymphs per day recorded on cotton in the USA (Akey & Butler 1993). In warmer climates the life cycle is completed much faster.

Temperature thresholds for development of the cotton aphid are generally between 4.19-10°C at the lower end and between 33-35°C at the upper end of the continuum (Perng *et al.* 2002; Adam 1998; Kocourek *et al.* 1994). A lower developmental threshold for *A. gossypii* was estimated at 7.34°C on squash in Taiwan (Liu & Perng 1987). In one extreme example an upper limit to *A. gossypii* survival in okra fields where the daytime temperature exceeded 45°C was reported by Aldyhim & Khalil (1993). Komazaki (1982) suggested optimum temperatures for *A. gossypii* are around 22 or 23°C.

6.3.2.1 *Aphis gossypii* as a vector

Melon aphid is a vector of some important plant viruses including Zucchini yellow mosaic virus which was first isolated in New Zealand from buttercup squash in Hawkes Bay (Fletcher 1996), and Water melon mosaic virus both of which have been isolated from populations of New Zealand's only native cucurbit *Sicyos australis* (Delmiglio & Pearson 2005). Cucumber mosaic virus also vectored by *A. gossypii* is present in New Zealand.

Regulated viruses for New Zealand transmitted by *A. gossypii* include Citrus tristeza virus (CTV) (some strains in NZ), Papaya ringspot virus [type P] (PRSV-P) which is non-persistent, Papaya ringspot virus [type W] also non-persistent, and Eggplant mosaic virus, a new strain of cucumber mosaic virus (CMV) 1. Melon aphids will transmit viruses to crops they don't colonise (Capinera 2005) as the apterous forms tend to be transient when searching for new host plants.

Of these viruses Zucchini yellow mosaic virus, and papaya ringspot virus occur in Taiwan (Lin *et al.* 2002; Kuan *et al.* 1999). Papaya ringspot virus (PVR) which is not found in New Zealand is known to affect many types of cucurbit species, papaya, *Chenepodium amaranticolor* and *Chenopodium quinoa* (PVO 1996). PRV is grouped into two types, PRV-p which infects both papaya and cucurbits and PRV-w which infects cucurbits but not papaya. PRV-w causes major damage to cucurbits and was previously referred to as Watermelon mosaic virus 1 (Gonsalves 1993). Neither type occurs in New Zealand (Pearson *et al.* 2006). Though many cucurbitae are susceptible to PRV-p, they don't serve as an important alternate host. Instead the dominant strain in cucurbits is PRV-w. The spread of the virus (PRV-p) into and within orchards is primarily from papaya to papaya.

Aphids normally retain non-persistent viruses for no more than an hour, but retention of up to 1-3 days has been reported (Celetti *et al.* 1992). Transmission efficiency of PRV by *A. gossypii* was found to range between 13.3 percent and 46.3 percent in experimental testing of cloned *A. gossypii* in France (Lupoli *et al.* 1992).

6.3.3 Hosts

Primary hosts of *A. gossypii* belong to five main families – Rutaceae, Malvaceae, Rubiaceae, Cucurbitaceae and Rhamnaceae. Plants that are potential hosts in New Zealand include: *Cucumis melo* (melon), *Cucumis sativus* (cucumber), *Cucurbita maxima* (banana squash), *Cucurbita moschata* (pumpkin), *Cucurbita pepo* (ornamental gourd), Cucurbitaceae (cucurbits), *Allium sativum* (garlic), *Apium graveolens* (celery), *Araceae, Arachis hypogaea* (groundnut), *Artocarpus altilis* (breadfruit), *Brassica napus var. napus* (rape), *Brassica oleracea var. gongylodes* (kohlrabi), *Brassica rapa* spp. *oleifera* (turnip rape), Brassicaceae (cruciferous crops), *Calendula officinalis* (Pot marigold), *Capsicum annuum* (bell pepper), *Citrullus lanatus* (watermelon), *Citrus, Citrus aurantiifolia* (lime), *Citrus limon* (lemon), *Citrus reticulata* (mandarin), *Citrus sinensis* (navel orange), *Citrus unshiu* (satsuma), *Citrus x* *paradisi* (grapefruit), *Daucus carota* (carrot), *Dianthus caryophyllus* (carnation), *Glycine max* (soyabean), *Helianthus annuus* (sunflower), *Ipomoea batatas* (sweet potato), *Jasminum* (jasmine), *Lactuca sativa* (lettuce), *Lilium longiflorum* (Easter lily), *Litchi chinensis* (litchi), *Lupinus angustifolius* (lupin), *Lycopersicon esculentum* (tomato), *Malus pumila* (apple), *Persea americana* (avocado), *Phaseolus* (beans), *Phaseolus vulgaris* (common bean), *Prunus armeniaca* (apricot), *Prunus persica* (peach), *Pyrus communis* (European pear), *Solanum melongena* (aubergine), *Solanum tuberosum* (potato), *Vigna unguiculata* (cowpea), *Vitis vinifera* (grapevine), *Zea mays* (maize), *Zinnia elegans* (Zinnia) (CPC 2006).

The main hosts of PRV are: *Carica papaya* (papaya), *Chenopodium amaranticolor* (amaranth), *Chenopodium quinoa* (quinoa), *Cucumis melo* (honeydew, musk melon), *Cucumis metuliferus* (horned cucumber), *Cucumis sativus* (cucumber), *Cucurbita maxima* (winter squash), *Cucurbita moschata* (summer squash), *Cucurbita pepo* (field pumpkin) (PVO 1996).

6.3.4 Distribution

A. gossypii is cosmopolitan in distribution and has been established in New Zealand since 1921 (PPIN 2006). It is common in Taiwan and is recorded as being a major pest of litchi in Vietnam (Chomchalow 2004).

6.3.5 Hazard Identification Conclusion

Although *Aphis gossypii* is found in New Zealand, some aspects of its biology here are unknown e.g. whether populations require special overwintering hosts or if sexual forms are present. Papaya ringspot virus which is transmitted by *A. gossypii* occurs in Taiwan but not in New Zealand and the prevention of its entry into the country would be a priority. However it is assumed that packing and transit of litchi fruit from Taiwan to New Zealand will take at least 3 days and therefore be longer than the retention time for semi-persistent viruses such as PRV, making it unlikely to become established here. For these reasons, *A. gossypii* and the vectored Papaya ringspot virus are not considered potential hazards in this risk analysis.

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6.4 *Kerria lacca* (Lac Insect)

6.4.1 Hazard Identification

Aetiological agent: *Kerria lacca* Kerr (Homoptera: Kerriidae)

Synonyms: Coccus gummilaccae, *Coccus lacca*, *Coccus ficus*, *Chermes lacca*, *Carteria lacca*, *Tachardia lacca*, *Lakshadia indica*, *Laccifer lacca*, *Kerria lacca lacca*

New Zealand Status: Not known to be present in New Zealand (not recorded in Scott & Emberson 1999; PPIN 2006).

6.4.2 Biology

In India, there are two "strains" of *Kerria lacca*, the Rangeeni strain and the Kusumi strain. Each strain is specific to particular host trees, has a different life cycle and produces different body extracts. However, morphologically these strains could not be separated into different species (Varshney, 1976; Sequeira & Bezkorowajnyj, 1998). In China several species exist including *K. sindica*, and *K. chinensis* (Li *et al.* 1994). Although *Kerria lacca* was originally introduced to Taiwan (Takahashi 1949) in 1940 for shellac (lac melted and run into thin plates or used as varnish or to dye materials) production, the industry declined and it is now considered an economically important pest there (Wen *et al.* 2002). It is one of the most serious pests of litchi in Taiwan (BAPHIQ 2006). *K. lacca* develops in an amber coloured resinous cocoon known as sticklac on the twigs of trees. Swarms of females have been recorded covering whole trees turning them a pinkish red with resin (Ecoport 2006).

There are two generations of *K. lacca* per year in Taiwan with the females undergoing three nymphal instars, while the males have two, with additional pupal and prepupal stages. Male adults are apterous, living only a few days. In laboratory conditions (reared on pumpkin) the lifecycle was between 100.9 and 184.9 days (Sharma & Ramani 1997). Females can produce eggs or be viviparous, with between 438.6 and 681.3 progeny produced in a single generation (Hwang & Hsieh 1981). Females produce between 600 and 1000 eggs in the case of the Nepalese Rangeeni strain introduced into China specifically for lac (resinous incrustation) production (He *et al.* 2004).

In southern Taiwan the first instar of the winter generation appears between early December and January and between late January and early February in the central region. In summer first instars appeared in the same areas in May and June respectively (Hwang & Hsieh 1981). The insects secrete wax and shellac in the first instar, with secretions increasing through the adult stage. The scale is generally found to attack the branches and stems of fruit trees (Hsieh & Hwang 1983) and its nymphal secretion (honeydew) induces the growth of sooty mould, which infects the host plant (Hwang & Hsieh 1981).

The lower developmental threshold temperatures for the 1^{st}, 2^{nd} and 3^{rd} instar larvae and the female of *Kerria lacca* are 9.1, 8.8, 10.2 and 18.1°C respectively, with that for the larval stage being 8.8°C as a whole (Yan 1989). The insect was observed to shelter under branches to avoid solar radiation and rainfall, and a symbiosis between *K. lacca* and ants was noted in Taiwan (Hwang & Hsieh 1981). It preferentially attacks young branches with a 95 percent host rate on branches less than one year old, and a 5 percent host rate on tree branches between one to two years old (Chen *et al* 2004). The shellac produced by *Kerria lacca* has been reported as an allergenic agent by Hausen & Nist (2001), though there is little quantitative information about this.

6.4.3 Hosts

K. lacca is known to attack 66 plant species in 27 families in Taiwan (Hwang & Hsieh 1981). Some species of economic importance include: *Mangifera indica* (mango), *Annona squamosa* (sugar apples), *Cucurbita moschata* (pumpkin), *Diospyros kaki* (persimmon), *Ricinus communis* (castor bean), *Carya pecan* (pecan nut), *Acacia* spp., *Cajanus Cajun* (pigeon pea), *Tamarindus indica* (tamarind), *Ficus* spp., *Ziziphus jujube* (common jujube), *Ziziphus mauritiana* (jujube), *Rosa chinensis* (China rose), *Citrus paradisi* (grapefruit), *Salix babylonica* (weeping willow), *Vitis vinifera* (grapevine) and *Litchi chinensis* (Ben-Dov *et al.* 2006; Subbarayudu & Ram 1997).

6.4.4 Distribution

It is widespread throughout Asia, is found in Guyana in South America and has established in two countries in the Palearctic region, Azerbaijan and Georgia (Ben-Dov *et al.* 2006).

6.4.5 Hazard Identification Conclusion

This scale insect has a high temperature threshold for development particularly in the larval forms and a high potential reproductive output. Its host range is wide and it has established in several countries where climatic conditions are more severe than in many parts of New Zealand. For these reasons it is considered a potential hazard in this risk analysis.

6.4.6 Risk Assessment

6.4.6.1 Entry Assessment

The larval instars are the size of apple seeds, and are a pinkish colour inside the resinous sticklac secretion. This colour would be well blended with the pinkish hue of the litchi skin and provide a cryptic habitat for the organism. Although the larval forms tend to occur on twigs the adults disperse to other areas after hatching, and would be more likely to be associated with the fruit and potentially enter the country.

There is a high likelihood that any lifestage of Kerria lacca will enter the country on the pathway. Therefore the likelihood of entry is non-negligible.

6.4.6.2 Exposure Assessment

Kerria lacca has a wide host range and some hosts are common in New Zealand. Grapevine, grapefruit, roses and persimmon are grown in parts of both North and South Islands. The most widely represented group of hosts come from the Leguminaceae, many members of which are cultivated or grown for amenity purposes here. Because of its long life cycle *K. lacca* would have a moderate chance of being exposed to potential hosts through the disposal of waste litchi material in compost, or gardens. The adult stages, particularly the winged males are mobile though comparatively short lived, with adult winged males only living a couple of days. There would be no shortage of potential hosts in urban environments, available throughout the year.

6.4.6.3 Establishment Assessment

Climatic conditions in New Zealand would be unlikely to be a limiting factor for the lac insect establishing in wild or cultivated crop habitats. Larval forms have a high cold tolerance as Yan (1989) demonstrated in China, surviving temperatures as low as 8.8°C. The thermal minimum for adult females is much higher at 18.1°C, which would limit the spread and development of juveniles into the adult stages. In warmer parts of the North Island (ND, AK, HB, GB for example) it is possible the insect could survive all year round.

The likelihood of exposure and establishment of K. lacca is high given suitable climatic conditions and availability of host material.

6.4.7 Consequence Assessment

6.4.7.1 Economic

Although originally introduced to Taiwan for commercial shellac production, *K. lacca* has become a major pest of orchard fruit trees such as litchis, sugar apples and longans among other crops. The banyan tree (*Ficus retusa*) is its favoured host in Taiwan (Chiu *et al.* 1985) but since the 1960s it has been considered a serious pest of 66 crop species (Hwang 1990). Its effect of infestation on the quality and quantity of fruit yield in *Zizyphus mauritiana* was studied in Haryana, India (Lakra & Kher 1990). Infestations of 5000 nymphs per 100cm of twig caused a weight loss in fruits of 52.5-58.5 percent. A large reduction in the total soluble sugar content of infested fruits (average 53.7 percent) was recorded (Lakra & Kher 1990). At times of swarming this high number of individuals would be considered normal. Pumpkin, persimmon, grapevine and roses could potentially be affected in New Zealand.

6.4.7.2 Environmental

If the scale were to establish it could find suitable wild hosts from within the native flora represented by members of the Leguminosae, Malvaceae, Proteaceae, Cucurbitaceae, Euphorbiaceae, Rutaceae, Meliaceae, and Rhamnaceae.

6.4.7.3 Health

There are a number of cases in the medical literature regarding allergic contact dermatitis as a result of exposure to shellac in cosmetics (e.g. Orton *et al.* 2001; Rademaker *et al.* 1986; Le Coz *et al.* 2002). Shellac is rarely reported as the causative agent of contact dermatitis in its natural state, usually only as a constituent of beauty products. There is no evidence that the insects themselves cause allergies in humans. It is highly unlikely that the establishment of *K. lacca* in New Zealand would lead to any significant adverse effects to human health.

The likelihood of negative consequences following entry and establishment of the scale are low to moderate.

6.4.8 Risk Estimation

This species in association with litchi fruit from Taiwan has a high likelihood of entry (section ***6.4.6.1***) and exposure(section ***6.4.6.2***), a high likelihood of establishment (***6.4.6.3***) and the potential to cause unwanted consequences to the economy, environment and human health is low to moderate (section ***6.4.7***). The risk estimation for *K. lacca* therefore is non-negligible.

6.4.9 Risk Management

6.4.9.1 Risk Evaluation

Since the risk estimate for *K. lacca* associated with fresh litchi fruit imported from Taiwan is non-negligible, phytosanitary measures will need to be employed to effectively manage the risks to reduce them to an acceptable level.

6.4.9.2 Option Evaluation

6.4.9.3 Risk Management Objective

To ensure that *K. lacca* does not enter the country and become established in New Zealand.

6.4.9.4 Options Available

There are a number of points on the import pathway at which effective measures could be applied to reduce the likelihood of live life stages of *K. lacca* being intercepted at the border. Pest management systems in the orchards, screening measures and visual inspection should be viewed as complementary options that need to be implemented in conjunction with the chosen disinfestation treatment to reduce pest numbers in fruit for export.
There is no specific efficacy data of either treatment measure for *K. lacca*.

Vapour heat treatment: Hansen *et al.* (1992) determined efficacy of vapour heat treatment for scales, mealybugs, thrips and aphids on cut flowers after 2 hours at 45.2°C. It is suggested that this temperature and timeframe will kill all adult and nymphal stages of these groups and would therefore be an appropriate treatment to remove *K. lacca* from litchi fruit.
Cold disinfestation treatment: In the absence of efficacy data it is assumed that the measure in the USDA treatment manual (2004) will be effective against scale insects i.e. fruit is to be cooled to .99°C or below for 17 days or cooled to 1.38°C or below for 20 days.

6.4.9.5 Recommended Management Options

Pest management systems in the orchards, screening measures and pre export visual inspection should be implemented in conjunction with the recommended disinfestations treatment.

a) Vapour heat treatment: 45.2ºC for 2 hours.
or
b) Cold disinfestation treatment: 1 ºC or below for 15 days.
and
c) Visual inspection will be undertaken in New Zealand after the consignment has arrived.

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Moths

6.5 *Adoxophyes orana* (Summer Fruit Tortrix Moth)

6.5.1 Hazard Identification

Aetiological agent: *Adoxophyes orana* Fischer von Röeslerstamm (Lepidoptera: Tortricidae)

Synonyms: Acleris reticulana, Adoxophyes congruana, Adoxophyes fasciata, Adoxophyes reticulana, Adoxophyes tripsiana, Cacoecia reticulana, Capua congruana, Capua orana, Capua reticulana, Tortrix orana, Tortrix reticulana

New Zealand Status: Not known to be present in New Zealand (not recorded in PPIN 2006; Scott & Emberson 1999; Dugdale 1988)

6.5.2 Biology

Adoxophyes orana is a leaf roller, recorded feeding on leaves, flowers, and fruit (CPC 2003). The larvae appear to prefer leaves and the fruit surface (Hill 1983) and will also use foliage for shelter while feeding (Whittle 1985). Egg laying begins after a period of 135 days with temperatures above 10°C from the start of the flight period onwards. Eggs are deposited in masses, of 25-150 per egg mass. Oviposition takes place mostly in the late afternoon and evening (CPC 2006) and lasts up to 11 days (Stamenkovic 1985) with more than 300 eggs potentially deposited per female.

The 2nd and 3rd larval stages hibernate and resume as the spring weather brings new developing buds, of which larvae spin the rosette leaves and eventual flower parts together. The duration of larval development in the field in western Serbia was 32.2-37.0 days (Stamenkovic & Stamenkovic 1985). If larvae are disturbed, they let themselves fall down on a spun thread in order to escape (CPC 2006). The thread is also used for wind aided migration (Bell *et al.* 2005; Barel 1973). Later in the season, the larvae are mostly present on new shoots high in the tree.

In north Western Europe *A. orana* has two generations per year, with a partial third generation appearing in warmer summers. Overlapping between late larvae of some generations and early instars of the next were observed in northern Greece (Savopoulou-Soultani & Hatzivassiliadis 1991). The pupal stage in western Serbia averaged 8.9 days (Stamenkovic & Stamenkovic 1985). Adult life span is temperature dependent (Barel 1973), with laboratory observations (Milonas & Savopoulou Soultani 2000) showing that the mean longevity for females and males was 13.5 days at 14°C to 7.6 days at 30°C, and 14.9 days at 21°C to 7.9 days at 30°C respectively. Flying activity is nocturnal and migration is especially limited for females, although males have been found more than 400m from their initial location. Mating and flight is virtually non-existent in some areas if temperatures drop below 12°C (Barel 1973).

A. orana typically occurs in warm, humid climates, and current reported distribution suggests it may be most closely associated with biomes characterized as: tropical and subtropical moist, broadleaf forests, and temperate, broadleaf and mixed forests (Davis *et al.* 2005). The lower threshold temperature for the development of eggs and overwintering larvae in Switzerland was 10°C, for summer larvae 7-8°C and for pupae slightly over 10°C (Charmillot & Megevand 1983). Mortality of non-diapause larvae in lab conditions in Greece reached 100 percent after 12 and 18 days at 0 and 5°C respectively. In field and laboratory investigations in Germany Jakob (1996) found that optimum temperature for development was between 25 and 30°C.

A granulosis virus associated with *Adoxophyes orana* has been tested as a potential biocontrol agent against the moth in Japan (Sekita 1996), where it was found in association with the larval stage. *A. orana* was sprayed at a dosage of 4000 diseased full grown larvae/ha on apples, and the virus proved more effective than chemical methods as a control treatment.

6.5.3 Hosts

A. orana is polyphagous and has been recorded from many host plants, primarily: *Pyrus bretschneideri* (*Ya Li* pear), *Cydonia oblonga* (quince), *Malus pumila* (apple), *Prunus armeniaca* (apricot), *Prunus avium* (sweet cherry), *Prunus domestica* (plum), *Prunus persica* (peach), *Pyrus communis* (European pear), *Ribes nigrum* (blackcurrant), *Rosa* (roses), *Rubus idaeus* (raspberry) (CPC 2003).

Other hosts include: *Acer campestre* (common maple), *Alnus* (alders), *Betula* (birches), *Carpinus betulus* (European hornbeam), *Crataegus* spp., *Fagus sylvatica* (common beech), *Forsythia suspense* (Forsythia), *Gossypium herbaceum* (Arabian cotton), *Humulus* spp., *Laburnum anagyroides* (laburnum), *Litchi chinensis* (Zhou & Deng 2005) *Ligustrum* spp., *Lonicera xylosteum* (Fly honeysuckle), *Malus baccata*, *Medicago* spp., *Pistacia lentiscus* (Mastic tree), *Populus* spp. (poplars), *Prunus padus* (bird cherry), *Prunus triloba* (Flowering almond tree), *Ribes rubrum* (red currant), *Ribes uva-crispa* (gooseberry), *Rosa canina* (Dog rose), *Rubus fruticosa* (blackberry), *Salix caprea* (great sallow), *Salix viminalis* (basket willow), *Symphoricarpos albus* (common snowberry), *Syringa vulgaris* (lilac), *Tilia* spp. (limes), *Ulmus minor* (European field elm), *Vaccinium* spp. (blueberries) (CPC 2003).

Although the host range includes several forest species, *A. orana* appears to feed preferentially on apples, pears, and other rosaceous hosts (INRA 2005).

6.5.4 Distribution

A. orana is found in Europe and parts of Asia including Japan, China, Korea (CPC 2003) and Taiwan (Razowski 2000).

6.5.5 Hazard Identification Conclusion

This species has a large host range, wide temperature tolerance, and is fairly mobile with male adults migrating up to 400m and larvae capable of wind aided flight via ballooning. One of its preferred natural wild habitats is temperate broadleaved mixed forest which is a significant component of New Zealand forest habitat. *A. orana* is therefore considered a potential hazard in this risk analysis.

6.5.6 Risk Assessment

6.5.6.1 Entry Assessment

Larvae feed on fruit, as well as foliage and shoots, and this life stage is highly likely to be associated with the commodity on the pathway. The 2^{nd} and 3^{rd} larval instars overwinter, hibernating until spring, making them less conspicuous during this sedentary period. Larvae can live up to 37 days which easily encompasses transit time from Taiwan to New Zealand. Adults are nocturnal, foliage feeding and short lived so it is much less likely this life stage would be associated with the pathway.

The likelihood of larval A. orana entering the country is high with other life stages such as the adult stage unlikely to be associated with the commodity.

6.5.6.2 Exposure Assessment

Infested fresh litchi fruit are likely to be distributed to the main city centres in New Zealand within the retail pathway. Although the intended use is human consumption, waste material (e.g. litchi skin) would be generated and infested plant material may be disposed into the environment. Larvae are capable of some limited movement via wind aided ballooning, but there are no quantitative records of distances achieved (Bell *et al.* 2005; Barel 1973). Adult males are capable of migrating up to 400m making them a higher risk for dispersal and exposure. There is little record of adult females migrating, and they are said to have limited dispersal ability in the literature (Barel 1973).

Many plants grown in New Zealand for horticultural purposes are host plants within the known distribution of *A. orana*. These include berry fruits such as gooseberries, blueberries, blackcurrants, raspberries and stone fruit like peaches, pears, apricots, and plums. Poplars, willows and roses are also host plants, and there would be no shortage of host material available for the moth year round.

6.5.6.3 Establishment Assessment

Climatic variables would not be a limiting factor in the establishment of *A. orana* in New Zealand. Although it typically occurs in warm humid climates the threshold temperature for the development of eggs and overwintering larvae in Switzerland were 10°C, for summer larvae 7-8°C and for pupae slightly over 10°C (Charmillot & Megevand 1983). Therefore the moth would likely find suitable climatic conditions for its establishment in most areas of New Zealand in summer and autumn. Litchis are likely to be exported during our winter and spring, when temperatures in South Island can be lower than these thresholds for longer periods of time. It is less likely *A. orana* would survive under these conditions.

The likelihood of exposure and establishment are moderate to high.

6.5.7 Consequence Assessment

6.5.7.1 Economic

The economic impact of *A. orana* is difficult to assess, as the species frequently occurs in mixed populations with other closely related species, and damage can result from the activity of secondary pests (Whittle, 1985, Davis *et al.* 2005). Crop losses from 10-50 percent have been attributed to this insect in fruit growing regions in Europe (Davis *et al.* 2005). Crops such as avocado and the pip and stone fruits (apples pears plums peaches and apricots) could potentially suffer similar losses. It would also disrupt IPM programmes for pipfruit.

Symptoms of fruit damage are a distinctive “gnawed” or misshapen appearance (Davis *et al.* 2005). This can cause huge reductions in the quantity and quality of fruit produced (Davis *et al.* 2005) with many young fruits dropping from the tree before maturity. External feeding may also assist attack on fruit by secondary organisms which further degrade the crop, reducing shelf and storage life (de Jong & Van Dieren 1974, Whittle 1985, INRA 2005, Davis *et al.* 2005). The insect feeds on foliage and young shoots in addition to fruit, although this feeding may not significantly affect plant growth (Davis *et al.* 2005).

The fruit damage of the first summer generation is different from that of the second summer generation. For the first, the damage of the fruits consists of large deep holes. For the second, very superficial and small holes of less than 5 mm in diameter occur (CPC 2003). Usually, several of these holes are adjacent to each other. This damage might cause desiccation and not lead to rotten fruit, in contrast to the damage of the first generation (CPC 2003).

6.5.7.2 Environmental

Native broadleaved forests in the North Island may be vulnerable to attack from the pest, especially in the north of the north island, where temperatures do not fall below 10°C regularly in winter. *A. orana* is less likely to attack native plants than horticultural species. As a pest of *Fagus* spp. overseas *Nothofagus* species in New Zealand may be more vulnerable than other native plants.

A. orana vectors a granulosis virus that regulates the population of this pest in its natural distribution and there is the potential for the virus to be spread to native tortricids if *Adoxophyes orana* was to become established.

There is a high likelihood that if A. orana became established in New Zealand it would cause considerable damage to horticulture and low to moderate damage in native forest.

6.5.8 Risk Estimation

The likelihood of larval stages entering the country is high (section ***6.7.6.1***), exposure and establishment moderate to high (sections ***6.7.6.2*** and ***6.7.6.3***), and potential consequences of establishment are moderate to high (section ***6.7.7***). As a result the risk estimate for *A. orana* associated with litchi fresh fruit imported from Taiwan is non-negligible.

6.5.9 Risk Management

6.5.9.1 Risk Evaluation

Since the risk estimate for *A. orana* associated with litchi fresh fruit imported from Taiwan is non-negligible, phytosanitary measures will need to be employed to effectively manage the risks to reduce them to an acceptable level.

6.5.9.2 Option Evaluation

6.5.9.3 Risk Management Objective

To ensure that *A. orana* does not enter the country and that the associated granulosis virus is not transmitted to a host plant in the New Zealand environment.

6.5.9.4 Options Available

There are a number of points on the import pathway at which effective measures could be applied to reduce the likelihood of live life stages of *A. orana* being intercepted at the border. Pest management systems in the orchards, screening measures and visual inspection should be viewed as complementary options that need to be implemented in conjunction with the chosen disinfestation treatment to reduce pest numbers in fruit for export.

Vapour Heat treatment or Cold disinfestation treatment.
There is no specific efficacy data for vapour heat or cold disinfestation treatment for *A. orana* but data for the gracillariid lepidopteran *Conopomorpha sinensis* the 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. Larvae feeding more externally like *A. orana* will be susceptible to similar cold treatment.

6.5.9.5 Recommended Management Options

Pest management systems in the orchards, screening measures and pre export visual inspection should be implemented in conjunction with the recommended disinfestations treatment.

a) Cold disinfestation treatment: 0-1 ºC or below for 14 days
and
a) Visual inspection will be undertaken in New Zealand after the consignment has arrived.

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6. 6 *Conopomorpha* spp. (Borer/Miner Moths)

6.6.1 Hazard Identification

Aetiological agents: *Conopomorpha cramerella* Snellen (Lepidoptera: Gracillariidae)
Conopomorpha litchiella Bradley (Lepidoptera: Gracillariidae)
Conopomorpha sinensis Bradley (Lepidoptera: Gracillariidae)

Synonyms for C. cramerella: *Acrocercops cramerella, Gracillaria cramerella, Zarathra cramerella*

New Zealand Status: None are known to be present in New Zealand (not recorded in PPIN 2006; Scott & Emberson 1999; Dugdale, 1988).

6.6.2 Biology

Bradley (1986) clarified the identity of the cocoa moth or cocao pod borer, *Conopomorpha cramerella*, and described three previously unrecognized congeneric species *C. oceanica*, *C. sinensis* and *C. litchiella* from South East Asia. Thus historically the host records in this group are confused. According to recent literature, *C. cramerella* is present but not prevalent in Taiwan, and does not attack litchis or longans there (Hwang & Hung 1996). Its primary host plant is cocoa (Bradley 1986). Subsequent literature and tentative sorting of earlier records suggest that of the four species treated by Bradley only C. *litchiella* and C. *sinensis* have been associated with litchi fruit.

C. cramerella
Presumably the following information though mostly pre-dating Bradley's paper, is assumed to refer to *C. cramerella* on the basis of its host association. In the Philippines the growth and development of *C. cramerella* was investigated in the lab, where it was found that at 28°C and 79 percent relative humidity, the egg hatch rate of the gracillariid was 98.14 percent (Alba *et al.* 1985). The egg and larval stages averaged 3.4 days and 15.2 days with the prepupal and pupal stages combined taking 9.8 days. There are 5 larval instars, which were completed within the cocoa pod, but pupation took place outside it. Adults lived for an average of 3.87 days.

The moths are most active at night, mating and laying of eggs being carried out at this time. During the day adults rest beneath branches of shaded fruit trees (Day 1983). A female can normally produce 50-100 eggs in her lifetime. Adult longevity is 1-30 days, but adults generally live for 1 week. In total, the entire life cycle takes about 1 month to complete (CPC 1997). In Malaysia it is suggested the mode of dispersal apart from being man-assisted, involves a small number of migrating adults that move to a new area and reproduce forming an epicentre. Their offspring are spread by air currents to the surrounding region (Zam & Azhar 1992).

C. litchiella
C. litchiella is a much less frequently recorded pest on *Litchi chinensis* than its congener *C. sinensis* in Taiwan and is of little economic significance (Hung & Hwang 1997). Though litchi is the primary host, in India after mining leaves of its preferred host during August to February it migrates in March-April to alternative food plants then returns to litchi in May to oviposit on the fruits. The larvae feed on the fruits, pupate on the leaves and give rise to new leaf mining and shoot boring generations (Lall & Sharma 1978). All members of the species complex pupate underneath leaves in a cocoon before emerging as adults. The life cycle takes about a month.

C. sinensis
Of all the species in the group *C. sinensis* is apparently found infesting litchi most often, and elicits the greatest economic effects. In a study in Taiwan it was found that the fecundity of litchi fruit borer feeding on litchi fruits was higher (160.3 eggs/female) compared to those feeding on young shoots (99.6 eggs/female). However the survival rate was higher on shoots than in fruit (Xie *et al.* 2005). The egg, larval and pupal stages of *C. sinensis* reared under high relative humidity (about 100 percent) on litchi fruit kernel and litchi shoot leaves were 2.8, 10.3, 7.1 days, and 3.0, 9.9 and 6.7 days respectively. Adults lived between 20 and 24 days on the kernel and only 6.5 and 13 days on the shoots. Mating and eclosion occurred at night with a peak in eclosion reached 3 hours after dark, and in mating 8 to 9 hours after dark (Hung *et al.* 2002). Males emerge earlier than females and lived slightly shorter adult lives (Huang *et al.* 1994a).

In Taiwan two overlapping generations have been observed during the litchi fruiting period from April to June (Huang *et al.* 1994b), with fruit drop caused by infestation highest in early May and early June, when most larvae in the dropped fruits had reached the 3rd and 4th instars. It is considered a serious pest of litchi fruit in Taiwan and cold disinfestation treatment to ensure its mortality in the commodity has been researched and efficacy data recorded. All larvae were dead after 14 days of refrigeration at 0-1°C (Su *et al.* 1993).

There is a native moth species in New Zealand *Conopomorpha cyanospila* in the genus which has a host specific relationship with a native Sapindaceous tree *Alectryon excelsus*.

6.6.3 Hosts

C. cramerella
Cola acuminata (cola), *Nephelium lappaceum* (rambutan), *Theobroma cacao* (cocoa) *Pometia pinnata* (pacific litchi) (CPC 1997). *Litchi chinensis* and *Dimocarpus longan* have been recorded as hosts erroneously (Gao *et al.* 2002, Hwang & Hsieh 1989).

C. litchiella
The litchi leaf miner has been recorded attacking fruits and or shoots of litchi, longan, *Syzygium cumini*, *Cassia tora* and erroneously on cocoa (Zhang *et al.* 1999; Huang *et al.* 1997; Zhang 1994; Bradley 1986).

C. sinensis
There are records of *C. sinensis* on *Dimocarpus longan* (Wen *et al.* 2002), possibly erroneous for *Theobroma cocao* (Zhang 1994), and *Litchi chinensis* (Huang *et al.* 1997).

6.6.4 Distribution

C. cramerella
It is found throughout Asia, and is listed as being present in Oceania in Australia, Samoa and the Solomon Islands though the latter three countries are not verified in the literature (CPC 1997).

C. litchiella
The species has a restricted range in Asia, and has been recorded in India (Zhang, 1994), Taiwan (Hwang & Hung 1996) China (Yao & Liu 1990) and Thailand (Thailand longan October 2004).

C. sinensis

Because the taxonomy was only recently clarified, it is possible that previous records for *Conopomorpha cramerella* in fact hold distribution information for *C. sinensis*, but there is little literature regarding this (the original paper by Bradley in 1986 suggests descriptions of life cycle for *C. cramerella* instead refer to *C. litchiella* or *C. sinensis* in some circumstances). China, Taiwan, Thailand and South East Asia are listed as countries and areas where *C. sinensis* occurs (CPC 1997; Zhang 1994).

6.6.5 Hazard Identification Conclusion

With a clearer resolution of its taxonomy it is apparent that *C. cramerella* was wrongly associated with the commodity and therefore is not considered a hazard in this risk assessment. *C. litchiella* and *C. sinensis* are both short lived (1-2 months) and very host specific. It is highly unlikely that after surviving transport either would find host material before dying. *C. litchiella* is not considered a common pest on litchi. Both species occur only in tropical latitudes and arriving in winter or spring (June-September) would be highly unlikely to survive temperatures in New Zealand. Although *C. sinensis* is considered a regulated organism and would be controlled were it to enter New Zealand the possibility of this occurring is negligible. For these reasons none of the *Conopomorpha* complex of species is considered a potential hazard in this risk assessment.

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6.7 *Cryptophlebia ombrodelta* (Macadamia Nut Borer)

6.7.1 Hazard Identification

Aetiological agent: *Cryptophlebia ombrodelta* Lower (Lepidoptera: Tortricidae)

Synonyms: Arctiophora ombrodelta, Argyroploce carpophaga, Arotrophora ombrodelta, Cryptophlebia carpophaga

New Zealand Status: Not known to be present in New Zealand (not recorded in PPIN 2006; Scott & Emberson 1999; Dugdale 1988)

6.7.2 Biology

Commonly called the Macadamia nut borer, *Cryptophlebia ombrodelta* is an important pest of macadamia in Australia (Quinlan & Wilk 2005). The larvae of *C. ombrodelta* penetrate to the forming kernel of young nuts, and develop in the husk of nuts after shell hardening. The latter causes premature nut drop and stunted kernel development (Quinlan & Wilk, 2005).

The full-grown larva leaves the ripe pod of legumes through a hole and pupates on the pod in a solid cocoon, partially made up of frass. Females start ovipositing 10 days before hatching and lay their eggs singly or in pairs on the maturing pods. Complete development takes about 26-32 days (Kalshoven, 1981). When attacking fruit such as litchi the newly hatched larva feeds on the fruit skin and then tunnels towards the seed. In immature fruit, the young larva bores directly into the seed, which is completely eaten. A single larva may damage two or three small fruit but they prefer mature colouring fruit with larger seeds (Menzel 2002). Studies in Hawaii found *Cryptophlebia* infestation rates for litchi and longan were 1.1 and 0.14% respectively (McQuate USDA pers. comm. in Follett & Lower 2000).

Several studies have been conducted on the duration of life stages under laboratory conditions. The temperatures in these studies ranged between 23 and 28°C and foods trialled included lima beans, maize, carambola and snap beans (Ho 1985; Chang & Chen 1989; Hung *et al.* 1998). The egg development took between 3-7 days, larval duration was 13-26 days, and the pupal life stage 4-10.8 days. Adults exhibited a larger variation in development time, living between 2-19 days but an average of 8.17 days across all studies. Females laid between 116-183.2 eggs per individual with fecundity increasing over successive lab raised generations (Hung *et al.* 1998).

6.7.3 Hosts

Cryptophlebia ombrodelta is polyphagous, its hosts are mainly in the Fabaceae family, but also include many other nut and seedpod plants. It has been recorded on 33 food crops in Australia and elsewhere (Ironside 1974).
Major hosts include: *Acacia* spp. (wattles), *Averrhoa carambola* (carambola), *Bauhinia* spp., *Cassia* spp.(sennas), *Glycine max* (soyabean), *Lablab purpureus* (hyacinth bean), *Litchi chinensis* (litchi), *Macadamia integrifolia* (macadamia), *Durio zibethinus* (durian), *Parkia* spp., *Phaseolus lunatus* (lima bean), *Phaseolus vulgaris* (common bean), *Tamarindus indica* (Indian tamarind), *Vigna unguiculata* (cowpea) and *Persea americana* (avocado) (CPC 2001).

6.7.4 Distribution

It is widespread throughout Asia, and in Oceania is found in Australia, Northern Mariana Islands, Papua New Guinea, Solomon Islands and Vanuatu (Robinson *et al,* 1994; CPC 2001).

6.7.5 Hazard Identification Conclusion

Cryptophlebia ombrodelta has a relatively short lifecycle and the larval stage survives inside the litchi seed for up to 26 days. A clear association is documented with the Fabaceae, a family that is well represented in New Zealand with horticultural and native species. Many other nut and pod plants are affected including Macadamia a member of the Proteaceae. For these reasons it is considered a potential hazard.

6.7.6 Risk Assessment

6.7.6.1 Entry Assessment

Eggs are oviposited onto fruit and develop over 3 to 7 days and the larvae penetrate into the seed core, making them difficult to detect at this life stage. Larvae take between 13 and 26 days to develop inside the fruit and would survive a lengthy transit time. Adults and pupae are unlikely to be associated with the fruit.

There is a high likelihood that C. ombrodelta will enter the country on the pathway given that larvae and eggs develop cryptically inside the litchi fruit seed. Therefore the risk of the organism entering the country is non-negligible.

6.7.6.2 Exposure Assessment

Infested fresh Litchi fruit are likely to be distributed to the main city centres in New Zealand within the retail sale pathway. Although the intended use is human consumption waste material would be generated and infested plant material may be disposed within the environment. The seed in particular is large and could harbour larvae. There is a higher risk of exposure if the seed is discarded in domestic compost. Acacia, macadamia, common beans and avocado are all grown commercially and as garden species in New Zealand, and would be potential hosts for *C. ombrodelta*.
Of the native flora the more common members of Fabaceae, *Sophora* spp. (kowhai), and *Carmichaelia* spp. could be exposed to the pest. *Clianthus* spp. (kaka beak), and the one species in the endemic genus *Montigena* are less likely potential hosts because of their highly restricted distributions. Although some specimens of *Litchi chinensis* are grown in the far north of the North Island it is highly unlikely that pests and pathogens would come into contact with these plants (of which there are approximately 15).

6.7.6.3 Establishment Assessment

Developmental progress is usually within a temperature range above 20°C, although there is no literature to suggest that the moth cannot survive below this. Climate is likely to be a limiting factor in the establishment of *C. ombrodelta* in most parts of the country especially in winter months when temperatures may not exceed 16°C even in the warmest parts of New Zealand.

The likelihood of exposure and establishment therefore is moderate to low.

6.7.7 Consequence Assessment

6.7.7.1 Economic

Macadamia and avocado industries could be affected. Macadamia orchards are found in coastal areas of Northland, Auckland, Taranaki, Coromandel, Bay of Plenty, East Cape and Hawkes Bay (NZMS 2006). Avocados are grown primarily in Bay of Plenty, Northland, Auckland and Poverty Bay (White 2001). Of these areas it is unlikely *C. ombrodelta* would survive outside Northland as a permanently established population. The economic impacts would probably be localised and seasonal. This would mean control and management strategies for the pest could be easily implemented.

6.7.7.2 Environmental

Most native plants are endemic and it is uncertain whether *C. ombrodelta* were to host switch, which native plants would be affected. Some likely examples are outlined. There are 4 native genera in the Fabaceae in New Zealand, and 2 in the Proteaceae. Two of the Fabaceae are represented by only one or two species, these are restricted to isolated areas of the eastern north island, offshore islands and scree slopes on the dry eastern mountains of the South Island. It is unlikely given the highly localised distribution of *Clianthus maximus*, *C. puniceus*, and *Montigena novae zelandiae* that they would be affected by the establishment of *C. ombrodelta*. *Sophora* and *Carmichaelia* species are common and widespread throughout the country, and could possibly be at risk as potential host species of *C. ombrodelta* in warmer areas. *Knightia excelsa* is a common component of many native forest systems in New Zealand while a less common relative *Toronia toru* would not be a likely host because of its more restricted distribution.

The consequences of establishment of this moth though non-negligible are likely to be moderate to low.

6.7.8 Risk Estimation

Although the likelihood of *C. ombrodelta* entering the country is high (section ***6.11.6.1***), exposure and establishment are moderate to low (sections ***6.11.6.2*** and ***6.11.6.3***), and the consequences of its establishment moderate to low (section ***6.11.7***). Therefore the risk is moderate to low but non-negligible.

6.7.9 Risk Management

6.7.9.1 Risk Evaluation

Since the risk estimate for *C. ombrodelta* associated with litchi fresh fruit imported from Taiwan is non-negligible, phytosanitary measures will need to be employed to effectively manage the risks to reduce them to an acceptable level.

6.7.9.2 Option Evaluation

6.7.9.3 Risk Management Objective

To ensure that *C. ombrodelta* does not enter the country and become established.

6.7.9.4 Options Available

There are a number of points on the import pathway at which effective measures could be applied to reduce the likelihood of live life stages of *C. ombrodelta* being intercepted at the border.
Pest management systems in the orchards, screening measures and visual inspection should be viewed as complementary options that need to be implemented in conjunction with the chosen disinfestation treatment to reduce pest numbers in fruit for export.

Vapour Heat treatment or Cold disinfestation treatment.
There is no specific efficacy data for vapour heat or cold disinfestation treatment for *C. ombrodelta* but data for the gracillariid lepidopteran *Conopomorpha sinensis* the 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. *Cryptophlebia ombrodelta* is also a fruit borer and should therefore be susceptible to the same treatment measures as *C. sinensis*.

6.7.9.5 Recommended Management Options

Pest management systems in the orchards, screening measures and pre export visual inspection should be implemented in conjunction with the recommended disinfestations treatment.

a) Cold disinfestation treatment: 0-1 ºC or below for 14 days
and
a) Visual inspection will be undertaken in New Zealand after the consignment has arrived.

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6.8 *Lymantria* spp. (Gypsy/Casuarina Moths)

6.8.1 Hazard Identification

Aetiological agent: *Lymantria dispar* Linnaeus (Lepidoptera: Lymantriidae).
Lymantria mathura Moore (Lepidoptera: Lymantriidae)
Lymantria xylina Swinhoe (Lepidoptera: Lymantriidae)

Synonyms of L. dispar: Porthetria dispar, Ocneria dispar, Bombyx dispar, Hypogymna dispar, Liparis dispar, Phalaena dispar, Porthesia dispar

New Zealand Status: Not known to be present in New Zealand (Scott & Emberson 1998, Dugdale 1988). *L. dispar* has previously been eradicated from Hamilton (Richardson *et al.* 2005)

6.8.2 Biology

Although there is no direct association of the moths in this genus with any fruit species all three lymantriids could potentially be hitch hikers on litchi fruit.

L. dispar
Little data is available on the biology of Asian gypsy moth in Taiwan, therefore research from other countries has been used. It is stated in the text which country the data is sourced from and which strain is being referred to.

Lymantria dispar consists of at least two distinct strains (Cowley *et al.* 1993). To date the main method for differentiation of the Asian from the European strain is the use of mitochondrial DNA analysis (Walsh 1993). The major differences between the two strains are the flightless females in the European form, whereas females are capable of long distance flight in the Asian form; dispersal by first instar larvae of the European form, whereas dispersal occurs in both first and second instar larvae (as well as in the adult females) in the Asian form: and it appears there is less premature eclosion from egg masses in European forms than in Asian forms (Cowley *et al.* 1993).

Gypsy moth is univoltine, producing one generation per year in China (Lin *et al.* 2000) with the Asian form developing earlier in lower latitudes within its range there. Schaefer *et al.* (1984) found the time of egg hatch and adult flight became progressively earlier with decreasing latitude. This suggests the possibility that it may produce more than one generation in New Zealand (Walsh 1993), but no evidence exists this may occur elsewhere. The female deposits all eggs in a single mass (Cowley *et al.* 1993) often on tree trunks, unless disturbed (Leonard 1974) and generally overwinters in the egg stage (Cowley *et al.* 1993). This stage can last up to 9 months, being longer than all other life stages combined (Glare *et al.* 2003). The pupal stage lasted 11 days in a study where eggs were collected from a forestry block in inner Mongolia and larvae raised on larch needles and branches (Lin *et al.* 2000). Egg masses are aggregated (Montgomery and Wallner 1988) and edge effects are important in selection of egg deposition sites (Bellinger *et al.* 1989).

Gypsy moth dispersal occurs when young larvae crawl upwards and extrude silk (Cowley *et al.* 1993) so as to balloon away on wind currents. Dispersal also occurs through the transport of pupae and egg masses on vehicles (Gibbs & Wainhouse 1986) and other inanimate objects. In Canada following hatching, larvae disperse by ballooning, feed for 6-8 weeks, males develop in 5 instars and females go through 6 instars, with early instar larvae feeding both night and day (Humble & Stewart 1994).

In China *Lymantria dispar* was reared on an artificial diet and the leaves of oak were used as a control (Wang *et al.* 2004). The average developmental durations of larvae from 1st to 6th instar fed with artificial diet were 15, 6, 6, 7, 9 and 14 days, and the general developmental duration of the larvae was 57 days. In the oak fed larvae developmental times were very similar with a shorter overall duration of the larval form at 52 days (Wang *et al.* 2004). Larvae develop rapidly, feeding continually until they reach a length of up to 7.7 cm in the last instar (CFIA 2007).

Adults are active shortly after emergence and live for about 1 week. They do not feed except to imbibe moisture. Males emerge 1-2 days before females and mating occurs soon after the female emerges. Oviposition begins once mating is completed. The Asian form of *L. dispar* is capable of travelling 100 kilometres (Cowley *et al.* 1993) though distances around 20-40 km are more common (Cowley *et al.* 1993). Average distances may be a lot less than this.

L. dispar is tolerant of a wide variation in temperatures. Sullivan and Wallace (1972) recorded survival of the European strain egg masses in air temperatures of -80°C when under a 200mm deep layer of snow. At the other end of the spectrum, temperatures above 32°C accelerated larval development. Yocum *et al.* (1991) reported survival in diapausing pharate larvae with shock protein synthesis after exposures to 37-41°C for 2 hours. The range at which development of Asian gypsy moth can occur is considered to be between 1-32°C (Matsuki *et al*. 2001).

An important prerequisite of survival at low temperatures is the diapausing state in which the volume of free water inside the egg is reduced to prevent the formation of ice crystals that could rupture cells and cause death (Leonard 1981). Gray *et al.* (1991) reported that eggs entered the diapausing state after 13 days exposure to 25°C and 10 days after exposure to 30°C.

L. mathura

Lymantria mathura has essentially the same life cycle as *L. dispar* taking a year to complete the developmental cycle in cooler climates and having the capability for two generations per year in India and possibly three in Hong Kong (Sonan 1936; Dey & Tiwari 1997, Kendrick 2002). Both the male and female are capable of flight (Wallner *et al.* 1995) and there is clear sexual dimorphism (EPPO 2006). *L. mathura* showed a higher dispersal tendency than *L. dispar*, and unlike *L. dispar* larval dispersal tendency was inversely related to larval weight with lighter individuals having a greater propensity to disperse (Zlotina *et al.* 1999). This suggests *L. mathura* disperses further via wind than *L. dispar*.

In outbreak years, on average every fourth year (EPPO 2006), *L. mathura* tends to lay eggs on many tree species, including non-hosts (Davis *et al,* 2005). The selection of a location for egg deposition depends on the presence or density of other egg masses, host preference and the extent of feeding that has already occurred on a host (Roonwal, 1979). Pupation typically occurs in soil litter or on any remaining foliage or branches of the host tree (Browne 1968). The egg stage in the field lasts about 8-9 months in Korea (Lee & Lee 1996), and larval feeding occurs at night on foliage with resting observed during the day (Roonwal *et al.* 1962). Pupae develop over a period of about 10 days in India (Roonwal *et al.* 1962).

Current reports suggest it may be closely associated with biomes characterized as temperate broadleaf and mixed forests, temperate conifer forests, tropical and subtropical dry broadleaved forests and tropical and subtropical moist broadleaved forests (Davis *et al,* 2005).

There is no data on temperature tolerance but the moth occurs in the Russian Far East (Gninenko 2002, 2000) where temperatures during winter reach below 0°C.

L. xylina
Sharing similar biological characteristics to its congeners *L. dispar* and *L. mathura*, *Lymantria xylina* can complete one generation annually in Taiwan and overwinters at the egg stage for several months (Tsay *et al.* 2001). The moth is a serious defoliator of hardwood and fruit trees there (Shen *et al.* 2006). Shortly after emergence and mating in the summer, females of *Lymantria xylina* lay a single egg mass consisting of 100-1000 eggs, which they cover with hairs from the abdomen (Shen *et al.* 2003). The moths enter an obligatory diapause as a pharate first instar larvae and hatch in April after an 8-9 month dormancy (Williams *et al.* 1990, Lee & Denlinger 1996). The pupal stage is passed in a cocoon and lasts about 12 days, the moths emerging in June and early July (Sonan 1936). Studies done by Hwang *et al.* (2004) indicated that diapausing eggs require exposure to cold temperatures (9-15°C) followed by warm temperatures (27°C) for successful emergence in lab conditions. There is a positive relationship between egg mass size and the number of eggs per mass, and weight explains about 98 percent of the variation in the number of eggs per egg mass (Shen *et al.* 2003).

6.8.3 Hosts

L. dispar
Host diversity for gypsy moth is vast. Miller and Hanson (1989) reported feeding responses by gypsy moth larvae on 658 species, 286 genera and 106 families of dicots (Cowley *et al.* 1993). There is no evidence in the literature that larvae infest fruits or burrow into the flesh of any fruit to feed but they do crawl all over the host plants and may be associated with parts not utilised for food (Melanie Newfield MAF pers.com., March 2006). All three species could be potential hitch hikers on the commodity.

Some of the host plants most frequently attacked by *L. dispar* are:
Quercus spp.(oaks), *Acer* spp.(maples), *Betula* spp. (birches) (CPC 2006).

Other lesser hosts include:
Carpinus spp. (hornbeams), *Carya* spp. (hickories), *Castanea sativa* (chestnut), *Corylus* spp., *Eucalyptus camaldulensis* (red gum), *Fagus* spp. (beeches), *Fagus grandifolia* (American beech), *Fagus sylvatica* (common beech), *Fraxinus americana* (white ash), *Fraxinus pennsylvanica* (downy ash), *Glycine max* (soyabean), *Hamamelis virginiana* (Virginian witch-hazel), *Larix* spp. (larches), *Liquidambar styraciflua* (Sweet gum), *Litchi chinensis* (Yu *et al.* 1995), *Lithocarpus edulis*, *Malus* (ornamental species apple), *Malus domestica* (apple), *Ostrya virginiana* (American hophornbeam), *Picea abies* (common spruce), *Picea jezoensis* (Yeddo spruce), *Pinus* spp.(pines), *Pistacia vera* (pistachio), *Platanus acerifolia* (London planetree), *Populus* spp.(poplars), *Prunus* spp. (stone fruit), *Pseudotsuga menziesii* (Douglas-fir), *Pyrus* spp. (pears), *Quercus ilicifolia* (bear oak), *Robinia* spp.(locust), *Robinia pseudoacacia* (black locust), *Salix* spp.(willow), *Salix babylonica* (weeping willow), *Taxodium distichum* (bald cypress), *Tilia americana* (basswood), *Tilia cordata* (small-leaf lime), *Vaccinium* spp.(blueberries), and *Zea mays* (maize) (CPC 2006).

L. mathura
L. mathura reportedly feeds on more than 45 genera in 24 families (Davis *et al.* 2005). Major hosts include: *Castanea* spp. (chestnuts), *Castanea mollissima* (hairy chestnut), *Liquidambar formosana* (beautiful sweetgum), *Litchi chinensis* (litchi) (Singh 1954), *Mangifera indica* (mango), *Neolamarckia cadamba* (common bur-flower tree), *Quercus leucotrichophora* (banj oak), *Quercus mongolica* (Mongolian oak), *Quercus serrata*, *Shorea robusta* (sal), *Syzygium cumini* (black plum), *Terminalia arjuna* (arjun), *Terminalia myriocarpa* (CPC 2006) and

many Fagaceae species (EPPO, 2006).

Other lesser hosts include:
Abies spp. (firs), *Larix* spp. (larches), *Pinus* spp. (pines), and *Pseudotsuga menziesii* (Douglas-fir)(CPC 2006).

L. xylina
The number of recorded host plants for this moth includes 69 species of trees and shrubs belonging to 29 families (Chang & Weng, 1985, Chao *et al.* 1996). The families include the Aceraceae, Anacardiaceae, Araliaceae, Betulaceae, Boraginaceae, Casuarinaceae, Combretaceae, Ebenaceae, Elaeocarpaceae, Ericaceae, Euphorbiaceae, Fagaceae, Flacourtinaceae, Hamamelidaceae, Lauraceae, Leguminosae, Lythraceae, Malvaceae, Moraceae, Myrtaceae, Oxalidaceae, Piperaceae, Rosaceae, Salicaceae, Sapindaceae, Scrophulariaceae, Theaceae, Ulmaceae and Verbenaceae.
Some major hosts are *Camellia* spp*.*, *Casuarina* spp. *Psidium guajava*, *Ricinus communis* (castor bean), *Salix babylonica* (weeping willow) *Litchi chinensis*, and *Dimocarpus longan* among others (Chao *et al.* 1996).

6.8.4 Distribution

L. dispar
Lymantria dispar is a native of both Europe and Asia (Walsh 1993) and the genus probably originated in East Asia where *L. dispar* shows greatest variability (Montgomery & Wallner 1988). Villemant & Fraval (2002) suggest its origins are in Japan and Korea. It occurs in North America, patchily distributed in Canada and the United States, to the far east of Russia, across Asia including Taiwan (EPPO 2005), and the middle east as well as Europe (CPC 2006). The geographical range extends from 20-60° North where the annual rainfall is 250-1000 mm and temperature isotherms are 15°C to 27°C in summer and -18°C to -12°C in winter (Cowley *et al*. 1993).

L. mathura
Lymantria mathura has been recorded in Bangladesh, China, Hong Kong, Taiwan, India, Korea, Russia, Siberia and some parts of the US (Browne 1968, Odell *et al.*1992, Mohn 2001, Pucat & Watler 1997, Lee & Lee 1996, Gninenko 2000, Zolatarenko & Dubatolov 1998 & Baranchikov *et al.* 1995, Bashford 2003).

L. xylina
The casuarina moth *Lymantria xylina* is recorded from Taiwan and the eastern coast of mainland China (Chao *et al.* 1996). It is also present in India and Japan (Xiao 1992).

6.8.5 Hazard Identification Conclusion

All three *Lymantria* species have a very broad host range, are tolerant to cold temperatures with speed of development increased in warmer temperatures. Adults are capable of travelling up to100km (in the case of *L. dispar*) and the larval forms balloon to disperse, making them highly mobile at some life stages. They each cause highly destructive outbreaks in the areas they occur. For these reasons, *L. dispar*, *L. mathura* and *L. xylina* are considered potential hazards in association with the pathway.

6.8.6 Risk Assessment

6.8.6.1 Entry Assessment

The likelihood that *Lymantria dispar, L. mathura* or *L. xylina* could enter the country on fresh litchi fruit is very low for the adult stages as the moths are large and conspicuous. The egg masses are equally visible and would probably be seen before or during packing. The most plausible possibility of entry into the country by any *Lymantria* species would be during the larval stage, as first instar larvae are crawling to balloon away from the egg mass seeking new food sources. With adequate nutrition larvae live for up to 57 days (*L. dispar*), more then enough time to survive transit from Taiwan to New Zealand.

Although the likelihood of first instar larvae associated with litchi fruit entering New Zealand is low the risk of entry is still non-negligible.

6.8.6.2 Exposure Assessment

Many common ornamental and amenity species are attacked by the three congeners, including apple, birch, Eucalypts, beech, poplars, pine, willow, elm, *Rhododendron* spp., *Camellia* spp., guava, maples, hibiscus and figs. Pine is grown extensively for commercial purposes in both North and South Islands.

In a study on the ability of *L. dispar* larvae to complete development on native plant species, larval performance was poor on all but *Nothofagus solandri* (Matsuki *et al*. 2001). This species is usually only found in native forest, which would generally be far from urban centres where fresh litchi fruit may be distributed, and it is unlikely the moth would come into contact with *N. solandri*. There would be no shortage of host plants available for *L. dispar, L. mathura* and *L. xylina* year round.

6.8.6.3 Establishment Assessment

Many regions of New Zealand would have suitable climate for development and survival of all three *Lymantria* species. Rainfall could reduce survivorship in some regions especially Whangarei, Auckland, Tauranga, New Plymouth and Wellington if the 1000mm maximum of Montgomery & Wallner (1988) is critical for development. During wet weather larvae do not disperse (Leonard 1971, Montgomery & Wallner 1988). Population density of *L. dispar*, Leonard (1974) noted, was inversely proportional to the amount of June rain in Connecticut. It is assumed that similar patterns of behaviour and survival related to rainfall would apply to *L. mathura* and *L. xylina*

Climate is unlikely to be a limiting factor in their establishment and survival. Recent models by Matsuki *et al*. (2001) demonstrated that Asian gypsy moth could potentially colonise most of New Zealand, with most suitable conditions occurring on the East Coast, although the wetter conditions on the West Coast of South Island would limit its establishment there.

There are many potential host plants that could be affected by the gypsy casuarina moths and climate in general would not be a limiting factor in the establishment of the 3 species, making the likelihood of both exposure and establishment very high. The risk of these factors occurring is therefore non-negligible.

6.8.7 Consequence Assessment

6.8.7.1 Economic

L. dispar

Lymantria dispar is one of the most destructive pests of shade, fruit, and ornamental trees throughout the northern hemisphere. It is also a major pest of hardwood forests.
A number of countries, including Australia, the USA and Canada have requirements for inspecting high risk ships entering their waters to prevent the arrival of *L. dispar*. New Zealand would likely be requested to undergo similar inspections were the moth to establish here. An economic risk assessment was undertaken in 1994 into the effect of *Lymantria*

dispar in New Zealand (Horgan 1994). Using the Drymat model and *Pinus radiata* it was suggested a reduction in expected harvest yield of 20 to 30m³ per hectare. $100 per m³ was taken as the average value of wood lost (in 1993) as a result of the introduction of the moth, making an average loss of some 20m³ per hectare equating to an expected income loss at harvest of $2000 per hectare (Horgan 1994). Harris Consulting (2003) re-estimated economic impacts of low medium and high impact scenarios at NZ$5 million, NZ$46 million and $400 million.

The cost of ongoing control for the moth was estimated from an eradication reported for Sunny Point, North Carolina of $16 million. Of this amount $12 million would cover the eradication attempt and $4 million the intensive monitoring of the sprayed area over the following 2 years to ensure success or otherwise (Horgan 1994).

Two lepidopteran pests recently eradicated in New Zealand, the Painted Apple moth, and the Fall Webworm would have had an estimated economic impact of $58-$356 million and $19-$83 million over 20 years respectively (MAF press release 2006). It is assumed that the total economic impact of the Gypsy moth would fall somewhere within these estimates.
The Painted Apple moth (an Australian native), was first detected here in 1999 and aerially treated 69 times between then and 2003. Its total cost for eradication was $62.4 million. A colony of Fall web worm (found in North America, Europe and Asia) was detected in March 2003 and ground treated and eradicated. The eradication costs totalled $6.7 million over 3 years.

L. mathura
L. mathura is known to adversely impact forest productivity and cause tree mortality with repeated outbreaks. Pink gypsy moth has the potential to directly and indirectly alter forest structure and function (Davis *et al.* 2005). Indirect effects stem from the arrival and establishment of secondary organisms, including outbreaks of wood borers from the families Scolytidae and Cerambycidae (EPPO 2006) and fungal pathogens (Davis *et al.* 2005). In an outbreak in far eastern Russia in 1998, 200,000 ha of forest were damaged. Pest populations may reach more than 1000 caterpillars per tree, and reforestation of these areas is often complicated and takes time, resulting in changes in the environment over large areas (EPPO, 2006).

Damage also occurs in orchards, leading to loss of fruit yield, and outbreaks have been reported at the same time as those of *L. dispar*, increasing the impact of the latter (EPPO 2006). *L. mathura* is regulated by Canada and the USA, on a basis similar to the Asian form of *L. dispar*. In 2005 it was added to the EPPO A2 action list, and endangered EPPO member countries are thus recommended to regulate it as a quarantine pest (EPPO, 2005).

L. xylina
The casuarina moth is one of the most damaging pests in the casuarina windbreaks of Taiwan and on its surrounding islands (Chao *et al.* 2001). Nine species of hardwood fruit trees are attacked in Taiwan, the economic damage being more apparent than for other plants. No quantitative data were found however. Fruit impacted include longan, litchi and wax apple. Relatives of the avocado *Persea japonica* and *Persea thunbergii* were infested too, and *P. thunbergii* was observed to become severely defoliated by the moth (Chao *et al.* 2001). *Persea americana* (avocado) is likely to become a potential host if *L. xylina* were to establish in New Zealand and could cause severe economic damage to the crop.

6.8.7.2 Environmental

In its natural distribution *L. dispar* is the cause of widespread defoliation and tree mortality, and has cyclic outbreaks related to resource availability and optimal climatic conditions. Most impacts of *L. dispar* are associated with the physiological stress in trees caused by defoliation, especially if it occurs several years in a row or in conjunction with drought. These effects include reduction in tree growth, crown dieback and tree mortality. Tree mortality is usually associated with other insects (wood borers) and pathogenic fungi that attack stressed trees. In extreme situations, nearly 100 percent tree mortality may occur over large areas (Liebhold 2006). Similar though less extreme environmental damage may be expected from *L. mathura* and *L. xylina*.

The following New Zealand native trees are in the same families as favoured hosts for the 3 lymantriids: *Nothofagus* spp. (Fagaceae), *Metrosideros* spp., *Leptospermum scoparium, Lophomyrtus* spp., *Elaeocarpus dentatus*., *Hibiscus spp., Neomyrtus pedunculatus, Syzygium* spp. (Myrtaceae), and *Entelea arborescens* (Tiliacea) and are considered the most likely species to be at risk. *Nothofagus* species are widespread throughout the country from Kaitaia to Fiordland, especially in the central North Island and the west coast of South Island where vast tracts of beech forest predominate. Native trees potentially at some risk include: *Grisilinia* spp. (Cornaceae), *Corokia spp. Libocedrus* spp.(Cupressaceae), *Beilschmedia* spp., *Litsea calicaris* (Lauraceae) *Streblus* spp. (Moraceae) and *Nestegis* spp. (Oleaceae) (Cowley *et al.* 1993). *L. xylina* attacks *Quercus* and *Piper* species (members of the Fagaceae and Piperaceae) in its known range, therefore *Macropiper* and *Nothofagus* could be affected by this moth in New Zealand.. *Schefflera digitata, Elaeocarpus dentatus*, *Macropiper excelsum* are common components of the understory in native beech/podocarp/broadleaf forest throughout the country

The consequences of the exposure and establishment of L. dispar, L. mathura and L. xylina in New Zealand are very high.

6.8.7.3 Health

Exposure to lepidopteran larvae can result in a variety of adverse reactions in humans, depending on the family and species involved (Balit *et al.* 2003). In Australia several species of lymantriids are reported as having larvae harmful to human health (Southcott 1978). Lymantriid caterpillars have long tufts of urticating hairs along their bodies, which may cause severe dermatitis, conjunctivitis, and upper respiratory irritation (Diaz 2005; Goddard 2003) with the possibility of systemic manifestations occurring (Diaz 2005). Contact with the hairs of *L. dispar* has been implicated as one cause of occupational asthma in the UK (Cullinan and Taylor 1997). Skin rash appears as the most common symptom of exposure to *L. dispar*, which may be extremely itchy and bothersome but short-lived (Tuthill *et al.* 1984).

In certain areas where lymantriid caterpillars reach high densities, associated illnesses in humans may reach epidemic proportions (Diaz 2005). These epidemics of gypsy moth dermatitis and urticaria result from contact between human skin or mucous membranes and the airborne urticating hairs and haemolymph of the caterpillars (Diaz 2005). Similar reactions may occur on contact with the wing scales and abdomen hairs of adult moths becoming airborne (Goddard 2003). Not much information is available on the adverse human health effects associated with exposure to *L. mathura* or *L. xylina*, but it's assumed effects will be like those caused by *L. dispar* as the effects to human health amongst lymantriid species appears to be similar (Diaz 2005; Goddard 2003).

The human health impact as a result of *L. dispar, L. xylina* or *L. mathura* establishment in New Zealand would likely depend on its density in a particular area. However, New Zealand has one of the highest rates of asthma in the developed world, and *L. dispar* could considerably aggravate the incidence of respiratory allergy, particularly in spring when gypsy moth populations appear to peak.

From a human health perspective L. dispar, L. xylina and L. mathura are considered potentially high consequence pests.

6.8.8 Risk Estimation

Although the likelihood of lymantriid larvae entering the country is low given they are hitch hiker species on litchi fruit (section ***6.9.6.1***), the likelihood of exposure and establishment is high (sections ***6.9.6.2*** and ***6.9.6.3***), and the potential consequences of establishment are very high (section ***6.9.7***) therefore the risk estimation for these three species is non-negligible.

6.8.9 Risk Management

6.8.9.1 Risk Evaluation

Since the risk estimate for the 3 lymantriids associated with fresh litchi fruit imported from Taiwan is non-negligible, phytosanitary measures will need to be employed to effectively manage the risks to reduce them to an acceptable level.

6.8.9.2 Option Evaluation

6.8.9.3 Risk Management Objective

To prevent entry and establishment of *L. dispar, L. mathura and L. xylina* in New Zealand.

6.8.9.4 Options Available

There are a number of points on the import pathway at which effective measures could be applied to reduce the likelihood of live life stages of *L. dispar*, *L. mathura* or *L. xylina* being intercepted at the border, to an acceptable level. Pest management systems in the orchards, screening measures and visual inspection should be viewed as complementary options that need to be implemented in conjunction with the chosen disinfestation treatment to reduce pest numbers in fruit for export. There is no specific efficacy data for any of the 3 lymantriid species.

Vapour Heat treatment or Cold Disinfestation treatment.
Egg masses are the overwintering life stage in the organism and are unlikely to be killed with cold treatment. They are also unlikely to be associated with the fruit. The larval lifestage may escape detection in the visual inspections so it is recommended that fruit are heat treated to kill any hitchhiking life stages of *L. dispar, L. mathura* or *L. xylina*.

6.8.9.5 Recommended Management Options

Pest management systems in the orchards, screening measures and pre export visual inspection should be implemented in conjunction with the recommended disinfestations treatment.

a) Vapour heat treatment: ≥ 46.5ºC for a minimum of 20 minutes
and
b) Visual inspection will be undertaken in New Zealand after the consignment has arrived.

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Scales

6.9 *Ceroplastes* spp. (Wax Scales)

6.9.1 Hazard Identification

Aetiological agent: *Ceroplastes pseudoceriferus* Green (Homoptera: Coccidae).
Ceroplastes rubens Maskell (Hemiptera: Coccidae)

Synonyms for C. rubens: Ceroplastes minor, Ceroplastes japonica, Ceroplastes rubens var. minor

New Zealand Status: Not known to be present in New Zealand (not recorded in Scott & Emberson 1998; Hodgson & Henderson 2000).

6.9.2 Biology

C. pseudoceriferus females have 3 nymphal stages. Only the 1st and 2nd instars are feeding stages, the scale lose their functional mouthparts at the moult to prepupa. Metamorphosis continues from prepupa to pupa to adult. After adult males emerge from their tests, they live for only a few days, just long enough to mate with females. The lifecycle of most exotic soft scales in New Zealand is parthenogenetic (Henderson 2001).

In lab experiments in Japan it was found that overwintering females oviposited in 6-8 days when kept in temperatures of 28°C. It is suggested that juvenile hormone is normally secreted in response to increased temperatures in spring (Kamei & Asano 1976).

In Korea the wax scale has one generation per year with the larval stage extending from mid-June to mid-October. The average number of eggs laid per female was 1073.0 +- 177.3. The hatching rate was 97.3 percent and was not affected by temperature or photoperiod.
On average eggs developed in 23.4 days, larvae in 128.3 days and adult females took 213.3 days to reach maturity (Park *et al.* 1990). In southern Taiwan 3 generations per year have been observed, and eggs laid per female averaged 1445.2, 1103.5 and 1287.7 for these 3 generations respectively (Wen & Lee 1986).

On mango *C. pseudoceriferus* infests young shoots in early spring, the lower surface of older leaves, and sometimes the base of the developing inflorescence, resulting in drying and wilting of leaves and flowers (Ali 1978). Twigs severely infested before flowering failed to produce flowers, while partially infested twigs produced malformed flowers and no fruit (Ali 1978).

C. rubens
Ceroplastes rubens has a similar life cycle to *C. pseudoceriferus* with the 1st instar being the most mobile stage in the life cycle and the post pupal stage losing functional mouthparts. It has one generation a year in China (Tao *et al.* 2003) and two in Australia (Smith 1976). The fertilised female overwinters before ovipositing. Mortality of *C. rubens* is greatest during the first 24 hours after hatching when approximately half disappear. The mean fecundity of females in a study in Queensland was 292 eggs per adult female, with a range of 5-1178 eggs (Loch & Zalucki 1997). Males have been recorded in Japan by Kuwana (1923) (CPC 2006) but not in Australia (Qin & Gullan 1994).

Ant attendance on *C. rubens* restricts the ovipositional ability of the parasitoid *Anicetus beneficus*. Under the natural conditions in which some generalist ant species attended host aggregations, host density remained at a high level or increased gradually over a 5 year period (Itioka & Inoue 1996).

C. rubens is a significant pest of *Citrus*, and is common on a range of other crop plants. On *Citrus* it feeds mainly on leaves, but also on twigs and fruit. In a study on citrus trees in Japan (Itioka & Inoue 1991) *C. rubens* showed a preference for settling on 1 and 2 year old twigs, with the survival rate being slightly higher on new twigs (under a year old) than on these preferred twigs. Mortality was primarily due to growth cessation, which is believed to be related to the twig quality as a food source. Predators and parasitoids were minor mortality factors (Itioka & Inoue 1991).

6.9.3 Hosts

C. pseudoceriferus
C. pseudoceriferus is highly polyphagous, attacking more than 122 plant species in 46 families (CPC 2006). Some host species include *Acer* spp. (maple) *Azadirachta indica, Camellia japonica, Camellia sasanqua, Camellia sinensis, Chrysanthemum indicum, Cinnamomum sericeum, Citrus natsudaidai, Citrus unshiu, Commelina communis* (Asiatic dayflower)*, Croton* spp., *Cucurbita moschata* (calabaza – squash), *Diospyros kaki* (persimmon), *Diospyros montana* (mountain persimmon). *Ficus* spp., *Gardenia jasminoides*, *Glycine max* (soybean), *Hibiscus rosa-sinensis*, *Ilex* spp., (holly), *Ipomoea batatas* (sweet potato), *Magnolia* spp., *Malus pumila* (apple), *Malus sieboldii* (crabapple), *Mangifera indica* (mango)*, Morus alba* (white mulberry).

Oxalis corniculata (wood sorrel), *Persea americana* (avocado), *Pittosporum tobira*, *Platanus occidentalis*, *Platanus orientalis* (sycamore), *Prunus mume* (Japanese apricot), *Prunus salicina* (Japanese plum), *Prunus yedoensis* (Tokyo cherry), *Prunus preslii, Prunus zippeliana*, *Psidium guajava* (guava), *Pyrus serotina* (wild pear), *Solanum melongena* (egg plant), *Solanum tuberosum* (potato), *Solidago vigra-aurea* (Ben-Dov 2005). The families with the most members attacked by *C. pseudoceriferus* are Compositae, Lauraceae, Moraceae, Rosaceae and Theaceae (Kajita 1964). It has also been recorded from *Litchi chinensis* (litchi) (CPC 2006).

C. rubens
Some preferred hosts include: *Citrus* spp., *Mangifera indica* (mango), *Alpinia purpurata* (gingerlily), *Annona* spp., *Artemisia* spp.(wormwoods), *Artocarpus altilis* (breadfruit), *Camellia sinensis* (tea), *Chrysanthemum* spp.(daisy), *Cinnamomum verum* (cinnamon), *Cocos nucifera* (coconut), *Coffea* spp.(coffee), *Eugenia* spp., *Ficus* spp. (fig), *Helianthus* spp., *Hibiscus* spp. (rosemallows), *Laurus nobilis* (sweet bay), *Litchi chinensis* (litchi), *Malus* spp.(apple), *Morus alba* (mora), *Musa* spp.(banana), *Myristica* spp.(nutmeg), *Myristica fragrans* (nutmeg), *Nerium* spp., *Olea* spp., *Persea americana* (avocado), *Pimenta dioica* (Allspice), *Pinus* spp.(pines), *Piper* spp. (pepper), *Prunus* spp. (stone fruit), *Psidium guajava* (guava), *Pyrus* spp. (pears), *Syzygium* spp., *Zingiber officinale* (ginger) (CPC 2006).

Other wild hosts include:
Acer spp.(maples), *Aglaonema* spp., *Allamanda cathartica*, *Alpinia* spp., *Alstonia scholaris* (white cheesewood), *Anacardium occidentale* (cashew nut), *Anthurium andreanum*, *Aralia* spp., *Ardisia* spp., *Asplenium* spp.(spleenworts), *Bixa* spp., *Blechnum* spp., *Buxus microphylla*, *Callistemon* spp. (Bottle brush), *Calophyllum* spp., *Camellia* spp., *Celosia argentea* (celosia), *Celtis* spp., *Coccoloba uvifera* (seaside grape), *Cycas* spp., *Cytisus* spp.(Broom), *Daphne* spp., *Diospyros* spp. (malabar ebony), *Dizygotheca elegantissima* (False aralia), *Eucalyptus* spp.(Eucalyptus tree), *Euonymus* spp.(spindle trees), *Euphorbia* spp.(spurges), *Fatsia japonica* (Japanese aralia), *Feijoa* spp., *Garcinia* spp.(mangosteen),

Gardenia spp, *Hedera helix* (ivy), *Heliconia* spp., *Ilex* spp. (Holly), *Illicium* spp., *Inocarpus fagifer*, *Ixora* spp., *Ligustrum* spp., *Lindera* spp., *Magnolia* spp., *Monstera deliciosa* (ceriman), *Nandina domestica* (heavenly bamboo), *Nephelium* spp. (rambutan), *Nephrolepis exaltata* (Boston fern), *Nerium oleander* (oleander), *Persea thunbergii*, *Philodendron*, *Pittosporum* spp., *Plumeria rubra var. acutifolia* (Mexican frangipani), *Polyscias quilfoylei*, *Poncirus* spp., *Rhododendron* spp.(Azalea), *Rhus* spp.(Sumach), *Schefflera actinophylla*, *Schinus* spp., *Spartium junceum* (Spanish broom), *Spiraea* spp., *Syzygium cumini* (black plum), *Tamarix* spp., *Ternstroemia* spp., and *Thevetia peruviana* (CPC 2006).

6.9.4 Distribution

C. pseudoceriferus
The Indian wax scale occurs predominantly in Asia including India, China, Taiwan, Bangladesh, Sri Lanka, Japan and South Korea (Ben-Dov 2005).

C. rubens
C. rubens is distributed throughout tropical and subtropical regions including Asia, Africa, and Oceania (CPC 2006). In Australia it has been found in the ACT, New South Wales and Victoria (Qin & Gullen 1995). Europe and South America are not known to have populations of this pest although it is found localised in Central and North America. It is erroneously recorded as being present in New Zealand in the Crop Protection Compendium (CPC 2006).

6.9.5 Hazard Identification Conclusion

Both *C. pseudoceriferus* and *C. rubens* are highly polyphagous, with the potential to impact a large number of plant species through direct feeding or secondary damage from sooty mould growth on their honey dew secretions. *C. pseudoceriferus* has a short generation time enabling fast reproductive output. Fertilised females of *C. rubens* overwinter before ovipositing, with little evidence of abiotic factors influencing its life history. Therefore both scale insects are considered a potential hazard in this risk analysis.

6.9.6 Risk Assessment

6.9.6.1 Entry Assessment

The first instar larvae of *C. pseudoceriferus* and *C. rubens* are mobile and capable of dispersing fairly widely among plant materials to search for hosts. The lifecycle is long with records of eggs and larvae of *C. pseudoceriferus* living a combined average of 151.7 days in Korea (Park *et al.* 1990). Populations of *C. rubens* undergo one generation annually in China (Tao *et al.* 2003) and two in Australia (Smith 1976). Juvenile and adult stages would live long enough to survive the transit time of litchis from Taiwan to New Zealand. Adults are sessile and remain attached to the plant even after death.

There is a high likelihood that any lifestage of Ceroplastes pseudoceriferus and C. rubens will enter the country on the pathway. Therefore the likelihood of entry is non-negligible.

6.9.6.2 Exposure Assessment

Dispersal of crawlers (1st instar nymphs) is accomplished by active wandering and the wind. Birds, insects and other animals including humans may act as vectors of scale insects (Beardsley & Gonzalez, 1975). This dispersal would be enhanced by waste material from litchi fruit (e.g. whole rotten fruits) being discarded in household compost. There are many ornamental and horticultural species attacked by *C. pseudoceriferus* and *C. rubens* overseas which occur in New Zealand. These include *Camellia*, *Citrus*, maple, *Chrysanthemum*, persimmon, *Eucalyptus*, holly, *Ficus*, feijoa, hibiscus, sweet potato, *Magnolia*, *Rhododendron*, apple, avocado, pine, guava, eggplant, potato and pears. There are also 5 genera of plants attacked by *C. rubens* overseas that occur here as natives, *Syzygium, Blechnum, Asplenium, Pittosporum* and *Schefflera.* There would be no shortage of potential hosts in urban environments, available throughout the year.

6.9.6.3 Establishment Assessment

Climate is likely to be a limiting factor in the establishment of both species in many parts of South Island. The fertilised female of *C. pseudoceriferus* is capable of overwintering, although there is no data for temperature tolerance at the lower range. Park *et al.* (1990) report that temperature and photoperiod do not affect hatch rate of eggs. *C. rubens* occurs in parts of Australia with similar climatic conditions to North Island New Zealand including ACT, New South Wales and Victoria. If *C. rubens* can survive in these areas year round they could survive in most parts of the North Island and some areas in the South. Areas with potential to support populations of the scales are listed (ND, AK, CL, WO, BP, TK, GB, HB, MB, NN). There is little evidence of abiotic factors influencing the life history of either scale so it is assumed nutritional requirements are more important. The natural distribution of these scales and research on their life cycle would imply a range between 15°C and 30°C is optimal. Equivalent conditions in New Zealand would be available for much of summer autumn and spring.

The likelihood of exposure is high and establishment of C. pseudoceriferus and C. rubens is moderate.

6.9.7 Consequence Assessment

6.9.7.1 Economic

Like its congener *C. rubens*, scale infestations of *C. pseudoceriferus* damage hosts directly through feeding and produce honeydew which encourages the growth of sooty moulds. These build up on foliage and reduce photosynthetic efficiency, causing reduced growth. In Australia, where *C. rubens* commonly occurs, it is of particular economic importance in Queensland and New South Wales (Qin & Gullan, 1994). On *Pinus* spp. the accumulation of sooty moulds due to *C. rubens* feeding results in sparse crowns and decreased tree height (Merrifield & Howcroft, 1975). Commercial forestry in New Zealand is based around *Pinus* species, particularly *P. radiata*. In 2004, 1.8 million hectares of pine was grown in New Zealand. Timber from the industry was the 3rd largest export commodity with NZ$3.1 billion earned in 2004, about 11 percent of the countries total export income (FI 2005). Potentially some percentage of this total would be lost due to attack on pine by this organism, which would likely have a moderate impact on the economic capacity of the industry.

6.9.7.2 Environmental

Six genera of plants attacked by *C. pseudoceriferus* and *C. rubens* occur in New Zealand as natives, *Asplenium*, *Blechnum*, *Pittosporum*, *Schefflera* and *Solanum*. The ferns (*Asplenium, Blechnum*) are a major component of the understory in all native forests here. Between these genera there are a total of 62 species which could potentially be affected by the scale. There are three native *Solanum* species, *S. aviculare, S. laciniatum* and *S. americanum* (FNZ 2004) which were traditionally eaten by Maori. In eastern Europe *S. laciniatum* is cultivated for its steroid precursors (FNZ 2004). There are over 20 native species of *Pittosporum* of which at least 3 are listed on the New Zealand threatened plants register, *Pittosporum obcordatum* (nationally endangered), *P. kirkii* (serious decline) and *P. turneri* (nationally endangered). It is unlikely that *C. rubens* or *C. pseudoceriferus* would come into contact with these species unless they were well established throughout the whole country.

As well as effects on the plants, native scale insects like *Poropeza cologabata*, and *Pounamococcus coccus* recorded from *Blechnum fraseri*, *Aphenochiton pubens*, *A. subtilis*, *Epelidochiton piperis, Inglisia patella, Kalasiris perforata* on *Pittosporum* spp. and *Ctenochiton paraviridis, Epelidochiton piperis, Poropeza cologabata* on *Schefflera digitata* (Hodgson & Henderson 2000) could compete with *C. rubens* and *C. pseudoceriferus* for host material. The effect of this competition would be much harder to quantify than the use of native plant host material by the two species.

The likelihood of negative consequences following entry and establishment of the scales are low to moderate.

6.9.8 Risk Estimation

For *C. pseudoceriferus* and *C. rubens* in association with fresh litchi fruit from Taiwan the likelihood of entry and exposure is high (sections ***6.11.6.1*** and ***6.11.6.2***), the likelihood of establishment is moderate (section ***6.11.6.3***) and the potential consequences of establishment are also low to moderate (section ***6.11.7***). Therefore the risk estimation for *C. pseudoceriferus* and *C. rubens* is non-negligible.

6.9.9 Risk Management

6.9.9.1 Risk Evaluation

Since the risk estimate for these wax scales associated with litchi fruit is non-negligible, phytosanitary measures will need to be employed to effectively manage the risks to reduce them to an acceptable level.

6.9.9.2 Option Evaluation

6.9.9.3 Risk Management Objective

To prevent the entry and establishment of *C. pseudoceriferus* and *C. rubens* in New Zealand.

6.9.9.4 Risk Management Options

There are a number of points on the import pathway at which effective measures could be applied to reduce the likelihood of live life stages being intercepted at the border to an acceptable level. Pest management systems in the orchards, screening measures and visual inspection should be viewed as complementary options that need to be implemented in conjunction with the chosen disinfestation treatment to reduce pest numbers in fruit for export.

Vapour Heat treatment or Cold Disinfestation treatment.
There is no specific efficacy data for the cold or heat treatment of either *C. pseudoceriferus* or *C. rubens* but Hansen *et al.* (1992) determined that optimum efficacy of vapour heat treatment for scales, mealybugs, thrips and aphids on cut flowers was after 2 hours at 45.2°C. This treatment should be effective against both scales.

6.9.9.5 Recommended Management Options

Pest management systems in the orchards, screening measures and pre export visual inspection should be implemented in conjunction with the recommended disinfestations treatment.

a) Vapour heat treatment: 45.2°C for 2 hours
and

b) Visual inspection will be undertaken in New Zealand after the consignment has arrived.

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6.10 *Ischnaspis longirostris* (Black Thread Scale)

6.10.1 Hazard Identification

Aetiological agent: *Ischnaspis longirostris* Signoret (Homoptera: Diaspididae)

Synonyms: Mytilaspis longirostris, *Ischnaspis filiformis*, *Ischnaspis piliformis*, *Mytilaspis Ritzemae Bosi*, *Lepidosaphes ritsemabosi*.

New Zealand Status: Not present in New Zealand (Charles & Henderson 2002)

6.10.2 Biology

Ischnaspis longirostris is parthenogenetic with no males of the species recorded (Dekle 1965). It is found on berries, twigs, flower-buds and the lower surface of the leaves in coffee plantations in India (Chacko & Ananda-Rao 1978). The adult female reaches 3mm in length when fully grown (Tenbrink & Hara 1992). The first sign of black thread scale in the field is usually the presence of armour on leaves, stems, and fruits. Litchi was recorded as a host in Florida in the 1960s (Dekle 1965).Vesey-Fitzgerald (1940) studied the life history of black thread scale in the Seychelles and found that females produced from 20 to 30 eggs each. Eggs hatch soon after being laid and crawlers settle to feed in about 24 hours. The second instar appears in about 3 days.

Development proceeds throughout the year, with the number of days for each developmental stage and the number of generations per year dependant on temperature, humidity and rainfall (Beardsley & Gonzalez 1975). Based on a generalized life history of other tropical species, 30 days is the approximate time to complete the life cycle from eggs to reproducing adults (Tenbrink & Hara, 1992). From surveys on imported products in Hawaii the scale is most frequently associated with potted plants, cut flowers and foliage (Tenbrink & Hara 1992).

6.10.3 Hosts

Some hosts include: *Strychnos* spp., *Dracaena australis*, *Dracaena kirkii*, *Citrus* spp., *Chaetacme* spp., *Theobroma* spp., *Ixora* spp., *Cordyline* spp., *Prunus armeniaca*, *Asparagus* spp., *Ziziphus jujube*, *Piper nigrum*, *Ligustrum japonicum*, *Jasminum* spp., *Psidium guajava*, *Eugenia* spp., *Musa* spp., *Ficus* spp., *Artocarpus* spp., *Swietenia macrophylla*, *Gossypium* spp., *Magnolia* spp., *Agave americana*, *Litchi chinensis* (Heu 2002), *Aloe* spp., *Persea americana*, *Litsea* spp., *Cinnamomum zeylanica*, *Acacia* spp., *Euphorbia* spp., *Diospyros* spp., *Cyperus* spp., *Viburnum tinus*, *Sabal jaguar*, *S. palmetto*, *Rhopalostylus baueri*, *Phoenix* spp., *Latania aurea*, *L. chinensis*, *Cocos nucifera*, *Areca* spp., *Monstera deliciosa*, *Annona cherimolia*, *A. muricata*, *A. reticulata*, and *Mangifera indica* (Ben-Dov *et al.* 2005).

6.10.4 Distribution

Ischnaspis longirostris has an almost cosmopolitan distribution found throughout tropical Africa, the Americas including Canada, Europe including Denmark, France, Germany, Czechoslovakia, UK, Ireland and Italy, and Asia including Taiwan (Watson 2002). It is also found in much of pacific Oceania including Australia (Ben-Dov *et al.* 2005) In parts of Europe it has been recorded mainly from greenhouses (Germain & Matile-Ferrero 2005).

6.10.5 Hazard Identification Conclusion

The scale appears to have a broad distribution and although there is no information on temperature tolerance or developmental thresholds, it occurs in countries in Scandinavia and in Canada for example, where climatic conditions would be much harsher than in New Zealand. The range of host plants also covers species with a temperate boreal distribution as well as tropical varieties. For these reasons *Ischnaspis longirostris* is considered a potential hazard in this risk analysis.

6.10.6 Risk Assessment

6.10.6.1 Entry Assessment

All stages of the lifecycle are extremely small (adults only grow to 3mm) and from the 2nd larval instar the scale is sedentary. These factors would make *I. longirostris* inconspicuous and unlikely to be detected on litchi fruit entering the country.

It is highly likely that I. longirostris could enter the country on the pathway.

6.10.6.2 Exposure Assessment

The lifecycle of *I. longirostris* is estimated as approximately 30 days based on other tropical species, which is quite short and would enable the development of multiple generations per year given suitable environmental conditions.

Its host range is broad, and includes many economically important species in New Zealand including *Citrus* spp., *Prunus armeniaca* (apricot), *Asparagus*, *Persea americana* (avocado), and *Eucalyptus* spp. as well as some native plants genera; *Dracaena*, *Cordyline*, *Piper*, *Eugenia*, *Litsea*, *Euphorbia* and *Cyperus*. There would be no shortage of host species available year round.

6.10.6.3 Establishment Assessment

There are no temperature thresholds available for the development of this species but it is unlikely climate would be a limiting factor in the establishment of *I. longirostris* given its current distribution from tropical to Palearctic regions. It is more likely to be found in glasshouse environments in cooler areas (Germain & Matile-Ferrero 2005).

The likelihood of Ischnaspis longirostris establishing and spreading in New Zealand is high.

6.10.7 Consequence Assessment

6.10.7.1 Economic

Armoured scales feed on plant juices and cause loss of vigour, deformation of infested plant parts, yellow leaf spots and loss of leaves with eventual death in severe cases (Beardsley & Gonzalez 1975).
Only minor damage from *I. longirostris* has been recorded in the literature, for example in field studies of coffee plantations in India (Rao & Chacko 1977) and on copra production on the Island Principe, in West Africa (Simmonds 1960). Where it does occur *I. longirostris* seems to be one of many scale species present and is not usually the primary agent of mortality or plant health decline.

6.10.7.2 Environmental

There are a number of hosts overseas that are represented by plant genera in New Zealand. These could become potential hosts for *Ischnaspis longirostris* in the future were it to establish here and spread. Genera at risk include *Dracaena, Cordyline, Macropiper, Eugenia, Litsea, Euphorbia* and *Cyperus*. In particular the cabbage trees (*Cordyline* spp) with the ubiquitous *C. australis* being widespread in urban and rural environments as well as occurring in native ecosystems, are most likely to come into contact with the pest. *Macropiper australis* is another common naturally occurring coastal shrub also grown for ornamental purposes particularly in the North Island. Although not from the same genus attacked overseas (*Piper*) the family (Piperaceae) members have very similar characteristics throughout its geographical distribution, making it likely that if one species in a related genus is attacked others in different genera could be. Species from the remaining groups tend to be more site specific (i.e. wetland, streamside, coastal sand dunes etc.) and less likely to come into contact with the scale.

The consequences of the exposure and establishment of I. longirostris in New Zealand are likely to be low.

6.10.8 Risk Estimation

For *I. longirostris* associated with fresh litchi fruit from Taiwan the likelihood of the organism entering the country is high, exposure and establishment are likely to be high and the potential consequences to the New Zealand economy and environment low. Therefore the risk estimation for *I. longirostris* is non-negligible.

6.10.9 Risk Management

6.10.9.1 Risk Evaluation

Since the risk estimate for *I. longirostris* associated with fresh litchi fruit imported from Taiwan is non-negligible, phytosanitary measures will need to be employed to effectively manage the risks to reduce them to an acceptable level.

6.10.9.2 Option Evaluation

6.10.9.3 Risk Management Objective

To prevent the entry and establishment of *I. longirostris* in New Zealand.

6.10.9.4 Risk Management Options

There are a number of points on the import pathway at which effective measures could be applied to reduce the likelihood of live life stages being intercepted at the border, or the establishment of new viruses associated with *I. longirostris* to an acceptable level.

Pest management systems in the orchards, screening measures and visual inspection should be viewed as complementary options that need to be implemented in conjunction with the chosen disinfestation treatment to reduce pest numbers in fruit for export.

Vapour Heat treatment or Cold Disinfestation treatment. There is no specific efficacy data for either cold or heat treatment of *I. longirostris* but Hansen *et al.* (1992) determined that optimum efficacy of vapour heat treatment for scales, mealybugs, thrips and aphids on cut flowers was after 2 hours at 45.2°C. This treatment should be effective against *I. longirostris*.

6.10.9.5 Recommended Management Options

Pest management systems in the orchards, screening measures and pre export visual inspection should be implemented in conjunction with the recommended disinfestation treatment.

a) Vapour heat treatment: 45.2°C for 2 hours
and
b) Visual inspection will be undertaken in New Zealand after the consignment has arrived.

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Mealybugs

6.11 *Ferrisia virgata* (Guava/Striped Mealybug)

6.11.1 Hazard Identification

Aetiological agent: *Ferrisia virgata* (Cockerell) (Homoptera: Pseudococcidae)

Synonyms: 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* (Ben-Dov *et al.* 2005).

New Zealand Status: Not known to be present in New Zealand (Scott & Emberson 1998; NZBugs 2006).

6.11.2 Biology

Ferrisia virgata is now recognized as a species complex (Gullen 2003) and has been easily confused with related species particularly with *Ferrisia malvastra* in India where both species occur (CPC 2006). Slide-mounted preparations are needed for examination. Descriptions and illustrations prior to 1980 appear to contain a combination of the diagnostic characters of both *F. virgata* and *F. malvastra*. Willink (1991) and Williams (1996) both separate or synonymise species from the complex and clarify the taxonomy.

F. malvastra is parthenogenetic and *F. virgata* is biparental. In India, *'F. virgata'* can produce several overlapping generations a year (Nayer *et al.* 1976), while three generations have been observed in Saudi Arabia (Ammar *et al.* 1979). It feeds on leaves twigs, inflorescences and fruit peduncles of cashew in India (Ikisan 2000).

In a laboratory experiment conducted in Iraq on the life history of *F. virgata* Awadallah *et al.* (1979) observed that eggs were laid singly, and total duration of the nymphal stage in females 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. Females lived longer in general than male *F. virgata* with total life span from egg stage to end of adult stage averaging 76.2-154.6 days in females as opposed to 19-47 days in males (Awadallah *et al.* 1979).

The adult female overwinters in cracks and junctions of trunks and large branches and on fallen leaves. In the laboratory females migrated to the soil in winter (Ammar *et al.* 1979). In another study in Saudi Arabia a significant positive correlation was found between population density and daily maximum and minimum temperatures, but not between population density and relative humidity (Ammar *et al.* 1979).

6.11.2.1 Ferrisia virgata as a Vector

Two distinct virus strains transmissible by *F. virgata* infect cacao in tropical central America and Africa; cocoa swollen shoot virus (CSSV), in West Africa and cocoa Trinidad virus (CTV, Diego Martin valley isolate) in Trinidad (CPC 2006). There is also a badnavirus associated with black pepper transmitted by *F. virgata* in India (Bhat *et al*. 2003) which shows a positive serological relationship with Banana streak virus (BSV) and Sugarcane bacilliform virus (ScBV). None of these viruses occur in Taiwan, and none are known to affect *Litchi chinensis*.

6.11.3 Hosts

Ferrisia virgata is one of the most highly polyphagous mealybugs known, attacking plant species belonging to some 150 genera in 68 families. Many of the host species belong to the Leguminosae and Euphorbiaceae (CPC 2006). In Taiwan the mealybug is recorded as a serious pest of bamboo and citrus trees (Tao 1963; Chang & Sun 1985).

Among the more important host plants are: *Abelmoschus esculentus* (okra), *Acalypha* (Copperleaf), *Anacardium occidentale* (cashew nut), *Ananas comosus* (pineapple), *Annona*, *Cajanus cajan* (pigeon pea), *Carica papaya* (papaw), *Citrus*, *Coccoloba uvifera* (seaside grape), *Cocos nucifera* (coconut), *Codiaeum variegatum* (croton), *Coffea* spp.(coffee), *Colocasia esculenta* (taro), *Corchorus* (jutes), *Cucurbita maxima* (giant pumpkin), *Cucurbita pepo* (ornamental gourd), *Dracaena* spp., *Elaeis guineensis* (African oil palm), *Ficus* spp., *Gossypium* spp. (cotton), *Ipomoea batatas* (sweet potato), *Leucaena leucocephala* (leucaena) (CPC 2006).

Litchi chinensis (litchi) (McKenzie 1967), *Lycopersicon esculentum* (tomato), *Mangifera indica* (mango), *Manihot esculenta* (cassava), *Manilkara* spp., *Musa* spp. (banana), *Nicotiana tabacum* (tobacco), *Phaseolus* spp. (beans), *Phoenix dactylifera* (date-palm), *Piper betle* (betel pepper), *Piper nigrum* (black pepper), *Psidium guajava* (guava), *Punica granatum* (pomegranate), *Solanum melongena* (aubergine), *Solanum nigrum* (black nightshade), *Theobroma cacao* (cocoa), *Vigna unguiculata* (cowpea), *Vitis vinifera* (grapevine), *Zingiber officinale* (ginger). Lesser hosts include: *Arachis hypogaea* (groundnut), *Hibiscus* spp. (rosemallows), *Malpighia glabra* (acerola), *Persea americana* (avocado), *Saccharum officinarum* (sugarcane) and *Zea mays* (maize) (CPC 2006).

6.11.4 Distribution

F. virgata is cosmopolitan, found throughout Africa, Asia including Taiwan (Wong 1999) and the Americas, and is widespread in the Pacific including Australia. Europe and New Zealand are two of the few areas unaffected by the pest (CPC 2006).

6.11.5 Hazard Identification Conclusion

F. virgata is a widespread and serious pest of many crops throughout the tropical and subtropical regions of the world. It has the capacity to produce several generations per year, and is a vector of a badnavirus that affects black pepper, which is from the Piperaceae family that has 3 representatives in New Zealand. As a result of its ecology, its longevity and overwintering capacity *F. virgata* is considered a potential hazard in this risk analysis.

6.11.6 Risk Assessment

6.11.6.1 Entry Assessment

Ferrisia virgata is likely to be associated with fresh litchi fruit at the time of harvest as both nymphs and adults attack fruit, terminal shoots and leaves. The life cycle averages from 24 days to 155, easily encompassing the transit time from Taiwan to New Zealand. Mealybugs are attached to their hosts very firmly, making the effect of mechanical or chemical control hard to evaluate, due to the remaining presence of dead individuals. It is unlikely that *F. virgata* would transmit any viruses here given that none of the three viruses mentioned occur in Taiwan or in association with litchi trees. Transport via ship would also exclude the possibility of transmitting a virus into the New Zealand environment.

The likelihood of F. virgata entering the country on the pathway is moderate to high, therefore non-negligible.

6.11.6.2 Exposure Assessment

Many of the host plants of this mealybug 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). There would be no shortage of host plants should *F. virgata* enter the New Zealand environment. It is unlikely viruses currently associated with *Ferrisia virgata* would be exposed given the lack of hosts (cocoa, black pepper) and the lack of evidence for the viruses occurring in Taiwan.

6.11.6.3 Establishment Assessment

Climate may be a limiting factor for *F. virgata* establishing in many parts of New Zealand as it is largely found in tropical and subtropical climates, surviving at an optimal temperature for growth and development of 25°C. There are no data for lower thresholds for development, but its lifespan is extended at cooler temperatures (e.g. 16.6°C). It is likely that a summer population could survive but establishment through the winter months is unlikely except in northern North Island. Greenhouse conditions could enable the establishment of a permanent population of *F. virgata*.

The likelihood of F. virgata being exposed to the local environment in New Zealand and establishing is moderate. The likelihood of any viruses that F. virgata vectors surviving and establishing are negligible.

6.11.7 Consequence Assessment

6.11.7.1 Economic

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* remain 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. 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. Ornamental plants and produce lose their market value (CPC 2006).

6.11.7.2 Environmental

Two plant species attacked by the guava mealybug 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 areas of New Zealand. There is the potential for *F. virgata* to attack this plant as an alternative host.

The likelihood of F. virgata and causing unwanted economic and environmental consequences is moderate to low, therefore non-negligible.

6.11.8 Risk Estimation

The likelihood of *F. virgata* entering the country, being exposed to suitable hosts and establishing is high to moderate. The risk estimation for *F. virgata* therefore is non-negligible. The likelihood of any viruses associated with the mealybug entering the country and establishing are low to negligible, therefore making the risk estimation for vectored viruses negligible.

6.11.9 Risk Management

6.11.9.1 Risk Evaluation

Since the risk estimate for *F. virgata* associated with litchi fresh fruit imported from Taiwan is non-negligible, phytosanitary measures will need to be employed to effectively manage the risks to reduce them to an acceptable level.

6.11.9.2 Option Evaluation

6.11.9.3 Risk Management Objective

To ensure that *Ferrisia virgata* does not enter the county and establish in New Zealand.

6.11.9.4 Risk Management Options

There are a number of points on the import pathway at which effective measures could be applied to reduce the likelihood of live life stages of *F. virgata* being intercepted at the border, to an acceptable level. Pest management systems in the orchards, screening measures and visual inspection should be viewed as complementary options that need to be implemented in conjunction with the chosen disinfestation treatment to reduce pest numbers in fruit for export.

Vapour Heat treatment or Cold Disinfestation treatment.
There is no specific efficacy data for either cold or heat treatment and *F. virgata* but Hansen *et al.* (1992) determined that optimum efficacy of vapour heat treatment for scales, mealybugs, thrips and aphids on cut flowers was after 2 hours at 45.2°C. This treatment should be effective against *F. virgata*.

6.11.9.5 Recommended Management Options

Pest management systems in the orchards, screening measures and pre export visual inspection should be implemented in conjunction with the recommended disinfestation treatment.

a) Vapour heat treatment: 45.2°C for 2 hours
and
b) Visual inspection will be undertaken in New Zealand after the consignment has arrived.

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6.12 *Pseudococcus jackbeardsleyi* (Banana Mealybug)

6.12.1 Hazard Identification

Aetiological agent: *Pseudococcus jackbeardsleyi* Gimpel & Miller (Homoptera: Pseudococcidae)

New Zealand Status: Not known to be present in New Zealand (not recorded in Spiller & Wise 1982; Scott & Emberson 1999; Hodgson & Henderson 2002).

6.12.2 Biology

The banana mealybug *Pseudococcus elisae* was described by Borchsenius in 1947. In 1996 *Pseudococcus jackbeardsleyi* was discovered to be a cryptic component within what was previously called *P. elisae*. True *P. elisae* occurs in Central America, northern South America, and is common on bananas (CPC 2004). *P. jackbeardsleyi* is much more widely distributed and has a larger host range than *P. elisae* (CPC 2004). It is considered to be a minor pest where it occurs (Williams & Watson 1988).

Although there is little literature on its biology or life cycle it is assumed to have a similar lifecycle to other mealybugs. There are generally four female and five male instars, with male adults being winged and having non-feeding stages. There may be overlapping generations annually depending on weather conditions and environmental factors.

6.12.3 Hosts

Over 100 plant species are recorded as hosts. Some major hosts include:
Annona spp., *Hibiscus* spp. (rosemallows), *Lycopersicon* spp. (tomato), *Musa* spp. (banana).

Other hosts include: *Acacia* spp. (wattles), *Aeschynomene americana* (American jointvetch), *Agave* spp., *Aglaonema commutatum*, *Alpinia purpurata* (gingerlily), *Ananas comosus* (pineapple), *Anthurium* spp., *Apium graveolens* (celery), *Aralia* spp., *Begonia* spp., *Blighia sapida* (Akee apple), *Cajanus cajan* (pigeon pea), *Capsicum frutescens* (chilli), *Carica papaya* (papaw), *Cattleya* spp., *Cereus peruvianus*, *Chrysophyllum cainito* (caimito), *Citrus aurantiifolia* (lime), *Citrus x paradisi* (grapefruit), *Codiaeum variegatum* (croton), *Coffea arabica* (arabica coffee), *Coleus* spp., *Conocarpus erectus* (buttonwood), *Cordia curassavica*, *Cosmos bipinnatus* (garden cosmos), *Cucumis melo* (melon), *Cucurbita* spp., *Dendrobium* spp., *Dracaena* spp., *Eugenia* spp., *Euphorbia* spp.(spurges), *Gardenia jasminoides* (cape jasmine), *Gossypium* spp.(cotton).

Haematoxylum campechianum (logwood), *Heliconia* spp., *Hoya carnosa* (Wax plant), *Hura crepitans*, *Ipomoea batatas* (sweet potato), *Iris* spp. (irises), *Jatropha curcas* (Barbados nut), *Lantana camara* (lantana), *Litchi chinensis* (litchi) (Gimpel & Miller 1996), *Macadamia* spp., *Mangifera indica* (mango), *Manihot esculenta* (cassava), *Mentha* spp.(mints), *Moringa oleifera* (horse-radish tree), *Morus* spp.(mulberrytree), *Mucuna* spp.(velvetbeans), *Nephelium lappaceum* (rambutan), *Nerium oleander* (oleander), *Paphiopedilum* spp.(lady's slipper orchid), *Pelargonium* spp. (pelargoniums), *Persea* spp., *Phaseolus lunatus* (lima bean), *Piper nigrum* (black pepper), *Psidium* spp., *Pueraria* spp., *Punica granatum* (pomegranate), *Salvia* spp., *Sechium edule*, *Solanum melongena* (aubergine), *Solanum tuberosum* (potato), *Spondias* spp. (purple mombin), *Tamarindus indica* (Indian tamarind), *Theobroma cacao* (cocoa), *Vitis* spp., *Yucca* spp., *Zea mays* (maize), *Zingiber* spp.(ginger) (Ben-Dov *et al.* 2006).

6.12.4 Distribution

The mealybug is widespread throughout the Americas, parts of Oceania and Asia including Taiwan (Gimpel & Miller 1996) Indonesia, Malaysia, Philippines, Thailand and Singapore (BenDov *et al.* 2006).

6.12.5 Hazard Identification Conclusion

Pseudococcus jackbeardsleyi is generally considered a minor pest where it is present (Williams & Watson 1988) and has not been the object of any research so it is assumed to pose little risk to the plants it is associated with. It appears restricted to tropical areas and is therefore unlikely to survive climatic conditions in New Zealand. As a result *P. jackbeardsleyi* is not considered a potential hazard in this risk analysis.

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Mites

6.13 *Aceria litchi* (Litchi gall mite)

6.13.1 Hazard Identification

Aetiological agent: *Aceria litchi* (Keifer) (Acarina: Eriophyidae).

Synonyms: Eriophyes litchii

New Zealand Status: Not known to be present in New Zealand (not recorded in Scott & Emberson 1999; PPIN 2006)

6.13.2 Biology

Aceria litchi is a serious pest of *Litchi chinensis* and has been recorded infesting up to 71 percent of whole plants in India (Singh *et al.* 2002). It attacks new growth foliage causing hairy, blister like galls on the upper side of the leaves, thickening, wrinkling and distorting them (Morton 1987), with brown velvety growths on infested leaves and fruits, curling, withering and premature fall of leaves, sometimes with inhibition of fruit production (Kumar 1992). The population tends towards a clumped distribution in orchards in winter (Zhou & Li 2001).

It is capable of very rapid population growth, exhibiting 15-16 generations per year in Fuzhou in China (Xu & Li 1996), where population density was found to respond to rising temperatures. In India the mite completed its life cycle in 15-20 days with 10-12 annual generations (Prasad & Singh 1981). Eggs are laid singly by the females at the base of hairs constituting the erineum on the leaf surface, and the incubation period averaged two days (Alam & Wadud 1963). The protonymphal stage in this study lasted 2-3 days and successive deutonymphal stages average 6 days and include two instars. Preoviposition was a brief 1.5 days. The length of adult life was 2-3 days with sexual dimorphism evident (Alam & Wadud 1963). Two peaks in population were observed in April and May and again in September and October, linked to unfavourable weather.

Observations on its dispersal in Taiwan (Wen *et al.* 1991) showed that the population was most mobile in March and again in August.

Two plant genera in the Sapindaceae which occur in New Zealand, *Dodonaea* and *Alectryon*, both occur in Hawaii and Australia (Mabberley 1997) where *Litchi chinensis* is grown. However no records have been made of the mite attacking species from either genus.

Aceria litchi is thought to be vectored by honeybees (Waite 1999) in Queensland, Australia. Up to 23 percent of honey bees (*Apis mellifera*) collected from flowering litchi trees severely infested with the litchi erinose mite were found to be carrying live mites which were picked up as the bees foraged (Waite & McAlpine 1992).

6.13.3 Hosts

The only recorded hosts of this species are *Litchi chinensis* (litchi) and *Dimocarpus longan* (longan)

6.13.4 Distribution

It is found in India (Singh *et al*. 2002), China and Taiwan (Wen *et al.* 1991, Zhou & Li 2001), parts of Australia (Waite 1999) and Hawaii (Keifer 1943).

6.13.5 Hazard Identification Conclusion

Aceria litchi has a very narrow host range, having only been recorded on two plant species throughout its native and introduced range. Neither of these plants (litchi and longan) occur in significant numbers in New Zealand and are unlikely to provide sufficient or accessible host material for the mite to establish. Other genera in the Sapindaceae which occur in New Zealand and where litchi and longan are grown (*Alectryon* and *Dodonaea*) have not been recorded as hosts. *A. litchi* therefore is not considered a hazard in this risk analysis.

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6.14 *Agistemus exsertus* (Stigmaeid Mite)

6.14.1 Hazard Identification

Aetiological agent: *Agistemus exsertus* Gonzalez-Rodriguez (Acari: Stigmaeidae**)**

New Zealand Status: Not known to be present in New Zealand (Fan & Zhang 2005)

6.14.2 Biology

Agistemus exsertus is a generalist predatory mite species feeding on phytophagous mites such as *Brevipalpus californicus* and *Tetranychus arabicus* in Egypt (CPC 2004, Atalla *et al.* 1972) and *Panonychus ulmi, P. citri* and *Oligonychus biharensis* among others in China (Wang 1981). It also feeds on scale insects. There is no direct association of the mite with litchi fruit, therefore it would be considered a hitch hiker species. Many experiments have been done to research the potential of *A. exertus* as a biological control agent. Females clearly exhibited a prey stage preference in a study conducted in China, with an average of 75.2 percent of prey consumed consisting of eggs, compared with 16.6 and 8.2 percent nymphs and adult males, respectively (Yue & Tsai 1995).

Temperature has a significant effect on reproduction, with rates of intrinsic natural increase higher at 20 and 25 °C than at 30 and 35°C (Yue & Tsai 1995). At 15°C the mean length of generation time was 35.9 days and at 35°C it was 12.6 days. More eggs were produced at 15°C than at 35°C, with females producing 66 eggs as opposed to only 18.8 (Yue & Childers 1994). The greatest net reproductive and intrinsic rates of increase were obtained at 20 and 25°C (Yue & Childers 1994). At 28-30°C, the average developmental time from larvae to adult female and male of *A. exertus* was 4.4 and 4.5 days. Females lived for 28-30 days on tetranychid eggs at this temperature (Elbadry *et al.* 1969).

A positive relationship was noted in Egypt (Abou Awad & Reda 1992) between the number of progeny and sex ratio at different intervals of the reproductive period. Old female *A. exertus* decreased egg production and produced proportionally more male progeny compared with young females. In laboratory conditions in Egypt, 21 generations were reached in one year (Zaher *et al.* 1971) and increasing temperature was found to have a significant accelerating effect on development and oviposition. Under natural conditions, *A. exsertus* numbers were very low in winter and increased steadily from May to October in China (Yue & Tsai 1995).

6.14.3 Hosts

As a predatory mite *A. exsertus* has no direct association with any host plant. Therefore it could potentially be associated with any plant species (as a hitch hiker) on which phytophagous mites are found.

6.14.4 Distribution

It is found in Taiwan (Tseng 1982), China, Japan, parts of Europe and Egypt (CPC 2006).

6.14.5 Hazard Identification Conclusion

Agistemus exsertus has a fairly broad host range but is not a pest of litchi fruit. It is a predator on phytophagous mite species such as *Brevipalpus phoenicis* and *Tetranychus arabicus* that attack *Litchi chinensis*. *A. exsertus* is therefore considered a potential hazard in this risk analysis.

6.14.6 Risk Assessment

6.14.6.1 Entry Assessment

A. exsertus is mobile throughout most of its life cycle. Adults can move easily between plant parts, and between plants in close proximity. At 15°C mean length of generation time of *A. exsertus* is 35.9 days (Yue & Tsai 1995) and more eggs are produced at this temperature than at 35°C. This time period would exceed the transit time of litchi fruit from Taiwan to New Zealand. As a small and inconspicuous mite which is fairly mobile and relatively long lived there is a moderate likelihood of *A. exsertus* entering the country on the pathway.

The likelihood of A. exsertus entering the country is non-negligible.

6.14.6.2 Exposure Assessment

Agistemus exertus is a generalist predator and is found on a wide range of fruiting plants and ornamentals. Most plants are therefore likely to be suitable hosts, as the presence of the mite will depend more on the occurrence of its prey. *A. exsertus* is likely to occur on native species as well as exotic plants. *Oligonychus biharensis* one of its prey species is associated with litchi trees in China and Taiwan. The other phytophagous mites mentioned – *Brevipalpus californicus*, *Tetranychus arabicus, Panonychus ulmi, and P. citri* feed on a variety of crop and horticultural plants including squash, cucumber, canteloupe, watermelon, citrus, raspberries, black berries, red currants and grapevine. If *A. exsertus* was to find suitable prey they could well be on some of these plants. However none of the mites listed occur in New Zealand.

6.14.6.3 Establishment Assessment

Climate would not be a limiting factor preventing the spread and establishment of *A. exsertus* in New Zealand as it produces more eggs at 15°C (Yue & Childers 1994) than it does at higher temperatures. There is no evidence in the literature that temperatures cooler than 15°C prevent development in any way. In addition climatic conditions in some parts of New Zealand are likely to be particularly suitable (BP, WK, AK, ND, NN, MO) for establishment.

There is a high likelihood that A. exsertus would establish in New Zealand.

6.14.7 Consequence Assessment

6.14.7.1 Economic

There are unlikely to be any economic consequences of the mite establishing in New Zealand, however if it established in horticultural plantation areas it could have a beneficial effect in reducing pest mites feeding on crops. The risk to the economy is therefore negligible.

6.14.7.2 Environmental

There are 5 native species of *Agistemus* in New Zealand all of which are predatory (Zhi-Qiang Zhang pers. com. 2006). *A. exsertus* could potentially out-compete these species, or predate native phytophagous mites. Most phytophagous mites *A. exsertus* is associated with are themselves found occurring predominantly to crop and horticultural plant species. It would be unlikely for *A. exsertus* to enter native forest and come into contact with native species unless it was in areas where crop plants were grown adjacent to native forest. The likely impact on the environment would be very low but non-negligible.

There is an overall non-negligible risk of associated with the entry and establishment of A. exsertus into New Zealand.

6.14.8 Risk Estimation

The likelihood of *A. exsertus* entering the country and establishing here is moderate to high, and the consequence assessment is non-negligible. The mite is a predatory species not directly associated with any particular host plant, and may even have a beneficial impact on pest phytophagous mites in New Zealand therefore *A. exsertus* is not considered further in this risk anlaysis. Measures specified for high risk organisms such as fruit flies and *Kerria lacca* would mitigate any risk posed by the mite.

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Fungi

6.15 *Lasiodiplodia theobromae* (Fruit Rot)

6.15.1 Hazard Identification

Aetiological agent: *Lasiodiplodia theobromae* (Patouillard) Griffon & Maublanc (Anamorphic: *Botryosphaeria*)

Synonyms: *Botryodiplodia ananassae, Botryodiplodia elasticae, Botryodiplodia gossypii, Botryodiplodia tubericola, Chaetodiplodia grisea, Diplodia ananassae, Diplodia cacaoicola, Diplodia gossypina, Diplodia natalensis, Diplodia theobromae, Diplodia tubericola, Lasiodiplodia triflorae, Lasiodiplodia tubericola, Macrophomina vestita, Botryodiplodia theobromae, Botryosphaeria rhodina, Physalospora rhodina.*

Teleomorph: Botryosphaeria rhodina

Synonym: Physalospora rhodina

New Zealand Status: Recorded once on *Ipomea batatas* in 1963 (Dingley 1969; NZFungi 2007) but is not considered established here.

6.15.2 Biology

Lasiodiplodia theobromae is a plurivorous (living and feeding on hosts from widely differing families), wound, secondary pathogen and a saprophyte. It is soilborne (Gupta *et al.* 1999), seedborne (Lima *et al.* 1998), air-borne (Sanders & Snow, 1978), insect transmitted (Nago *et al.* 1998) and occurs as an endophyte (Johnson *et al.* 1998; Gonzalez *et al.* 1999). It sporulates readily on host tissue on incubation. Infections usually occur when there is a wound in the host tissue. Conidiomata (pycnidia) are produced with fluffy mycelium, and optimum growth is obtained at 30°C (CPC 2004).

In citrus, *L. theobromae* is one of the fungi causing stem end rot of fruit. In undamaged fruit, infection occurs from conidia lodged at the stem end (CPC 2004). Actual penetration does not occur until natural openings develop in the separation layer between button and fruit at abscission (CPC 2004). Decay may appear at the stylar end as a result of the rapid spread of internal decay, which mostly occurs 2-3 weeks after harvest (CPC 2004). Fruit on the tree is not usually attacked unless injured or over-ripe. Infection originates from dead wood. Wood decay caused by *L. theobromae* has the ability to degrade the gelatinous layer of the cell wall (Encinas & Daniel, 1996). The fungus is frequently reported causing a postharvest rot of mango. Infection can occur via the exposed surfaces of the attached pedicel, the injured pedicel, abscission zone and wounded exocarp. Fruit can be completely rotten in 2-3 days (CPC 2004).

L. theobromae is also a rare but important causal agent of human keratitis (inflammation of the cornea) endophthalmitis (inflammation of the aqueous or vitreous humor) and panophthalmitis (inflamation of the whole eye). The fungus can infect the cornea, orbit and other ocular structures and has also been reported as subcutaneous (beneath the skin) infection on other body parts or as an ulcerated skin lesion. These infections have been reported in France (Donnio *et al.* 2006) on a Cambodian patient in Australia (1996), Sri Lanka (Gonawardena et al. 1994) India (Thomas *et al.* 1991), and the US (Slomovic *et al.* 1985; Rebell & Forster 1976). This fungus has the potential to be an opportunistic pathogen (Maslen *et al.* 1996) however the clinical cases described indicates that it does affect immunocompetent individuals. It can lead to permanent damage of the eyes, including blindness if left untreated.

6.15.3 Hosts

Major hosts include:
Allium spp. (onions, garlic, leek, etc.), *Ananas comosus* (pineapple), *Arachis hypogaea* (groundnut), *Araucaria cunninghamii* (colonial pine), *Capsicum annuum* (bell pepper), *Citrus* spp., *Cocos nucifera* (coconut), *Dioscorea* spp. (yam), *Gossypium* spp. (cotton), *Hevea brasiliensis* (rubber), *Mangifera indica* (mango), *Musa* spp. (banana), *Persea americana* (avocado), *Solanum melongena* (aubergine), *Theobroma cacao* (cocoa), *Zea mays* (maize)

Some lesser hosts include:
Artocarpus integer, *Cajanus cajan* (pigeon pea), *Camellia sinensis* (tea), *Corchorus olitorius* (jute), *Cornus florida* (Flowering dogwood), *Cucumis melo* (melon), *Cynara scolymus* (artichoke), *Elaeagnus angustifolia* (oleaster), *Glycine max* (soyabean), *Ipomoea batatas* (sweet potato), *Manihot esculenta* (cassava), *Musa balbisiana*, *Nicotiana tabacum* (tobacco), *Oryza sativa* (rice), *Oxalis tuberosa* (oca), *Passiflora quadrangularis* (giant granadilla), *Phoenix dactylifera* (date-palm), *Saccharum officinarum* (sugarcane), *Sorghum bicolor* (sorghum), *Vigna unguiculata* (cowpea), *Vitis vinifera* (grapevine) (CPC 2004), *Dimocarpus longan* (Zhang *et al.* 2005) and *Litchi chinensis* (Prasad 1967).

6.15.4 Distribution

This fungus is cosmopolitan in distribution, found widely throughout Asia, Africa the Americas, Oceania and parts of Europe. It has been recorded in Taiwan (Kuo & Liu 2000) on lima beans. It was found on *Ipomoea batatas* growing in Avondale – Auckland once (Dingley 1963) and apparently has not been recorded in New Zealand since.

6.15.5 Hazard Identification Conclusion

Although there is no literature suggesting *L. theobromae* attacks litchi fruit in Taiwan it has been recorded on litchi in India and occurs on other plant species in the Sapindacae in China (longan). It does pose rare but potentially significant health risks. It has been found in New Zealand previously but has never extended its distribution from the initial recorded area. Presumably it is unable to survive the climatic conditions here. Being a predominantly tropical species it is unlikely to establish in New Zealand. For these reasons it is not considered a potential hazard in this risk analysis.

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6.16 *Peronophythora litchii* (Litchi Brown Blight)

6.16.1 Hazard Identification

Aetiological agent: *Peronophythora litchii* Chen (Oomycota: Pythiales: Pythiaceae)

New Zealand Status: Not known to be present in New Zealand (not recorded in Pennycook 1989; Pennycook & Galloway 2004; PPIN 2006; NZFungi 2006)

6.16.2 Biology

Peronophythora litchii is a facultative necrotroph (feeds on dead host tissue), which produces colourless, aseptate mycelium 4-6µm wide, irregularly branched at right or acute angles (Hall, 1989). Asexual reproduction is initiated by sporangia developing from the mycelial hyphae in the presence of water movement. Production of zoospores occurs at temperatures of 8-22°C, by hyphae at 26-30°C, and by both sporangia and zoospores at 24°C (Chi *et al.* 1984).

The kidney shaped zoospores are highly motile and have two flagella one long and smooth, the other shorter and bearing a row of hairs (CPC 1996). Zoospores swim around and may swarm in response to a suitable stimulus for example a host plant exudate. They infect host tissues directly when dispersed to surface water films on aerial plant parts. Mycelial growth inside the host tissues follows, on flower, fruit and leaf tissues, repeating the asexual phase (CPC 1996). A sexual stage follows this development where gametes are produced, but sexual reproduction has not been observed on fruit (Vien *et al.* 2001).

The optimum temperature for lesion formation and enlargement is 25°C. Incubation takes less than one day at this temperature and 2-3 days at 18°C, while at 11°C incubation is prolonged to 7 days (Chi *et al.* 1984). Only a few sporangia were produced at 30°C.
Continuous rain and re-infection are the most important factors leading to the wide distribution of this disease in Guangzhou province in China (Chi *et al.* 1984).
It attacks both young and ripe fruit, pedicels and leaves of litchi and is the cause of one of the most serious diseases of fruit crops in south China (Chi *et al.* 1984).

The pathogen probably persists as oospores or dormant mycelium in the soil or in plant debris (CPC 1996). Higher temperatures during the day are suitable for sporulation, germination and infection by the pathogen, and lower temperatures and high humidity at night facilitate zoospore release and distribution. In China the optimal temperature for disease outbreak is 22-25°C (Li 1997) with rainy spring days during infection causing serious losses.

6.16.3 Hosts

Litchi chinensis is the only known host but some fruits of tomato, pawpaw and loofah have been artificially inoculated (CMI 1989).

6.16.4 Distribution

China, Taiwan (Lee 2006), Papua New Guinea (CPC 1996), Thailand (Anapunt & Sukhvibul 2005), and Vietnam (Ngo *et al.* 2001).

6.16.5 Hazard Identification Conclusion

Due to the visible symptoms of the disease at the flower budding and fruitlet stage, control measures can be applied before fruit maturity and most infected developing fruit will have fallen from the tree prematurely (AFFA 2004). It is highly host specific and its host plant *Litchi chinensis* is not grown in significant numbers in New Zealand to be considered available as such. Conditions for its growth and survival would be found only in a small area of the country were its host to occur here in numbers large enough to provide accessible host material (AK & ND). For these reasons it is not considered a potential hazard in this risk analysis.

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6.17 *Phytophthora palmivora* (Phytophthora Fruit Rot)

6.17.1 Hazard Identification

Aetiological agent: *Phytophthora palmivora* (Butler) Butler (Oomycota: Pythiales: Pythiaceae)

Synonyms: *Phytophthora faberi, Phytophthora theobromae, Phytophthora palmivora* var. *theobromae, Phytophthora omnivore, Phytophthora fici, Phytophthora carica*

New Zealand Status: Not known to be present in New Zealand (not recorded in Pennycook 1989; Pennycook & Galloway 2004; PPIN 2006; NZFungi 2006)

6.17.2 Biology

Phytophthora palmivora is heterothallic, having an incompatibility system by which only genetically different strains can undergo nuclear fusion during sexual reproduction. There are 2 mating types of *P. palmivora* A1 and A2, and both are found in many areas of the world (Zentmyer 1988). It is suggested that central and South America may be the centre of origin for the pathogen (Zentmyer 1984) with subsequent worldwide dissemination by human transport of infected cacao and rubber plants. Transmission in cacao is by direct contact between diseased and healthy pods, by rain splash from diseased pods, leaves and infested soil and by insect vectors and ant tents (Stamps 1985). In rubber plantations rain is the transmission agent while soil is the inoculation source for pawpaw root rot (Stamps 1985).

In cocoa plantations in Ghana the incidence of *P. palmivora* cankers was concentrated between 41 and 100cm from ground level. The majority (71.8 percent) of the cankers in the solely *P. palmivora* infected area were cushion borne, followed by 24.3 percent from unknown sources and only 3.9 percent from the soil. These results emphasise the importance of different reservoirs as sources of primary inoculum for the species (Appiah *et al.* 2004).

In durian zoospores of *P. palmivora* are preferentially attracted to wounds which are shown to be key infection centres (O'Gara *et al.* 2004). When infection occurred through fresh wounds in leaves, lesions appeared within 2 days and leaves were entirely diseased within 6 days (O'Gara *et al.* 2004). Artificial or natural wounds caused by cuttings or induced by wind or rain were the two main methods for penetration and dissemination of *Phytophthora* in orchards in Taiwan (Ann 1995).

Although sporangia and zoospores may survive in soil for short periods, chlamydospores are the main survival structure for *P. palmivora* in nature. Oospores are capable of long-term survival but do not play a significant role in the disease cycle because sexual reproduction requires the presence of opposite mating types, and the chance for this to occur in nature is very low (Ko 1993). The pathogen produces abundant sporangia on the surface of infected fruit that are further dispersed by wind blown rain. Chlamydospores formed in fallen fruit survive in soil and serve as the main source of inoculum for infection of roots of papaya seedlings in subsequent plantings (Ko 1993).

Maximum, optimum and minimum temperatures for mycelial growth of isolates on agar in lab conditions were approximately 35°C, 24-32°C and 10°C respectively. The optimum temperature for sporangial production both on 5 percent V-8 agar and on the surface of *Cattleya* leaves was 24°C. The number of sporangia produced was highest at 100 percent relative humidity, whereas no sporangia were produced below 80 percent relative humidity.

The optimum temperature for direct germination of sporangia of tested isolates was at 24 °C. No zoospores were formed at 35°C (Yeh *et al.* 1998). Ann (1994) found that in general soils with a pH <5.0 were more suppressive of sporangial germination than those with a higher pH although this was variable among soil types. These soils were found to be widely distributed in western Taiwan (Ann *et al.*1991).

Major diseases caused are: black pod, stem canker and chupon wilt of *Theobroma cacao*; purple blotch and fruit rot of *Annona squamosa*; fruit rot of *Artocarpus communis*; root and fruit rot of *Carica papaya*; bud rot and premature nut fall of *Cocos nucifera* and other palms and foot rot of *Piper nigrum* (Erwin & Ribeiro 1996).

6.17.3 Hosts

There are 166 species from various plant families listed as hosts (Stamps 1985; Erwin & Ribeiro 1996). Some major hosts are:
Areca catechu (betelnut palm), *Carica papaya* (papaw), *Cocos nucifera* (coconut), *Hevea brasiliensis* (rubber), *Theobroma cacao* (cocoa). Other hosts include:
Anacardium occidentale (cashew nut), *Ananas comosus* (pineapple), *Annona* spp., *Areca* spp., *Artocarpus altilis* (breadfruit), *Citrus x paradisi* (grapefruit), *Durio zibethinus* (durian), *Elaeis guineensis* (African oil palm), *Euphoria longana* (Kooariyakul & Bhavakul 2005; Erwin & Ribeiro 1996) *Ficus carica* (fig), *Gossypium hirsutum* (Bourbon cotton), *Manihot esculenta* (cassava), *Manilkara zapota* (sapodilla), *Myristica fragrans* (nutmeg), *Piper nigrum* (black pepper) (CPC 2004). *Litchi chinensis* is not recorded as a host.

6.17.4 Distribution

P. palmivora is widespread throughout Asia, Africa, the Americas and large parts of Oceania. It is also found in the Mediterranean area of Europe including France, Greece, Italy and Spain (CPC 2006).

6.17.5 Hazard Identification Conclusion

Phytophthora palmivora occurs in Taiwan and is a major pathogen on woody fruit trees and ornamental species, primarily occurring in soil, but has never been associated with *Litchi chinensis* there. It is thought to occur on litchi fruit in Thailand but there is no published literature around this. It occurs on another Sapindaceae relative, longan, in the Philippines and Thailand. Without sufficient literature to support an association *P. palmivora* is not considered a hazard in this risk analysis.

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6.18 *Uredo nephelii* (Rust Fungi)

6.18.1 Hazard Identification

Aetiological agent: *Uredo nephelii* (Basidiomycota: Teliomycetes: Uredinales)

Synonyms: *Skierka nephelii*

New Zealand Status: Not known to be present in New Zealand (not recorded in Pennycook 1989; Pennycook & Galloway 2004; NZFungi 2006)

6.18.2 Biology

Rusts (Uredinales or Urediniomycetes) are obligate parasites of vascular plants. Some are economically serious crop pathogens, others being minor or major nuisances in horticulture. Infection is usually local, forming individual colonies in leaves or other aerial parts of the host and dependent on re-infection each year. Infection is sometimes systemic and persistent in the plant (Silverside 2001).
Life cycles are usually complex, involving up to five distinct types of spore and often two different hosts.

In general Uredinales are highly host-specific, restricted to single or closely related hosts at a particular stage of their life-cycle, though the two hosts of a heteroecious (alternating between two different hosts) species are usually very different. When rusts infect closely related species, it may show further minor morphological and or physiological specialisation to single hosts without cross infection being possible (Silverside 2001).

Uredo nephelii is a little documented rust fungus that has been recorded from *Litchi chinensis* in Asia, there is no information available on its life cycle, or environmental tolerances. It is associated with the leaves of litchi in China (Hiratsuka & Chen, 1991; Hiratsuka *et al*., 1992).

6.18.3 Hosts

It is only known to occur on *Litchi chinensis* (Farr *et al.* 2006).

6.18.4 Distribution

U. nephelii is recorded from China, Japan and Taiwan (Hiratsuka & Chen 1991; Hiratsuka *et al.* 1992; Tai 1979).

6.18.5 Hazard Identification Conclusion

This rust appears to be highly host specific, with a very simple life cycle, consisting of one spore type that can infect only the same host it originated from. It would be very unlikely for *Uredo nephelii* to enter New Zealand on the pathway and then find host material. It usually attacks leaves and would not commonly be associated with fruit. Litchi and related Sapindaceous plants such as longan and rambutan don’t grow in significant numbers in New Zealand to provide accessible host material. It is not perceived as an important pathogen in litchi production given the lack of information available about the species and is therefore not considered a potential hazard in this risk assessment.

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Witches' Broom

6.19 Longan Witches' Broom (LWBDV)

6.19.1 Hazard Identification

Aetiological agent: *Mycoplasma like virus organism*

New Zealand Status: Not known to be present in New Zealand (not recorded in PPIN 2006)

6.19.2 Biology

The cause of this plant disease has remained controversial over the last three decades, with various authors proposing a viral agent (So & Zee 1972, Ye *et al.* 1990 in DAFF 2004, Chen *et al.* 1996, Chen *et al.* 2001), a mite *Aceria dimocarpi* and a transmitted phytoplasma (Chantrasri *et al.*1999, Visitpanich *et al.* 1999 in DAFF 2004), or a mycoplasma (Menzel *et al.* 1989) with other insect vectors including *Tessaratoma papillosa* (litchi stinkbug) and a longan psyllid *Corynegenasylla sinica* (Koizumi 1995). Another possible vector of longan witches' broom is dodder weeds. Dodder feeding on infected longan shoots in India was able to transfer the causal organism and produce symptoms in periwinkle plants (*Catharanthus rosea*) (Chantrasri *et al.* 1999). None of the vectors occur in New Zealand.

It is transmitted from one longan tree to another and also from longan to litchi. The symptoms in longan are very similar to those produced by litchi witches' broom disease. A close relationship between the two diseases is indicated (Koizumi, 1995). The disease in litchi is transmitted by seedling, inarching and by vectors. It is also associated with the presence of filamentous virus particles in leaf phloem cells (DAFF 2004). Young leaves on the shoots of infected plants become rolled and reduced in size, with excessive proliferation of shoots that become broom like in appearance. The flowering panicles become considerably aggregated in clumps (Chen *et al.* 1992).

Germination in laboratory conditions in China occurred between 15 and 20 days after inoculation (Wang 2001) with daily illumination of 2000 lux for 8 to 10 hours and temperatures of 25 +or_1°C. A study conducted in Hong Kong revealed that disease symptoms were more frequent on younger longan trees (10-25 years) than on older trees (So & Zee 1972).

Other members of the Sapindaceae such as *Dodonea viscosa* in Hawaii (this plant also occurs naturally in New Zealand) are seriously affected by a witches' broom disease (Borth *et al.* 1995), but there has been no examination of the relationship between these pathogenic agents.

6.19.3 Hosts

Plant parts affected are the flowers, leaves, shoots and seeds (Menzel *et al.* 1989, Chen *et al.* 2001) of its major hosts *Dimocarpus longan* (Qui 1941 in DAFF 2004) and *Litchi chinensis* (Chen *et al.* 1996).

6.19.4 Distribution

It has been recorded from Brazil, China, Taiwan, and Thailand, (So & Zee 1972, Kitajima *et al.* 1986, Menzel *et al.* 1989, Zhu *et al.* 1994, Chen *et al.* 2001).

6.19.5 Hazard Identification Conclusion

Longan witches' broom is a major pathogen of litchi and longan in Taiwan, and is generally found in tropical environments with higher temperatures. Climate would be a limiting factor in its establishment here in New Zealand. There would be no host material as neither litchi nor longan are grown here in significant numbers to provide accessible host material. No vector agents known to transmit the disease occur in New Zealand either. Were the vectors and the disease itself present there is uncertainty around the potential for the disease to host switch to a native Sapindaceae, e.g. *Dodonea viscosa* which is attacked by a similar witches' broom in Hawaii. Due to these factors longan witches' broom is not considered a potential hazard in this risk assessment.

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6.20 Tropical Pests

Many species of insects and mites occur principally in tropical latitudes and can have a narrow band of temperature tolerance for their growth and development. They are often not recorded occurring outside a particular temperature range and may be characterised by fast generation rates and high reproductive output. Many in the context of this risk analysis are broad generalists while others have a specific association with litchi and its close relative longan. All pests considered in this category are directly associated with litchi fruit. Under current climatic conditions in New Zealand the probability of establishment of these "tropical pests" here is very low. Greenhouses and glasshouses are the exception to this generalisation, with conditions within these environments providing the humidity and temperatures required for such organisms to reproduce. The likelihood that fruit available in supermarkets harbouring pests or pathogens would come into contact with a greenhouse is estimated to be very low or negligible. This scenario is therefore not discussed within the individual pest assessments as a potential risk.

The following species (Table 4.) were reviewed and researched, but all had similar temperature requirements for growth and development (over 15°C) that suggested climate would be a significant limiting factor in their establishment and spread in New Zealand. Mean monthly air temperature in New Zealand between the years 1971-2000 during the 6 months when litchis are likely to be imported from Taiwan (May to October) was reviewed. 14.8ºC was the highest temperature recorded (NIWA 2007). This occurs in Kaitaia one of the most likely regions to provide adequate environmental and climatic conditions for newly establishing pests. This temperature is lower than the minimum thresholds for survival and development of many of the species representing typical examples of tropical pests.

Table 4. Tropical Pest Species

Species Name	Order
Chaetanaphothrips orchidii	Thysanoptera (thrips)
Selenothrips rubrocinctus	
Brevipalpus phoenicis	Acari (mites)
Thysanofiorinia leei	
Orthotydeus kochi	
Oligonychus litchi	Hemiptera (bugs)
Planococcus lilacinus	
Pseudaonidia trilobitiformis	
Pseudococcus jackbeardsleyi	
Pulvinaria psidii	
Selenaspidus articulatus	
Tessaratoma papillosa	
Homona coffearia	Lepidoptera (moths)
Statherotis discana	

Should a change in climate increase the current average temperatures recorded in New Zealand then pests not currently able to establish now, could be a biosecurity issue in the future and this pest list should be reviewed. Treatment measures including vapour heat or cold disinfestation and visual inspection will mitigate the current low risk of potential entry of these organisms.

6.21 Risk Management Conclusions

The following risk management measures and phytosanitary procedures are recommended to mitigate the risks identified in this import risk analysis.

- Pre-export vapour heat treatment (VHT) for the management of *A. gossypii*, *K. lacca*, *Lymantria* spp., *Ceroplastes rubens* and *C. pseudoceriferus*, *I. longirostris* and *F. virgata*. No efficacy data exists for scales or aphids on litchi fruit, so data for the disinfestation of fresh flowers is used as a surrogate (Hansen *et al.* 1992). This recommended temperature is 45.2ºC for 2 hours. Because other organisms such as fruit flies require higher temperatures to ensure disinfestation from mangoes this higher temperature of ≥ 46.5 ºC at 20 minutes (Kuo *et al.* 1987) is the recommended measure overall.

- Cold disinfestation treatment pre-export or in transit for the management of *Bactrocera cucurbitae*, *B. dorsalis* and *Conopomorpha sinensis*. Two sources of efficacy data exist for the elimination of fruit flies, one for longan (Liang *et al.* 1999) recommending fruit are held at a temperature of 1 ºC for 13 days. The other for litchi fruit (Lin *et al.* 1987) recommending fruit are held at 1 ºC for 12 days. Su *et al.* (1993) provide efficacy data for the elimination of *Conopomorpha sinensis* in litchi which recommends fruit are cooled to 1 ºC for 14 days. Previous IHSs have suggested 1 ºC for 14 days as the cold disinfestation treatment for litchi fruit. In this risk analysis however it is determined that *C. sinensis* is not a potential hazard were it to enter New Zealand. It is therefore recommended that fruit be held at 0-1 ºC for 13 days in accordance with the more recent data of Liang *et al*. (1999).

- Continued control of fruit fly in litchi orchards in Taiwan. An audit is needed to verify this system. Inspections post harvest and after entering New Zealand should remain an integral part of the systems approach to biosecurity of both countries.

- Supporting operating systems to maintain and verify phytosanitary status

There are a number of points on the import pathway at which effective mitigating measures could be applied. The aim is to reduce the likelihood of live life stages of pests being intercepted at the border to an acceptable level. It is assumed with all fruits coming into New Zealand that the country of origin has a pest management system in place so these systems are not covered in this risk analysis in detail. They include:

1. Pest management systems in the production of fruit for export.
2. Screening to remove infested fruit before packaging and exports to New Zealand. Screening measures would be reliant primarily on the efficacy of visual inspection.
3. Visual inspection as a performance measure.

Appendix 1 Organisms Not Identified as Potential Hazards.

Aetiological agent*: *Abgrallaspis cyanophylli (Signoret) (Homoptera: Diaspididae)

Although *A. cyanophylli* occurs in Taiwan (Wong *et al.* 1999) there is no evidence to suggest that it is associated with *Litchi chinensis* in that country (Ben-Dov *et al.* 2006).

Aetiological agent*: *Acaspina litchii Huang & Hong (Acarina: Phytoseiidae)

There is only one published article on *A. litchii*, where the species is described for the first time, but which provides little information on its ecology or life history (Huang *et al.* 1990). It is unlikely to be even a minor pest of litchi fruit.

Aetiological agent*: *Achaea janata Linnaeus (Lepidoptera: Noctuidae)

This moth is a foliage feeder, and completes its development in leaf litter, and the adults are nocturnal (Mau & Kessing 1992). It is not associated with litchi trees in the literature, although it has been reported attacking longan and is unlikely to be associated with litchi fruit.

Aetiological agent*: *Adoretus sinicus Burmeister (Coleoptera: Scarabaeidae)

Adults are nocturnal and are the only life stage associated directly with plant parts; usually just foliage. The eggs are laid in the soil, and larvae spend most of their developmental stage underground (Williams 1931), so it is unlikely that these phases of the lifecycle would be associated with litchi fruit.

Aetiological agent*: *Aleurocanthus woglumi Ashby (Homoptera: Aleyrodidae)

Currently *A. woglumi* is recorded as absent from Taiwan but was formerly present there (EPPO 2006), and no literature exists to associate it with litchi fruit.

Aetiological agent*: *Alternaria alternata (Fr.) Keissel (Anamorphic Lewia)

This fungus is widespread in New Zealand and has multiple hosts (PPIN 2006).

Aetiological agent*: *Andaspis hawaiiensis Maskell (Hemiptera: Diaspididae).

There is no evidence in the literature that this species is a pest in Taiwan despite litchi being recorded as a minor host in Florida (Dekle 1965).

Aetiological agent*: *Anomala cupripes Hope (Coleoptera: Scarabaeidae).

The first instars are subterranean and later instars primarily foliage feeders so it is unlikely to be associated with fruit of its host plants. Although it is found in Taiwan there is no record in the literature of *A. cupripes* associated with *Litchi chinensis* (CPC 2006).

Aetiological agent*: *Anoplophora chinensis Forster (Coleoptera: Cerambycidae).

This beetle feeds on foliage and wood both during the adult and larval stages, so it is unlikely to be associated with litchi fruit (Lieu 1945)

Aetiological agent*: *Anoplophora maculata Thomson (Coleoptera: Cerambycidae)

Some authors consider *A. chinensis* and *A. maculata* the same species (Lingafelter & Hoebeke 2002). Their life histories and plant associations are basically identical, so *A. maculata* is not considered a hazard associated with the commodity (Lieu 1945).

Aetiological agent*: *Aphelenchus avenae Bastian (Apelendiida: Aphelenchidae)

This nematode is associated with litchi trees, but not with the fruit. It has been recorded in New Zealand three times on garlic bulbs in 1977 and 1986 (PPIN 2006). It is probably established here and is not considered of economic importance to garlic.

Aetiological agent*: *Aspergillus niger Van Tiegh (Hyphomycetes: Trichocomaceae).

This fungus has been recorded on a variety of species in New Zealand, most commonly onion and garlic (PPIN 2006).

Aetiological agent*: *Aspergillus restricutus Smith (Hyphomycetes: Trichocomaceae)

Aspergillus restrictus has been cultured from air and identified from shredded coconut in New Zealand (NZFungi 2006).

Aetiological agent*: *Attacus atlas Linneaus (Lepidoptera: Saturniidae)

A. atlas is a foliage feeder and would be highly conspicuous given its large size (it is the largest butterfly in the world). There is no evidence that it feeds on litchi fruit and it is not considered a hazard on the pathway.

Aetiological agent*: *Bacillus subtilis (Ehrenberg) Cohn (Sphingobacteriales: Flexibacteraceae)

This bacterium has been recorded from potato in central Canterbury in the South Island (PPIN 2006) and is probably common in New Zealand at low levels.

Aetiological agent*: *Brevipalpus phoenicis Geijskes (Acari: Tenuipalpidae)

B. phoenicis has been recorded in New Zealand (PPIN 2006) in 1991, and appears to be able to survive only within a very narrow temperature band (CPC 2006) making it highly unlikely to survive here.

Aetiological agent*: *Camposporium japonicum Ichinoe (Anamorphic Ascomycetes: Hyphomycetes).

C. japonicum is recorded from *Litchi chinensis* in Taiwan (Matsushima 1980) is terrestrial and usually found on submerged litter as a facultative aquatic (Goh 1997). It is likely to be associated with soil and leaf litter and not litchi fruit.

Aetiological agent*: *Cephaleuros virescens Kunsze (Chroolepidales: Chroolepidaceae)

This alga has been found on leaves of both native and introduced species in New Zealand (PPIN 2006) including *Metrosideros kermadecensis, Grisilinia littoralis, Passiflora edulis, Banksia serrata, Eucalyptus* spp. and *Callicoma serratifolia*.

Aetiological agent*: *Chaetanaphothrips orchidii Moulton (Thysanoptera: Thripidae)

C. orchidii has a very narrow temperature range for development and survival (between 21°C – 27°C, Hata & Hara 1992), and climate would be a severely limiting factor in the thrips establishing and spreading in New Zealand.

Aetiological agent*: *Cletus trigonus Thunberg (Hemiptera: Coreidae)

Although *C. trigonus* has been associated with longan orchards in China (Tan *et al.* 1997) there is no evidence that it affects litchi. It feeds primarily on foliage (Kwon 1995).

Aetiological agent*: *Coccus hesperidum Linnaeus (Hemiptera: Coccidae)

This scale insect is widespread throughout New Zealand (PPIN 2006; Hodgson & Henderson 2000; Scott & Emberson 1999). It is associated with the veins found on stems leaves and green twigs of its host plants (Copland & Ibrahim 1985).

Aetiological agent*: *Coccus longulus (Douglas) (Hemiptera: Coccidae)

This scale insect has been recorded in New Zealand (PPIN 2004) on native and exotic plant species (Hodgson & Henderson 2000). It is associated with the veins found on stems leaves and green twigs of its host plants (Copland & Ibrahim 1985).

Aetiological agent*: *Coccus viridis (Green) (Homoptera: Coccidae)

Although *C. viridis* has been recorded associated with *Litchi chinensis* in Hawaii (Nakahara 1981), there is no evidence for it attacking the fruit. It has only been found associated with citrus (Tao & Wu 1969) and mulberry (Maki 1916) in Taiwan and occurrs primarily along veins on stems, leaves and twigs (Copland & Ibrahim 1985).

Aetiological agent*: *Corynespora cassiicola Berkeley & Curtis (Mitosporic fungi Hyphomycetes).

Although *C. cassiicola* has been recorded on sesame and cucumber in Taiwan (Wu 1988; Tsay & Kuo 1991) there is no evidence to suggest that it occurs on *Litchi chinensis*. It has also been recorded on cucumber and *Anthurium* in New Zealand (NZFungi 2006).

Aetiological agent*: *Curvularia lunata (Wakker) Boedijn (Anamorphic *Cochliobolus*)
Teleomorph: Cochliobolus lunatus Nelson & Haasis (Dothideomycetidae: Pleosporaceae).

C. lunata has a localised distribution in North Island New Zealand. Its optimum developmental conditions are concurrent high temperatures and high humidity (Pratt 2006), factors which may explain why it doesn't occur south of Auckland and suggests it is unlikely to become more widespread.

Aetiological agent*: *Dasychira mendosa Hübner (Lepidoptera: Lymantriidae)

Shiraki (1920) and Maki (1916) both record the moth as being present in Taiwan, on tea and mulberry, and it is recorded on litchi in Thailand (Kuroko & Lewvanich 1983). There is no evidence to suggest the organism is associated with litchi in Taiwan. Furthermore *D. mendosa* is a foliage feeder and is not associated with fruit.

Aetiological agent*: *Deudorix epijarbas Moore (Lepidoptera: Lycaenidae)

Past literature (Fullaway 1927, Djou 1938, Liu 1964) states that *D. epijarbas* has been considered a pest of litchi fruit in south China, Hong Kong, Hawaii and South Africa. It is also recorded being a minor pest of Macadamia in Australia (Ironside 1979), but there is no evidence that the butterfly occurs in Taiwan.

Aetiological agent*: *Dimeriella dendrocalami Sawada & Yamam (Dothidiales: Parodiopsidaceae)

There is very little information available on this fungus. There is only one published article by Sawada (1959) on taxonomic description. It is unlikely to be a significant pathogen of litchi fruit, as it has only been associated with the leaves of the tree (AFFA 2004).

Aetiological agent*: *Epilachna vigintioctopunctata (Fabricius) (Coleoptera: Coccinellidae)

Epilacna vigintioctopunctata is a specialist herbivore of solanaceous plants, but it will feed briefly on other plants outside this group. However it does not overcome its constitutive and induced resistance to non host plants to utilise them fully (Shinogi *et al.* 2005).

Aetiological agent*: *Ernothrips lobatus Bhatti (Thysanoptera: Thripidae).

Although *E. lobatus* is found in Taiwan (Masumoto & Okajima 2000) and its congeners are associated with floral inflorescences it is unlikely to be found on mature litchi fruit (Sakai *et al.* 1999).

Aetiological agent*: *Erythricium salmonicolor (Berkeley & Broome) Burdsall (***Corticium salmonicolor*** Berkeley & Broome) (Polyporales: Phanerochaetaceae).

Its categorisation on the Landcare Fungal Database is indigenous, but non-endemic to the region (NZFungi 2006). It has been found in North Island on *Malus sylvestris*, *Malus pumila* and *Pinus comunis*.

Aetiological agent*: *Eudocima fullonia Clerck (Lepidoptera: Noctuidae)

E. fullonia is recorded as an occasional immigrant occurring throughout New Zealand (Dugdale 1988) but has not become established. It is assumed that the conditions for its survival are limited here in New Zealand. It is occasionally blown over from Australia.

Aetiological agent*: *Eucalymnatus tessellatus (Signoret) (Homoptera: Coccidae).

Dekle (1999) states that *E. tessellatus* is a pest on *Litchi chinensis*, but there is no evidence it is associated with fruit, only the leaves of its host.

Aetiological agent*: *Eumeta variegata Snellen (Lepidoptera: Psychidae)

Although Sonan (1923) and Maki (1916) reported the moth on tea and mulberry tree in Taiwan earlier last century there is no evidence in the literature that it is associated with litchi fruit. It is only known to be associated with the stems and trunk (AFFA 2004).

Aetiological agent*: *Euwallacea fornicatus Eichhoff (Coleoptera: Scolytidae)

E. fornicatus feeds on certain kinds of fungi which the females carry from tree to tree and inoculate in their burrow system (Thomas 2006) not feeding on the woody tissue as most other bark beetles do. It is not known to be associated with litchi fruit.

Aetiological agent: Geotrichum candidum Link (Sacharromycetales: Dipodascaceae) **(Teleomorph: *Galactomyces geotrichum*** (Butler & Petersen) Redhead & Malloch (Saccharomycetales: Dipodascaceae)).

This fungus has been recorded in New Zealand on *Actinidia deliciosa* (kiwifruit), *Citrus* spp., *Ipomoea batatas* (kumara), *Lycopersicon esculentum* (tomato), *Solanum tuberosum* (potato) and *Prunus persicae* (peach) and as a pathogen on insects (NZFungi 2006).

Aetiological agent*: *Geotrichum ludwigii (Saccharomycetales: Dipodascaceae)

The optimal temperatures for the growth of *G. ludwigii* in Taiwan was found to be between 28-32°C with the optimal pH level between 6-9 (Tsai & Hseih 1998). These temperatures exceed the monthly averages of both New Zealand winters and summers. There would be no host plants for the fungus were it to enter the country.

Aetiological agent: Glomerella cingulata (Stoneman) Spaulding & Schrenk (Sordariomycetidae: Glomerellaceae) ***(*Anamorph: *Colletotrichum gloeosporioides)*** (Penzig) Penzig & Saccardo).

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).

Aetiological agent*: *Helicotylenchus crenacauda Sher (Secernentea: Tylenchida: Hoplolaimidae)

Helicotylenchus crenacauda has been recorded infecting roots of longan trees in China (Liu & Zhang 1999), and rice in Taiwan (Tsay 1996) but there is no evidence the nematode infects *Litchi chinensis* in either country.

Aetiological agent*: *Helicotylenchus exallus (Secernentea: Tylenchida: Hoplolaimidae)

H. exallus occurs naturally in native vegetation and undisturbed soils in New Zealand (Wouts & Yeats 1994).

Aetiological agent*: *Homona coffearia Nietner (Lepidoptera: Tortricidae)

Given its current longevity under optimal laboratory conditions (with relative high humidity, 75%RH and temperature 24°C) which appear close to longevity observed in the wild (Gadd 1946), it is assumed that *H.coffearia* would be unlikely to survive climatic conditions in New Zealand.

Aetiological agent*: *Hypomeces squamosus Fabricius (Coleoptera: Curculionidae)

The larvae of this weevil feed on the roots of host plants and the adults are foliage feeders and eat vegetative growing parts (Khen 2001). There is no evidence of an association with litchi trees in Taiwan or elsewhere.

Aetiological agent*: *Icerya seychellarum (Westwood) (Hemiptera: Margarodidae)

Although *I. seychellarum* is recorded as occurring in Taiwan (Wong *et al.* 1999) there is only one record of the scale associated with litchi, and that is from Mauritius in 1939 (Jepson 1939). With no subsequent data of an association anywhere in its range (CPC 2006) it is not considered a hazard in this risk analysis.

Aetiological agent*: *Kilifia acuminata (Signoret) (Homoptera: Coccidae)

Kilifia acuminata has been recorded on litchi in Hawaii (Nakahara 1981) and is present in Taiwan (Tao 1989), but is associated with the stems of the tree not the fruit (Ali 1971; Nakahara 1981). Therefore it is not considered a potential hazard in this risk analysis.

Aetiological agent*: *Locusta migratoria (Linnaeus) (Orthoptera: Acrididae).

This locust is a common insect in summer months in both North and South Islands of New Zealand but does not reach plague proportions, probably because temperatures are not high enough to trigger swarming (Landcare Research 2006).

Aetiological agent*: *Megalurothrips distalis Karny (Thysanoptera: Thripidae)

High population density of *Megalurothrips distalis* occurs in the blooming stage of many plant species, leading to damaged flowers and young fruits (Chiu *et al.* 1991). It is also reported occasionally on leaves but is unlikely to be associated with mature litchi fruit.

Aetiological agent*: *Meloidogyne incognita Kofoed & White (Tylenchida: Meloidogynidae)

This nematode has been recorded in New Zealand (Scott & Emberson 1998) on members of the Fabaceae, Cucurbitaceae, Solanaceae, Alliaceae and Rutaceae. It is most commonly found on potato and tomato (PPIN 2006), and had been implicated in reduction in productivity of tamarillo (Cooper & Grandison 1987).

Aetiological Agent: Nezara antennata Scott (Heteroptera: Pentotomidae)

Although Hsu & Hsu (1977) record the incidence of *N. antennata* on asparagus in Taiwan there is no evidence in the literature that this pentatomid is associated with litchi. It has been recorded in longan orchards in China (Tan *et al.* 1997)

Aetiological Agent: Nipaecoccus viridis (Newstead) (Homoptera: Pseudococcidae)

Although this scale insect occurs in Taiwan there is no record of it as a pest on litchi trees (Ben-Dov 2006). It does attack *Nephelium lappaceum* (rambutan), (Williams 2004) which is in the Sapindaceae but is not considered a potential hazard in this risk analysis.

Aetiological agent*: *Odontotermes formosanus Shiraki (Isoptera: Termitidae)

O. formosanus occurs in Taiwan and has been associated with longan orchards there (Wen *et al.* 2002). However termites feed primarily on wood and species within the Termitidae will grow fungi inside their nests on faecal pellets to use as a primary food source. It is therefore unlikely *O. formosanus* would be associated with litchi fruit.

Aetiological agent*: *Oligonychus biharensis Hirst (Acarina: Tetranychidae)

O. biharensis feeds primarily on cell tissue of leaves (Lee *et al.* 1994) and is not likely to be associated with the fruit of litchi. Temperature is an important variable influencing reproductive rate and population growth of *O. biharensis*. It was observed (Ji *et al.* 2005) that under lab conditions in China the lowest finite rate of increase (lambda), and intrinsic rate of natural increase of the population was at 15°C. Temperature would be a severely limiting factor to its establishing in New Zealand.

Aetiological agent*: *Oligonychus litchi Lo & Ho (Acarina: Tetranychidae)

Low rainfall (Ho 2000) and high temperatures of approximately 27°C (Fasulo & Denmark 2000) are optimum for development of *O. litchi*. These would be severely limiting factors in the survival of *O. litchi* in New Zealand.

Aetiological agent*: *Orthotydeus kochi (Oudemans) (Acarina: Tydeidae)

O. kochi is regarded primarily as a predatory mite, associated with mealybugs and other phytophagous pests (Abou *et al.* 1994). There is no evidence of it causing damage to its plant hosts, and it is assumed it would have a negligible impact if it was to enter New Zealand.

Aetiological agent*: *Panonychus citri McGregor (Acari: Tetranychidae)

P. citri is widespread throughout New Zealand and occurs on many citrus species (PPIN 2007).

Aetiological agent*: *Parasaissetia nigra (Nietner) (Hemiptera: Coccidae)

This mealybug is distributed sporadically 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 & Henderson 2000).

Aetiological agent*: *Phaeosaccardinula javanica (Zimmermann) Yamamoto (Chaetothyrium: Dothideales: Chaetothyriaceae)

This fungus is predominantly associated with leaves (Eriksson & Yue 1985; Tai 1979), and is unlikely to be a significant pest on litchi fruit.

Aetiological agent*: *Phellinus noxius (Corner) Cunningham (Hymenochaetales: Hymenochaetaceae)

This fungus, known as root rot or wood rot, is primarily associated with the roots of fruit trees and ornamental plants (Ann *et al.* 1999) and is unlikely to be associated with litchi fruit.

Aetiological agent*: *Phyllotreta striolata Fabricius (Coleoptera: Chrysomelidae)

The crucifer flea beetle has a narrow host range restricted to plants primarily in the mustard family (Knodel & Olson 2002). Larvae tend to feed on root hairs, and adults on foliage. There is no recorded association with litchi fruit in the literature.

Aetiological agent*: *Pinnaspis strachani (Cooley) (Hemiptera: Diaspididae)

Although it is said to attack litchi trees (Williams & Watson 1988) it feeds on xylem from stem and leaf parts of the plant (Tenbrink & Hara 1992) and is therefore not considered a hazard in this risk assessment.

Aetiological agent*: *Planococcus citri (Risso) (Hemiptera: Pseudococcidae)

This mealybug is a major pest of citrus species throughout its cosmopolitan distribution. It is found in Taiwan but there is no record of it attacking litchi there or elsewhere (Ben-Dov 2006). There are no records of it attacking any member of the Sapindaceae.

Aetiological agent*: *Pratylenchus brachyurus Godfrey (Secernentea: Tylenchida: Pratylenchidae)

In common with other species of *Pratylenchus*, *P. brachyurus* invades the cortical tissues of roots producing cavities or tunnels resulting in lesions (Lindsey & Cairns, 1971). It is very unlikely to be associated with the fruit of litchi in Taiwan.

Aetiological agent*: *Pratylenchus coffeae (Zimmerman) Filipjev & Steckh (Tylenchida: Pratylenchidae)

This nematode causes lesions on roots of many plant species including citrus (MacGowan 1978) and banana (Elsen *et al.* 2005), and is very unlikely to be associated with litchi fruit.

Aetiological agent*: *Pseudaonidia trilobitiformis (Green) (Homoptera: Diaspididae)

This scale insect has been recorded in Taiwan (Wong *et al.* 1999) but is not associated with litchi there or elsewhere.

Aetiological agent*: *Pulvinaria polygonata Cockerell (Homoptera: Coccidae)

This scale insect has been recorded in Taiwan (Takahashi 1939) but has not been associated with litchi (Ben-Dov *et al.* 2006).

Aetiological agent*: *Pulvinaria psidii Maskell (Homoptera: Coccidae)

P.psidii was observed to be abundant in Egypt when both temperature and humidity were relatively high (26-27.3°C and 72 percent respectively) Salama & Saleh (1970). It is unlikely given the cooler temperatures in New Zealand and its current tropical distribution that it would establish here.

Aetiological agent*: *Ricania speculum Walker (Homoptera: Ricaniidae)

This ricaniid occurs in Taiwan but is not associated with *Litchi chinensis* in the literature there or anywhere in its range (Yang 1989; Oben *et al.* 1986).

Aetiological agent*: *Rotylenchulus reniformis Linford & Oliveira (Secernentea: Tylenchida: Hoplolaimidae)

R. reniformis is associated with the rhizosphere of litchi trees (Tu *et al.* 1972; Tsay *et al.* 1994) but does not directly affect fruit.

Aetiological agent*: *Saissetia coffeae (Walker) (Homoptera: Coccidae)

This scale insect is widespread in New Zealand (Cottier 1938; Everett 1945; Hodgson & Henderson 2000) and is a major pest on citrus fruit.

Aetiological agent*: *Selenaspidus articulatus (Morgan) (Homoptera: Diaspididae)

Evidence suggests the optimum range of temperature for survival of *S. articulatus* is between 17 and 35°C (Bartra 1974; Perruso & Cassina 1993). Climate in New Zealand would present a severe limiting factor to the scale's establishment.

Aetiological agent*: *Selenothrips rubrocinctus (Giard) (Thysanoptera: Thripidae)

Selenothrips rubrocinctus is restricted to tropical areas and appears to have optimum reproduction and growth at high temperatures and high light environments (Boboye 1968; Darling 1942), conditions that are only met at the height of summer in some parts of New Zealand. It is unlikely that if *S. rubrocinctus* did enter the country on the pathway that it would survive the winter months here.

Aetiological agent*: *Solicorynespora litchi (Matsushima) Castañeda & Kendrick (Anamorphic: Ascomycetes).

S. litchi is present in Taiwan (Matsushima 1980) but is only associated with leaves of litchi trees (IndexFungorum 2006). Lack of literature on the fungus suggests it is a minor pathogen on its host plant.

Aetiological agent*: *Spodoptera litura Fabricius (Lepidoptera: Noctuidae)

This moth occurs in localised areas of New Zealand (Malone & Wigley 1980) and has been associated with *Malus domestica* (apple), *Actinidia deliciosa* (kiwifruit), *Vitis vinifera* (grapes), *Pyrus communis* (pear), *Triticum* spp., (wheat) and *Zea maize* (maize).

Aetiological agent*: *Sporidesmium filiferum (Hyphomycetes)

S. filiferum was originally described from decaying leaves in tropical leaf litter (Pirozynski 1972) and in the absence of any known sexual stage, the life cycle is probably confined to a soil, leaf litter habitat.

Aetiological agent*: *Sporidesmium tropicale M.B. Ellis (Anamorphic Ascomycetes)

Sporidesmium tropicale was described as a saprophyte, occurring on dead branches of many different trees (Ellis 1958). It is unlikely to be associated with litchi fruit.

Aetiological agent*: *Statherotis discana Felder & Rogenhofer (Lepidoptera: Tortricidae)

Statherotis discana is a minor pest of litchi (Sauerborn *et al.* 2003) throughout its tropical distribution. Winter temperatures would be a limiting factor in its survival in New Zealand.

Aetiological agent: Thysanofiorinia leei Williams (Homoptera: Diaspididae)

Like other scales it is assumed *T. leei* is not directly associated with litchi fruit, but feeds as most coccids do, on the parenchyma cell sap accessed through leaves and stems (Koteja 1990). With its tropical distribution it is also unlikely to survive cooler temperatures over winter in New Zealand.

Aetiological agent: Tylenchorhynchus nudus Allen (Secernentea: Tylenchida: Tylenchulidae)

T. nudus is an ectoparasitoid on epidermal cells and root hairs, moving along the roots as it feeds, mostly at the tips (Hagen 2005). It is unlikely to come into contact with litchi fruit.

Aetiological agent*: *Tylenchulus semipenetrans Cobb (Tylenchida: Tylenchulidae)

This nematode is associated with persimmon (*Diospyros kaki*) avocado (*Persea americana*) and passionfruit (*Passiflora* spp.) in New Zealand (Yeates 2004; Knight 2001).

Aetiological agent*: *Xiphinema americanum Cobb (Dorylaimida: Longidoridae)

X. americanum has been found in soil beneath tamarillo (*Cyphomandra betacea*), grape vines (*Vitis vinifera*), kiwifruit (*Actinidia deliciosa*), feijoa (*Feijoa sellowiana*), passionfruit (*Passiflora* spp.) and avocado (*Persea americana*) in New Zealand (PPIN 2006). It has only been linked conclusively in a pest host relationship with tamarillo (Cooper & Grandison 1987).

Aetiological agent*: *Xiphinema elongatum Stekhoven & Teunissen (Adenophorea: Dorylaimida: Longidoridae)

Xiphinema elongatum has been isolated from the rhizomes of litchi trees in Taiwan (Chen *et al* 2004b), but is not known to be associated with the fruit.

Aetiological agent*: *Xiphinema hunaniense Wang & Wu (Adenophorea: Dorylaimida: Longidoridae)

Populations of *X. hunaniense* have been isolated from the rhizomes of *Litchi chinensis* (Chen *et al.* 2004c) but there is no evidence that it is associated with fruit.

Aetiological agent*: *Xiphinema insigne Loos (Adenophorea: Dorylaimida: Longidoridae)

Xiphinema insigne like its congener *X. elongatum* has been isolated from the rhizosphere of litchi trees in Taiwan (Chen *et al.* 2004a & 2004b) but is not known to be associated with the fruit.

Aetiological agent*: *Zeuzera coffeae Nietner (Lepidoptera: Cossidae)

Zeuzera coffeae is common in Taiwan attacking grape vines (Chang 1987a; 1987b; 1988a; 1988b) and tea (Shiraki 1920). It was associated 91 years ago (Duport 1915) with litchi as a host plant in Vietnam (Tonkin and North Annam), but there is no literature or information to suggest it is a pest of litchi in Taiwan. It is a shoot and wood boring insect and is not normally associated with fruit.

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Appendix 2: Organisms considered in this risk analysis

Common name	Scientific name	In NZ?	Vector of a hazard	More virulent strains on goods overseas	Associated with litchi fruit	Unwanted organism or controlled	Potential Hazard?
Arthropods							
Acari (mites)							
Litchi gall mite	*Aceria litchii* Huang, Huang & Horng (Phytoseiidae)	n	n	n	Y Morton (1987)	n	n
Stigmaeid mite	*Agistemus exsertus* Gonzalez-Rodriguez (Stigmaeidae)	n	n	n	N Wang (1981)	n	y
False spider mite	*Brevipalpus phoenicis* (Geijskes, 1936) (Tetranychidae)	Y Collyer (1973)	n	n	N Childers *et al.* (2003)	n	n
Cassava red mite	*Oligonychus biharensis* Hirst (Tetranychidae)	n	n	n	N Lee *et al.* (1994)	n	n
Litchi spider mite	*Oligonychus litchii* Lo & Ho (Tetranychidae)	n	n	n	N Ho 2000	n	n
Tydeid mite	*Orthotydeus kochi* (Oudemans) (Tydeidae)	n	n	n	N Abou *et al.* (1994)	n	n
Citrus red mite	*Panonychus citri* McGregor (Tetranychidae)	n	n	n	N Hidenari (2002)	n	n
Insecta							
Coleoptera							
Chinese rose beetle	*Adoretus sinicus* (Burmeister) (Scarabaeidae)	n	n	n	N Mau & Kessing (1991)	n	n
Large green chafer beetle	*Anomala cupripes* Hope (Scarabaeidae)	n	n	n	N Talekar & Nurdin (1991)	n	n
Black & white citrus longhorn beetle	*Anoplophora chinensis* (Forster) (Cerambycidae)	n	n	n	N Lieu (1945)	n	n
White spotted longhorn beetle	*Anoplophora maculata* Thomas (Cerambycidae)	n	n	n	N NAPPO (2006)	n	n
Tea shot hole borer	*Euwallacea fornicatus* Eichhoff (Scolytidae)	n	n	n	N Thomas (2006)	n	n
Hadda beetle	*Epilachna vigintioctopunctata* (Fabricius) (Coccinellidae)	n	n	n	N Shinogi *et al.* (2005)	n	n
Gold dust weevil	*Hypomeces squamosus* Fabricius (Curculionidae)	n	n	n	N Khen (2001)	n	n
Cabbage flea beetle	*Phyllotreta striolata* Fabricius (Curculionidae)	n	n	n	N Knodel & Olson (2002)	n	n
Diptera							
Melon fly	*Bactrocera cucurbitae* Cocuillet (Tephritidae)	n	n	n	Y Wen (1985)	y	y
Oriental fruit fly	*Bactrocera dorsalis* Hendel (Tephritidae)	n	n	n	Y Ho *et al.* (2003)	y	y
Hemiptera							

Common name	Scientific name	In NZ?	Vector of a hazard	More virulent strains on goods overseas	Associated with litchi fruit	Unwanted organism or controlled	Potential Hazard?
Cyanophyllum scale	*Abgrallaspis cyanophylli* Signoret (Diaspididae)	Y Charles & Henderson (2002)	n	n	N CPC (2006)	n	n
Citrus black fly	*Aleurocanthus woglumi* Ashby (Aleyrodidae)	n	n	n	N EPPO (2006)	n	n
Hawaiian scale	*Andaspis hawaiiensis* (Maskell) (Diaspididae)	n	n	n	N Ben-Dov *et al.* (2006)	n	n
Melon/cotton aphid	*Aphis gossypii* Glover (Aphididae)	Y Martin & Cameron (2003)	Y Brunt *et al.* (1996)	Y Brunt *et al.* (1996)	Y FAO (2004)	y	y
Indian wax scale	*Ceroplastes pseudoceriferus* Green (Coccidae)	n	n	n	Y Wen & Lee (1986)	n	y
Pink wax scale	*Ceroplastes rubens* Maskell (Coccidae)	n	n	n	Y Wen *et al.* (2002)	n	y
Rice slender bug	*Cletus trigonus* Thunberg (Coreidae)	n	n	n	N Kwon (1995)	n	n
Brown soft scale	*Coccus hesperidum* Linnaeus (Coccidae)	Y Charles *et al.* (2005)	n	n	N Copland & Ibrahim (1985)	n	n
Long brown scale	*Coccus longulus* Douglas (Coccidae)	Y Charles *et al.* (2005)	n	n	N Copland & Ibrahim (1985)	n	n
Green coffee scale	*Coccus viridis* (Green) (Coccidae)	n	n	n	N Copland & Ibrahim (1985)	n	n
Tessellated scale	*Eucalymnatus tessellatus* Signoret (Coccidae)	n	n	n	N Dekle (1999)	n	n
Striped mealybug	*Ferrisia virgata* Cockerell (Pseudococcidae)	n	Y Bhat *et al.* (2003)	Y Ollennu (2001)	Y McKenzie (1967)	n	y
Seychelles scale	*Icerya seychellarum* Westwood (Margarodidae)	n	n	n	N CPC (2006)	n	n
Black thread scale	*Ischnaspis longirostris* (Signoret) (Diaspididae)	n	n	n	N Dekle (1965)	n	n
Lac insect	*Kerria lacca* Kerr (Kerridae)	n	n	n	N BAPHIQ (2006)	n	y
Mango shield scale	*Kilifia acuminata* Signoret (Coccidae)	n	n	n	N Nakahara (1981)	n	n
Green stink bug	*Nezara antennata* Scott (Pentatomidae)	n	n	n	N Tan *et al.* (1997)	n	n
Spherical mealybug	*Nipaecoccus viridis* Newstead (Pseudococcidae)	n	n	n	N Williams (2004)	n	n
Black coffee scale	*Parasaissetia nigra* Nietner (Coccidae)	n	n	n	N Rutherford (1914)	n	n
Cotton white scale	*Pinnaspis strachani* (Cooley) (Diaspididae)	n	n	n	N Tenbrink & Hara (1992)	n	n
Citrus mealybug	*Planococcus citri* (Risso) (Pseudococcidae)	n	n	n	N Ben-Dov *et al.* (2006)	n	y
Coffee mealybug	*Planococcus lilacinus* Cockerell (Pseudococcidae)	n	n	n	N Cox (1989)	n	y

Common name	Scientific name	In NZ?	Vector of a hazard	More virulent strains on goods overseas	Associated with litchi fruit	Unwanted organism or controlled	Potential Hazard?
Banana shaped scale	*Prococcus acutissimus* (Green) (Coccidae)	n	n	n	N Fernandes (1993)	n	n
Trilobite scale	*Pseudaonidia trilobitiformis* Green (Diaspididae)	n	n	n	Y Borchsenius (1966)	n	n
Jack Beardsley scale	*Pseudococcus jackbeardsleyi* Gimpel & Miller (Pseudococcidae)	n	n	n	Y Gimpel & Miller (1996)	n	n
Cottony citrus scale	*Pulvinaria polygonata* Cockerell (Coccidae)	n	n	n	N Ben-Dov *et al.* (2006)	n	n
Guava mealy scale	*Pulvinaria psidii* Maskell (Coccidae)	n	n	n	Y Waite (1986)	n	n
Black leafhopper	*Ricania speculum* (Walker) (Ricaniidae)	n	n	n	N Oben *et al*. (1986)	n	n
Litchi bark scale	*Rutherfordia major* (Cockerell) (Diaspididae)	n	n	n	N Dekle (1976)	n	n
Coffee helmet scale	*Saissetia coffeae*Walker (Coccidae)	Y Hodgson & Henderson (2000)	n	n	Y Nakahara (1981)	n	n
Rufous scale	*Selenaspidus articulatus* (Morgan) (Diaspididae)	n	n	n	Y Williams & Watson (1988)	n	n
Litchi stinkbug	*Tessaratoma papillosa* Drury (Tessaratomidae)	n	n	n	Y Zhang (1997)	n	n
Scale	*Thysanofiorinia leei* Williams (Hemiptera: Diaspididae)	n	n	n	N Koteja (1990)	n	n
Hard scale	*Thysanofiorinia nephelii* Maskell (Diaspididae)	n	n	n	N Das & Das (1962)	n	n
Isoptera							
Subterranean termite	*Odontotermes formosanus* Shiraki (Termitidae)	n	n	n	N DEH (2006)	n	n
Lepidoptera							
Castor oil looper	*Achaea janata* Linnaeus (Noctuidae)	n	n	n	N Common (1990)	n	n
Apple peel tortricid	*Adoxophyes orana* Fisher von Röeslerstamm (Tortricidae)	n	n	n	Y Hill (1983)	n	Y
Atlas moth	*Attacus atlas* Linnaeus (Saturniidae)	n	n	n	N CPC (2006)	n	n
Cocoa pod borer	*Conopomorpha cramerella* (Snellen) (Gracillariidae)	n	n	n	N Hwang & Hung (1996)	n	n
Litchi leafminer	*Conopomorpha litchiella* Bradley (Gracillariidae)	n	n	n	Y Lall & Sharma (1978)	n	y
Litchi fruit borer	*Conopomorpha sinensis* Bradley (Gracillariidae)	n	n	n	Y Xie *et al*. (2005)	n	y
Macadamia nut borer	*Cryptophlebia ombrodelta* Lower (Tortricidae)	n	n	n	Y Menzel (2002)	n	y
Tussock caterpillar	*Dasychira mendosa* Hübner (Lymantriidae)	n	n	n	N Nagalingam & Savithri	n	n

Common name	Scientific name	In NZ?	Vector of a hazard	More virulent strains on goods overseas	Associated with litchi fruit	Unwanted organism or controlled	Potential Hazard?
					(1980)		
Grey litchi butterfly	*Deudorix epijarbas* Moore (Lycaenidae)	n	n	n	Y Herbison -Evans & Crossley (2002)	n	n
Fruit piercing moth	*Eudocima fullonia* Clerck (Noctuidae)	n	n	n	Y Fay & Halfpapp (1999)	n	n
Giant bagworm	*Eumeta variegata* (Snellen) (Psychidae)	n	n	n	N FAO (2007)	n	n
Tussock moth	*Euproctis taiwana* Shiraki (lymantriidae)	n	n	n	N CPC (2006)	n	y
Tea flushworm	*Homona coffearia* (Nietner) (Tortricidae)	n	n	n	Y Menzel (2002)	n	n
Asian gypsy moth	*Lymantria dispar* Linnaeus (Lymantriidae)	n	n	n	N Lin *et al.* (2000)	y	y
Pink gypsy moth	*Lymantria mathura* Moore (Lymantriidae)	n	n	n	N Roonwal *et al.* (1962)	y	y
Tussock/gypsy moth	*Lymantria xylina* Swindoe (lymantriidae)	n	n	n	N Shen *et al.* (2006)	n	y
Cocoa tussock moth	*Orgyia postica* Walker (Lymantriidae)	n	n	n	N Kumar & Ahmad (2000)	n	n
Noctuid moth	*Spodoptera litura* Fabricius (Noctuidae)	Y Malone & Wigley (1980)	n	n	N Yasui *et al.* (2006)	n	n
Litchi leaf roller	*Statherotis discana* (Felder & Rogenhofer) (Tortricidae)	n	n	n	N Wakamura *et al.* (1997)	n	n
Coffee leopard moth	*Zeuzera coffeae* Nietner (Cossidae)	n	n	n	N Mathew (1986)	n	n
Orthoptera							
Citrus locust	*Chondracris rosea* De Geer (Acrididae)	n	n	n	N Tinkham (1940)	n	n
Oriental migratory locust	*Locusta migratoria* (Linnaeus) (Acrididae)	Y Clunie (2004)	n	n	N Raubenheimer & Simpson (2003)	n	n
Thysanoptera							
Anthurium thrips	*Chaetanaphothrips orchidii* (Moulton) (Thripidae)	n	n	n	Y Hata & Hara (1992)	n	n
Thrips	*Ernothrips lobatus* (Bhatti) (Thripidae)	n	n	n	N Sakai *et al.* (1999)	n	n
Thrips	*Megalurothrips distalis* (Karny) (Thripidae)	n	n	n	Y Chiu *et al.* (1991)	n	n
Chilli thrips	*Scirtothrips dorsalis* Hood (Thripidae)	n	Y Meena *et al.* (2005)	n	N Chandrasekaran (2005)	n	y
Red banded thrips	*Selenothrips rubrocinctus* Giard (Thripidae)	n	n	n	N Fennah (1963)	n	y
Hawaiian flower thrips	*Thrips hawaiiensis* (Morgan) (Thripidae)	n	Y Inoue *et al.* (2004)	n	N Chiu *et al.* (1991)	n	y
Nematoda							
Nematode	*Aphelenchus avenae* Bastian (Apelendiida: Aphelenchidae)	Y Wood (1973)	n	n	N Ishibashi *et al.* (2005)	n	n
Spiral nematode	*Helicotylenchus crenacauda* Sher (Tylenchida: Hoplolaimidae)	n	n	n	N Chen *et al.* (2006)	n	n

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Spiral nematode	*Helicotylenchus exallus* Sher (Tylenchida: Hoplolaimidae)	n	n	n	N Eissa *et al.* (2003)	n	n
Root knot nematode	*Meloidogyne incognita* Kofoed & White (Tylenchida: Meloidogynidae)	Y Knight *et al.* (1997)	n	n	N Bibha & Bora (2005)	n	n
Root lesion nematode	*Pratylenchus brachyurus* (Godfrey) (Tylenchida: pratylenchidae)	n	n	n	N Brooks & Perry (1967)	n	n
Banana root nematode	*Pratylenchus coffeae* (Zimmerman) (Tylenchida: Pratylenchidae)	n	n	n	N Oramas-Nival & Roman (2006)	n	n
Reniform nematode	*Rotylenchulus reniformis* (Linford & Oliviera) (Tylenchida: Rotylenchulidae)	n	n	n	N Oramas-Nival & Roman (2006)	n	n
Stunt nematode	*Tylenchorhynchus nudus* Allen (Tylenchida: Belolaimidae)	n	n	n	N Pandey (1998)	n	n
Citrus root nematode	*Tylenchulus semipenetrans* Cobb (Tylenchida: Tylenchulidae)	Y Knight *et al.* (1997)	n	n	N Yin *et al.* (1994)	n	n
Dagger nematode	*Xiphinema americanum* Cobb (Dorylaimida: Longidoridae)	Y Knight *et al.* (1997)	n	n	N Yin *et al.* (1994)	n	n
Nematode	*Xiphinema elongatum* Schuurmans (Dorylaimida: Longidoridae)	n	n	n	N Chen *et al.* (2004)	n	n
Nematode	*Xiphinema hunaniense* (Dorylaimida: Longidoridae)	n	n	n	N Chen *et al.* (2004)	n	n
Nematode	*Xiphinema insigne* Loos (Dorylaimida: Longidoridae)	n	n	n	N Chen et al. (2004)	n	n
Pathogens							
Algae							
Algal spot	*Cephaleuros virescens* Kunsze (Chroolepidales: Chroolepidaceae)	Y Chapman *et al.* (1957)	n	n	Y Coates *et al.* (2005)	n	n
Bacteria							
Bacteria	*Bacillus subtilis* (Ehrenberg) Cohn (Sphingobacteriales: Flexibacteraceae)	Y Pang *et al.* (2005)	n	n	Y Jiang *et al.* (2001)	n	n
Fungi							
Alternaria leaf spot	*Alternaria alternata* (Fries) Keissler (Anamorphic *Lewia*)	Y Duffill & Coley (1993)	n	n	Y Johnson *et al.* (2002)	n	n
Aspergillus ear rot	*Aspergillus niger* Tieghem (Anamorphic Trichomaceae)	Y Balasubramaniam (1997)	n	n	Y Kaiser & Sahar (2005)	n	n

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Fruit rot	*Aspergillus restrictus* Smith (Anamorphic Trichocomaceae)	Y NZFungi Database (2007)	n	n	Y Huang & Scott (1985)	n	n
Fruit rot	*Botryosphaeria rhodina (anamorph Lasiodiplodia theobromae)* Pat. (Mitosporic fungi: Coelomycetes)	n	n	n	Y Coates *et al.* (2005)	n	n
Fungi	*Camposporium japonicum* Ichinoe (Anamorphic Ascomycetes)	n	n	n	N Goh (1997)	n	n
Leaf blight, blossom blight	*Glomerella cingulata (anamorph Colletotrichum gloeosporioides)* Penz & Sacc. (Phyllachorales: Phyllachoraceae)	Y Molloy *et al.* (1991)	n	n	Y Menzel (2002)	n	n
Damping off	*Erythricium salmonicolor* (Berkeley & Broome) Burdsall *Corticium salmonicolor* Berkeley & Broome (Polyporales: Phanerochaetaceae)	Y NZFungi (2007)	n	n	N Simone (1999)	n	n
Leaf spot	*Corynespora cassiicola* (Berkeley & Curtis) Wei (Anamorphic: Corynesporasca)	Y NZFungi (2007)	n	n	N Farr et al. (2007)	n	n
Fruit rot	*Cochliobolus lunatus (anamorph Curvularia lunata)* (Wakk.) Boedijin (Mitosporic fungi)	Y NZFungi (2007)	n	n	Y Wells *et al.* (1981)	n	n
Sour rot	*Geotrichum candidum* Link (Anamorphic Dipodascaceae) (Teleomorph: *Galactomyces geotrichum* (Butler & Petersen) Redhead & Malloch (Saccharomycetales: Dipodascaceae))	Y NZFungi (2007)	n	n	Y Tsai & Hsieh (1999)	n	n
Sour rot	*Geotrichum ludwigii* (Anamorphic Dipodascaceae)	n	n	n	Y Tsai & Hsieh (1999)	n	n
Litchi brown blight	*Peronophythora litchii* Chen (Oomycota: Pythiales: Pythiaceae)	n	n	n	Y Liu et al. (2006)	n	n
Blight	*Pestalotia litchii* Sawada (Anamorphic Broomella)	n	n	n	Sawada (1959)	n	n
Sooty mould	*Phaeosaccardinula javanica* (Zimm.) Yammamoto	n	n	n	N Eriksson & Yue (1985)	n	n
Root rot, wood rot	*Phellinus noxius* (Corner) Cunningham (Hymenochaetales: Hymenochaetaceae)	n	n	n	N Ann *et al.* (1999)	n	n
Leaf blight, fruit rot	*Phytophthora palmivora* (Butler)Butler (Oomycota: Pythiales: Pythiaceae)	n	n	n	N Ann (2001)	n	n

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Rust	*Skierka nephelii* (S. Ito & Murray) (Uredinales: Pileolariaceae)	n	n	n	N AFFA (2004)	n	n
Fungi	*Solicorynespora litchi* (Matsushima) Castañeda & Kendrick (=*Teratosperma litchii*) (Anamorphic Ascomycetes)	n	n	n	N Farr *et al.* (2007)	n	n
Fungi	*Sporidesmium filiferum* Pirozynski (Anamorphic Ascomycetes)	n	n	n	N Pirozynski (1972)	n	n
Fungi	*Sporidesmium tropicale* Ellis (Anamorphic Ascomycetes)	n	n	n	N Ellis (1958)	n	n
Rust	*Uredo nephelii* (Ito & Murayama) Hiratsuka (Uredinomycetes: Uredinales)	n	n	n	Y Farr *et al.* (2007)	n	n
Diseases of unknown aetiology							
Longan witches broom disease	LWBD possibly virus	N	n	n	N Chen *et al.* (1996)	n	n

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