BIOSECURITY NEW ZEALAND

Import Risk Analysis: Litchi (*Litchi chinensis*) fresh fruit from Australia

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Ministry of Agriculture and Forestry
Te Manatū Ahuwhenua, Ngāherehere

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Biosecurity New Zealand
Ministry of Agriculture and Forestry
Wellington
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.
CPC	Crop Protection Compendium. Internet Database.
Endemic	Plants or animals that are indigenous only 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.

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1. Executive Summary

Australia has requested access for the export of fresh litchi fruit to New Zealand. This import risk analysis examines the biosecurity risks of importing fresh litchi fruit in to New Zealand and irradiation as the primary treatment to mitigate the risks. It will inform the development of an import health standard (IHS) to govern the import of litchis from Australia.

Litchi chinensis is a member of the Sapindaceae family and is native to Southern China, Northern Vietnam and Malaysia. Chinese immigrants probably introduced litchi seed into Australia during the gold rush in north Queensland in the late 1800s. It is a growing fruit industry in Australia, with most fruit being distributed on the domestic market. The total annual production in Australia is around 4,000 to 6,000 tonnes (Diczbalis & Campbell 2004). Currently in Australia there are about 250 commercial growers along the east coast of Australia from Cairns to northern New South Wales (Diczbalis & Campbell 2004). The litchis season depending on the variations in cultivars continues for about 5 months from November until March. Litchis will be imported during the summer when climatic conditions in New Zealand will be suitable for the establishment and spread of some new pests and diseases. However many organisms associated with litchi occur principally in tropical latitudes and can have a narrow band of temperature tolerance for growth and development.

In this risk analysis pests and pathogens are grouped according to their biology and members of the same genus are considered within one pest risk assessment. A total of 70 pests and pathogens associated with litchi were considered. Of these, 11 were considered potential hazards and subjected to risk assessment (Table 1).

The following risk management options in ascending order of stringency were assessed:
Option 1: Pest management in the orchards, area freedom for fruit fly, screening measures and pre export inspection and inspection on arrival for all hazards
Option 2: An irradiation treatment (as summarised in Table 1), which is expected to reduce risk from insect hazards. Note this will not manage the risk of fungi
Option 3: Combination of option 1 and 2 with washing of fruit which will manage the risk from insects and fungi
Table 1 summarises the irradiation levels required to mitigate the risks of pests and diseases associated with litchi (see chapter 5).

Table 1. Irradiation levels required to mitigate the risks of identified hazards associated with litchis imported from Australia

Hazard organism	Group	Irradiation level
Bactrocera jarvisi	Tephritid fruit fly	150 Gy
Bactrocera neohumeralis	Tephritid fruit fly	150 Gy
Bactrocera tryoni	Tephritid fruit fly	150 Gy
Amblypelta lutescens lutescens	Hemiptera (bugs)	250 Gy
Amblypelta nitida	Hemiptera (bugs)	250 Gy
Ceroplastes rubens	Hemiptera (bugs)	250 Gy
Ischnaspis longirostris	Hemiptera (bugs)	250 Gy
Nysius vinitor	Hemiptera (bugs)	250 Gy
Cryptophlebia ombrodelta	Lepidoptera (moths)	250 Gy
Bipolaris hawaiiensis	Fungi	More than maximum permitted under food safety standard.
Pestalotiopsis sp.	Fungi	More than maximum permitted under food safety standard.

2. Project Background and Process

2.1. Background

There is currently no import health standard for fresh litchi fruit from Australia. But import health standards do exist for Litchi fruit from New Caledonia (MAF 2000) Thailand (MAF 2005) and Taiwan (MAF 2007). This will be the first full risk analysis done for irradiated litchi fruit from Australia, and will inform the development of an import health standard (IHS) for importing fresh litchis from Australia.

2.2. Scope of the Risk Analysis

The risk analysis assesses the biosecurity risks of potential hazard organisms or diseases associated with fresh fruit of *Litchi chinensis* imported from Australia. For the purposes of this analysis "fresh fruit" means the fruit complete with skin, flesh and seed, with or without a small portion of stem attached not including attached leaves. As requested by Australia Irradiation was assessed as the primary treatment of litchi fruit. In addition in field pest management treatments, pre export measures, washing of fruit and visual inspection were assessed.

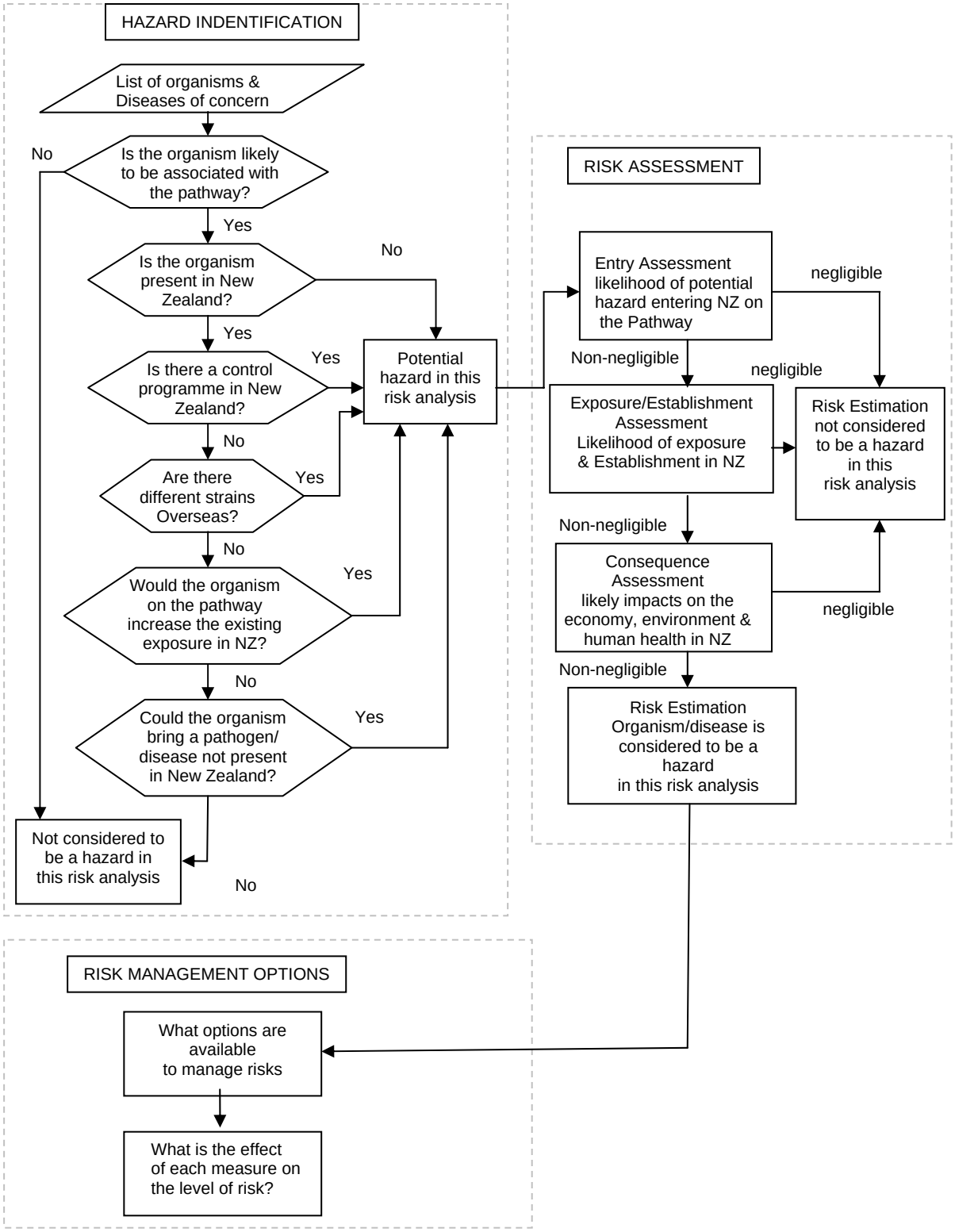
2.3. Risk Analysis Process and Methodology

The following briefly describes the MAF Biosecurity New Zealand process and methodology for undertaking import risk analyses. For a more detailed description of the process and methodology please refer to the Biosecurity New Zealand Risk Analysis Procedures (Version 1 12 April 2006) and recent amendments which is available on the Ministry of Agriculture and Forestry web site[1].

This process is summarised in Figure 1.

1 http://www.biosecurity.govt.nz/files/pests-diseases/surveillance-review/risk-analysis-procedures.pdf

Figure 1. Diagrammatic representation of the risk analysis process



The process outlined in figure 1 is further supported by the following:

- **ASSESSMENT OF UNCERTAINTIES**

In this aspect of the risk analysis process the uncertainties and assumptions identified during the preceding hazard identification and risk assessment stages are summarised. 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 can then be considered for further research with the aim of reducing the 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 reviewed as soon as additional information becomes available[2] and be consistent with other measures where equivalent uncertainties exist.

▪ REVIEW AND CONSULTATION

Peer review is a fundamental component of a risk analysis to ensure the analysis 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, and recognised and relevant experts from New Zealand or overseas. The critique provided by the reviewers is reviewed and where appropriate, 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 it is then published and released for public consultation. The period for public consultation is usually 6 weeks from the date of publication of the risk analysis.

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

2 Article 5.7 of the SPS Agreement states that "a Member may provisionally adopt sanitary …. measures" and that "Members shall seek to obtain additional information …. within a reasonable period of time." Since the plural noun "Members" is used in reference to seeking additional information a co-operative arrangement is implied between the importing and exporting country. That is the onus is not just on the importing country to seek additional information.

3. Commodity and Pathway Description

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. *Litchi chinensis* – Commodity Description

In this risk analysis fresh *Litchi* species from Australia is defined as fruits in their skins with or without a panicle and no other vegetative parts attached.

Litchi chinensis is a member of the Sapindaceae, which includes other edible plants like the mamoncillo (*Melicoccus bijugatus*) of the West Indies and Western Caribbean and the longan (*Dimocarpus longan*), also of Asian origin. Its 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. A tree flowers for up to 21 days in Australia (ARC 2006). 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). 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. Cultivation originated in the region between southern China, northern Vietnam and Malaysia. 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).

In Australia lychee trees perform best on well drained clay loam soils, in drier areas along the coastal strip of north east Australia and the Atherton Tablelands. They require a period of cool weather (15-20°C) for successful flower initiation, but may be killed by frosts (AFFA 2002).

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. The main producing countries are Taiwan, India, China, Madagascar, Thailand, South Africa, Australia, Mauritius and Reunion Island. There is also interest in the crop in Vietnam, and the USA. Thailand and Taiwan export to Singapore and Hong Kong. Fruits are exported to Europe, mainly from South Africa, Mauritius and Reunion (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.

There is a variation in harvest times between countries. April to June is the harvest season in northern Thailand. In Bali the fruit is picked around October; in East Kalimantan fruit from forest trees is available in February-March. In Taiwan fruit develop between April and September (Hwang & Hsieh 1989). 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 *Aceria litchii*, *Pulvinaria psidii*, *Conopomorpha sinensis*, and *Deudorix epijarbas*. Where relevant, longan is mentioned if it is a major host of a particular pest agent. This elucidates the specificity of the organism, or its potential likelihood of host switching to native Sapindaceae if it enters New Zealand.

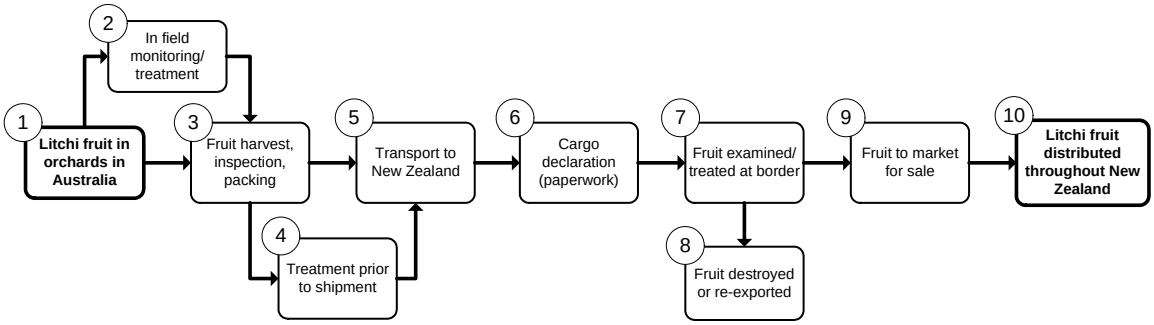
3.2. Sapindaceae in Australia

Australia has some 30 genera including 193 species of Sapindaceae (Flora of Australia 1985), making it unsurprising that many uniquely Australian pest associations with sapindaceous plants exist.

3.3. Description of the Import Pathway

For the purpose of this risk analysis, litchi fruit are presumed to be from the main growing areas in Australia along the eastern coast in New South Wales and Queensland. 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 below illustrates the pathway of litchi fruit from the orchard in Australia to New Zealand.

Figure 2. Linear Pathway Diagram



Steps in the Pathway:

1) Litchi fruit in Australia 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 graded with the best quality fruit washed, pre-treated and packed in boxes.
4) Post harvest disinfestation by irradiation is undertaken before transport of the fruit to New Zealand.
5) Transport to New Zealand is by air.
6) Each shipment must be accompanied by the appropriate biosecurity papers, e.g. a phytosanitary certificate attesting to the identity of the fruit, any treatments completed, or other information required helping 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 not eliminated by irradiation i.e. fungi) are either fumigated, re-shipped or destroyed.
9) Fruit are stored at the transitional facility 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.

3.4. Australia – Description of Climate and Geography

Growing regions for litchi are spread 2,100 km along the east coast of Australia (Figure 3), with a season stretching from November-December until February-March (Diczbalis & Campbell 2004). Production centres on the Atherton Tableland in north Queensland but occurs in small areas along the east coast of Queensland into northern New South Wales. The native environment of litchi is sub-tropical with a period of relatively cool weather (12-20°C) required for flower initiation. Approximately 50 percent of Australia's litchi production occurs north of the Tropic of Capricorn (Mackay, Ingham, Cardwell, Mossman, and the Atherton tableland). The remaining production occurs in central Queensland (Rockhampton, Bundaberg and Childers) southern Queensland (Gympie, Nambour and Beerwah) and northern New South Wales as far as Coffs Harbour (Diczbalis & Campbell 2004).

Figure 3. Litchi growing areas in Australia. Based on a map from Diczbalis and Campbell (2004).

Queensland experiences tropical and subtropical climate conditions, lying between the low latitudes of 10º S and 29º S. Summer temperatures are high, with average January maxima from 28º C on the coast to 37º C in the interior. Winters are mild and sunny, with July maxima from 20º C in the south to 26º C in the north. The interior experiences the most prolonged summer heat, while the southern interior and highlands have cooler winters, with a frost period of up to 100 days (Encyclopaedia Britannica 2007).

Rainfall and humidity show a persistent decline from the coast to the interior. A narrow coastal zone receives from 750 to 1,5000mm annually, declining to only 127 to 152mm in the southwest. The climate of the coastal strip is influenced by the warm waters of the Coral and Tasman Seas, which in general keep the region free from extremes of temperature and provide moisture for rainfall (BOM 2007). In the northern tropics particularly, rainfall is concentrated in a wet season extending through summer and early autumn. Southern Queensland receives sufficient winter rain to support winter cropping of wheat (Encyclopaedia Britannica 2007). A restricted coastal zone in northern Queensland receives copious year round rainfall from the prevailing southeast winds, with annual totals of up to 4,572mm. Rainfall is highly variable with extremes of drought and flood and a high risk of cyclone damage on tropical coasts (Encyclopaedia Britannica 2007).

On the western side of the Great Divide, the rainfall drops quickly to an annual median of about 700 mm. and then gradually decreases further. At the same time, average maximum temperatures gradually increase with increasing distance from the coast. Further to the west the land slowly flattens out to the dry inland plains, marked by cold nights. It is here that the hottest temperatures in the State most commonly occur during summer, and where the annual median rainfall drops below 200 mm (BOM 2007).

New South Wales has a generally mild climate. The seasons are well-defined in the south, with a hot summer and cooler winter, set off by a pronounced spring and autumn. Seasonal variation is less apparent in the north, where summers are hot and wet and winters cooler and

drier (Encyclopaedia Britannica 2007). About 12 percent of the state receives less than 250 mm of rainfall a year, the westerly limit of wheat growing. About 22 percent receives between 250 and 380mm. The coastal districts have the most annual rainfall, varying from 890mm in the south to 1,524 or more millimetres in the north (EB 2007). Precipitation is highest with the orographic effect of the rise to the tablelands but generally declines westward. The Western Division, which consists of semiarid western plains, is recognized as an area of marked rainfall deficiency. Droughts which afflict the area in summer seem to be related to the El Niño effect in Pacific Ocean waters (Encyclopaedia Britannica 2007).

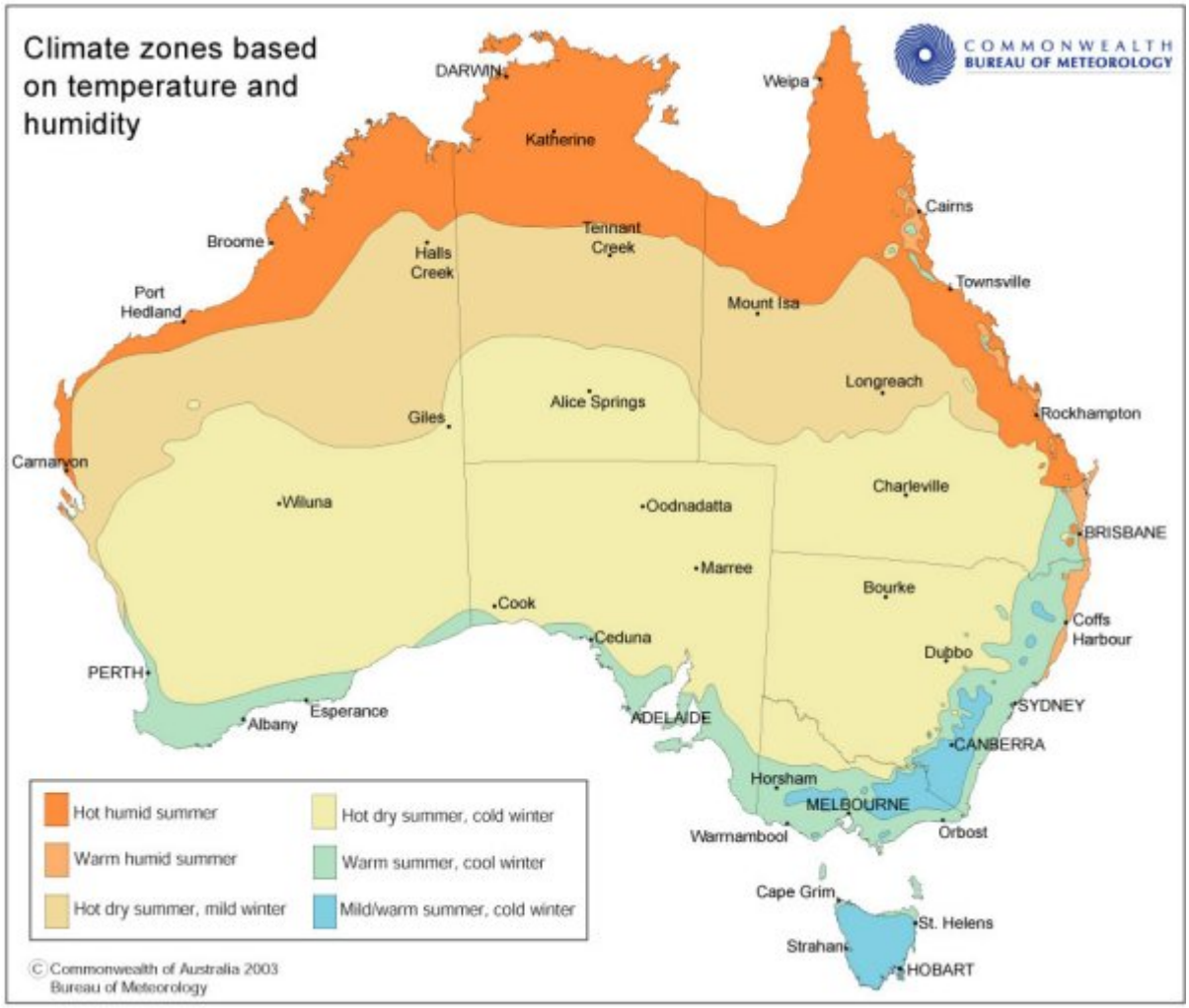
Inland it is both hotter in summer and colder in winter. Average temperatures range from about 24° to 29° C in summer and from about 45° 7° to 15° C in winter. Temperatures over 38° C are not uncommon in the summer months, and frost at night is common in winter on the tablelands and southern slopes. In the Snowy Mountains (Kosciusko massif), heavy snow falls over an area larger than the Swiss Alps (Encyclopaedia Britannica 2007).

3.5. Definition of Tropical and Subtropical Climate

Climatic zones can be defined according to the geographical partitioning of the earth based on the way daylight is distributed across its surface during the year. Each part of the earth recieves approximately the same number of daylight hours per year – at varying rates. The poles have half a year of darkness and then half a year of daylight. Near the equator daylight is evenly spread for half a day every single day of each year. At the mid latitudes daylight is delivered in greater or lesser amounts throughout the year (Seligman 2007). Regions near the poles receive only a fraction of the sunlight and heat per day that equatorial regions receive in just a few hours because the sun is on average closer to the horizon at the poles and higher overhead at the equator.

The boundaries of the region are defined according to the amount which the sun moves north and south in the sky during the planetary year which is equal to its axial inclination.
On earth the tilt is about 23.5º, so going from the poles, which are at 90º latitude, we define the position of the arctic and Antarctic circles as being 66.5 º North or South latitude. Going from the equator towards the poles, the Tropics of Cancer and Capricorn are 23.5 º North or South latitude. The tropical zone is marked by heavy rainfall. Water is abundant and temperatures remain relatively stable. There are seasons of heavier and less heavy rainfall but the region is not known to exhibit great swings in temperature. In general, it is wet and warm.

Figure 4. Climate zones in Australia based on temperature and humidity. Taken from the Australian Bureau of Meteorology (2007).



The north temperate zone extends from the Tropic of Cancer at 23.5 º North to the Arctic Circle at about 66.5 º, and the south Temperate zone extends from the tropic of Capricorn at 23.5 º South latitude to the Antarctic Circle. The changes in these regions between summer and winter are generally subtle, warm or cool rather than extreme burning hot or freezing cold. However a temperate climate tends to have very unpredictable weather. Within the borders of this zone there are two main categories: continental and maritime. Maritime climates are clearly affected by oceans, and westerly prevailing winds. The continental climate is situated inland with warmer summers and colder winters. The large land mass increases its effects on heat reception and loss (Reference.com 2007).

The subtropics are said to be the two bands around the earth adjacent to the tropics from 10 degrees north latitude to 23.5 degrees north latitude and from 10 degrees south latitude to 23.5 degrees south latitude (SFSU 2002). This zone is noted for its lack of rainfall and low humidity. Most of the world's great deserts lie in the subtropics. The Australian outback for example is subtropical. Large landmasses that lie in the subtropics invariably exhibit desert terrain in their interior regions (Bonan 2002). Small sub-tropical land masses like the Hawaiian Islands combine low humidity with plentiful sun.

Australia by these definitions predominantly falls within the subtropical and tropical zones. The eastern coastal strip where litchi's are produced follows the band of hot humid and warm humid summer climate represented in the climate zones of Australia based on temperature and

humidity outlined in Figure 4. New Zealand on the other hand is firmly within the temperate zone, and only has a small area of subtropical climate in the far northern North Island. El Niño and La Niña southern oscillation can cause the seasonal climate (the cumulative effects of the weather over a season) of both countries to deviate from normal (NOAA Research 2007).

3.6. Tropical and Subtropical Pests

Many species of insects and mites occur principally in tropical/subtropical 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/subtropical pests" here is very low given the very small area of the country with suitable subtropical climatic conditions.

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 either a greenhouse or the climatically suitable geographic areas for establishment is estimated to be very low or negligible. Greenhouse scenarios are therefore not discussed within the individual pest assessments as a potential risk, however the small regions where suitable climate exists for these pests are.

3.7. History of Litchi Cultivation in Australia

It is thought that Chinese immigrants introduced litchi seed to north Queensland during the gold rush of the late 1800s. Litchi marcotts (cultivars Tai So and Wai Chee) were introduced from China in 1930 by the Wah Day family who had settled in Cairns (Diczbalis & Campbell 2004). Commercialisation of litchis began in the 1970s and production has expanded since then. Australia is a relatively small producer of litchi, with 4,000-6,000 tonnes produced annually by some 250 commercial growers. It is a difficult crop to grow and produce consistent yields, with irregular flowering and premature fruit drop being major problems (Diczbalis & Campbell 2004).

Currently the annual production of litchis in Australia is around 4,500 tonnes per annum and worth AU$16/kg. Production has steadily increased over the past eight years. About 50 percent of the litchi production is in northern Queensland (Ingham, Cairns and the Atherton Tablelands), 30 percent in central and southern Queensland (Rockhampton, Bundaberg, Gympie, Nambour and Caboolture) and about 10 percent in northern New South Wales (AFFA 2002). Orchards range in size from small family units of about 200 trees to large commercial plantations of 10,000-14,000 trees. Plantings generally range from 100-300 trees/ha. Cultivars with spreading forms such as Fay Zee Siu and Souey Tung are planted 12m x 6m (about 140 trees/ha). In cooler growing regions, the densities tend to be higher (AFFA 2002).

Commercial crops are irrigated, and some systems can also be used to fertigate trees. In dry areas, young plants usually require watering at least weekly until they are well established. Litchi trees are generally fertilised about every three months during their early life before they start to crop, with fertiliser quantities increasing as the trees become larger (Biosecurity Australia 2002).

3.8. Production and Pre-export Handling of Commodity

The litchi season lasts from mid October in northern Queensland to March in northern New South Wales. Maturity is indicated by a minimum brix:acid ratio of 35:1. The primary method for determining harvest date is a taste test. Harvesting occurs in the early morning and generally ceases around 10:00 a.m. Commonly the bulk of the crop is picked in clusters. Fruit should then be kept at high humidity and cooled to 5°C as quickly as possible. Cool rooms or hydrocoolers are frequently used for this purpose. After picking, fruit is destalked and sorted visually on mechanical conveyors to remove small poorly coloured or damaged specimens (Biosecurity Australia 2002).

Industry quality standards have been developed for litchi. For litchi "Extra class" must be practically free of defects, and typically comprises no more than 10 percent of the crop. "'First class" fruit can have moderate defects, with skin blemishes not exceeding 60mm² in total on any one fruit. Other standards operate for other segments of the industry that have a commitment to quality assurance and are members of the United Lychee Marketing Association (ULMA).

The fruit is marketed in bulk or in crispywrap bags to reduce water loss and browning. Cartons hold 5kg of fruit, which can also be packed in two 2.5kg low density polybags. Some fruit is also packed in 250g punnets, with a cling wrap film. Fruit is free of surface moisture before being packed to reduce the potential for disease development. Fruit is normally shipped by refrigerated transport at >95 percent humidity and 5°C. Export fruit is airfreighted and time from harvest to arrival at the export market is 4-7 days (Biosecurity Australia 2002).

3.9. Pest Control Programme for Litchi in Australia

Pest management of litchis is based on the principles of Integrated Pest Management (IPM). Biological and cultural control measures are integral to the management of pests and diseases and chemical sprays are used only when pests reach levels that cause economic injury (Waite 2005, AFFA 2002).

Area freedom from fruit flies is considered an approved measure for those areas where approved trapping regimes are in place in accordance with the minimum Standards covered by the Australian Code of Practice for the Management and Control of Queensland Fruit Fly and where equivalent permanent trapping regimes are in place for Mediterranean fruit fly and Oriental species of fruit fly as stipulated in the New Zealand NASS Standard 158.03.06 and NASS Standard 158.03.07.

Only a few of the pests associated with litchi in Australia adversely affect production and need to be controlled (Biosecurity Australia 2002). These pests are listed in Table 2.

Table 2. The key species identified as serious pests on litchi. Taken from the RIRDC handbook for farmers (Diczbalis & Campbell 2004) and Biosecurity Australia (2007). Based on information from Waite (2005) and Waite & Hwang (2002).

Common name	Scientific Name	Order
Litchi erinose mite	*Aceria litchi*	Acari
Banana spotting bug	*Amblypelta lutescens lutescens*	Hemiptera
Fruit spotting bug	*Amblypelta nitida*	Hemiptera
Macadamia nut borer	*Cryptophlebia ombrodelta*	Lepidoptera
Pepper Spot	*Colletotrichum gloeosporiodes*	Fungi
Fruit piercing moth	*Eudocima fullonia*	Lepidoptera
Fruit piercing moth	*Eudocima salamina*	Lepidoptera
Orange fruitborer	*Isotenes miserana*	Lepidoptera
Flower caterpillar	*Lobesia* spp.	Lepidoptera
Leaf swarming beetle	*Monolepta* spp.	Coleoptera
Flower caterpillar	*Phycita leucomiltra*	Lepidoptera
Flower caterpillar	*Platypeplus aprobola*	Lepidoptera
Flower caterpillar	*Prosotas* spp.	Lepidoptera
Leaf swarming beetle	*Rhyparida* spp.	Coleoptera

Spray applications of azinphos-methyl for *Cryptophlebia ombrodelta* are timed to coincide with the hatching of the oldest 10 percent of the eggs. This ensures newly emerged larvae are killed before entering the fruits' skin. Effective control requires a minimum of 2-3 sprays (Biosecurity Australia 2002). Flower caterpillars are controlled with endosulfan or carbaryl before the flowers open. Endosulfan is a broad spectrum insecticide which has been used effectively on vegetable and horticulture crops to control various insect pests, including fruit spotting insects and other chewing and sucking insects. Endosulfan is used to reduce the incidence and provide control of fruit spotting and banana spotting insects on lychee fruit (Fay 2002; CAB International 2006; Waite 1999). There are several reports that document the effectiveness of this chemical in reducing the incidence of fruit spotting insects on vegetable and horticulture crops.

In crops such as litchi, where its presence can be monitored through the inspection of fallen fruit, sprays are targeted to periods when the bugs are most active. These crops have a relatively narrow window of phenological susceptibility to fruit spotting insects so that continuous spraying throughout the season is not required. Endosulfan is the most widely used insecticide on lychee due to reports of good efficacy against these pests and is widely used in all IPM programmes in tree fruits that include control of fruit spotting pests (Waite et al. 1999).

Two sprays of endosulfan starting two weeks after fruit set generally provide adequate control for the fruit spotting and banana spotting bugs, and fruit piercing moths are excluded with mesh nets (15-20mm) (Biosecurity Australia 2002).

3.10. Transportation of Commodity

3.10.1 Air Freighted

Export fruit is airfreighted and the time from harvest to arrival at the export market is 4-7 days.
Day 1 – Harvest and pack
Day 2 – Inspection/quarantine treatment/dispatch
Day 3/5 – Airfreight
Day 4/7 – Arrival at export market

Because of the short distance between Australia and New Zealand it is estimated that airfreight will not take more than 1 day. Litchi fruit should arrive in New Zealand from Australia within 4-5 days from harvest.

It is most likely that the consignment will be on a plane which transports passengers as well. The transit time would be under 12 hours. There are direct flights from Brisbane in Queensland to Auckland with Quantas taking 3 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 there is not the cold storage available or required. Humidity is also likely to be much lower.

3.11. New Zealand's 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).

3.12. 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 daytime maximum air temperatures range from 22°C to 26°C, but seldom exceed 30°C. Winter daytime maximum air temperatures range from 12°C to 17°C.

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.

3.13. Potential Sapindaceae Hosts 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 of mature fruit to set seed, that they would present a minimal risk of providing host material to potential pests and pathogens imported on litchi from Australia. Should more trees be planted in future or cultivated for commercial purposes this assumption will need to be reviewed. Several specimens of *Dimocarpus longan* (with which some pest species of litchi are shared) are cultivated in New Zealand, 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 from the family in New Zealand *Alectryon excelsus* (titoki), 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 and so titoki trees often occur as sparse components of most lowland forest types, throughout 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.

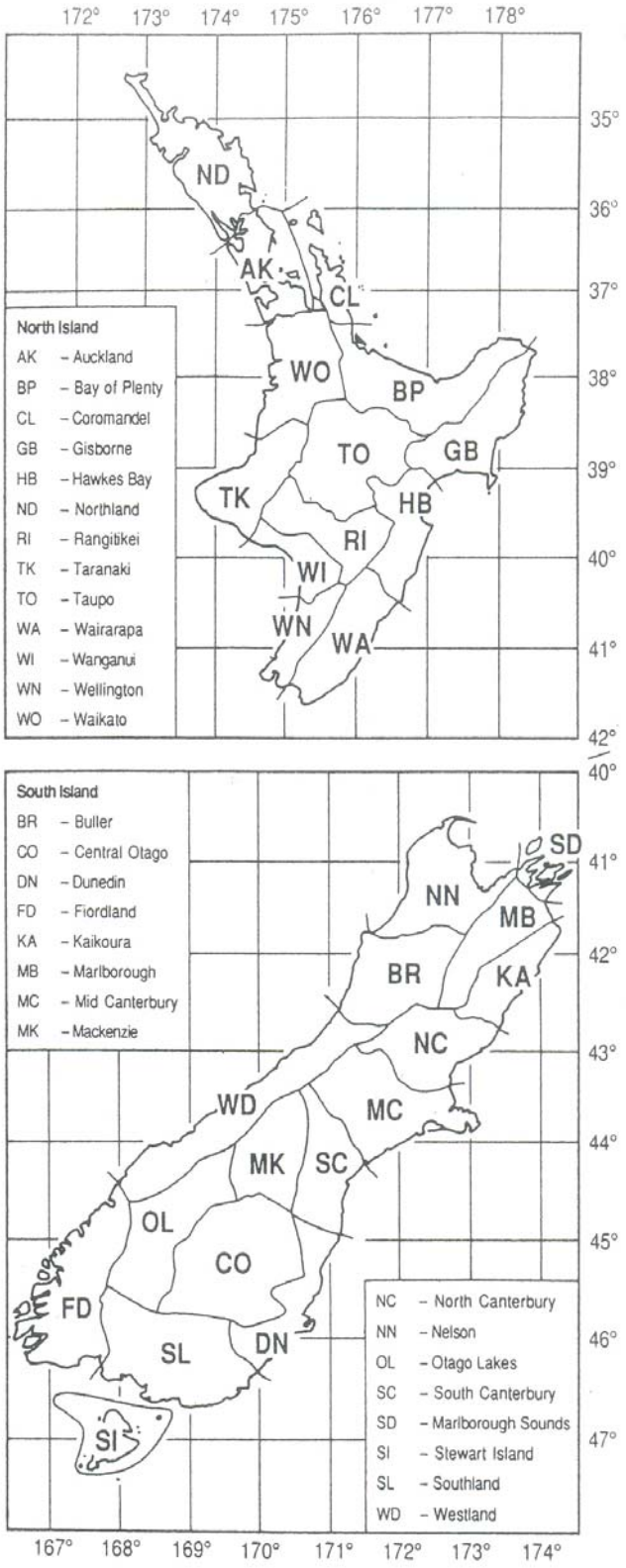
Akeake (*D. viscosa*) is an erect shrub or small tree found in exposed coastal situations, lowland scrub and forests from sea level to 550 metres. Its synonyms include *Dodonaea angustifolia, D. eriocarpa, D. sandwicensis, D. scottsbergii* and *Dodonaea spathulata* (Stevens *et al.* 1999). *D. viscosa* flowers from September to January and it is dioecious. It is moderately frost tolerant, and is highly wind, salt and drought tolerant (TRC 2002).

3.14. 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. The places referred to on the map (Figure 5) 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.

There are obvious limitations in the arbitrary nature of the Crosby *et al.* (1976) system when it comes to uncovering biogeographic patterns. However it continues as a well established approach used by most New Zealand entomological collections, museums, and publication series. It has the advantages of allowing distributional information to be uniformly recorded and easily compared (Larivière & Larochelle 2004).

Figure 5. Crosby Codes of New Zealand. A map reproduced from the Fauna of New Zealand series showing all Crosby codes for New Zealand.



4. Hazard Identification

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.

Appendix 1 lists organisms thought to be associated with lichis from Australia. Potential hazards are identified through the application of the following criteria:

- Is the organism present in New Zealand?
- For those organisms that are present in New Zealand could it vector a pathogen/disease not present in New Zealand, or are there different strains overseas?
- Is the organism likely to be associated with the commodity as described in chapter 3?

A risk assessment is undertaken (Chapter 6) for organisms identified as potential hazards and further consideration is given (Chapter 6) to those organisms for which the initial assessment of potential hazard status is uncertain.

4.1. Interceptions on Litchi Fruit from Existing Pathways

Between 2001 and August 2006 a total of 116795 kg of fresh litchi fruit were imported into New Zealand from existing pathways as commercial consignments (QuanCargo Database 2006). Treatments used were Vapour Heat and Cold Disinfestations. The size of consignment ranged from 250 kg to 18840 kg. From this volume there were a total of 9 inspection interceptions. 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 so last year (QuanCargo Database 2006). This reflects the higher volume of litchi's entering the country in recent years. The data suggest there was a 0.007 percent rate of pest organisms arriving 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.The 600 unit sample gives a 95 percent confidence level around the likelihood of finding pests if they are present in a consignment. This makes assumptions around consignment homogeneity, that samples will be random, and that the inspector has a 100 percent likelihood of detecting pests if they are present in the sample. There are no predicted volumes for litchi arriving from Australia.

4.2. Interceptions on Other Irradiated Produce from Australia

Currently there are no irradiated litchis entering New Zealand from anywhere in the world and therefore no interception data. There is however interception data for irradiated mango and papaya from Australia. Between 2004 and 2006, 70 shipments with a total of 256,473 kgs of fresh mango and in 2007 six shipments with a total of 3124 kgs of fresh papaya were imported. There have been interceptions on 3 consignments of mango and 1 on papaya. The identifications are listed below. The numerical value is the number of times each pest category was found.

Mango	Papaya
Diaspididae: 2	Coccidae: 1
Aulacaspis tubercularis: 1	Araneae:1
	Acari: 1
	Litargus balteatus (beetle): 1

All organisms were identified to at least order level. Three of the 7 pests identified were reported as non-viable. Information on the status of the other 4 organisms is not available. It is assumed that because two of the consignments were treated with methyl bromide after entry that live organisms were found on these shipments. Previous regulations meant all live organisms intercepted on fruit fly host material had to be treated at the border. Because irradiation produces sterility in invertebrates without consequent instant mortality this regulation has been reviewed in the case of irradiated produce. There are currently no tests available in New Zealand to check for invertebrate sterility. It appears that although there have only been 6 shipments of papaya to New Zealand during 2007, a large number of pest items were recovered from this pathway on one consignment . The mango pathway by contrast has a high volume and low number of interceptions.

Although this data can not be extrapolated to predict likely pest interception numbers for litchi fruit from Australia it does reveal the type and quantity of risk associated with a similar pathway where similar treatment types have been used. As the mango and papaya data illustrate different pathways with the same treatment can differ markedly in their interception record. There is no testing for sterility of organisms arriving alive on produce, so the assessment of residual risk as far as treatment efficacy is concerned is still open. These treatments are as follows (Australian Mango IHS 2003; Australian Papaya IHS 2007).

4.3. Significant Uncertainties in this Risk Analysis

Uncertainties for individual organisms are at the end of each individual risk assessment. Generic issues are discussed here.

4.3.1 Unlisted Pests

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, including 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.

4.3.2 Symptomless Micro-organisms

Pests such as microbes (bacteria, viruses and mycoplasmas etc.) 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".

It is accepted in the scientific community that it is usual for plants to form associations with micro-organisms that are considered to be endophytes or saprobes (saprophytes). Some organisms are capable of acting as a pest or causing diseases on one plant or group of plants, but can form an association with another plant or group of plants on which they act beneficially. In the case of endophytes these organisms live symbiotically within the plant tissue and, in return for a safer environment and perhaps some nutrition, it is believed can in some circumstances provide limited protection to the plant from other disease-causing organisms. In some studies endophytes were found to be relatively host specific.

Saprophytes live on or around the plant and survive on dead organic material. In contrast to endophytes, saprophytes are not usually host specific. While neither type of micro-organism is likely to cause disease on plants, it is likely that the majority of disease-causing micro-organisms were at one stage saprophytes or endophytes as the mechanisms for plant invasion by these disease-causing micro-organisms are modified from those used by endophytes and saprophytes. *Botryosphaeria* species in Australia for example can act as both endophytes and stress-related pathogens of various woody hosts (Slippers *et al*., 2005).

From a biosecurity risk-perspective therefore, latent or asymptomatic organisms pose a significant problem as their association with a plant in all likelihood is unknown, as their biosecurity risk is unmeasured.

4.3.3 Assumptions and Uncertainties about Hazard Biology

- 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).

- In the case of hybrids, it is assumed the hybrid form will either exhibit characteristics intermediate between the two original species or characteristics of both. Discussions of host range, climate tolerance and any specific life cycle traits for the hybrids will be considered within the known data for each parent species. For example *Bactrocera tryoni* and *Bactrocera neohumeralis* hybridise within their current distributions in Australia. They have similar origins, hosts, and adult morphology but different mating times. *B. tryoni* mates only at dusk and *B. neohumeralis* mates only during the day but hybrids can mate at both times (Pike *et al.,* 2003). Hybrids could possibly retain a host range either narrower or wider than each species respectively.

- 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.

- For fungal pathogens it is sometimes unclear from the literature or current databases whether an organism is a synonym of another closely related species in the genus or its own entity. This becomes more complicated when a closely related species and possible synonym occurs in New Zealand while the organism in question does not. The taxonomy of *F. pallidoroseum* for example is still partially unresolved. Until it is proven that *F. semitectum* or *F. incarnatum* are synonyms of *F. pallidoroseum* it was treated as a separate species. Because *F. semitectum* already occurs in New Zealand and it is confirmed to be a synonym of *F. incarnatum, F. pallidoroseum* would no longer be considered a hazard in the risk analysis.

4.3.4 Assumptions and Uncertainties about the Inspection of Produce

Some 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 assumptions around consignment homogeneity, that samples will be random, and that the inspector has a 100 percent likelihood of detecting pests if they are present in the sample.It is accepted that the sampling system is based on a level (percentage) of contamination rather than a level of surviving individuals, and that 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.

4.3.5 Assumption about *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 Australia. Should more trees be planted in future or cultivated for commercial purposes this assumption will need to be reviewed.

4.3.6 Uncertainty around the Efficacy of In-Field treatments, pre export system control and Irradiation

Although information is provided on the types of pesticide regimes and integrated pest management carried out in litchi orchards, there is no direct efficacy data for the success of such treatments. The data tend to be qualitative rather than quantitative. If a pest reaches an economic threshold level it is usually treated, as physical damage will lead directly to economic losses. Because of the grading system the Australian litchi industry uses, it is assumed a very high quality in the outside appearance of fruit must be maintained for export purposes. What remains unknown is how much systems controls such as fruit grading and in-field treatments reduce the risk of pest organisms entering the country.

There are very few data on effective irradiation doses on insect species identified as hazards for litchi. Extrapolation of treatment efficacy to specific pests on litchi was based on knowledge and experiences that radiation dosimetry systems measure the actual radiation dose absorbed by the target pest independent of host commodity, and evidence from research studies on a variety of pests and commodities. It is accepted that it would be impossible to get sufficient data to confirm that all genera within a family conform to the same treatment dose. Therefore in this risk analysis some assumptions have been made when extending irradiation treatments to this taxonomic level. It is assumed that in general if a dose for one particular species in a genus is effective this dose will be sufficient for other members of the same genus and to a lesser extent to members of the same family. For members outside the same family but in the same order there is less certainty. If information becomes available to show that the extrapolation of the treatment to cover litchi for these pests is incorrect, then the treatment will be reviewed.

5. Review of Management Options

5.1. Introduction

This chapter reviews some management options for organisms considered to be an unacceptable risk on litchi fruit imported from Australia. Irradiation is the only produce treatment considered.

5.2. In-field control, pre export measures and area freedom

There is a comprehensive pest management and pest control system for specific pests of litchi in Australia. Control of Macadamia nutborer, flower caterpillars and fruit spotting and banana spotting bugs is achieved with carefully timed applications of insecticide (Chapter 3.9). There is no quantitative data indicating the efficacy of such field treatments. It is assumed that all litchi fruit exported from Australia into New Zealand will follow the industry quality standards for production of litchi, screening measures and pre export inspection.
The International Standards for Phytosanitary Measures number 4: *Requirements for the establishment of pest free areas* (ISPM No 4) describes the requirements for the establishment and use of PFAs as a risk management option for meeting phytosanitary requirements for the import of plants. The standard identifies three main components or stages that must be considered in the establishment and subsequent maintenance of a PFA:

- systems to establish freedom
- phytosanitary measures to maintain freedom
- checks to verify freedom has been maintained.

Normally PFA status is based on verification from specific surveys such as an official delimiting or detection survey. It is accepted internationally that organisms or diseases that have never been detected in, or that have been detected and eradicated from, an area should not be considered present in an area if there has been sufficient opportunity for them to have been detected.

When sufficient information is available to support a PFA declaration, this measure is usually considered to provide a very high level of protection.

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. Irradiation

The major commercial uses of ionising radiation for fruit and vegetables include the inhibition of sprouting (potatoes and onions) and the extension of shelf-life in strawberries (Frazier *et al.* 2006, Todoriki & Hayashi 2004, Pan *et al.* 2004, Ignatowicz 1998). Although irradiation can prolong the life of foods in cases where microbial spoilage is the limiting factor in shelf life, fruits and vegetables, with the exception of strawberries, generally do not retain satisfactory quality at the irradiation doses required (Lacroix & Vigneault 2007). Irradiation can also delay ripening of fruits and vegetables but commercial use for this purpose has been limited. The major commercial uses of irradiation have been to reduce food-borne pathogens in seeds, herbs and spices, fresh meats and dried fish, an application requiring higher doses than suitable for fresh produce (Aziz *et al.* 2007, Chamul 2007, Zhu 2006, Rita *et al.* 2002).

Irradiation is an efficient, non-residue, broad spectrum disinfestation treatment that has been recognised for its quarantine potential in fresh produce. It is a low dose application that is tolerated well by most fresh commodities. Its use in trade, however, has been limited by the need for quarantine agencies to ensure that the risks for multiple pest-host situations are fully understood and managed. It has been used as a quarantine treatment in the U.S. since 1995 for Hawaiian tropical fruits sent to the contiguous states. Since 2002 the USDA-APHIS has also recognised irradiation as a quarantine treatment for imported fruits and vegetables.

Since 2004, 70 shipments (256 tonnes) of fresh mango and 6 shipments (3 tonnes) of fresh papaya grown and irradiated in Australia have been imported into New Zealand (See section 4.2 for more detail). The food safety standard for the importation of this produce (FSANZ Standard 1.5.3 for tropical fruit3) sets a maximum dose of 1000 Gy for food safety and a minimum of 150 Gy where the purpose is a phytosanitary treatment. This does not exclude a higher minimum being set if required for quarantine purposes.

Four sources of ionising radiation are permitted for use with food under the Codex General Standard for Irradiated Foods (Codex Standard 106-1983, Rev 1-2003). The sources are cobalt-60, cesium-137, electrons (β particles) with a maximum energy of 10 MeV (million electron volts) and X-rays (bremsstrahlung) with a maximum energy of 5 MeV. In practice, cesium-137 is not used commercially in New Zealand, see FSANZ standard 1.5.3 (P. Roberts Pers. Comm. 2007).

Cobalt-60 is a radioisotope that continuously produces γ rays which can penetrate pallets loads. A dose uniformity ratio (the ratio of maximum to minimum dose absorbed by the product) of three or better is possible within the produce (Hallman 1999). Although a 3:1 ratio is considered to be large, there are many fruits that tolerate relatively high doses well

3 http://www.foodstandards.gov.au/_srcfiles/FSC_Standard_1_5_3_Irrad_v88.pdf

(Hallman 2000). Electrons are produced in an accelerator, a machine which only produces radiation when switched on. At the energy limit of 10 MeV, electrons can penetrate only a few centimetres into packages and dose uniformity can be more difficult to achieve than with γ rays. If the electrons strike a high-density metal target, they are converted to X-rays. Over 90 percent of the energy is lost as heat in the conversion. X-rays differ from γ rays only in the means by which they are produced, and have the same ability to penetrate packages. The treatment effects of using x-rays, γ-rays or β-rays that produce the same dose in treated products, will be similar provided that the doses are accumulated over similar time periods (Dohino *et al.,* 1994).

When selecting which source to use, processors base their decision on relative costs which in turn depend on factors such as the range of foods to be treated, packaging, throughput, efficiency of energy use and the type of applications (low, medium or high dose, or a combination in multi-purpose facilities), as well as the capital and general running costs.

It is the energy absorbed in the food as the radiation passes through it that brings about both its potential beneficial (disinfestation) and deleterious (vitamin loss, loss of flavour and texture) effects. The energy absorbed is called the absorbed dose and is measured in "Gray" (Gy). A Gy is 1 Joule of energy absorbed per kg of the target material. An earlier unit of absorbed dose was the rad, which equals 0.01 Gy. The key parameter that must be measured in the radiation facility is the absorbed dose of ionising radiation energy imparted to the food (Hallman 1999). Ionizing energy is so called because, in its passage though the product, it ionizes (i.e. removes electrons from) some of the atoms in its path. These atoms then undergo further chemical alteration (Hallman 1999).

Only a small number of the larger, biochemically important molecules need to be slightly altered for essential functions in an organism to be affected. For example, irradiation interferes with cell division by damaging the DNA in chromosomes (USEPA 2006). As chromosome size and the complexity of the organism increases, the dose needed to affect cell division decreases. Thus lower doses are needed to affect insects than fungi or bacteria. In contrast to cell division, many small molecules must be altered to cause a significant change in the sensory properties of fresh produce. It is these characteristics of irradiation that allow insects to be affected at relatively low doses (Vose 1980) with little effect on the sensory and nutritional properties of fruit.

Treatments against the immature stages of holometabolous insects (those with larval and pupal stages) are effective at relatively low doses (Corcoran & Waddell 2003).
The most tolerant life stage in insects is targeted. In fruit flies this is the third instar (last larval stage) before the fully developed fly leaves the fruit to pupate in soil.
Efficacy for irradiation has been defined as prevention of adult emergence (Ohta *et al.,* 1985), prevention of emergence of flies capable of flight (APHIS 1987) and prevention of flies capable of reproducing (APHIS 1989).

Based on existing data (with more recent relevant papers included), Corcoran and Waddell (2003) state the following recommended doses for the listed arthropod pests (Table 3). Table 3 indicates that arthropods can be successfully sterilised at a range of doses from 150Gy to 350Gy.

Table 3. Effective irradiation levels for particular Arthropod groups (after Corcoran & Waddell 2003)

Arthropod Pest Group	Effective irradiation level (Gy)	Author/(s)
Fruit flies in the Tephritidae	150 (non-emergence treated eggs, larvae)	Bustos *et al.* 1991, Gould & Hallman 2004
Hemiptera (bugs, scales, mealybugs)	250 (sterility)	Hara *et al.* 2002, Follett 2006
Thysanoptera (thrips)	250 (sterility)	Dohino *et al.* 1996, Yalemar *et al.* 2001
Lepidoptera (moths, butterflies)	250 (non-emergence – treated eggs, larvae)	Follett & Lower 2006
Coleoptera (beetles)	250 (sterility)	Tilton *et al.* 1966, Todoriki *et al.* 2006
Acari (mites)	350 (sterility)	Lester & Petry 1995, Jadue *et al.* 1997

In 2003, the IPPC issued ISPM No. 18, guidelines for irradiation use as a phytosanitary measure (ISPM 2003). To date the guidelines have not recommended any Specific Approved Treatments (Annex 1) and this remains on-going work. Appendix 1 provides estimates of the minimum dose range required to achieve a pest response relevant to quarantine treatments. The dose required to achieve mortality of insects is greater than the doses required to prevent adult emergence or the ability to reproduce and is usually greater than fresh produce can tolerate.

The IPPC Technical Panel on Phytosanitary Treatments (TPPT) found in their 2007 report (TPPT 20074) that irradiation treatments could be extended to all strains within a species. The panel noted that Bakri *et al*. (2005) indicated, with few exceptions, there was no need to develop radiation biology data for all species within the same genus. While the paper made a case for extrapolating irradiation doses to all species within a genus, this needs to be explored more fully before being internationally accepted (TPPT 20074).

When extrapolating irradiation doses beyond genus to family the TPPT noted that within Tephritidae a wide range of genera has been tested and this had supported extending irradiation treatments to the family level in this case. For other insect families it would be impossible to get sufficient data to confirm that all genera within a family conform to the same treatment dose (TPPT 20074). This would be an enormous undertaking, which is unlikely to happen. A case could also be made for extrapolating irradiation doses to all insects, apart from lepidopteran pupae and adults. Again this requires further study to validate this suggestion.

The guidelines note that live target pests may be found because mortality will rarely be technically justified as the required response. The country of destination must therefore accept a treatment that does not provide for insect kill or Probit 9 mortality. It is essential the irradiation treatment ensures the pests are unable to reproduce. The guidelines suggest it is preferable that the pests are unable to emerge or escape the commodity unless they can be practically distinguished from non-irradiated pests (ISPM 2003).

If fruit fly are detected in New Zealand we must notify our international trading partners promptly, and this could mean significant economic losses if flies are not proven to be sterile. Methods for determining DNA damage in larval or adult arthropods exposed to gamma irradiation have been proposed and tested. Chestnut weevil larvae (*Curculio sikkimensis*) in Japan were irradiated with 0.4 kGy (Todoriki *et al.* 2006) and exhibited significant damage at

4 https://www.ippc.int/servlet/CDSServlet?status=ND01OTIzNSY2PWVuJjMzPSomMzc9a29z

the DNA level. A comet assay showed that tail length, moment, olive tail moment and percent head and tail DNA and DNA damage were greater in treated individuals (Todoriki *et al.* 2006).

Molecular tests such as this to ascertain the effectiveness of treatments from individuals post border, would be expensive, and the likelihood of having an adequate sample size to be sure of the results is small. Currently there are not enough data to support this methodology in practical use. A library database of images and DNA assessment for various organisms including fruit flies needs to be assembled and made available for general biosecurity purposes. The technology does warrant further investigation. In the meantime it will be necessary to have predictable and clearly stated time frames for the times of survival until death of arthropod pests arriving here on fresh produce.

There are few examples of nematodes being treated effectively by irradiation treatments. Research suggests they require over 4 kGy dosages (ISPM 2003) to sterilise actively reproducing adults. As there are no nematode species associated with litchi fruit in this assessment this group of organisms is not considered further.

APHIS set a minimum generic dose of 400 Gy of irradiation for imported fruits and vegetables. This dose was adopted based on Follett's (2007) "toughest insect" concept and in view of the groups of insects being targeted. Follett's concept involves setting a dose high enough to kill the most radiation-tolerant insects known to infest the product. APHIS followed the Proposed Rule with a Final Rule within six months (Federal Register, February 18, 2004). This dosage has recently been discussed by the TPPT (TPPT 20074) who suggest doses up to 600 Gy may be appropriate, but realise that this is not achievable given current limitations by food safety standards for acceptable levels of irradiation in food. This risk analysis while reviewing relevant theories around appropriate irradiation levels looks specifically at efficacy data for litchi and its associated pests and diseases.

Mature fungi are more resistant to irradiation than insects since they are a less complex organism, they have an extensive mycelium which can re-grow from various points and they often contain fungal spores that are highly radiation resistant. Therefore fungi have typically higher D-values (the dose of radiation that will leave behind 10 percent of an undesired pathogen) than insects, ranging from around 0.25 kGy to 2 kGy. In general dematiaceous fungi (dark in colour with melanin in the cell walls and septa in the hyphae) are more resisitant than moniliaceous fungi (Marsh & Wilkins *et al.,* 2005).
Many fungi causing human or animal infections belong to the dematiaceous fungi and are pale brown, dark brown or black (Mount Sinai Hospital 2005). The presence of multicelled thick-walled macroconidia may impart radiation protection to fungi from the *Alternaria* and *Curvularia* generas (Saleh *et al.,* 1988).

There is currently little definitive research and no scientific consensus on the application of irradiation as specific treatments for a fungus or bacterium on fresh produce (Richards & Winter *et al*. 2003). Frequently a few individuals of pathogenic fungi and bacteria will survive irradiation treatment implying post-irradiation storage conditions are highly important in retaining low numbers of pathogens (Marsh *et al.,* 2005). Oxygen for example can increase irradiation susceptibility but also increase post-irradiation repair.
Doses required for sterilization of most insects is below 0.75 kGy, while dosages required for effective decay control are often greater than 1 kGy (Mitcham 1999).

Investigations in the U.S. (Saleh *et al.,* 1988) used a Cs137 source irradiation with a dose of 10 kGy at a rate of 1.7 kGy/hour on fungi suspended in water. They found D-values of

0.3 kGy for *Cladosporium eladosporioides* and 2.9 kGy for *Curvularia geniculata*. Further genera were tested including *Alternaria*, *Aspergillus, Cladosporium*, *Fusarium* and *Penicillium* in agar, which indicated inactivation doses for dematiaceous fungi were up to 20 kGy, while for moniliaceous fungi they were less than 3 kGy (Saleh *et al.,* 1988).

Based on existing data (with more recent relevant papers included) Marsh *et al.* (2005) have compiled the following recommended doses for the listed fungal pathogens below (Table 4). Many results of fungal irradiation research quote D-values. In practice it is not only the irradiation dose which is important, but also the irradiation environment and post irradiation storage. Aziz *et al.* (2006) looked at tolerance and mycotoxin production in grains treated with gamma irradiation and fungal counts taken after 100 days of storage at room temperature.

Table 4. Estimated dosage required to reduce an undesirable pathogen to 10 percent. Taken from Marsh et al. 2005

Species	D-value (kGy)	Author/(s)
Alternaria spp.	4 6	Ramakrishna et al. (1991) Aziz et al. (2006)
Fusarium oxysporum	4 6	Ramakrishna et al. (1991) Shahin et al. (2006)
Penecillium spp.	1.4 6	Müzner (1969) Aziz et al. (2006)

Differences between electron beam and gamma irradiation processes with regards to microbial lethality focus mainly on efficiency (Blank & Corrigan 1995). The efficiency of electron accelerators is higher because the electron beam can be focussed on the product or micro-organism, whereas the gamma sources emit radiation in all directions (Diehl 1990). Pathogens are usually more susceptible to irradiation treatment when at a temperature above 45°C (for vegetative cells) or 90°C (for spores) or below subfreezing (for vegetative cells) or ambient (Marsh *et al.,* 2005). Some author's state that heat and cold treatments applied successively with irradiation can act synergistically (Kiss & Farkes 1981). Others authors report an increased sensitivity of some fruit types to hot and cold temperatures after irradiation.

In experiments on the "Brewster" variety of litchi in Hawaii irradiation was considered as a means to control decay and molding. Only excessively high doses (over 2000 Gy) controlled the decay and moulding in storage periods of 3 to 9 days. The fruit were severely scalded, with flavour and aroma impaired at these doses. The maximum dose litchi's can tolerate is limited by the effect of radiation on surface darkening (scalding). This maximum tolerant level is 250 Gy for fruits stored at room temperature in a polythene bag (Akamine & Goo 1977).

Currently Horticulture Australia views irradiation as an unlikely appropriate treatment for fungi and bacteria. With a lack of supporting scientific evidence and the fact that at high doses of irradiation many horticultural products may be damaged (Richards *et al*. 2003) its uses are likely to be restricted to eliminating insects and arachnids.

It is unlikely in this author's opinion that the irradiation dosages required to sterilise fungal pathogens would be tolerated by the fruit itself. Good pest control systems, post harvest handling of fruit such as washing and grading for quality plus inspection pre shipment are alternative options for reducing the likelihood of unwanted fungal organisms entering the

country on litchis. In addition, the maximum absorbed dose permitted under FSANZ Standard 1.5.3 is only 1000 Gy.

It is essential to ensure that the minimum absorbed dose prescribed for a quarantine treatment has been applied. For this, the principles of Good Irradiation Practice (GIP) must be followed, for example the Codex recommended code of practice for irradiation facilities used for the treatment of food (Codex Alimentarius Commission1984). Dose verification is only possible through in-plant procedures before and during irradiation treatment that include calibration of absorbed dose by a standard method, dose mapping within the food, knowledge of source activity (cobalt-60 or electricity) control and recording of conveyor speed, package and batch identification, and full documentation to allow traceability of packages back to a verified delivery of dose. ISPM 18 briefly outlines these requirements in Annex 2, Checklist for Facility Approval. However, procedures recommended in manuals of the International Atomic Energy Agency and the American Society for Testing and Materials should be consulted for a full understanding of GIP (ISPM 2003).

Three main technologies exist to determine whether food has been irradiated, with varying suitability for different types of food (McMurray *et al.* 1996). The European Union has established standards for the application of these methods such as EN 1785, EN 1786 and EN 1788. The low doses involved in quarantine treatments pose a problem for the detection methods in all but specialized laboratories. It is essential to note that such methods are not quantitative or suitable for dose verification (P. Roberts Pers. Comm. 2007). However, they may be useful as a check that irradiation has been performed in the event of a query.

Electron spin resonance spectroscopy (ESR) is used for relatively dry components of food and provides a unique signature for irradiated foods containing bone and shell. Seeds from irradiated fruits do not display a unique ESR response but the response usually differs sufficiently from that of seeds from unirradiated fruits (Raffi 1992). Luminescence can be clearly detected from absorbed or attached mineral dust particles when trapped energy from the irradiation is released by heating (Thermoluminescence, TL) or pulsed infra-red light (Photo-stimulated Luminescence, PSL). Luminescence can be applied to irradiated fresh produce when a few milligrams of soil contamination can be isolated (Schreiber *et al.* 1993). Gas chromatography-mass spectrometry (GC-MS) can detect a unique product of irradiation (2-alkylcyclobutanones) if the food contains at least some amount of fat. GC-MS has been used with reasonable success on fruits such as avocado, mango and papaya (Schreiber et al, 1993) in experiments that were notable because the doses used were in the range applicable to quarantine treatment.

5.5. Washing Fruit to Reduce Fungal Contamination

In general fungi are more dominant on harvested fruit, whereas bacteria are more prominent on vegetables (de Roever 1999). Some fungi, *Botryosphaeria* spp. for example are known to move down fruit during fruit development resulting in postharvest stem end rot (Lonsdale 1993).Because irradiation treatments at the dosages required to control arthropod pests are inneffective in controlling fungal pathogens other methods for reducing post harvest decay are required.

Various washing regimes have been trialed. A short hot water rinse and brush system in Israel has reduced post harvest losses to less than 2 percent, saving farmers more than $15 million (Fallik *et al.* 2000). Fruit are first washed with tap water (20-23ºC) by nozzles from above, while rolling on brushes for about 10 seconds. The fruit continues to roll on brushes to the hot water for a rinse from above with hot water at 50-60 ºC for 10-25 seconds depending on the type and cultivar of fresh produce (Fallik *et al.* 2000). A 3-4 log reduction of the total

microbial colony forming units of epiphytic microorganisms was noted compared to untreated fruit (Fallik 2000).

This technology has been further developed for litchi and other small fruits. It consists of a revolving drum covered internally with a bristled surface fitted with hot water nozzles (Lichter *et al.* 2000). After brushing, fruits are then treated with hydrochloric acid maintaining a uniform red colour for at least 35 dyas, without apparent deterioration in external or internal quality or taste (Fallik *et al*. 2000).

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

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

5.6. 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 may or may not be acceptable and can result in changes to risk management. Residual risk information in this case would be interception data from the litchi consignments coming into New Zealand from Australia. 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. There can be no assessment of residual risk until this data eventuates.

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. Irradiation treatment does not sterilise fungi at the dosages used to sterilise insects or at which litchi fruit quality is not compromised. Therefore there will be residual risk associated with fungal pathogens.

Because a small proportion of insects may enter the country alive, visual inspection would be less relevant as a risk management option in this case. This differs from its use in the detection of unwanted fungi. It is suggested that development of a system similar to that in South Africa for spices and medical products be implemented; where irradiation levels are recorded on pads outside of the cardboard boxes produce are treated and transported in. These pads change colour when the appropriate level of irradiation has been reached in the treatment

chamber and can be checked easily by MAF inspectors giving clearance to the consignment at the border (HEPRO 1986).

This will not give information on treatment efficacy per se, as interceptions of live organisms and determination of sterility would. However it will confirm that the treatment has been carried out.

There is a certain amount of extrapolation around treatment efficacy from one species within or outside a genus or family group to another. Uncertainties and assumptions made around these extrapolations may be reviewed when technology such as sterilisation tests allow residual risk to be measured in the future.

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6. Potential Hazard Organisms: Risk Analyses

6.1. Tephritid Fruit Flies

6.1.1. Hazard Identification

Aetiological agent: *Bactrocera* (*Bactrocera*) *aquilonis* (May) (Diptera: Tephritidae)
Bactrocera (*Afrodacus*) *jarvisi* (Tryon) (Diptera: Tephritidae)
Bactrocera (Bactrocera) neohumeralis (Hardy) (Diptera: Tephritidae)
Bactrocera (*Bactrocera*) *tryoni* (Froggatt) (Diptera: Tephritidae)
Ceratitis capitata (Weidermann) (Diptera: Tephritidae)

Synonyms for B. aquilonis: Dacus aquilonus, Strumeta aquilonis

for B. jarvisi: Dacus jarvisi, Afrodacus jarvisi, Chaetodacus jarvisi, Dacus australis

for B. neohumeralis: Dacus neohumeralis, Chaetodacus humeralis, Chaetodacus tryoni var. sarcocephali, Dacus tryoni var. neohumeralis

for B. tryoni: Dacus tryoni, Chaetodacus sarcocephali, Strumeta melas, Strumeta tryoni, Dacus ferrugineus tryoni, Tephritis tryoni

for C. capitata: Ceratitis hispanica, Tephritis capitata, Ceratitis citriperda, Pardalaspis asparagi

New Zealand Status: None of these species is known to be present in New Zealand (not recorded in PPIN 2007; Scott & Emberson 1999). *C. capitata* was recorded in New Zealand in 1996 and was successfully eradicated (ISSG 2007). Currently New Zealand has area freedom status from all fruit flies of economic importance including *Ceratitis capitata* and *Bactrocera tryoni* (MAF 2007)

6.1.2. *Bactrocera aquilonis* Biology

B. aquilonis is extremely difficult to separate taxonomically from *B. tryoni* (Queensland fruit fly) and will produce viable offspring when crossed under laboratory conditions (Drew & Lambert 1986). It is still not certain whether "Queensland fruit fly" in the Northern Territory is pure *B. tryoni*, pure *B. aquilonis* or a fertile hybrid of the two. For quarantine purposes, Northern Territory administration approaches management of the fly as if it is pure *B. tryoni* (Yonow & Sutherst 1998). There is very little information available in the literature about *B. aquilonis*. It is assumed to have a similar life history and ecology to its congeners.

6.1.3. Hosts

This fly has been recorded on 63 species from the following families: Anacardiaceae, Annonaceae, Apocynaceae, Arecaceae, Chrysobalanaceae, Combretaceae, Ebenaceae, Elaeocarpaceae, Euphorbiaceae, Flacourtiaceae, Lauraceae, Malpighiaceae, Meliaceae, Musaceae, Myrtaceae, Oxalidaceae, Rhamnaceae, Rosaceae, Rubiaceae, Rutaceae, Sapindaceae, Sapotaceae, Solanaceae (Carroll *et al.* 2005). It infests 3 cultivated sapinds *Blighia sapida* (ackee), *Chrysophyllum cainito* (star apple) and *Manilkara zapota* (sapodilla), and many *Syzygium* species (Smith *et al.* 1988). The commonly cultivated *Mangifera indica* and *Averrhoa carambola* are also significant hosts. It has not been recorded on litchi.

6.1.4. Distribution

B. aquilonis is found in north Western Australia in the Northern Territory particularly around Darwin (Smith *et al.* 1988).

6.1.5. *Bactrocera jarvisi* Biology

B jarvisi has a wide host range and similar distribution to *B. tryoni*. Early experiments rearing the fly on apple and pear in the laboratory provide some of the few published observations on the life cycle of the species. Egg, larval and pupal stages were approximately 7, 11 and 23 days long respectively (Jarvis 1927). In food choice experiments conducted in Sydney (Fitt 1986) *B. jarvisi* readily accepted other cultivated fruits in the absence of its preferred native host *Planchonia careya* (Fitt 1986). In general the occurrence of this species in cultivated fruits is constrained more by the behavioural preferences of adult females than by larval specializations (Fitt 1986).

CLIMEX model predictions of climatic requirements for establishment of *Dacus* (*Bactrocera*) spp. in New Zealand (Sutherst & Maywald 1989), had parameter values indicating population growth rates of *B. jarvisi* would be maximised around 30ºC and soil moisture levels around their holding capacity. According to this analysis cold stress indices of 0 meant the establishment of permanent populations of *B. jarvisi* in New Zealand are unlikely.

6.1.6. Hosts

B jarvisi is recorded utilising a wide variety of hosts including many of those attacked by *B. tryoni*. Persimmon, avocado, feijoa, *Ficus*, *Citrus* and *Prunus* species are among the significant horticultural plants infested. It has also been recorded on both rambutan and litchi but only as an occasional pest (Hancock *et al.,* 2000). It shares some food resources with *B. neohumeralis* and *B. tryoni* where their distributions overlap in coastal Queensland (Gibbs 1967).

6.1.7. Distribution

B. jarvisi is found in Northern Australia from Broome, Western Australia to eastern Arnhem land, Northern Territory and northwest Queensland, Torres Strait Islands and eastern Australia from Cape York to the Sydney district, New South Wales (Hancock *et al,* 2000).

6.1.8. *Bactrocera neohumeralis* Biology

Bactrocera tryoni and *B. neohumeralis* are sympatric species which hybridise yet remain distinct in the field. *B. tryoni* mates only at dusk and *B. neohumeralis* mates only during the day but hybrids can mate at both times (Pike *et al.,* 2003). It is likely that despite differences in mating time between the two species some gene flow still occurs (Wang *et al.,* 2003). A rapid molecular diagnostic technique for fruit flies (Armstrong *et al.,* 1997) found that *B. tryoni* and *B. neohumeralis* could not be differentiated. They have overlapping origins, hosts and adult morphology. Hybrids could have characteristics and behaviours of either parent species, therefore comparisons between *B. tryoni* and *B. neohumeralis* are considered in the following paragraphs.

In their CLIMEX model predictions for establishment of *B. neohumeralis* in New Zealand, Sutherst and Maywald (1989) indicate similar parameter values and optimum temperature for growth as for *B. jarvisi* (30 ºC). From this model it was concluded *B. neohumeralis* would not find the suitable climatic conditions to establish permanently anywhere in New Zealand.

B. *neohumeralis* can survive longer in the field than *B. tryoni* with survival rates for both sexes to 130, 144 and 159 days better than those for *B. tryoni* to the same dates (Meats 2006).

Although *B. tryoni* can live in places with a much colder winter, the current range of *B neohumeralis* in Queensland includes places of moderately high altitude that have colder winter weather than those of much of the coastal range of *B. tryoni* in new South Wales. *B. neohumeralis* can mate at 18 ºC suggesting it could mate in colder temperatures as low as 16 ºC. Temperatures drop to this level over night in the region (Meats 2006). *B. jarvisi* and *B. neohumeralis* are 2 species that may require quarantine treatments but are generally not listed in international trade agreements (Smith 2000).

6.1.9. Hosts

B. neohumeralis has not been recorded using *Litchi chinensis* as a host, however it has been recorded from native Sapindaceae including *Castanospora alphandii* and *Ganophyllum falcatum* (Hancock *et al.* 2000). *B. neohumeralis* can hybridise with *B. tryoni* and so hybrids could possibly retain a host range either narrower or wider than each species respectively.

6.1.10. Distribution

B. neohumeralis is found in Torres Strait Islands and eastern Australia, south to Coffs Harbour, northern New South Wales and in a few localities in Queensland (Osborne *et al.,* 1997; Hancock *et al.,* 2000).

6.1.11. *Bactrocera tryoni* Biology

Females of *B. tryoni* are essentially monandrous (mate with only one male), although males can mate several times (Fay & Meats 1983) within a few weeks. Sexually mature insects are found in the field during spring, summer and winter (Fletcher 1975). After larval feeding, late third instar larvae leave the host and enter the wandering phase (Zdarek & Denlinger 1991) during which they locate pupation sites, taking between 2 minutes to 2 hours, after which they enter the soil to pupate. Adults emerge to find suitable host material. Duration of each life stage is dependent on environmental factors, with estimates for egg, larval, pupal, and adult longevity between 2-3 days, 5-31 days, 9-63 days and 27-340 days respectively (Jarvis 1926; Allman 1939; O'Loughlin 1964; Bateman & Sonleitner 1967; Hulthern & Clarke 2006). The entire lifecycle from egg to adult lasts between 43 - 437 days.

Some authors observed pupation lasting between 10 and 14 days (Hulthen & Clarke 2006) but Bateman and Sonleitner (1967) found that at low temperatures of 13 ºC development of pupae took up to 63 days. Adults survived for an average of about 6 months, and for up to 11 months at 24 ºC (O'Loughlin 1964). Early experiments revealed little activity in fruit flies in laboratory conditions below 18.33 ºC (O'Loughlin 1964). Later research by Fay & Meats (1983) produced flies with a mean cold torpor threshold due to warm and cold thermal histories of 6.8 ºC and 3.2 ºC respectively. More recent studies observed the mean threshold for development for *B. tryoni* was 2.04ºC (±0.23) and 2.2 ºC (±0.2) for *B. neohumeralis* (Meats 2006).The lower threshold for mating in *B. tryoni* is thought to be around 16 ºC (Meats & Fay 2000). CLIMEX modelling applied to New Zealand climate conditions suggest *B. tryoni* is likely to establish on the east coast of Northland, around Auckland, Bay of Plenty, and Gisborne (Sutherst & Maywald 1989).

Flies overwinter if they experience 5 consecutive days when the maximum temperature does not reach 18ºC, and they stop over-wintering life stages when they experience 4 days in a row when the maximum temperature reaches or exceeds 18 ºC (Yonow *et al.,* 2004). Both newly emerged and mature males are capable of long distance dispersal, travelling over 517 km² (Fletcher 1974) when released at distances of 0.5-15 miles from the orchard they were trapped in.

CLIMEX modelling predictions in Australia (Yonow & Sutherst 1998) suggest *B. tryoni* distribution there is strongly limited by available moisture. A recent study assessed the impact of urban environments on the potential growth rate of the Queensland fruit fly in south eastern New South Wales (Dominiak *et al.* 2006). Urban environments were found to be warmer and moister than adjacent rural environments, making rural landscapes less attractive for the fruit fly. In summer when moisture was a major limiting factor the health and greenness of urban backyards and parks is maintained with frequent use of urban irrigation and resulted in a large increase in the duration of a favourable period for potential growth of *B. tryoni*.

However in winter, low temperatures kept *B. tryoni* under control, irrespective of favourable moisture conditions (Dominiak *et al.* 2006). Towns appear to be oases within the surrounding rural desert. The authors suggest that Queensland fruit fly is unlikely to travel freely between towns in this area, minimising chances of reinvasion once a resident population has been eliminated (Dominiak *et al.* 2006).

6.1.12. Hosts

B. tryoni is not a common or significant pest of litchi fruit in Australia, although sporadic severe infestations occur in some seasons (G.K. Waite pers. comm. 2007, Waite and Hwang 2002, Waite 2005).

Major hosts include:
Anacardium occidentale (cashew nut), *Annona* spp. *Averrhoa carambola* (carambola), *Capsicum annuum* (bell pepper), *Carica papaya* (papaw), *Casimiroa edulis* (white sapote), *Chrysophyllum cainito* (caimito), *Coffea arabica* (arabica coffee), *Eriobotrya japonica* (loquat), *Eugenia uniflora* (surinam cherry), *Fortunella japonica* (round kumquat), *Lycopersicon esculentum* (tomato), *Malus sylvestris* (crab-apple tree), *Mangifera indica* (mango), *Manilkara zapota* (sapodilla), *Morus nigra* (black mulberry), *Passiflora edulis* (passionfruit), *Passiflora suberosa* (Corky passionflower), *Prunus persica* (peach), *Psidium* spp. (guava), *Syzygium* spp., and *Terminalia catappa* (Singapore almond).

Minor hosts include:
Aegle marmelos (golden apple), *Annona squamosa* (sugarapple), *Averrhoa bilimbi* (blimbe), *Blighia sapida* (Akee apple), *Calophyllum inophyllum* (Alexandrian laurel*), Cananga odorata* (perfume tree), *Citrus* spp., *Clausena lansium* (wampi), *Cucurbita moschata* (pumpkin), *Cydonia oblonga* (quince), *Cyphomandra betacea* (tree tomato), *Dimocarpus longan* (longan tree), *Diospyros blancoi* (mabolo), *Diospyros kaki* (persimmon), *Dovyalis caffra* (kei apple), *Eremocitrus glauca* (Australian desert lime), *Eugenia dombeyi* (brazil cherry), *Feijoa sellowiana* (Horn of plenty), *Ficus racemosa* (cluster tree), *Flacourtia* spp. *Fortunella x crassifolia* (meiwa kumquat), *Grewia asiatica* (phalsa), *Juglans regia* (walnut), *Litchi chinensis* (litchi), *Malpighia emarginata*, *Mimusops elengi* (spanish cherry), *Momordica charantia* (bitter gourd), *Morus alba* (mora), *Musa x paradisiaca* (plantain), *Myrciaria cauliflora* (jaboticaba), *Nephelium lappaceum* (rambutan), *Nerium oleander* (oleander), *Olea europaea* subsp. europaea (olive), *Opuntia ficus-indica* (prickly pear), *Passiflora* spp., *Persea americana* (avocado), *Phoenix dactylifera* (date-palm), *Phyllanthus acidus* (star gooseberry), *Physalis peruviana* (cape gooseberry), *Pometia pinnata* (fijian longan), *Pouteria* spp., *Prunus* spp., *Psidium guineense* (Guinea guava), *Punica granatum* (pomegranate), *Pyrus communis* (European pear), *Rollinia mucosa*, *Rollinia pulchrinervis*, *Rubus* spp., *Solanum* spp., *Spondias* spp., *Synsepalum dulcificum*, *Syzygium cumini* (black plum), *Syzygium* spp., *Thevetia peruviana* (exile tree), *Trichosanthes cucumerina var. anguinea* (snakegourd), *Vitis labrusca* (fox grape), *Vitis vinifera* (grapevine), and *Ziziphus mauritiana* (jujube) (CPC 2007; Hancock *et al.* 2000).

6.1.13. Distribution

B. tryoni ranges from the Cape York Peninsular, northern Queensland, to regions as far south as Gippsland, Victoria in Australia (Osborne *et al.* 1997), and has a restricted distribution in French Polynesia (Purea *et al.,* 1997) and New Caledonia (Amice & Sales 1997).

6.1.14. *Ceratitis capitata* Biology

Mediterranean fruit fly has a similar life cycle to other fruit flies in the Tephritidae, with larvae leaving fruit hosts and completing development in the late larval instars and pupating beneath plant remains or in the upper soil layer (Rigamonti 2004). Estimates for egg, larval, pupal and adult longevity are 2-7, 6-14, 9-42 and 30-180 days respectively (Rigamonti 2004; Back & Pemberton 1915). Three to 4 generations may be completed annually in Lombardy (Northern Italy), the 4th generation usually only by a small number of precocious specimens (Rigamonti 2004). Sexual maturity is reached after 4 days for males and between 6-8 days for females (Back & Pemberton 1915). In Israel experiments found that the lower thresholds for development of larvae and pupae were 11-12ºC and 11 ºC respectively. Eggs failed to develop at 18-22 ºC. The optimum temperature for egg development was 27-29 ºC (Rivnay 1950).

Worner (1988) looked at the potential establishment of *C. capitata* in New Zealand based on the CLIMEX model which uses temperature and moisture parameters to predict its likely range. In North Island, Auckland, parts of Northland, south of Coromandel Peninsula, Hawkes Bay, Bay of Plenty and Malborough in South Island are all areas predicted to provide locations favourable for establishment (Worner 1988). Other more marginal areas include the west coast of North Island from Manawatu through to Taranaki.

6.1.15. Hosts

C. *capitata* is a pest of litchi fruit in South Africa (Grove *et al.,* 2004), but although adults lay eggs in the fruit, larval development seldom takes place. It is therefore considered a poor host. It has not been recorded on litchi in Australia (Hancock *et al.,* 2000) as the litchi production area is far from C. *capitata*'s only Australian stonghold in Western Australia.

Major hosts include:
Annona cherimola (cherimoya), *Capsicum annuum* (bell pepper), *Citrus* spp, *Coffea* spp. (coffee), *Ficus carica* (fig), *Malus domestica* (apple), *Prunus* spp. (stone fruit), *Psidium guajava* (guava), and *Theobroma cacao* (cocoa).

Minor hosts include:
Anacardium occidentale (cashew nut), *Annona reticulata* (bullock's heart), *Calophyllum* spp. (beauty-leaf), *Capsicum frutescens* (chilli), *Carica papaya* (papaw), *Carissa* spp., *Casimiroa edulis* (white sapote), *Chrysophyllum* spp, *Citrus* spp., *Coffea* spp. *Cydonia oblonga* (quince), *Cyphomandra betacea* (tree tomato), *Diospyros* spp. (malabar ebony, persimmon), *Dovyalis caffra* (kei apple), *Eriobotrya japonica* (loquat), *Eugenia* spp., *Feijoa sellowiana* (feijoa), *Fortunella* spp.(kumquats), *Garcinia mangostana* (mangosteen), *Juglans regia* (walnut), *Litchi chinensis* (litchi), *Malpighia glabra* (acerola), *Mangifera indica* (mango), *Manilkara zapota* (sapodilla), *Mespilus germanica* (medlar), *Morus nigra* (black mulberry), *Muntingia calabura* (Jamaica cherry), *Opuntia* spp. (Pricklypear), *Passiflora coerulea* (blue-crown passionflower), *Persea americana* (avocado), *Phoenix dactylifera* (date-palm), *Physalis peruviana* (cape gooseberry), *Pouteria* spp.(sapote), *Prunus* spp.(apricot, plum, peach), *Psidium longipes* (strawberry guava), *Punica granatum* (pomegranate), *Pyrus communis* (European pear), *Rubus loganobaccus* (loganberry), *Santalum album* (Indian sandalwood), *Solanum* spp. (grey bitter-apple, black nightshade), *Spondias* spp. (otaheite apple, red mombin), *Syzygium* spp., *Terminalia catappa* (Singapore almond), *Thevetia peruviana* (exile tree), *Vitis vinifera* (grapevine)

Wild hosts include:
Acokanthera spp., *Antidesma* spp., *Argania spinosa* (argan tree), *Azima tetracantha* (beehanger), *Brucea antidysenterica*, *Calophyllum tacamahaca*, *Capparis sepiaria* (indian caper), *Carissa* spp. (caranda plum, natal plum), *Chrysobalanus icaco* (icaco plum), *Chrysophyllum viridifolium*, *Cinnamomum verum* (cinnamon), *Clausena anisata* (horsewood), *Coccoloba uvifera* (seaside grape), *Cola natalensis*, *Cucumis dipsaceus* (hedgehog gourd), *Dovyalis hebecarpa* (ketembilla), *Drypetes natalensis*, *Ehretia cymosa*, *Ekebergia capensis*, *Englerophytum magalismontanum*, *Euclea divinorum*, *Eugenia paniculata*, *Filicium decipiens*, *Flacourtia indica* (governor's plum), *Flagellaria guineensis*, *Flueggea virosa*, *Garcinia livingstonei* (african mangosteen), *Guettarda speciosa*, *Harpephyllum caffrum*, *Lycium* spp. (boxthorn), *Manilkara* spp., *Mimusops* spp., *Myrianthus arboreus*, *Olea woodiana*, *Opilia amentacea*, *Pithecollobium dulce*, *Podocarpus elongatus* (african yellow wood), *Scaevola* spp., *Sideroxylon inerme*, *Solanum* spp. (local garden egg, tree tobacco, star potato vine), *Strychnos* spp., *Synsepalum dulcificum*, *Vangueria infausta*, and *Vepris lanceolata* (CPC 2007).

6.1.16. Distribution

C. capitata is found in Western Australia with occasional outbreaks recorded from South Australia around Adelaide (Perkram & Hancock 1995). It has been intercepted from Northern Territory (Hancock *et al.,* 2000), and originally appeared near Perth (in 1895), Tasmania and the eastern states of Australia before disappearing from the latter two regions by the 1940s (Bonizzoni *et al.,* 2005). *B. tryoni* has been credited with displacing *C. capitata* in eastern Australia (Vera *et al.,* 2002).

6.1.17. Hazard Identification Conclusion

Although *B. aquilonis* is able to hybridise with *B. tryoni* in laboratory conditions producing fertile offspring and infesting 3 species of cultivated sapinds in northern Australia there is no direct evidence for *B. aquilonis* utilising *Litchi chinensis* as a host. It has a very restricted distribution (Northern Territory) outside of prime litchi growing areas in Australia. Therefore it cannot be considered a potential hazard in this risk analysis. If evidence of its direct association with litchi fruit were to emerge, a reconsideration of its hazard status would be necessary.

B. tryoni and *B. jarvisi* both use litchi fruit as host material and have an overlapping distribution throughout much of their ranges. *B. tryoni* is considered one of the most destructive fruit fly pests in the world, and is capable of long distance dispersal. It is thought to be strongly moisture limited in its current distribution in Australia. Although *B. neohumeralis* has not been recorded associated with litchi it occurs on native Sapindaceae and has a similar distribution range to *B. tryoni* with which it hybridises. Both species have overlapping hosts, origins and morphology. Therefore *B. jarvisi, B. neohumeralis* and *B. tryoni* are considered potential hazards in this risk assessment.

C. capitata is not currently found in commercial litchi growing areas in Australia, and has not been recorded utilising this plant as a host there. It is therefore not considered a potential hazard on the pathway. However given its historic distribution in eastern Australia and the fact it is a pest of litchi in South Africa, if it was reported from eastern or northern Australia in the future a reconsideration of the potential risk of the species would be required.

6.1.18. Risk Assessment

6.1.18.1 Entry Assessment

B. tryoni is able to lay eggs in almost all commercially grown fruit including litchi (Hancock *et al.* 2000). The unpredictability of fruit fly infestation in litchis causes Australian growers problems. Because fruit flies are not regarded as a problem pest in the crop usually preventative sprays are not normally applied in the field (G.K. Waite pers. comm. 2007). Eggs and larvae live for up to 30 days in total which would more than encompass the transit time for fruit coming either by sea or air.

Similarly *B. jarvisi* egg and larval stages extend to approximately 18 days (Jarvis 1927). Little information exists on the longevity of egg and larval stages of *B. neohumeralis*, it is assumed to be similar to that of its congeners.

Generally, fly-stung fruit would be detected either at harvest in the field or failing that, in the packing shed. It is possible that fruits stung within three days of harvest could escape detection at pre-export inspection, because eggs would not have hatched and the effect of larvae within (weeping) would not yet be evident (G.K. Waite pers. comm. 2007).

The likelihood of entry of B. tryoni into New Zealand is low given its occasional association with litchi fruit, with B. jarvisi recorded only twice from the fruit its likelihood of entry is also low and for B. neohumeralis very low because although it is not recorded on litchi it can hybridise with B. tryoni.

6.1.18.2 Exposure Assessment

There would be no shortage of hosts for the three *Bactrocera* species were they to enter the country. Hosts found in New Zealand include persimmon, avocado, banana, feijoa, guava, passionfruit, apple, apricot, peach, pear, *Citrus* spp., capsicum, blackberry, cherry, nashi, tomato and grapevine. Some ornamental trees such as *Ficus macrophylla* (Moreton Bay fig) and *Acmena* spp. are commonly found around the Auckland region. *Syzygium australe* is naturalised and *S. paniculatum* is widely planted in North Island.

6.1.18.3 Establishment Assessment

A study in south eastern New South Wales (Dominiak *et al.* 2006) determined that urban environments were more attractive than adjacent rural landscapes for *B. tryoni*, being warmer and moister particularly in summer when moisture is a limiting factor to population growth. Towns appear to be oases within the surrounding rural desert. The authors suggest that Queensland fruit fly is unlikely to travel freely between towns, minimising chances of reinvasion once a resident population has been eliminated (Dominiak *et al.* 2006).
Because of the more temperate and greener nature of the rural landscape in New Zealand it is highly likely that a different trend would be seen here. Moisture would not be a limiting factor in the same way it is in Australia, and establishment of *B. tryoni* in both urban and rural environments is expected.

Research on mean cold torpor thresholds in *B. tryoni* due to warm and cold thermal histories were 6.8 ºC and 3.2 ºC respectively (Fay & Meats 1983) indicating the fly could be capable of surviving in most coastal areas of North Island New Zealand and some areas of South Island. CLIMEX models predict parts of Northland, Auckland, Bay of Plenty and Gisborne as the most suitable areas for establishment (Sutherst & Maywald 1989). Although no similar thermal threshold data exist for *B. jarvisi* or *B. neohumeralis* the current range of *B. neohumeralis* in Queensland includes places of moderately high altitude that have colder winter weather than those of much of the coastal range of *B. tryoni* in new South Wales.

CLIMEX modelling done for *B. jarvisi* and *B. neohumeralis* suggest that both species are unlikely to survive anywhere in New Zealand under current climatic conditions. Limited weather station data were used in these original models, and changing weather patterns over the last 15 years could influence contemporary remodelling for both species. It is suggested that permanent populations of *B. neohumeralis* which has a very similar distribution in Australia to *B. cucumis* could establish in the far northern North Island based on CLIMEX modelling for *B. cucumis* in New Zealand (Kriticos *et al.* 2007). Further research would need to be undertaken to predict possible distribution.

The likelihood of exposure for all three Bactrocera species is high, establishment for B. tryoni is high and for B. jarvisi and B. neohumeralis low.

6.1.19. Consequence Assessment

6.1.19.1 Economic impact

The current annual national cost of *B. tryoni* in Australia is estimated to be $AUD28.5 million with 60 percent of the cost borne by commercial growers (Sutherst *et al.* 2000). Climate warming threatens the sustainability of area freedom in the Fruit Fly Exclusion Zone and is likely to increase damage and control costs everywhere except in northern Australia. Costs to mainland apple, orange and pear growers are estimated to increase by $3.1, $4.7 and $12.0 million with increases of 0.5ºC, 1.0 ºC and 2 ºC respectively. The fly is thought to pose a real threat to southern States under modest projected increases in temperature (Sutherst *et al.* 2000). The main economic loss in passion fruit in Queensland results from stinging of the fruit by *B. tryoni*. Quality of the mature fruit is downgraded, as it shows the effects of the stinging. Stinging was most important in the late summer crop and to a lesser extent the winter crop (Hargreaves *et al.* 1986). Between 76 and 100 percent infestation may occur in untreated peach crops in south east Queensland (Bull 2004).

Under current climatic conditions *B. tryoni* would be able to establish in warmer regions of the North Island. If climate warming did occur widening the potential distribution of permanent populations of *B. tryoni* many areas with similar landscapes and climatic conditions to southern Australia would be likely to experience significant economic impacts from the introduction of the fly (Sutherst 1990).

There is little information on the economic impact of *B. jarvisi* and *B. neohumeralis*. They are 2 species that may require quarantine treatments but are generally not listed in international trade agreements (Smith 2000). Temporary populations of any fruit fly species could have an economic impact in New Zealand. Ongoing surveillance for fruit fly requires that we notify trading partners of any incursions, which could disrupt trade and potentially mean large economic losses for exporters of fruit fly host material produce.

6.1.19.2 Environmental

There are several plant genera: *Passiflora*, *Syzygium*, *Eleocarpus* and *Ripogonum* attacked by *B. jarvisi*, *B. neohumeralis* and *B. tryoni* represented in the native flora. Many species are in the Myrtaceae, a family widely distributed in New Zealand as forest and scrubland species. *B. jarvisi* and *B. neohumeralis* utilise 13 spp. of *Syzygium*, and *B. tryoni* 23 spp. in the genus. *Syzygium maire* is native to New Zealand. It is highly likely that if any of these flies were to establish *S. maire* would become a host given the apparently favourable nature of *Syzygiums* as hosts in Australia.

Other species (*Eleocarpus dentatus*, *E. hookerianus*; *Passiflora tetranda*; *Ripogonum scandens*) could become hosts if *Bactrocera* flies become widespread, but horticultural plants with larger fruits in mono cultured systems would most likely be more important. The ornamental *Murraya paniculata* is a host of *Bactrocera* spp. in eastern Australia. This plant is sometimes cultivated in warmer regions of upper North Island.

The consequences of establishment of B. tryoni, jarvisi and neohumeralis are likely to be moderate to very high and therefore non-negligible.

6.1.20. Risk Estimation

The likelihood of *B. tryoni*, *B. jarvisi* and *B. neohumeralis* entering the country is high moderate and low for each species respectively, exposure and establishment are high for *B. tryoni*, and low for *B. jarvisi* and *B. neohumeralis*. The consequences of establishment are highest for *B. tryoni* and moderate for *B. jarvisi* and *B. neohumeralis*.

There is some uncertainty around the potential host range of hybrid *B. tryoni* x *neohumeralis* and therefore its likelihood of being associated with litchi fruit. Were evidence of it infesting litchi to become known the potential likelihood of its entry exposure and establishment would increase.

As a result the risk estimate for B. tryoni, B. jarvisi and B. neohumeralis is non-negligible and they are classified as hazards on the commodity. Therefore risk management measures can be justified.

6.1.21. Risk Management

6.1.21.1 Options

Heather, Corcoran & Banos (1991) irradiated *B. tryoni* and *B. jarvisi* within mangoes in efficacy experiments in Australia and determined that 74-101Gy were sufficient for disinfestation purposes. In trials in which >100,000 individual 24hr old egg and 5day old larval stages of each species were treated, no adults emerged. This mortality rate assures quarantine security to Probit 9 (mortality of 99.9968 percent of pests in a test of 100,000 individuals) at the 95 percent confidence level, however some treated eggs and larvae still developed to the pupal stage (Heather *et al.* 1991). Irradiation of 150 Gy has been established as a sufficient level to cause non-emergence in treated eggs and larvae (Bustos *et al.* 1992; Gould & Hallman 2004) of *B. cucurbitae* and *B. dorsalis*.

Extrapolation of treatment efficacy to litchi was based on knowledge and experiences that radiation dosimetry systems measure the actual radiation dose absorbed by the target pest independent of host commodity, and evidence from research studies on a variety of pests and commodities. These include studies on the following pests and hosts: *Anastrepha ludens* (*Citrus paradisi* and *Mangifera indica*), *A. suspensa* (*Averrhoa carambola*, *Citrus paradisi* and *Mangifera indica*), *Bactrocera tryoni* (*Citrus sinensis*, *Lycopersicon lycopersicum*, *Malus domestica*, *Mangifera indica*, *Persea americana* and *Prunus avium*), *Cydia pomonella* (*Malus domestica* and artificial diet) and *Grapholita molesta* (*Malus domestica* and artificial diet) (Bustos *et al*., 2004; Gould & von Windeguth, 1991; Hallman, 2004, Hallman & Martinez, 2001; Jessup *et al*., 1992; Mansour, 2003; von Windeguth, 1986; von Windeguth & Ismail, 1987). It is recognised, however, that treatment efficacy has not been tested for the target pests on litchi. If evidence becomes available to show that the extrapolation of the treatment to cover litchi for these pests is incorrect, then the treatment will be reviewed

Because a small proportion of insects may enter the country alive, visual inspection on arrival would be less relevant as a risk management option in this case. This differs from its use in the detection of unwanted fungi. Pest management systems in the orchards, screening measures and pre export visual inspection should be implemented in conjunction with the recommended disinfestation treatment.

Risk management options in ascending order of stringency:

Option 1: An irradiation dose of 150 Gy (Bustos *et al.* 1992; Gould & Hallman 2004) which is expected to reduce risk from *B. tryoni, B. jarvisi and B. neohumeralis.*
Option 2: Area freedom for *B. tryoni, B. jarvisi and B. neohumeralis* and inspection on arrival

6.1.22. Assessment of Uncertainty

The likely natural rates of hybridisation of *B. jarvisi* and *B. neohumeralis* with *B. tryoni* are fairly low but essentially unknown. It is also not known exactly what the host range of these hybrids would be. In the absence of this data the three species should be treated as a risk complex. Treatment appropriate for *B. tryoni*, about which the most information is known, should be applied.

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Hemiptera (Bugs/Scales)

6.2. Banana Spotting/ Fruit Spotting Bugs

6.2.1. Hazard Identification

Aetiological agent: *Amblypelta lutescens lutescens* Distant (Hemiptera: Coreidae)
Amblypelta nitida Stål (Hemiptera: Coreidae)

Synonyms for A. lutescens lutescens: Dasynus lutescens, Pendulinus lutescens

New Zealand Status: Not known to be present in New Zealand (not recorded in PPIN 2007; Lariviére & Larochelle 2004; Scott & Emberson 1999).

6.2.2. *Amblypelta lutescens lutescens* Biology

A. lutescens lutescens like its congener *A. nitida* is a serious pest of many crop species in Queensland and New South Wales. *A. lutescens lutescens* shares much of its geographical range in Queensland with *A. nitida*. It utilizes many of the same hosts, but feeds on fewer species and rarely on terminal growth (Waite and Huwer, 1998).
Adults of these two species may sometimes be confused, especially paler specimens of *A. nitida*, which are normally a bright green with a blackish sheen (CPC 2006). In appearance of the adult stage and its host range, *A. lutescens lutescens* is also very similar to *A. cocophaga* from Papua New Guinea, Fiji and the Solomon Islands. They both have a wide host range and share many hosts. Both show a propensity to feed on plant terminals as well as fruit.

A. lutescens lutescens can produce up to 3 generations per year (spring, summer and autumn generations) in the climatic conditions of south-east Queensland (Brimblecombe 1948). Though this is probably more likely to be 4-5 overlapping generations (G.K. Waite pers. comm. 2007).
Eggs hatch within 4-10 days (Sloan 1946; Brimblecombe 1948; Huwer 1996), with females capable of laying up to 434 eggs over a 197 day period (Huwer 1996). In macadamia and papaya orchards the five nymphal instars have been recorded completing development in 4-6 weeks (Sloan 1946; Brimblecombe 1948; Huwer 1996). Huwer (1996) estimated average lifespan of adults to be around 5 months under laboratory conditions, growing up to 15mm in length (Waite & Pinese 1991). The entire lifecycle from egg to egg took about 50-80 days (Huwer 1996).

Generally optimal conditions for *A. lutescens lutescens* are relatively high humidity and high temperatures although there is no literature stating optimal or minimum thresholds for development. Waite *et al.* (2000) conducted studies on the effect of temperature on developmental time of both *A. lutescens lutescens* and *A. nitida.* Time from egg to adult took 63.3 and 78.6 days for *A. nitida* and *A. lutescens lutescens* respectively at 20ºC. This time reduced to 29.5 and 40.9 days for each species respectively at 30ºC. Minimum temperatures in winter in the Atherton Tablelands where *A. lutescens lutescens* occurs range from 10.9-12.8ºC (Anonymous 1978; Anonymous 1987).

Fruitspotting bugs are active in Queensland throughout the year, with activity diminishing during the cooler months between June and September (Huwer 1996). A significant proportion of bugs invading crops breed in the native bushland and forest (Huwer 1996). Adults over-winter on citrus or non-crop native or exotic ornamentals, moving into litchi and longan orchards in spring when trees flower. They prefer to feed on green fruit, and so are very common after fruit set. Orchards near rainforests where the bugs breed are particularly

susceptible (Waite & Huwer 1998). All species of the genus are strong fliers but do not cover large distances (Brown 1958).

6.2.3. Hosts

The natural hosts of *A. lutescens lutescens* in Australia are mainly fruits of rainforest and young growth of open forest trees (Pinese & Piper 1994), but they have adapted to utilise numerous commercial crop hosts (Huwer 1996) and show a preference for dicot over monocot species. For a more detailed discussion see Waite & Huwer (1998)

Some of the major hosts include:
Carica papaya (papaw), *Cocos nucifera* (coconut), *Litchi chinensis* (litchi) (Waite 1990), *Macadamia integrifolia* (macadamia), *Mangifera indica* (mango), *Manihot esculenta* (cassava), *Persea americana* (avocado), *Phaseolus* (beans) (CPC 2006).

Lesser hosts include:
Anacardium occidentale (cashew nut), *Annona squamosa* (sugarapple), *Citrus*, *Dimocarpus longan* (longan tree), *Eriobotrya japonica* (loquat), *Glycine max* (soyabean), *Musa* (banana), *Passiflora edulis* (passionfruit), *Psidium guajava* (guava) (CPC 2006).

6.2.4. Distribution

In Australia *A. lutescens lutescens* has been recorded from Brisbane to the tip of Cape York Peninsula and the Torres Strait Islands, and in the Northern Territory around Katherine and Darwin (Donaldson 1983). It has been found at several localities in north Western Australia including Kununurra and the Ord River area (Smith 1985).

6.2.5. Amblypelta nitida Biology

A. nitida is cryptically coloured and difficult to see (Waite & Huwer 1998) with biology very similar to that of its congener *A. lutescens lutescens*. The complete life cycle from egg through 5 nymphal stages to adult takes about 5 to 6 weeks in summer and there are 3 to 4 overlapping generations per year (Waite & Pinese 1991). There is little data on temperature thresholds for development and it is assumed *A. nitida* is similar to *A. l. lutescens*. Minimum temperatures in winter in the Atherton Tablelands where *A. lutescens* occurs range from 10.9-12.8ºC (Anonymous 1978; Anonymous 1987).

6.2.6. Hosts

Major hosts include:
Litchi chinensis (litchi), *Macadamia integrifolia* (macadamia), *Persea americana* (avocado) (CPC 2007).
Minor hosts include:
Eriobotrya japonica (loquat) and *Psidium guajava* (guava) (CPC 2007).

6.2.7. Distribution

A. nitida has been recorded in coastal eastern Australia from Sydney to Iron Range on Cape York Peninsula. However it is uncommon in north and central Queensland where *A. l. lutescens* is the dominant species (Waite & Pinese 1991)

6.2.8. Hazard Identification Conclusion

A. lutescens lutescens is a serious pest with a broad host range within the localised area that it occurs. *A. nitida* is a cryptic species with a broad host range and high reproductive output given suitable conditions. Although there is no data on thermal tolerances for either species their current restricted distributions suggests they could be limited by climatic factors (optimal development is at higher temperatures and humidity). Climate data from the

Atherton Tablelands in Queensland indicate that *A. lutescens lutescens* could potentially survive winter temperatures in warmer parts of New Zealand, indicating *A. nitida* would also survive. Therefore both *A. lutescens lutescens* and *A. nitida* are considered potential hazards in this risk analysis.

6.2.9. Risk Assessment

6.2.9.1 Entry Assessment

Eggs are laid on leaves and are very unlikely to be associated with fresh litchi fruit. Nymphs and adults live for 4-6 wks and up to 5 months respectively while feeding on unripe fruit. Nymphs hatching from eggs laid by adults feeding on green fruit are forced to feed on maturing fruit. Feeding is probably restricted to the skin surface, as the seed which is the preferred target, is too deep for their proboscis to reach. Adults are about 15mm long making them more conspicuous than nymphs and less likely to pass quality control checks of fruit post harvest. Although nymphs are the most likely lifestage to be associated with litchi at the time it is harvested, their natural reaction when disturbed is to somersault or drop off the fruit.

There is a very low likelihood that A. lutescens lutescens or A. nitida will enter the country on the pathway. The risk of the organism entering the country is therefore non-negligible.

6.2.9.2 Exposure Assessment

Infested fresh Litchi fruit are likely to be distributed to the main city centers 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.
Citrus, macadamia, common beans, avocado, passion fruit loquat and guava are all grown commercially or as garden species in New Zealand, and would be potential hosts for *A. lutescens lutescens* and *A. nitida.*

6.2.9.3 Establishment Assessment

Development of *A. lutescens lutescens* and *A. nitida* appears to be optimal in more tropical environments, reflected by their current distributions. There is a lack of thermal threshold data for each species but climate data for Atherton Tablelands (Queensland) with minimum temperatures in winter of between 10.9-12.8ºC indicate *A. lutescens lutescens* could survive winter temperatures in New Zealand in some parts of the country. Areas in New Zealand with suitable hosts and temperatures include AK, ND, BP and GB (Crosby *et al.,* 1988). *A. nitida* would be assumed to have a similar potential distribution.

The likelihood of exposure and establishment is therefore very low.

6.2.10. Consequence Assessment

6.2.10.1 Economic

A. lutescens lutescens
The banana spotting bug is a major pest of many horticultural crops including papaw, avocado, macadamia nut, custard apple, litchi and cashew nut (Ryan 1994), and has the potential to cause damage far in excess of that expected from the numbers present (Waite & Pinese 1991). Avocado, macadamia and citrus crops would be particularly vulnerable in warmer parts of New Zealand. Most horticultural crops fail to support *A. l. lutescens* populations for more than about 2 months (Ryan 1994). In north Queensland it has caused green fruit drop in litchi's ranging from 24.8 percent to 98.5 percent suggesting fruitspotting bugs may be the most important factor inducing litchi fruit abscission in some areas (Waite 1990). Damage caused by *A. lutescens lutescens* is readily found in cashew orchards, but

often the insects are not (Peng *et al.,* 2005). Because of their overwintering habit in some areas and utilisation of secondary hosts it can be difficult to assess population structure, and previously damage by the bug was often attributed to other causes (Waite *et al.,* 1993).

A. nitida
Between 1985-1987 *A. nitida* was responsible for between 24.8 percent to 98.5 percent green fruit drop of litchi's at Maroochy Horticultural Research Station, in Nambour, North Queensland (Waite 1990).

6.2.10.2 Environmental

Of the families which contain species attacked by *A. lutescens lutescens* and *A. nitida* the following are represented in the native flora of New Zealand: Asteraceae, Convolvulaceae, Cucurbitaceae, Cyatheaceae, Eleocarpaceae, Euphorbiaceae, Fabaceae, Lauraceae, Malvaceae, Myrtaceae, Orchidaceae, Passifloraceae, Pipaceae, Pittosporaceae, Proteaceae, Rhamnaceae, Rutaceae, Solanaceae, Urticaceae. Although not all species within these families are common others particularly the *Metrosideros*, *Beilschmiedia* and *Coprosma* spp. contribute a diverse and widespread range of species to native forest canopy and understory throughout both islands. Native forest adjacent to horticultural areas could potentially act as a reservoir for fruitspotting bugs with non-adjacent forest less likely to harbour individuals.

The consequences of establishment of A. lutescens lutescens or A. nitida is considered moderate.

6.2.11. Risk Estimation

The likelihoods of *A. lutescens lutescens* or *A. nitida* entering the country are very low, exposure and establishment are low, and the consequences of establishment moderate.

As a result the risk estimation for A. lutescens lutescens and A. nitida is non-negligible and it is classified as a hazard on the commodity. Therefore risk management measures can be justified.

6.2.12. Risk Management

6.2.12.1 Options

Irradiation of 20 Krad (200 Grays) or more caused heavy mortality and sterilisation of *Gonocerus acuteangulatus* (Rhynchota: Coreidae) in laboratory experiments in Italy (Cavalloro & Delrio 1976). Presumably this treatment would cause a similar rate of mortality and sterilisation of fruitspotting bugs in the same family. Green scales (Homoptera: Coccidae) were treated with 250 Gy (Hara *et al.* 2002) in a quarantine experiment in Hawaii. While 250 Gy did not completely eliminate development of immature stages or adult emergence from nymphs, all life stages were sterile after treatment (Hara *et al.* 2002). This treatment rate should be effective against many species in the order Hemiptera as scales due to their morphology often require stronger doses to induce mortality than other organisms. This is an extrapolation between different genera in the same family and this assumption will be reviewed when new information on effective irradiation dosages for the Coreidae are available.

Because a small proportion of insects may enter the country alive, visual inspection on arrival would be less relevant as a risk management option in this case.
Pest management systems in the orchards, screening measures and pre export visual inspection will be more useful in reducing the risk of *A. lutescens lutescens* and *A. nitida* entering the country.

Risk management options in ascending order of stringency:

Option 1: Pest management in the orchards, screening measures and pre export inspection and inspection on arrival
Option 2: As *A. lutescens lutescens* and *A. nitida* nympal life stage is likely to be associated with litchi, an irradiation dose minimum of 250 Gy (Cavalloro & Delrio 1976; Hara *et al.* 2002)

6.2.13. Assessment of Uncertainty

A lack of thermal threshold data for both species makes it difficult to predict the tolerance for climatic conditions in New Zealand for both *A. lutescens lutescens* and *A. nitida*. There is some uncertainty around the efficacy of irradiation doses between different genera within the same family.

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6.3. Pink/Red Wax Scale

6.3.1. Hazard Identification

Aetiological agent: *Ceroplastes rubens* Maskell (Hemiptera: Coccidae)

Synonyms: *Ceroplastes minor, Ceroplastes japonica, Ceroplastes myricae*
Ceroplastes rubens var. minor

New Zealand Status: Not present in New Zealand (not recorded in Scott & Emberson 1999, Hodgson & Henderson 2000).

6.3.2. Biology

Ceroplastes rubens has a similar life cycle to its congener *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).

There are no data on thermal tolerances or developmental thresholds in the literature.

6.3.3. Hosts

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., *Thevetia peruviana* (CPC 2006).

6.3.4. Distribution

C. rubens is distributed throughout tropical and subtropical regions including Asia, Africa, and Oceania (CPC 2006). In Australia it is recorded from Queensland (Loch and Zalucki 1998) and New South Wales (Herron et al., 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).

6.3.5. Hazard Identification Conclusion

C. rubens is an extremely polyphagous pest species, causing serious damage to young citrus trees and *Pinus* species which are important as crops and for forestry in New Zealand. The fertilised female overwinters before ovipositing and the lifecycle is long with little evidence of abiotic factors influencing the life history. It is therefore considered a potential hazard in this risk analysis.

6.3.6. Risk Assessment

6.3.6.1 Entry Assessment

The first instar larvae of *C. rubens* are mobile and capable of dispersing fairly widely among plant materials to search for hosts. The lifecycle is long with populations undergoing 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 the litchis from Australia 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 rubens will enter the country on the pathway. Therefore the possibility of entry is non-negligible.

6.3.6.2 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 the scale (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. rubens* which occur in New Zealand, including avocado, citrus, apple, plum, guava, feijoa, pear and ornamentals like *Camellia*, *Daphne*, *Ilex*,

Magnolia, Monstera deliciosa, and *Rhododendron*. All are potential hosts in New Zealand and would be available all year round.
There are also 5 genera of plants attacked by the scale overseas that occur here as natives, *Syzygium, Blechnum, Asplenium, Pittosporum* and *Schefflera.*

6.3.6.3 Establishment Assessment

Distribution records suggest warmer temperatures (20-30°C) are optimal for this species. It is likely that temperature will be a limiting factor in most parts of New Zealand. Areas with potential to support populations of the scale are listed (ND, AK, CL, BP, GB, HB). Although, because there are no thermal thresholds for development in the literature this is an estimate of potential areas only.

There is a low likelihood that given adequate exposure time Ceroplastes rubens could establish in New Zealand, and then only in warmer parts of the country.

6.3.7. Consequence Assessment

6.3.7.1 Economic

Infestations of *C. rubens* cause economic damage directly to citrus through phloem feeding and indirectly through the promotion of sooty mould growth. Sooty moulds, promoted by *C. rubens* feeding, can also be of considerable economic importance on mango, figs, bananas, pears and other fruit (Williams and Watson, 1990). These build up on foliage and reduce photosynthetic efficiency, causing reduced growth. In Australia, where it 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.

6.3.7.2 Environmental

Five genera of plants attacked by *C. rubens* overseas occur here as natives, *Syzygium, Blechnum, Asplenium, Pittosporum* and *Schefflera.* The ferns (*Asplenium, Blechnum*) are a major component of the understory in all native forests in New Zealand. Between these genera there are a total of 62 species which could potentially be affected by the scale.

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 perforate* on *Pittosporum* spp. and *Ctenochiton paraviridis, Epelidochiton piperis, Poropeza cologabata* on *Schefflera digitata* (Hodgson & Henderson 2000) could compete with *C. rubens* for host material. The effect of this competition would be much harder to quantify than the use by *C. rubens* of native plant host material.

There is a moderate likelihood of economic and environmental consequences occurring if C. rubens was introduced into New Zealand.

6.3.8. Risk Estimation

For *C. rubens* in association with fresh litchi fruit although the likelihood of entry and exposure is high, establishment of pink wax scale is low to moderate and the potential consequences to New Zealand's economy and environment are moderate.

As a result the risk estimate for C. rubens is non-negligible and it is classified as a hazard on the commodity. Therefore risk management measures can be justified.

6.3.9. Risk Management

6.3.9.1 Options

Hara and others (2002) conducted irradiation experiments on all life stages of *Coccus viridis* in Hawaii. 17,268 *C. viridis* on gardenia (of which 33 percent were crawlers, 41.8 percent nymphs and 25.2 percent adults), and 2690 on coffee plants (58.5 percent crawlers, 33 percent nymphs and 8.5 percent adults) were irradiated at a minimum absorbed dose of 250 Gy. At this dosage there was prolonged survival, with 8.8-11.4 percent of nymphs and up to 8.8 percent of crawlers alive 3 months after irradiation. Levels of irradiation ≥ 500 Gy killed scales faster. While 250 Gy did not completely eliminate development of immature stages or adult emergence from nymphs, all life stages were sterile after treatment (Hara *et al.* 2002). It is assumed that this treatment will be effective against *C. rubens* as *C. viridis* is a member of the same genus.

Because a small proportion of insects may enter the country alive, visual inspection on arrival would be less relevant as a risk management option in this case. This differs from its use in the detection of unwanted fungi.
Pest management systems in the orchards, screening measures and pre export visual inspection will be more useful in reducing the risk of *C. rubens* entering the country.

Risk management options in ascending order of stringency:

Option 1: Pest management in the orchards, screening measures and pre export inspection and inspection on arrival
Option 2: An irradiation treatment dose of 250 Gy (Hara *et al.* 2002) is expected to reduce risk from *C. rubens*.

6.3.10. Assessment of Uncertainty

There are no data on thermal tolerances or developmental thresholds in the literature making it hard to predict how widely *C. rubens* would establish in New Zealand were it to enter the country. Assessment of the environmental impact of *C. rubens* on native scale insects is not quantifiable, and therefore unknown without testing or observation. The uncertainty around the efficacy of irradiation dose for *C. rubens* is lower as the data used was extrapolated from a member of the same genus *C. viridis*.

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6.4. *Seychelles* Scale

6.4.1. Hazard Identification

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

Synonyms: Dorthesia seychellarum

New Zealand Status: Not known to be present in New Zealand
(Not recorded in CPC 2007; PPIN 2007; Scott & Emberson 1999; Morales 1991; Spiller & Wise 1982). Scott &. Fernald's world catalogue of Coccidae (1903) listed *Icerya seychellarum* as occurring in New Zealand on the basis of a paper by Maskell (1897) in which he identified some coccoids sent to him by Koebele from China and Formosa (Morales 1991). There is no evidence for the scale occurring here.

6.4.2. Biology

I. seychellarum is a highly polyphagous and widespread pest throughout the tropics (Ben-Dov 2005) and has been intercepted several times on fresh produce entering New Zealand (Morales 1991). There is no literature associating it directly with fruit but the mobility of its crawlers means it could potentially be a hitch hiker species. Females are orange-red covered in a granular yellowish-white waxy covering with silky tubular threads. They produce posterior ovisacs almost as long as their bodies (Williams & Watson 1990). *I. seychellarum* can grow up to 10mm long and feeds largely on the undersides of leaves (Hill 1980).

There are three nymphal instars and typically a larviform ovoviviparous (reproducing by means of eggs that hatch in the body of the parent) adult stage (Veyssiere 1961 in Hill 1980). Alate males are rare and reproduction is asexual (Hill 1980). Five or six days after production of the ovisac the female will begin laying eggs, and does so for about 6-17 days. First instar nymphs hatch within 24 hours, remaining in the egg sac for 2-3 days then emerge to crawl over the leaves of the host. There are three instars to adulthood and the development time from egg to adult is about 3 months. In Japan there is one generation per year with winter passed as mature females (Kuwana 1922).

This species produces copious amounts of honey dew and is often attended by ants (Roberts & Seabrooks 1989).

In a study on Aldabra Atoll in the West Indian Ocean, Hill (1980) determined that aerial dispersal of *I. seychellarum* on the atoll is by removal of a small proportion (though large numbers) of the population with a periodic diurnal rhythm (Hill 1980). This dispersal is generated by the earlier rhythm of crawler emergence from adult brood pouches in response to a light-dark cue. Evidence of large numbers of crawlers leaving individual bushes, and their ability to survive reasonable lengths of time under extreme conditions confirms that the atoll was colonised by aerial dispersal of *I. seychellarum* crawlers (Hill 1980).

Although thriving at minimum night temperatures well above 20ºC (Hill 1980) there is no information on the developmental thresholds for this species.

6.4.3. Hosts

Icerya seychellarum is highly polyphagous. Major hosts include:
Acacia spp.(wattles), *Albizia* spp., *Annona* spp., *Artocarpus* spp.(breadfruit trees), *Casuarina equisetifolia* (casuarina), *Citrus* spp., *Cocos nucifera* (coconut), *Ficus* spp., *Grevillea robusta*

(silky oak), *Magnolia* spp., *Persea americana* (avocado), *Psidium guajava* (guava), *Pyrus* spp.(pears), *Rosa* spp.(roses)

Minor hosts include:
Acalypha spp. (Copperleaf), *Alpinia purpurata* (gingerlily), *Anthurium andreanum*, *Areca catechu* (betelnut palm), *Asplenium nidus* (bird's nest fern), *Averrhoa carambola* (carambola), *Bixa orellana* (annatto), *Broussonetia papyrifera* (paper mulberry), *Caesalpinia pulcherrima* (Paradise flower), *Cajanus cajan* (pigeon pea), *Calophyllum* spp. (beauty-leaf), *Camellia sinensis* (tea), *Capsicum annuum* (peppers), *Carica papaya* (papaw), *Cassia* spp. (sennas), *Ceiba pentandra* (kapok), *Chrysophyllum cainito* (caimito), *Cinnamomum* spp., *Citharexylum quadrangulare* (Fiddlewood), *Clerodendrum* spp.(Fragrant clerodendron), *Coffea* spp.(coffee), *Convolvulus* spp. (morning glory), *Coprosma* spp., *Cordyline* spp., *Crotalaria* spp., *Cycas* spp., *Derris elliptica* (Tuba root), *Dioscorea* spp.(yam), *Dodonaea viscosa* (switch sorrel), *Elaeis guineensis* (African oil palm), *Epipremnum pinnatum* (Hunters-robe), *Eriobotrya japonica* (loquat), *Eugenia* spp., *Euphorbia* spp. (spurges), *Feijoa sellowiana* (Horn of plenty), *Fragaria* spp.(strawberry), *Garcinia mangostana* (mangosteen), *Gerbera* spp.(Barbeton daisy), *Heliconia* spp., *Hibiscus* spp. (rosemallows), *Inocarpus fagifer*, *Ipomoea batatas* (sweet potato), *Jasminum* spp. (jasmine), *Lactuca sativa* (lettuce), *Litchi chinensis* (litchi) (Williams & Watson 1990), *Lycopersicon esculentum* (tomato), *Malus sylvestris* (crab-apple tree), *Mangifera indica* (mango), *Manilkara zapota* (sapodilla), *Mimosa pudica* (sensitive plant), *Monstera deliciosa* (ceriman), *Musa* spp. (banana), *Passiflora edulis* (passionfruit), *Phaseolus* spp. (beans), *Phoenix* spp.(date palm), *Piper* spp. (pepper), *Plumeria rubra* var. *acutifolia* (Mexican frangipani), *Poncirus trifoliata* (Trifoliate orange), *Prunus persica* (peach), *Punica granatum* (pomegranate), *Raphanus sativus* (radish), *Rubus* spp. (blackberry, raspberry), *Samanea saman* (rain tree), *Schefflera* spp. (umbrella tree), *Solanum* spp. (nightshade), *Spondias purpurea* (red mombin), *Syzygium* spp., *Tectona grandis* (teak), *Vitis vinifera* (grapevine), *Xanthosoma sagittifolium* (yautia (yellow)), *Zinnia* spp (CPC 2007, Williams & Watson 1990).

6.4.4. Distribution

I. seychellarum is widespread in Asia and Africa. It is present in Australia, American Samoa, Belau, Cook Is., Federated States of Micronesia, Fiji, French Polynesia, Kiribati, New Caledonia, Niue, Papua New Guinea, Samoa, Soloman Is., Tonga, Tuvalu and Vanuatu and Japan (CPC 2007; Williams & Watson 1990; Kuwana 1922).

6.4.5. Hazard Identification Conclusion

There is literature recording *I. seychellarum* on *Litchi chinensis* (Williams & Watson 1990) but there is no published evidence the scale occurs on fruit. However it has been intercepted on fresh produce coming in to New Zealand on a number of occasions. Its crawlers are quite mobile, capable of short distance and aerial dispersal giving it the potential to hitch hike on litchi. For these reasons *I. seychellarum* is considered a potential hazard in this risk analysis.

6.4.6. Risk Assessment

6.4.6.1 Entry Assessment

I. seychellarum is not inconspicuous growing up to 1cm in length and has been intercepted on produce entering New Zealand a number of times in the past (Morales 1991). There is no published evidence for the scale appearing on litchi fruit however. Crawlers live for up to three months, with one generation per year and adult females overwintering in Japan. The longevity of these life stages would more than encompass the transit time for litchi fruit coming from Australia by air.

There is a low to moderate likelihood that I. longirostris could enter the country on the pathway

6.4.6.2 Exposure Assessment

As imported fruit is destined for sale, those that are infested would likely be distributed by retail outlets throughout New Zealand.
A recently mated female or parthenogenetic scale about to lay or already laying eggs could survive in warm, dry or slightly humid conditions allowing the eggs to hatch. Newly hatched crawlers have the greater likelihood of exposure. Although they appear to actively disperse only over short distances, scale insects may disperse over several kilometres by wind (Greathead, 1990). *I. seychellarum* is capable of this kind of aerial dispersal as was recorded by Hill in the late1970s throughout the Aldabra Atoll.

There would be no shortage of hosts for *I. seychellarum* were it to enter the country. Commercial hosts found in New Zealand include capsicum, feijoa, strawberry, lettuce, tomato, passionfruit, bean, peach, blackberry, raspberry and grapevine.
Ornamentals such as *Clerodendron*, *Convolvulus*, *Hibiscus* and jasmine, plus several genera represented by native species in the New Zealand flora including *Coprosma*, *Cordyline*, *Syzygium* and *Schefflera* spp. could provide host material all year round.

6.4.6.3 Establishment Assessment

Although there are no published data on its developmental thresholds or environmental tolerances its distribution is currently restricted entirely to countries within tropical latitudes. There is some doubt that *I. seychellarum* would survive winter temperatures anywhere in New Zealand as it has not established in other temperate or boreal zones. It is suggested the likelihood of *I. seychellarum* establishing here is negligible.

6.4.9.1 Risk Estimation

As the likelihood of *I. seychellarum* establishing in New Zealand is negligible the risk estimate for *I. seychellarum* is negligible and it is not classified as a hazard on the commodity. Therefore risk management measures are not justified.

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6.5. Black Thread Scale

6.5.1. 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)

6.5.2. 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 (Vesey Fitzgerald 1940).

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).

6.5.3. 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).

6.5.4. 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).

6.5.5. 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.

6.5.6. Risk Assessment

6.5.6.1 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.

6.5.6.2 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.

6.5.6.3 Establishment Assessment

There is 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.

6.5.7. Consequence Assessment

6.5.7.1 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.

6.5.7.2 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.

6.5.8. Risk Estimation

For *I. longirostris* associated with fresh litchi fruit from Australia 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.

As a result the risk estimate for I. longirostris is non-negligible and it is classified as a hazard on the commodity. Therefore risk management measures can be justified.

6.5.9. Risk Management

6.5.9.1 Options

Hemiptera including bugs, scales and mealybugs are irradiated to the point of sterility between 150 and 250Gy (Hara *et al.* 2002; Follett 2006). In large scale validation and dose response tests, a total of 32,716 adult female *Aspidiotus destructor* scales with eggs were irradiated with doses between 100 and 150 Gy (Follett 2006). The irradiated females produced no F_1 adults with eggs. Hara and others (2002) conducted irradiation experiments on all life stages of *Coccus viridis* in Hawaii. 17,268 *C. viridis* on gardenia (of which 33 percent were crawlers, 41.8 percent nymphs and 25.2 percent adults), and 2690 on coffee plants (58.5 percent crawlers, 33 percent nymphs and 8.5 percent adults) were irradiated at a minimum absorbed dose of 250 Gy.

At this dosage there was prolonged survival, with 8.8-11.4 percent of nymphs and up to 8.8 percent of crawlers alive 3 months after irradiation. Levels of irradiation ≥ 500 Gy killed scales faster. While 250 Gy did not completely eliminate development of immature stages or adult emergence from nymphs, all life stages were sterile after treatment (Hara *et al.* 2002). No direct data for irradiation of *I. longirostris* exists. It is assumed this treatment would be sufficient, but some uncertainty exists because the two scales are from different family groups. This will be reviewed when new information on effective irradiation dosages for *I. longirostris* is available

Because a small proportion of insects may enter the country alive, visual inspection on arrival would be less relevant as a risk management option in this case. This differs from its use in the detection of unwanted fungi. Pest management systems in the orchards, screening measures and pre export visual inspection will be more useful in reducing the risk of *I. longirostris* entering the country.

Risk management options in ascending order of stringency:

Option 1: Pest management in the orchards, screening measures and pre export inspection and inspection on arrival
Option 2: An irradiation treatment dose of 250 Gy (Hara *et al.* 2002) is expected to reduce risk from *I. longirostris.*

6.5.10. Assessment of Uncertainty

There are no data on thermal tolerances or developmental thresholds in the literature making it hard to predict how widely *I. longirostris* would establish in New Zealand were it to enter the country. Assessment of the environmental impact of *I. longirostris* is unknown without testing or observation. There is a higher level of uncertainty around the efficacy of the irradiation dose for *I. longirostris* as the data is extrapolated from *C. viridis* a member of another family.

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6.6. Soapberry Bugs

6.6.1. Hazard Identification

Aetiological agent: *Leptocoris isolatus* Distant (Hemiptera: Rhopalidae)
Leptocoris rufomarginatus Fabricius (Hemiptera: Rhopalidae)
Leptocoris tagalica Burmeister (Hemiptera: Rhopalidae)

Synonyms for L. tagalica: L. tagalicus
for L. rufomarginata: L. ruformarginatus

New Zealand Status: *L. tagalicus* has been incorrectly recorded from New Zealand (Larivière & Larochelle 2004).

6.6.2. *Leptocoris isolatus* Biology

There is virtually no information on the biology of this species, with museum records indicating it is restricted to north-eastern Queensland where it has been found on both native and introduced sapinds (Carroll *et al.* 2005) and in Papua New Guinea (Braekman *et al.* 1982). In Papua New Guinea the larvae have been observed feeding on fallen fruit under bushes of *Allophylus cobbe* and have also been recorded canabilising wounded larvae and opportunistically feeding on other invertebrates (Braekman *et al.* 1982).

6.6.3. Hosts

L. isolatus has been found on: *Allophylus cobbe*, *Litchi chinensis* and *Nephalium lapaceum* (Carroll *et al.* 2005).

6.6.4. Distribution

L. isolatus occurs only in the eastern wet tropics of Australia (Carroll *et al.* 2005).

6.6.5. *Leptocoris rufomarginatus* Biology

As with its congener *L. isolatus* there is very little information on the biology of this species. It co-occurs with *L. tagalicus*, and *L. mitellatus* on *Alectryon tomentosa*, *A. diversifolius* and *E. xylocarpa* (Carroll *et al.* 2005). Mating in *L. ruformarginatus* occurs in the absence of feeding and eggs are laid on the undersides of leaves (Carroll *et al.* 2005). Adults can be found on the ground and in trees they are infesting (Carroll *et al.* 2005).

6.6.6. Hosts

Its host plants are: *Alectryon diversifolius* (scrub boonaree), *Alectryon tomentosus* (hairy birds eye), *Allophylus cobbe*, and *Elattostachys xylocarpa* (white tamarind) (Carroll et al. 2005).

6.6.7. Distribution

L. rufomarginatus is restricted to the far eastern and northern wet subtropics and tropics of Australia (Carroll *et al.* 2005).

6.6.8. *Leptocoris tagalica* Biology

Soapberry bugs feed on seeds of plants in the Sapindales particularly from the Sapindaceae (Carroll *et al.* 2005) and have been shown to cause green litchi fruit to fall when they infest the tree on a sporadic basis in Queensland (Waite 1992). It has also developed a host shift to the non-native environmental weeds *Cardiospermum* and *Koelreuteria* in Australia. This shift is thought to have occurred in less than 50 years (Carroll & Fox 2007). There are two forms of *L. tagalica* based on differences in body size and to a lesser extent coloration. The form found in the interior of the east coast is smaller with more orange or red, and the larger coastal

form is usually darker in colour and closer to dry and wet rainforest. The range of the interior form follows that of Whitewood (*Atalaya hemiglauca*) across the northern half of Australia (Carroll *et al.* 2005).

As fruit begin development thousands of inactive adults form clusters beneath leaflets. Eggs are laid on the underside of leaves. Although there is no data for *L. tagalica* a congener *L. varicornis* lays about 12-19 eggs per female over 3 days (Akbar 1958). *L. tagalicus* appears on trees once fruit has set. Nymphs go through 5 instars (Kumar 1966) and both nymphs and adults can be found on the ground and on trees during the life cycle. When fruit have dehisced and dropped off the trees, the bugs gather near walls and buildings exposed to the sun and bask through much of the day. Adults can host switch during the lifecycle (Carroll *et al.* 2005). *Leptocoris* species leave a pin-prick on the seed that is easily distinguishable from the damage caused by *Amblypelta* spp. (Waite 1992)

There is no information on thermal thresholds or longevity for *L. tagalica* or any of its Australian congeners. Another species of *Leptocoris* from North America, *L. trivittatus*, was found to be active in the laboratory as its temperature threshold for activity was reached at 20ºC (Tinker 1952). Low temperature may stimulate flight and the search for hibernation sites (Tinker 1952).

In all three species the females are between 1-2.5cm long (Carroll *et al.* 2005).

6.6.9. Hosts

L. tagalica is the most polyphagous of the Leptocorids and its host list includes: *Alectryon connatus* (grey birds eye), *Alectryon coriaceus* (beach birds eye), *Alectryon diversifolius* (scrub boonaree), *Alectryon oleifolius* (boonaree), *Alectryon subcinereus* (native quince), *Alectryon subdentatus* (hard *Alectryon*), *Alectryon tomentosus* (hairy birds eye) , *Allophylus cobbe, Atalaya hemiglauca* (whitewood), *Atalaya salicifolia* (scrub whitewood), *Elattostachys xylocarpa* (white tamarind), *Cardiosperma grandiflorum* (balloon vine), *Dimocarpus longan* (longan), *Koelreuteria elegans* (Chinese rain tree), and *Litchi chinensis* (litchi) (Carroll *et al.* 2005). Waite & Hwang (2002) report damage to litchi crops by seed feeding *L. tagalica* and *L. rufomarginatus*. Another genus of Sapindaceae that occurs both in New Zealand and Australia, *Dodonea*, does not appear to host any of the *Leptocoris* species.

6.6.10. Distribution

L. tagaliga is found in Australia, Philippines, Tahiti and Indonesia (Carroll *et al.* 2005).

6.6.11. Hazard Identification Conclusion

There is little direct evidence that *Leptocoris* species cause significant damage to mature litchi fruit in Australia. They appear to attack green fruit, causing it to drop prematurely, and fallen fruits on the ground beneath trees. Adults would be very conspicuous reaching 1-2.5cm when fully grown and it is highly unlikely nymphs or eggs would be associated with the fruit at all. Therefore *L. isolatus*, *L. rufomarginatus* and *L. tagalica* are not considered further in this risk analysis.

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6.7. Rutherglen Bug

6.7.1. Hazard Identification

Aetiological agent: *Nysius vinitor* Bergroth (Hemiptera: Lygaeidae)

New Zealand Status: Not known to be present in New Zealand (not recorded in PPIN 2006; Larivière & Larochelle 2004; Scott & Emberson 1999)

6.7.2. Biology

Nysius vinitor is often present in its distributional range in a mixed population with *Nysius clevelandensis*. They have similar biology and hosts and are difficult to tell apart (G.K. Waite Pers. Comm. 2007). *N. vinitor* lives primarily on seeds of plants of economic importance in a wide range of families, and is found throughout temperate and subtropical environments in Australia (Greaves & Rochford 1946; Kehat & Wyndham 1972). In Queensland, *N. vinitor* infests litchis at flowering or early fruit set, but the true pest status of the bug is uncertain (Waite & Hwang 2002). Like its congener *N. huttoni* in New Zealand *N. vinitor* is most likely to be a hitch hiker pest on fruit where it occurs. Between 2001-2007 there were 8 interceptions of the Rutherglen bug on imported fruit, including on oranges, capsicum, strawberries and honeydew melon (Quantam Database 2007). Water is a severely limiting factor for *N. vinitor*, with lack of this resource even for short periods preventing egg production and increasing mortality (Kehat & Wyndham 1972), although Attia (1982) observed that increasing humidity reduced oviposition in the bug.

N. vinitor had overlapping generations from February until the winter months on *Polygonum aviculare* in Victoria (McDonald & Smith 1988) and about 7-8 generations reared per year under laboratory conditions (Attia 1982). Laboratory studies in Adelaide revealed that the threshold temperature for development of eggs and nymphs was 14.5 ºC and 15 ºC respectively. Temperatures of 12ºC and 40 ºC killed all individuals of both life stages. Adults had the highest thermal thresholds surviving exposure to 4.5 ºC for a mean of 27.5 days (Kehat & Wyndham 1974b). They are thought to be able to overwinter as adults or nymphs, particularly in the 5th instar (Attia 1982). At 15 ºC eggs took 36 days to hatch and at 32 ºC only 3.8 days. The nymphal stage lasted 45 days at 20 ºC and 12 days at 32 ºC. In adults, males lived longer than females at the same temperatures with survival of 115 and 90 days respectively at 22 ºC and 31 and 18 days at 30 ºC (Kehat & Wyndham 1972).

Females may lay as many as 400 eggs in clusters on weeds or cultivated plants (Newman 1928). There are 5 nymphal instars which crawl on the ground between plants to invade new hosts (Ramesh 1997). Distance travelled by the nymphs is dependent on the instar life stage and the ambient temperature. First instars moved as little as 0.8cm at 15ºC and as far as 65.8cm at 30 ºC in the 5th instar. They could move at speeds of up to 20cm/min (Ramesh 1994) in the later most mobile instars. Adults are about 5mm long (Gellatley & Forrester 1985).

Major migrations of the bug occur at night in eastern Australia, following dusk take-off, in disturbed weather associated with prefrontal airflows. Major immigration flights into central-western New South Wales and regions to the south regularly occur in early spring (September to October) with southward displacements of about 200-300km depending on flight duration (McDonald & Farrow 1988). These migrations probably arise from breeding areas in subtropical latitudes.

Previous authors (Kehat & Wyndham 1974a; Kehat & Wyndham 1973) viewed female flight as important for the increase of future populations of the lygaeid, observing displacement flights of immature females an a synchronised migratory phenomenon, and flights in mature females as dispersive, with no indication that the flight of males was migratory. McDonald and Farrow (1988) in aerial sampling in surface and upper air columns found females were generally less common than males, although during major flights in spring, there was less than a two fold difference.

Although it swarms on litchi during flowering and early fruit set, when fruit exceed 3mm in length the bugs usually emigrate and are not seen on developing or mature fruit (G.K.Waite Pers. Comm. 2007).

Nysius vinitor as a vector
N. vinitor is presumed to vector a seed-rotting disease caused by a yeast with distinctive ascospores closely resembling those of *Nematospora sinecauda* (Oram *et al.* 2005) but this association has not been tested.

Although it has been ruled out as a vector of phytoplasmas that cause economically significant diseases of pawpaw fruit White *et al.* (1997) suggest it should be considered in future studies in the vector of a pawpaw dieback, mosaic and yellow crinkle viruses.

6.7.3. Hosts

Hosts include *Carica papaya* (pawpaw), *Helianthus annuus* (sunflower), *Solanum tuberosum* (potato), *Brassica juncea* (Indian mustard), *Vitis vinifera* (grapevine), *Arctotheca calendula* (Cape dandylion), *Eucalyptus* spp., *Portulaca oleracea* (pigweed), *Polygonum aviculare* (knotweed), *Carthamus tinctorius* (safflower), *Dianthus caryophyllus* (carnation), *Opuntia* spp. (prickly pear), *Linum usitatissimum* (linseed), *Brassica rapa* (turnip), *Pastinaca sativa* (parsnip), *Dacus carota* (carrot), *Meddicago sativa* (lucerne), *Brassica oleracea* (cauliflower/cabbage), *Fragaria* spp. (strawberry), *Beta vulgaris* var *cicla* (silver beet), *Brassica napus*, *Brassica campestris* (rapeseed), *Sorghum* spp.(grain sorghum), *Nicotiana tobacum* (tobacco), *Allium cepa* (onion), *Carthamus tinctorius* (safflower), *Prunus persica* (peaches), *Prunus armeniaca* (apricot), *Prunus avium* (cherry), *Lycopersicum esculentum* (tomato) (CAB Abstracts 2007) and *Litchi chinensis* (litchi) (Waite & Hwang 2002). *Nysius vinitor* is primarily a seed feeder, but in swarms may feed on vegetative tissue (G.K.Waite Pers. Comm. 2007).

6.7.4. Distribution

The bug is endemic to Australia and has been recorded in Victoria, Queensland, ACT, South Australia, New South Wales and Tasmania (Oram *et al.* 2005; Ramesh 1994; McDonald & Farrow 1988; McDonald & Smith 1988; Broadley & Rossiter 1982; Nicholls 1932).

6.7.5. Hazard Identification Conclusion

Although development of *N. vinitor* is restricted at temperatures lower than 15 ºC in the egg and nymphal forms there is evidence adults can survive temperatures as low as 4.5 ºC and can overwinter enduring cool periods. It has multiple generations per year and lives on a wide variety of plants of economic importance though it relies on weeds such as capeweed (*Arctotheca calendula*), cudweed and thistles to breed. Because of its previous interception history on fresh produce it has to be considered a potential hitch hiker species on litchi. Therefore *Nysius vinitor* is considered a potential hazard in this risk analysis.

6.7.6. Risk Assessment

6.7.6.1 Entry Assessment

Eggs took 36 days to hatch at 15 ºC and only 3.8 days at 32 ºC. It is highly unlikely that eggs would be laid directly on fruit, as most hemipterans lay eggs on foliage and stems, although there is no evidence to suggest they aren't laid on fruit. It is more likely that young instars would crawl onto fruit as they search for food. Nymphal stages last up to 45 days at 20ºC, and 12 days at 32 ºC, this is much longer than the expected time frame for litchi to reach New Zealand from Australia by air or sea. Adult females grow to about 5mm long, and would be fairly inconspicuous on litchi at this size.

There is no definitive evidence linking *N. vinitor* as a vector of any particular disease organism so the likelihood of entry of vectored diseases cannot be considered further at this point in the assessment. If new information becomes available linking the bug to any pathogenic agents a reassessment would be required.

The likelihood of entry of all life stages of N. vinitor would therefore be low for eggs and moderate for nymphs and adults. The likelihood of entry of viral and bacterial diseases vectored by N. vinitor is considered negligible.

6.7.6.2 Exposure

Nymphal stages crawl along the ground between host plants, and are very mobile with first instars moving as little as 0.8cm at 15ºC and as far as 65.8cm at 30 ºC in the 5th instar. They could move at speeds of up to 20cm/min (Ramesh 1994) in the later most mobile instars. Major migrations occur from subtropical latitudes in eastern Australia in disturbed weather associated with prefrontal airflows. Southward displacements of about 200-300km depending on flight duration (McDonald & Farrow 1988) have been observed. This kind of migration after entry is unlikely, it is much more likely that nymphal instars will disperse widely along the ground and on plants looking for food material.

Many of the recorded hosts in Australia occur here as garden specimens or are grown for commercial purposes. Potential hosts include apricot, strawberry, peaches, grapevine, silver beet, onion, tomato, cauliflower, turnip, potato and sunflowers. The seed head of sunflowers is the most likely host to be utilised to any extent for breeding (G.K.Waite Pers. Comm. 2007).

There is a high potential for nymphal and adult stages to crawl and disperse over short distances to find host material, making the likelihood of exposure high.

6.7.6.3 Establishment

Egg and nymphal stages have a higher temperature threshold for development (14.5 and 15ºC respectively) than adults which tolerate temperatures as low as 4.5 ºC for up to 27 days. While adults arriving here in summer would survive and reproduce in many parts of New Zealand, their capacity to overwinter could help maintain permanent populations in parts of BP, HB, ND, AK and WK. Eggs and nymphs will only be able to develop in late spring and summer, probably mirroring developmental patterns in New South Wales and Victoria.

The likelihood of establishment of N. vinitor is therefore moderate.

6.7.7. Consequence Assessment

6.7.7.1 Economic

Nysius vinitor can cause serious damage to fruit trees, bush fruits and vegetables, being particularly injurious to stone fruit (Newman 1923) damaging different types of fruit in all stages of development (Froggatt 1916). In canola crops *N. vinitor* causes irregular and unpredictable damage to the flowering and podding plants (Gu *et al.* 2007). In sunflower crops where irrigation was applied, *N. vinitor* reduced grain yield by 7.5 percent, oil content by 17 percent, linoleic acid by 13 percent and germination by 44 percent. In dryland crops grain yield (33 percent), oil content (28 percent), linoleic acid (6.4 percent) and germination (97 percent) were more severely impacted (Forrester & Saini 1982). Moisture limitation thus becomes an important reason to treat crops for the bug. New Zealand is far less moisture restricted than Australia and any potential economic impacts *N. vinitor* might have on crops here would presumably be at a lower level.

The bug has been responsible for reduced honey production in Victoria, while swarming on flowers of *Eucalyptus* and other plants taking nectar (French 1918).

6.7.7.2 Environmental

There are no host plants attacked in Australia that are represented by native or endemic species in the flora of New Zealand. An endemic wheat bug in the same genus, *N. huttoni*, is an important pest of brassicas and wheat as well as many introduced weeds such as *Polygonum aviculare* and *Stellaria media*. It also occurs on native wheat grass, koromiko (*Hebe salicifolia*) and high altitude native plants such as red tussock (*Chionochloa rubra*) (Every & Stufkens 1999).

For an endemic species it has a lot of introduced host plants, which could lead to querying its endemic status or conversely appreciate its flexibility in adaptation to new host species. Many of the species *N. vinitor* infests in Australia are introduced horticultural plants, but mostly weeds. Like *N. huttoni* it has the potential to expand its host range across a spectrum of plant families and the possibility of it impacting native grasses, weeds or trees cannot be ruled out.

6.7.7.3 Health

N. vinitor ejects a harmful defensive fluid when threatened (Southcott 1988). The bug builds up into large populations given the right environmental conditions and has strong dispersal behaviour, becoming a nuisance in homes. Because of their small size the insects can enter through screens and attack people, causing painful bites and skin irritations (Gellatley & Forrester 1985; Southcott 1988).

The consequences of Nysius vinitor establishing in New Zealand are likely to be moderate to high for human health and economic impact and unknown for environmental impact. It is assumed some environmental impact is possible given the current broad host range of the bug.

6.7.8. Risk Estimation

The likelihood of *N. vinitor* entering the country is low to moderate. The likelihood of vectored disease agents entering the country is negligible. The likelihood of exposure and establishment are moderate to high, and the consequences of establishment low to moderate for economic and human health impacts. Consequences for environmental impacts are possibly non-negligible but given current knowledge the extent or breadth of impact is unknown.

As a result the risk estimate for N. vinitor is non-negligible and it is classified as a hazard on the commodity. Therefore risk management measures can be justified.

6.7.9. Risk Management

6.7.9.1 Options

Hemiptera including bugs, scales and mealybugs are irradiated to the point of sterility between 150 and 250Gy (Hara *et al.* 2002; Follett 2006). In large scale validation and dose response tests, a total of 32,716 adult female *Aspidiotus destructor* scales with eggs were irradiated with doses between 100 and 150 Gy (Follett 2006). The irradiated females produced no F_1 adults with eggs. Hara and others (2002) conducted irradiation experiments on all life stages of *Coccus viridis* in Hawaii. 17,268 *C. viridis* on gardenia (of which 33 percent were crawlers, 41.8 percent nymphs and 25.2 percent adults), and 2690 on coffee plants (58.5 percent crawlers, 33 percent nymphs and 8.5 percent adults) were irradiated at a minimum absorbed dose of 250 Gy.

At this dosage there was prolonged survival, with 8.8-11.4 percent of nymphs and up to 8.8 percent of crawlers alive 3 months after irradiation. Levels of irradiation ≥ 500 Gy killed scales faster. While 250 Gy did not completely eliminate development of immature stages or adult emergence from nymphs, all life stages were sterile after treatment (Hara *et al.* 2002). No direct data for irradiation of *N. vinitor* exists. It is assumed this treatment would be sufficient, but some uncertainty remains around efficacy because data is extrapolated from species in other family groups. This information will be reviewed when new data on effective irradiation dosages for *N. vinitor* is available
Because a small proportion of insects may enter the country alive, visual inspection on arrival would be less relevant as a risk management option in this case. This differs from its use in the detection of unwanted fungi. Pest management systems in the orchards, screening measures and pre export visual inspection will be more useful in reducing the risk of *N. vinitor* entering the country.

Risk management options in ascending order of stringency:

Option 1: Pest management in the orchards, screening measures and pre export inspection and inspection on arrival.
Option 2: An irradiation treatment dose of 250 Gy (Follett & Lower 2000) is expected to reduce risk from *N. vinitor*.

6.7.10. Assessment of Uncertainty

Some uncertainty exists around the likelihood of a pathogen being vectored by *N. vinitor*. There is a higher uncertainty around the efficacy of irradiation doses for *N. vinitor* as extrapolations were made from different family groups within the order Hemiptera.

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6.8. Guava/Green Shield Scale

6.8.1. Hazard Identification

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

Synonyms: *Chloropulvinaria psidii, Pulvinaria cupaniae, Pulvinaria psidii philippina, Pulvinaria darwiniensis, Lecanium vacuolatum, Pulvinaria cussoniae Pulvinaria gymnosporiae*

New Zealand Status: Not known to be present in New Zealand (not recorded in Hodgson & Henderson 2000; Scott & Emberson 1999)

6.8.2. Biology

Pulvinaria psidii has three immature larval instars. It is parthenogenetic and its growth and development appear to be relatively slow. The life cycle is completed in two or three months with the young taking from 50 to 70 days to reach maturity (Coleman & Kannan 1918). Green (1909) reported overlapping generations of the scale in Sri Lanka, and Takahashi (1939) recorded three generations per year in Taiwan. In Alexandria (Egypt) Salama & Saleh (1970) observed two generations per year with *P. psidii* being most abundant when both temperature and humidity were relatively high (26-27.3°C and 72 percent respectively).

In Australia the scale is found on leaves and twigs of litchi during the non-fruiting season, but quickly colonises flower panicles then fruit when they appear on the tree (Waite 1992). It tends to avoid excessively hot situations and both very bright light or deep shade. Most tropical soft scale species suffer increasing mortality over 29°C (CPC 2006). Under laboratory conditions El-Mishanwy & Moursi (1976) reared *P. psidii* on pumpkin fruits, with females laying about 200 eggs each.

6.8.3. Hosts

Pulvinaria psidii is associated with over 145 plant species (ScaleNet 2006). Some of the most economically important hosts are.

Litchi chinensis (litchi), *Mangifera indica* (mango), *Pouteria sapota*, *Psidium guajava* (guava) *Anthurium*, *Cajanus cajan* (pigeon pea), *Camellia* spp., *Camellia sinensis* (tea), *Citrus* spp., *Cocos nucifera* (coconut), *Coffea* spp. (coffee), *Euonymus* spp. (spindle trees), *Ficus* spp., *Ilex* spp.(Holly), *Jasminum* spp. (jasmine), *Macadamia* spp., *Manilkara zapota* (sapodilla), *Nerium oleander* (oleander), *Persea americana* (avocado), *Psidium* spp., *Syzygium* spp., *Tamarix* spp., *Terminalia* spp.(CPC 2006).

6.8.4. Distribution

Pulvinaria psidii is widely distributed throughout Asia, Africa, the Americas and most of the pacific Oceania including Australia (CPC 2006). It is not currently recorded from Europe. *P. psidii* was mistakenly recorded as present in New Zealand by Fernald in her 1903 catalogue of Coccidae of the world and later by Wise in 1977, but has never been found here (Hodgson & Henderson 2000).

6.8.5. Hazard Identification Conclusion

Pulvinaria psidii has a relatively long life cycle and wide host range but appears to be restricted to tropical and subtropical areas. Its optimal environmental conditions include high temperatures and humidity. It has not established in temperate or boreal zones. It is unlikely that were the scale to enter the country it would establish especially through the winter months. Therefore it is not considered a potential hazard in this risk analysis.

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Beetles

6.9. Elephant beetle

6.9.1. Hazard Identification

Aetiological agent: *Xylotrupes gideon* (Linnaeus) (Scarabaeidae: Coleoptera)

Synonyms: Scarabaeus gideon, Scarabaeus oromedon, Geotrupes dentatus, Xylotrupes beckeri, Xylotrupes sumatrensis, Xylotrupes borneensis, Xylotrupes bourgini, Xylotrupes gideon sumatrensis, Xylotrupes gideon borneensis

New Zealand Status: Not present in New Zealand (not recorded in PPIN 2007; Scott & Emberson 1999, Klimaszewski & Watt 1997)

6.9.2. Biology

Adults of *Xylotrupes gideon* have been observed feeding on the flesh of developing fruit after breaking through the skin surface, causing losses to litchi crops in Queensland (Rogers & Blair 1981). Of 12 insect species studied on *Passiflora edulis* in India, *X. gideon* was the major insect pest causing economic damage (up to 39.75 percent) to fruits (Shylesha & Rao 2004). Eggs are deposited in the soil with the larvae feeding on decaying organic matter in the humus layer (Mishra 1995). The pupal stage is also passed in the soil (Froggatt 1936).
In laboratory studies conducted in Fiji it was found that the average duration of the egg, larval, prepupal and pupal stages was 21, 188, 14 and 32 days respectively. Females lived slightly longer that males at 102 days compared to 90 (Bedford 1975). The average number of eggs laid per female was 55 (Bedford 1975).

This beetle can reach 60mm in length and the males are easily recognised by their large horns (Monteith 2000).

6.9.3. Hosts

Cocos nucifera (coconut), *Poinciana regia* (poinciana), *Bauhinia* sp., *Passiflora edulis* (passionfruit), *Abelmoschus esculentus* (okra) and *Litchi chinensis* (litchi) (Rogers & Blair 1981).

6.9.4. Distribution

X. gideon is thought to be one of the most widespread large dynastine beetles in the world, and has been reported from Sri Lanka, India, the Himalayan region, south east Asia, Australia, Papua New Guinea and into Melanesia as far as Vanuatu (Rowland 2003).

6.9.5. Hazard Identification Conclusion

Egg larval and pupal stages are passed in the soil and would not be associated with fruit on the tree. Adults feed on developing fruit after breaking the skin surface. It is highly likely that any adult *X. gideon* and its feeding damage will be detected given the beetles large size (up to 6cm) and its distinctive appearance. Therefore it is not considered a potential hazard in this risk analysis.

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Moths

6.10. Macadamia Nut Borer

6.10.1. 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)

6.10.2. 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 egg hatching and lay 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). In a study in Hawaii *Cryptophlebia* spp. infestation rates for litchi and longan were found to be as low as 1.1 and 0.14 percent respectively (G.T. McQuate USDA pers. comm. to Follet & 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 on average per individual with fecundity increasing over successive lab raised generations (Hung *et al.* 1998).

6.10.3. 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), *Dimocarpus longan* (longan), *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) (Chang & Chen 1989), *Tamarindus indica* (Indian tamarind), *Vigna unguiculata* (cowpea) and *Persea americana* (avocado) (CPC 2001).

6.10.4. 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).

6.10.5. 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.

6.10.6. Risk Assessment

6.10.6.1 Entry Assessment

Eggs are deposited on fruit and develop over 3 to 7 days and the larvae penetrate the skin and head for the seed, making them difficult to detect at this life stage, although the light brown frass is visible as it is pushed out of the entry tunnel. Larvae take between 13 and 26 days to develop inside the fruit in the seed, and pupate within, and would survive a lengthy transit time. Adults and pupae are unlikely to be associated with the fruit. Fruit often start deteriorating or fermenting due to damaged skin and flesh providing easily identifiable infestation symptoms in many cases.

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

6.10.6.2 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).

6.10.6.3 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.

6.10.7. Consequence Assessment

6.10.7.1 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.

6.10.7.2 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.

6.10.8. Risk Estimation

Although the likelihood of *C. ombrodelta* entering the country is high, exposure and establishment are moderate to low, and the consequences of its establishment moderate to low.

As a result the risk estimate for C. ombrodelta is non-negligible and it is classified as a hazard on the commodity. Therefore risk management measures can be justified.

6.10.9. Risk Management

6.10.9.1 Options

Follett & Lower (2000) conducted irradiation experiments in Hawaii to disinfest longan litchi and rambutan of all life stages of *Cryptophlebia illepida* and *C. ombrodelta*. In a concurrent study, it was found that *Cryptophlebia* infestation rates for litchi and longan in Hawaii were 1.1 and 0.14 percent respectively (G.T. McQuate, USDA pers. comm. to Follett & Lower 2000). Of 11,256 late instars irradiated with a target dose of 250 Gy, 951 pupated (8.4 percent) and none eclosed as adults. In general pupae had the highest tolerance to irradiation treatment with increased age. In 7 to 8 day old pupae, survival to adult after treatment with 250 Gy was 52.4 percent. Of adults irradiated at the same rate 0.9 percent of eggs laid developed to stage 2 (pink colour) and no eggs developed farther or hatched (Follett & Lower 2000). All life stages of *C. ombrodelta* and *C. illepida* are sterilised at this dose.

Because a small proportion of insects may enter the country alive, visual inspection on arrival would be less relevant as a risk management option in this case. This differs from its use in the detection of unwanted fungi. Pest management systems in the orchards, screening

measures and pre export visual inspection will be more useful in reducing the risk of *C. ombrodelta* entering the country.

Risk management options in ascending order of stringency:

Option 1: Pest management in the orchards, screening measures and pre export inspection and inspection on arrival
Option 2: As larvale stage of C. *ombrodelta* is likely to be associated with litchi fruit an irradiation treatment dose of 250 Gy (Follett & Lower 2000) is expected to reduce the risk .

6.10.10. Assessment of Uncertainty

For *C. ombrodelta* it is unknown what the lower thresholds for development and survival are, making it difficult to estimate likely areas of establishment in New Zealand.

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Mites

6.11. Litchi Erinose Mite

6.11.1. Hazard Identification

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

Synonyms: Eriophyes litchii, Eriophyes litchi, Aceria litchi

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

6.11.2. Biology

Aceria litchii 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 two periods of greatest population mobility during the spring and autumn seasons.

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 and where *A. litchii* occurs. However no records have been made of the mite attacking species from either genus. *A. litchii* is regarded as being specific to litchi, despite numerous references to its presence on longan in the literature. The longan erinose mite is a separate species, *A longana*, and it is specific to longan (G.K.Waite Pers. Comm. 2007).

Aceria litchii is thought to be vectored by honeybees (Waite 1999) in Queensland. 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).

Recent research has shown a positive relationship between mite density on leaves infested by *Cephaleuros virescens*, a parasitic agla which uses the punctiform lesions caused by *A. litchii* to penetrate the leaf epidermis, and algal density and degree of erineum leaf cover (Schulte *et al.* 2007). *Cephaleuros virescens* is widespread in New Zealand.

6.11.3. Hosts

The only recorded host of this species is *Litchi chinensis* (litchi). Longan erinose mite is a separate species, *Aceria longana* (see Waite and Hwang, 2002).

6.11.4. 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).

6.11.5. Hazard Identification Conclusion

Aceria litchii is specific to litchi which is grown in such small numbers in New Zealand that it is 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. litchii* therefore is not considered a hazard in this risk analysis.

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6.12. False Spider Mite

6.12.1. Hazard Identification

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

Synonyms: Brevipalpus pseudocuneatus, Brevipalpus macbride, Brevipalpus papayensis, Brevipalpus yothersi, Tenuipalpus phoenicis

New Zealand Status: Considered non-regulated as it is present in New Zealand, but can be a vector so is regulated if it is intercepted and is likely to be vectoring a regulated virus. Recorded in New Zealand but not established (Collyer 1973; PPIN 1990; Scott & Emberson 1999)

6.12.2. Biology

The three most important agricultural pest species in the genus, *Brevipalpus californicus* (Banks), *B. obovatus* Donnadieu, and *B. phoenicis* (Geijskes), have been consistently confused and misidentified for more than 50 years (Welbourn *et al.* 2003). *B. phoenicis* is polyphagous, exhibits parthenogenetic, haploid thelytokous reproduction (producing predominantly female offspring), has a relatively long life cycle and general tolerance to organophosphorus insecticides and acaricides (Haramoto 1969). This is similar to its congeners *B. obovatus* and *B. californicus*. The incidence of males in the population is as low as 1 percent on papaya which led Haramoto (1969) to assume that the genetic composition of the mite within an area is fairly uniform.

The endosymbiotic bacterium *Wolbachia* is theorised to contribute to the feminisation of haploid genetic *B. phoenicis* males (Otto & Jarne 2001). Dispersal is extremely limited (Alves *et al.* 2005) with experimentally released mites in laboratory, greenhouse and field conditions moving less than 1 cm in a day. Oomen (1982) noted that populations of the mite were relatively sedentary on the lower surface of tea leaves in West Java until deteriorating leaf quality triggered migration towards younger leaves.

In contrast to other well known spider mites *B. phoenicis* has very low mortality during the developmental stages (CPC 2006) and only thrives within a fairly narrow temperature band. In laboratory experiments in Brazil the duration from egg to adult was 29.9 days at 23°C and 23.8 days at 27°C (Trindade & Chiavegato 1994). The lower temperature thresholds for egg development, postembryonic development and preoviposition period were 9.1, 15.5 and 11°C respectively in laboratory conditions in Cuba (Prieto Trueba 1975). Females laid averages of 16.3 eggs each in summer and 12.5 eggs per individual in winter (Zaher *et al.* 1970).

According to some authors eggs don't hatch in constant temperatures below 20°C and above 30°C regardless of humidity and its believed temperatures beyond these for prolonged periods are fatal to immature stages (Haramoto 1969). However Zaher *et al*. (1970) reported a generation taking up to 96.5 days to complete at 13.8°C under laboratory conditions in Egypt. The duration of all life stages was shortened with increasing temperatures, with the incubation and quiescence periods being the most affected (Trindade & Chiavegato 1994). Mite populations in tea gardens in India increased with moderately high temperature (25-30°C), high relative humidity (88-92 percent) low precipitation (10-12mm) and longer sunshine hours (Muraleedharan & Chandrasekharan 1981). In Taiwan *B. phoenicis* occurs throughout the year on passionfruit, but was susceptible to precipitation, especially during the dry season. It infested the upper leaf surfaces, twigs and fruits, causing vine dieback and fruit drop (Wen & Lee 1984).

6.12.3. Hosts

Pritchard and Baker (1958) list over 65 hosts. Some of the preferred hosts include: *Camellia sinensis* (tea), *Carica papaya* (papaw), *Citrus aurantium* (sour orange), *Citrus limon* (lemon), *Citrus reticulata* (mandarin), *Citrus sinensis* (navel orange), *Cocos nucifera* (coconut), *Coffea* (coffee), *Coffea arabica* (arabica coffee), *Eriobotrya japonica* (loquat), *Ficus carica* (fig), *Juglans* (walnuts), *Malus domestica* (apple), *Olea europaea subsp. europaea* (olive), *Phoenix dactylifera* (date-palm), *Prunus persica* (peach), *Psidium guajava* (guava), *Pyrus* (pears), *Vitis* (CPC 2006).

Other hosts include:
Abutilon spp. (Indian mallow), *Acalypha hispida* (Copperleaf), *Acer* spp. (maples), *Ageratina adenophora* (Croftonweed), *Albizia* spp., *Alcea rosea* (Hollyhock), *Alpinia* spp., *Anacardium occidentale* (cashew nut), *Annona squamosa* (sugarapple), *Anthurium andreanum*, *Apium* spp., *Aralia* spp., *Artocarpus altilis* (breadfruit), *Bauhinia* spp., *Buddleia* spp. (Butterflybush), *Cajanus* spp., *Caladium* spp., *Callistemon* spp. (Bottle brush), *Canna indica* (Queensland arrowroot), *Citrus medica* (citron), *Citrus x paradisi* (grapefruit), *Clerodendrum* spp. (Fragrant clerodendron), *Cordyline fruticosa* (Good-luck-plant), *Cosmos* spp., *Dendrobium* spp., *Dipladenia* spp., *Dodonaea* spp., *Elaeis guineensis* (African oil palm), *Erythrina spp.*, *Gardenia* spp., *Geranium* spp. (cranesbill), *Gerbera* spp.(Barbeton daisy).

Grevillea spp., *Helianthus annuus* (sunflower), *Hibiscus rosa-sinensis* (China-rose), *Ipomoea batatas* (sweet potato), *Jatropha curcas* (Barbados nut), *Lagerstroemia* spp., *Litchi chinensis* (litchi), *Malpighia glabra* (acerola), *Mangifera indica* (mango), *Maranta* spp., *Mimosa* spp.(sensitive plants), *Morus* spp. (mulberrytree), *Musa* spp.(banana), *Myrtus* spp., *Nerium oleander* (oleander), *Passiflora edulis* (passionfruit), *Phoenix* spp., *Pittosporum* spp., *Polyscias quilfoylei*, *Pyrostegia venusta* (Goldenshower), *Rosa* spp. (roses), *Solanum melongena* (aubergine), *Swietenia mahagoni* (Cuban mahogany), *Theobroma cacao* (cocoa), *Zea mays* (maize), *Ziziphus* spp. (CPC 2006).

6.12.4. Distribution

This is a tropical-subtropical species that has been accidentally transported by man to many areas where it survives well in greenhouses. *B. phoenicis* is found throughout Asia and Africa, localised in the Americas and parts of Europe, and in Fiji, Tonga, Norfolk and Solomon Islands and Australia in Oceania (CPC 2006). There have been several records of the mite occurring in New Zealand (PPIN 1990, Collyer 1973) in the last 30 years, but it is not established here.

Brevipalpus phoenicis as a Vector
B. phoenicis is a vector of passion fruit green spot virus, coffee ring spot virus, and citrus leprosis virus (Chagas *et al.* 2003, Rodrigues *et al.* 2003 Kitajima *et al.* 2003). Citrus leprosis virus is transmitted transstadially but not transovarially (CPC 2006) and is an internationally recognised pathogen of citrus species around the world. Once the mites are infected they persistently transmit the virus which is a regulated disease in New Zealand. There is no evidence that any of these viruses occur in Australia (no records found on the VIDE database 2007 or in CPC 2007).

6.12.5. Hazard Identification Conclusion

Brevipalpus phoenicis is a serious pest of some plant species grown here for commercial purposes and a vector of plant viruses, but from research appears to thrive only within a narrow temperature band between 20-30°C. It has entered the country before within the last 30 years but has not become established. It is likely that climatic conditions are not suitable for its establishment. As none of the major viruses that *B. phoenicis* vectors occur in

Australia, no viruses of economic significance would be likely to enter New Zealand in association with this mite species. It is therefore not considered a potential hazard in this risk analysis.

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6.13. Chilli/Broad Mite

6.13.1. Hazard Identification

Aetiological agent: *Polyphagotarsonemus latus* (Banks) (Acari: Tarsonemidae).

Synonyms: Acarus translucens, Tarsonemus translucens, Hemitarsonemus latus, Hemitarsonemus translucens, Polyphagotarsonemus translucens, Tarsonemus phaseoli

New Zealand Status: Locally distributed in the upper North Island – 12 records since the 1970s (PPIN 2007).

6.13.2. Biology

Polyphagotarsonemus latus is an important pest of diverse crops in tropical and subtropical regions (Gerson 1992) and has been observed causing damage to greenhouse crops in temperate areas (Karl 1965). The sex ratio tends towards 1:4, male: female and reproduction is arrhenotokous with unmated females producing only males. Srinivasulu and others (2002) observed female mites on average laying about 34.7 eggs per individual per life cycle in laboratory conditions in India. The average longevity of males and females was 6.41 and 7.92 days respectively (Srinivasulu *et al.,* 2002). The mite may raise a generation in 1 week under optimal conditions (ca 25°C and high relative humidity). The theoretical lower threshold for development is below 12-14°C (Jones & Brown 1983). Ferreira and others (2006) in laboratory experiments on the thermal tolerance of *P. latus* in grape found that for egg, larva, pupa and egg-adult life stages thermal thresholds were 11.23, 9.45, 12.19 and 9.71°C respectively.

P. latus disperses by various means. Short distance movement can be achieved by walking, with mites reaching distant uninfested plants aided by wind. Males carry pharate (quiescent nymphal stage) females towards the plant's apical parts, mating with them as they emerge, effectively choosing the female oviposition sites by this dispersal mechanism (Gadd 1946). There is significant evidence that *P. latus* has a phoretic relationship with several species of whitefly; *Bemisia tabaci* on beans (*Phaseolus vulgaris*) in Colombia and watermelon in Venezuela (Flechtmann *et al.,* 1990), with *B. argentifolii* (Fan & Petitt 1998) in the US, and *Trialeurodes vaporariorum* (Parker & Gerson 1994). Females attach themselves to the tarsi and tibiae of the whiteflies when they land on infested plants. *P. latus* may sometimes be a problem in litchi nurseries in Australia, but is rarely encountered in the field, and has never been noted in association with litchi fruit (G.K.Waite Pers. Comm. 2007).

There is no evidence that *P. latus* vectors any known plant diseases.

6.13.3. Hosts

Major Hosts include: *Camellia sinensis* (tea), *Capsicum frutescens* (chilli), *Carica papaya* (pawpaw) *Citrus limon* (lemon) *Corchorus* spp. (jutes), *Cucumis sativus* (cucumber), *Gossypium* spp. (cotton), *Solanum melongena* (aubergine), *Vitis vinifera* (grapevine) (CPC 2007).

Minor hosts include: Brassicaceae spp. (mustard family), *Capsicum annuum* (bell pepper), *Coffea* spp. (coffee), Fabaceae (beans), *Gerbera* spp. (Barbeton daisy), *Lycopersicon esculentum* (tomato), *Mangifera indica* (mango), *Persea americana* (avocado), *Phaseolus* spp. (beans), *Psophocarpus tetragonolobus* (winged beans), *Ricinus communis* (castor bean), *Solanum tuberosum* (potato), *Datura* spp. (thorn apple) (CPC 2007).

6.13.4. Distribution

P. latus is cosmopolitan in distribution occurring throughout Asia, Africa, Europe and the Americas. It is also recorded from Australia and other Pacific Islands in Oceania (CPC 2007). It has been recorded 12 times in New Zealand since the 1970's and has been found in the Waikato, Bay of Plenty, Northland and Auckland. It was last recorded here in 1992 (PPIN 2007).

6.13.5. Hazard Identification Conclusion

Although *P. latus* has been recorded previously in New Zealand it seems generally restricted to warmer areas of the country where citrus is grown. It is phoretic on some species of whitefly but there are no recorded *Bemisia* spp. (its primary vector) associated with *Litchi chinensis* anywhere in its host range. Despite it being a serious pest in a range of climatic zones it is a non-regulated pest in New Zealand and is therefore not considered a potential hazard in this risk analysis.Were *Bemisia* spp. to be found in New Zealand or associated with litchi a reassessment of *P. latus* would b required.

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6.14. Fungal Pathogens and Saprobes

6.14.1. Hazard Identification

Aetiological agent: *Bipolaris hawaiiensis* (Ellis) Uchida & Aragaki
(Pleosporales: Pleosporaceae)
Lasiodiplodia theobromae (Patouillard) Griffon & Maublanc
(Anamorphic Botryosphaeria)
Teleomorph: *Botryosphaeria rhodina*
Pestalotiopsis mangiferae (Hennings) Steyaert (Xylariales: Amphisphaeriaceae)

Synonyms:
For B. hawaiiensis: *Dreschlera hawaiiensis, Helminthosporium hawaiiense, Pseudocochliobolus hawaiiensis*

For L. theobromae: Botryodiplodia theobromae, Diplodia theobromae, Lasiodiplodia tubericola, Diplodia tubericola, Botryodiplodia tubericola, Physalospora rhodina

For P. mangiferae: Pestalotia mangiferae

New Zealand Status: None of these species are known to be present in New Zealand (NZFungi 2007).

6.14.2. Bipolaris hawaiiensis Biology

A widespread heterothallic (having a sexual incompatibility system so only genetically compatible strains can fuse during sexual reproduction) fungus that is most frequently associated with grasses, plant material, and soil. Its conidia are air dispersed (Sivanesan & Holliday 1982). The species has been collected as two specimens from litchi with stem end rot in northern Queensland. One of the isolates was taken from a fruit after three weeks in storage. It is not thought to be a pathogen of litchi (Hancocks, B. Biosecurity Australia pers. comm. 2007). *B. hawaiiensis* was found to be pathogenic on bermudagrass (*Cynodon* spp.) in Guangdong Province in China (Xiang & Zhong 1999). However in experiments conducted in Florida, Brecht and others (2007) concluded that *B. hawaiiensis* should be considered senectopathic (able to incite disease only in senescing plant tissue) on bermudagrass at higher temperatures. A higher disease severity resulted at 30 ºC than at 20 ºC (Brecht *et al.* 2007).

B. hawaiiensis is considered allergenic and causes severe cases of mycotic keratitis, phaeohyphomycosis and chronic fungal sinusitis in humans (Sharkey *et al.* 1991; Sharkey *et al.* 1990; Washburn *et al.* 1988). It has also been reported in cases of pulmonary and cerebral disease, meningoencephalitis, and endophthalmitis.

6.14.3. Hosts

Hosts include *Sorghum halepense, Chloris gayana, Triticale* sp.(wheat) *Litchi chinensis* and *Zea mays* (NCOF Database 2007, Bonilla *et al.* 1999; Sonoda 1991; Hiremath *et al.* 1991). It has been recorded once on *Oryza sativa* (rice) imported for consumption in New Zealand, and is common on *Lepturus repens* (Pacific Island thintail) and *Cynodon dactylon* (Bermuda grass) in the Pacific Islands (NZFungi 2007).

6.14.4. Distribution

There is one record of *B. hawaiiensis* in New Zealand (NZFungi 2007), on rice. This is very likely from an interception as *Oryza sativa* is not grown commercially here, and would not thrive as an ornamental either. It is found in the Americas, north to south, the Caribbean,

Australia, Taiwan, Thailand, India, Pakistan and Nepal. It is also in parts of Africa including Zimbabwe, Kenya, Egypt and South Africa (Farr *et al.* 2007; Brecht *et al.* 2007; Mohamed *et al.* 2000; Saleem & Amer-Zareen 1999; John *et al.* 1992).

6.14.5. Lasiodiplodia theobromae Biology

This fungus 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 endophytes (Johnson *et al.* 1998; Gonzalez *et al.* 1999). Field experiments in Brazil noted that conidia were released whenever precipitation reached a minimum of 25mm whereas above 80mm of rain the conidia were precipitated out of the air column (Correia & Costa 2005).It sporulates readily on host tissue on incubation usually when there is a wound present. In lab culture *L. theobromae* grew from 20-45ºC with optimum growth and maximum numbers of pycnidia produced between 30-40ºC. There was no growth below 15ºC (Khanzada *et al.* 2006).

In Australia *L. theobromae* causes branch blight and fruit rot in litchi (Coates *et al.* 2005). It is most important as a cause of postharvest food decay, on mango (Mascarenhas *et al.* 1996), sweet potato (Ray & Ravi 2005), durian (Sivapalan *et al.* 1998) and quince (Sharma & Sumbali Geeta 1997) among other produce. Fruit on the tree is not usually attacked unless injured or over-ripe and can be completely rotten in 2-3 days.

L. theobromae is also a rare but important causal agent of human keratitis, endopthalmitis and panopthalmitis. These infections have been reported in France (Donnio *et al.* 2006) on a Cambodian patient in Australia (Maslen & Matsumoto 1996), Sri Lanka (Gonowardena *et al.* 1994) India (Thomas *et al.* 1991) and the US (Slomovic *et al.* 1985; Rebell & Forster 1976).

6.14.6. Hosts

Hosts include *Allium* spp. (onion, garlic, leek etc.), *Ananas comosus* (pineapple), *Arachis hypogaea* (groundnut), *Araucaria cunninghamii* (colonian 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), *Artocarpus integer*, *Cajanus cajun* (pigeon pea), *Camellia sinensis* (tea), *Corchorus olitorius* (jute), *Cornus florida* (Flowering dogwood), *Cucumis melo* (melon), *Cynara scolymus* (artichoke), *Eleagnus angustifolia* (oleaster), *Glycine max* (soyabean), *Ipomea batatas* (sweet potato), *Manihot esculenta tuberosa* (oca), *Passiflora quadrangularis* (giant granadilla), *Phoenix dactylifera* (date palm), *Saccharum officinarum* (sugarcane), *Sorghum bicolor* (sorghum), *Vigna unguiculata* (cowpea), *Vitis vinifera* (grapevine) (CPC 2006), *Dimocarpus longan* (Zhang *et al.* 2005) and *Litchi chinensis* (Coates *et al.* 2005).

6.6.14.1. Distribution

This fungus is cosmopolitan in distribution, found widely throughout Asia, Africa the Americas, Oceania and parts of Europe. In Australia it is common in Queensland (Johnson & Coates 1993) and has been recorded in New South Wales (Wade *et al.* 1993). It has been isolated twice from litchi in northern Queensland, once from fruit with fruit rot and once from fruit with pepper spot (Roger Shivas pers. comm. to Hancocks, B. Biosecurity Australia 2007). A few infected tubers were found in the sprouting beds of sweet potatoes in Avondale, Auckland, in November 1963 (Dingley 1969). This common tropical fungus has not been reported from any other locality. It is often present on tropical fruits, tubers of *Ipomoea,* and roots of *Colocasia* imported from Pacific islands (NZFungi 2008). It is likely the 3 specimens were on imported produce.

6.14.7. Pestalotiopsis sp. Biology

There are five records of *Pestalotiopsis* sp. associated with fruit rot and one with leaf pepper spot on litchi in Australia. It is considered to be a minor pathogen on litchi in Queensland (Roger Shivas pers. comm. to Hancocks, B. Biosecurity Australia pers. comm. 2007). The specific identity of the *Pestalotiopsis* species is not known. *P. mangiferae* has not been recorded on litchi in Australia (Roger Shivas pers. comm. to Hancocks, B. Biosecurity Australia pers. comm. 2007)) but since it is present in Australia, and infects litchi plants in India (Kang & Singh, 1991) it is used in the assessment to represent the wider grouping of *Pestalotiopsis* fungi.

P. mangiferae is known as a weak parasite, capable of infecting young injured leaves, injured fruits, older uninjured leaves and healthy fruits if in contact with the diseased tissue (Mordue 1980; Tandon *et al.* 1955). It has also been isolated from soil (Mordue 1980).

P. mangiferae over summers in acervuli (flat masses of fungal conidiophores embedded in host plant tissue) and in the necrotic spots on plants as dormant mycelium (Verma & Singh 1996). During flowering and fruit set in mango, fungal colonisation increased as flowers senesced and the young fruit were formed (Johnson *et al.* 1991). Mycelia of the fungi colonize inflorescence tissue as it matures and in certain conditions, including specific water regimes, defoliation and pruning practices, reach the stem end of fruit. Infections then remain latent until after harvest or until the unharvested fruit senesce (Johnson *et al.* 1991). Experiments to determine the optimal temperature for growth of the fungi put the range between 20-30 ºC (Sawant & Raut 1995; Sarkar 1960). Storage of mango fruits below 8 ºC in India prevented fruit rot by *P. mangiferae* (Tandon *et al.* 1955).

6.14.8. Hosts

Hosts include *Anacardium occidentale* (cashew), *Combretum decandrum*, *Eucalyptus* spp., *Mangifera indica* (mango), *Mimusops* spp., *Terminalia belerica, Litchi chinensis* and *Vitis vinifera* (grape vine), (Kang & Singh 1991; Chauhun & Gupta 1984; Mordue 1980).

6.14.9. Distribution

P. mangiferae is found in subtropical and tropical regions including India, China, Hong Kong and Malaysia, Brazil, Venezuela, the Caribbean, South Africa (Farr *et al.* 2007) and Australia (Mordue 1980).

6.14.10. Hazard Identification Conclusion

All three fungi exhibit optimal development at temperatures between 20-35ºC. Lower thresholds for development are available only for *L. theobromae* however (15ºC). Although occuring as an endophyte in some circumstances, in its association with litchi fruit *L. theobromae* is typically recorded as a secondary pathogen in decaying plant material. Fruit grading systems would ensure damaged fruit are discarded before export. Despite being recorded in New Zealand on *Ipomea* tubers in 1963 there has been no record of the fungus found in other localities suggesting either that its presence here was a result of its association with imported produce and - or that temperature is a significant limiting factor in the establishment of the species here.

For these reasons *L. theobromae* is not considered further in this risk analysis.
If climatic temperature increases in the future result in conditions conducive to establishment or it is demonstrated that *L. theobromae* can be associated with litchi fruit endophytically, this assessment may need to be reviewed.
B. hawaiiensis and *Pestalotiopsis* sp. are present in Australia but not in New Zealand. They have an association with the commodity and *P. mangifera* in particular has a high impact on

mangoes and other cultivated fruits where it occurs. Whilst there is uncertainty about the pathogenicity of *B. hawaiiensis* on litchi, they are both considered potential hazards in this risk analysis. Since the identity of the *Pestalotiopsis* sp. found on litchi in Australia is not known, *P. mangiferae* is used to asses the risk, but the assessment will need to be revisited if the species identity is clarified.

6.14.11. Risk Assessment

6.15.9.1 Entry Assessment

Disease expression is an interaction between a pathogen its host plants and the environment. Environmental conditions and plant vigour will influence how pathogenic a species is under a range of circumstances. Because it is unknown whether the potential fungal hazards are pathogenic on litchi fruit, an assumption on the likelihood of association has been made. Varying reports consider *B. hawaiiensis* either directly pathogenic on its hosts (Xiang & Zhong 1999) or senectopathic only (Brecht *et al.* 2007).

Despite the lack of evidence for *B. hawaiiensis* pathogenicity on litchi, it is possible it could enter the country on fruit at a stage where it is not detectable by visual inspection.

Pestalotiopsis mangiferae is known as a weak parasite, capable of infecting healthy fruits if in contact with the diseased tissue. The fungus can colonize inflorescence tissue reaching the stem end of fruit, oversummer as dormant mycelium (Verma & Singh 1996), and remain as latent infections until after harvest (Johnson *et al.* 1991).

The likelihood of entry for B. hawaiiensis is low and for Pestalotiopsis mangiferae moderate.

6.15.9.2 Exposure Assessment

Conidia are wind dispersed in the case of *B. hawaiiensis*, making it more likely for rotten host material to distribute infection to nearby plants. It is not known what mode of infection is most common for the other species. It is assumed that air and moderate precipitation will be typical forms of dispersal. Host plants of both fungi occur in New Zealand. There is likely to be host material available in the vicinity of any infected litchi disposed of in New Zealand.

6.15.9.3 Establishment Assessment

Both fungi exhibit optimal development at temperatures between 20-30ºC.
Although there are no available lower thermal thresholds for *B. hawaiiensis,* and *P. mangiferae*, their current distributions in subtropical and tropical regions suggest permanent establishment in New Zealand would only be possible in northern Northland, or in a greenhouse environment.

The likelihood of exposure for both fungi would be low and the likelihood of establishment very low.

6.14.12. Consequence Assessment

6.15.10.1 Economic

There is little information on economic impacts of these species.

The economic impacts of the establishment of a new *Pestalotiopsis* species in New Zealand are uncertain. *Pestalotiopsis* sp. is considered a minor pathogen of litchi in Australia but Kang & Singh (1991) reported an incidence of 85 percent infection of litchi plants with *P. mangiferae* in and around Chandigarh in India. *P. mangiferae* has been implicated as one of the key species causing fungal decay in wooden fishing boats in India, which has

significant economic impacts (Gupta & Ravindran 1988). *P. mangiferae* has impact on mangos and other cultivated fruits where it occurs.

6.15.10.2 Environmental

Both species have polyphagic non-phyllogenetic host ranges (i.e. hosts cover a broad spectrum of families which are not closely related) including grasses and fruit trees. No genera recorded as hosts overseas occur in New Zealand. Two members in the Sapindaceae are represented here. *Dodonea viscosa*, which is cosmopolitan in distribution and is grown in areas where litchi is also cultivated (Hawaii), and *Alectryon excelsa* and *A. excelsa* var. *grandis*. Neither *D. viscosa* or any *Alectryon* species in Australia have been recorded as hosts for any of the fungi assessed. It is impossible to predict how likely it is that *B. hawaiiensis*, and *Pestalotiopsis* sp. would host switch to native plants after establishment. Without adequate host testing it is assumed that the likelihood of any native plants being negatively impacted by these pathogens would be very low but non-negligible.

6.15.10.3 Health

B. hawaiiensis is considered allergenic and causes severe cases of mycotic keratitis, phaeohyphomycosis and chronic fungal sinusitis in humans (Sharkey *et al.* 1991; Sharkey *et al.* 1990; Washburn *et al.* 1988). It has also been reported in cases of pulmonary and cerebral disease, meningoencephalitis, and endophthalmitis. Some 40-50 cases exist in the available literature. These examples are most often from tropical countries such as India and Brazil where environmental and climatic conditions are more conducive to prolific growth of the fungus.

There are no known health consequences associated with *Pestalotiopsis* sp.

The consequences of establishment of B. hawaiiensis, and Pestalotiopsis sp. are likely to be low to very low but still non-negligible.

6.14.13. Risk Estimation

The likelihood of *B. hawaiiensis* and *P. mangiferae* entering the country is low. The likelihood of exposure would be low and the likelihood of establishment very low.

As a result the risk estimates for B. hawaiiensis, P. mangiferae are non-negligible and they are classified as hazards in the commodity.

6.14.14. Risk Management

6.14.10.4 Options

Risk management options are described in chapter 5. Whilst the efficacy of these measures against these specific fungi are not known, their broad effect is described and they are listed here in ascending order of stringency. Irradiation at the levels used to cause mortality in invertebrates and sterilise any survivors is not adequate to kill off fungi (See section 5.4 for a more detailed discussion). It is assumed that fruit will be graded for export quality, and any diseased fruits removed before export. Optimum washing and drying procedures to reduce re-infection and post harvest decay are discussed in section 5.5.

The following risk management options in ascending order of stringency:

Option 1: Pest management in the orchards, screening measures and pre export inspection and inspection on arrival for fungi
Option 2: Washing litchi to remove fungal contmination.

A combination of Option 1 and 2 will manage the risk of fungi adequately.

6.14.15. Assessment of Residual Risk

Fungi that are apparent on the fruit surface during packaging and post harvest handling are highly likely to be discarded. However fungi that have a latent period and can become apparent after shipment and sale will be able to enter the country. *Pestalotiopsis mangiferae* is in this latter category.

6.14.16. Assessment of Uncertainty

The identity of the *Pestalotiopsis* species which is a minor pathogen of litchi in Queensland is unknown. Therefore ***P. mangiferae*** was used as an example in this assessment, which will need to be revisited if the species identity is clarified.

The pathogenicity of *Bipolaris hawaiiensis* on litchi fruit is uncertain.

It is assumed that irradiation at the levels used to cause mortality in invertebrates and sterilise any survivors is not adequate to kill off fungi. Specific higher risk groups could be tested to determine the necessary irradiation levels for complete mortality.

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Appendix 1 Organisms considered in the analysis

All organisms thought to be associated with litchis in Australia are listed in the table. Potential hazards are identified as those organisms that are not present in New Zealand and for which there is evidence of association with litchi fruit. None of the organisms that are present in New Zealand, except *Aphis gossypii* are vectors of a pathogen or disease not present in New Zealand, and none are known to have different strains overseas.

A risk assessment is undertaken for organisms identified as potential hazards and further consideration is given to those organisms for which the initial assessment of potential hazard status is uncertain (Chapter 6). Organisms assessed as having a non negligible risk are considered to be hazards.

Common name	Scientific name	In NZ?	Associated with litchi fruit?	Potential Hazard?	Hazard?
Arthropods					
Acari (mites)					
Litchi gall mite	*Aceria litchii* Huang, Huang & Horng (Phytoseiidae)	N	Y Morton (1987)	N See Chapter 6.12	N
False spider mite	*Brevipalpus phoenicis* (Geijskes, 1936) (Tetranychidae)	Y Collyer (1973)	N Childers *et al.* (2003)	N See Chapter 6.12	N
Broad mite	*Polyphagotarsonemus latus* (Banks) (Tarsonemidae)	Y PPIN (2007)	N Hidenari (2002)	N See Chapter 6.12	N
Insecta					
Coleoptera					
	Monolepta rosea Blkb. (Chrysomelidae)	N	N Veitch (1936)	N[5]	N
Red shouldered leaf beetle	*Monolepta australis* Jacoby (Chrysomelidae)	N	N Fay & DeFaveri (1990)	N	N
	Rhyparida australis Boh. (Chrysomelidae)	N	N Simmonds (1924)	N[6]	N
Elephant beetle	*Xylotrupes gideon* (Linneaus) (Scarabaeidae)	N	Y Rogers & Blair (1981)	N See Chapter 6.9	N
Diptera					
Northern Territory fruit fly	*Bactrocera aquilonis* (May) (Tephritidae)	N	N Smith *et al.* (1988)	N[7]	N
Jarvis' fruit fly	*Bactrocera jarvisi* (Tryon) (Tephritidae)	N	Y Hancock *et al.* (2000)	Y	Y
Lesser Queensland fruit fly	*Bactrocera neohumeralis* (Hardy) (Diptera: Tephritidae)	N	N Hancock *et al.* (2000)	Y	Y
Queensland fruit fly	*Bactrocera tryoni* (Froggatt) (Tephritidae)	N	Y Hancock *et al.* (2000)	Y	Y

5 *M. rosea* is normally a minor pest but occasionally appears in enormous numbers and destroys leaves, fruit and flowers in a few days (Veitch 1936). More generally the blossoms and foliage are attacked (Gurney 1919). Duration of the infestation is usually brief (Veitch 1936). At these levels pest controls would be implemented (chapter 3) and at lower levels it is likely only foliage and blossoms will be eaten.
6 Larvae feed at night eating around the soft outer tissue of stems on the leafstalks of cotton causing ring barking and wilt (Simmonds 1924). It is unlikely except in plague proportions that *R.. australis* or other *Rhyparida* spp. which have similar feeding habits (Fischer *et al.* 2003) would be found on litchi fruit.
7 This species hybridises with other *Bactrocera* species. Therefore it is assessed further in Chapter 6.1.

Common name	Scientific name	In NZ?	Associated with litchi fruit?	Potential Hazard?	Hazard?
Mediterranean fruit fly	*Ceratitis capitata* (Weidermann) (Tephritidae)	N	Y Grove *et al.* (2004)	N See Chapter 6.1	N
Hemiptera					
Banana spotting bug	*Amblypelta lutescens lutescens* (Distant) (Coreidae)	N	Y Waite (1990)	Y	Y
Fruitspotting bug	*Amblypelta nitida* (Stål) (Coreidae)	N	Y Waite (1990)	Y	Y
Melon aphid	*Aphis gossypii* Glover (Aphididae)	Y Scott & Emberson (1999)	Y Chomchalow (2004)	N[8]	N
Pink wax scale	*Ceroplastes rubens* Maskell (Coccidae)	N	Y Qin & Gullan (1994)	Y	Y
Soft brown scale	*Coccus hesperidium* (Linnaeus) (Coccidae)	Y Charles *et al.* (2005)	N Copland & Ibrahim (1985)	N	N
Seychelles scale	*Icerya seychellarum* Westwood (Margarodidae)	N	N Jepson (1939)	Y See Chapter 6.4	N
Black thread scale	*Ischnaspis longirostris* Signoret (Diaspididae)	N	Y Dekle (1965)	Y	Y
Soapberry bug	*Leptocoris isolatus* Distant (Rhopalidae)	N	N Braekman et al. (1982)	N See Chapter 6.6	N
Soapberry bug	*Leptocoris ruformarginata* (Fabricius) (Rhopalidae)	N	Y Waite (1992)	N See Chapter 6.6	N
Soapberry bug	*Leptocoris tagalica* (Burmeister) (Rhopalidae)	N	Y Waite (1992)	N See Chapter 6.6	N
Litchi stink bug	*Lyramorpha rosea* (Westwood) (Tessaritomidae)	N	N Sinclair (2000)	N	N
Rutherglen bug	*Nysius vinitor* (Bergroth) (Lygaeidae)	N	Y Waite & Hwang (2002)	Y	Y
Black coffee scale	*Parasaissetia nigra* Nietner (Coccidae)	Y Hodgson & Henderson (2000)	N Rutherford (1914)	N	N
Guava mealy scale	*Pulvinaria psidii* Maskell (Coccidae)	N	Y Waite (1992)	N See Chapter 6.8	N
Coffee helmet scale	*Saissetia coffeae* Walker (Coccidae)	Y Hodgson & Henderson (2000)	Y Nakahara (1981)	N	N
Lepidoptera					
	Adoxophyes templana (Walker) (Tortricidae)	N	Y Storey & Rogers (1980)	N[9]	N
	Anarsia spp.(lineatella?) (Gelechiidae)	N	Y Storey & Rogers (1980)	N[10]	N
Pencilled blue	*Candalides absimilis*	N	Y Hancocks,	N[11]	N

8 Whilst it is a serious pest of litchi in Vietnam, the association with litchi fruit is uncertain. *A. gossypii* is a vector for a number of viruses including Papaya ring spot virus which is not present in New Zealand. However it is assumed that the time period between picking and arrival in New Zealand will exceed the retention time for such viruses.

9 It is likely that because it feeds on the large seed within the fruit (Storey & Rogers 1980) the fruit will drop if young or become unmarketable and detectable at a later stage of maturity.

10 Three species of *Anarsia* occur in Australia; *A. anartoides*, *A. anaspila* and *A. anassa* (Nielsen *et al.* 1996). *Anarsia* sp. feed on the seed by burrowing through the outer flesh. This causes the fruit to drop if young, or it makes it unmarketable (Storey & Rogers, 1980). Such fruit will be detected during grading.

Common name	Scientific name	In NZ?	Associated with litchi fruit?	Potential Hazard?	Hazard?
	(Felder) (Lycaenidae)		pers. comm. (2007)		
	Cateremna quadriguttella (Walker) (Pyralidae)	N	Y APPD (2007)	N[12]	N
Yellow peach moth	*Conogethes punctiferalis* (Synonym: Dichocrocis punctiferalis) (Guenee) (Pyralidae)	N	Y Storey & Rogers (1980)	N[13]	N
Macadamia flower caterpillar	*Cryptoblabes hemigypsa* (Turner) (Pyralidae)	N	N Ironside (1981)	N	N
Macadamia nut borer	*Cryptophlebia ombrodelta* Lower (Tortricidae)	N	Y Menzel (2002)	Y	Y
Cornelian	*Deudorix epijarbas dido* Waterhouse (Lycaenidae)	N	Y Storey & Rogers (1980)	N[14]	N
Dull Cornelian	*Deudorix epijarbas diovis* (Hewitson) (Lycaenidae)	N	Y Biosecurity Australia (2007)	N[15]	N
	Dudua aprobola (Meyrick) (Tortricidae)	N	Y Menzel (2002)	N[16]	N
	Echiomima fabulosa (Meyrick) (Oecophoridae)	N	N Common (1990)	N	N
	Eublemma versicolor (Walker) (noctuidae)	N	Y Storey & Rogers (1980)	N[17]	N
Fruit piercing moth	*Eudocima aurantia* (Moore) (Noctuidae)	N	Y Herbison - Evans & Crossley (2002)	N[18]	N
Fruit piercing moth	*Eudocima fullonia* Clerck (Noctuidae)	N	Y Fay & Halfpapp (1999)	N[19]	N
Fruit piercing moth	*Eudocima jordani* (Holland) (Noctuidae)	N	Y Fay & Halfpapp (1999)	N[20]	N
Fruit piercing	*Eudocima materna*	N	N CPC	N	N

11 *C. absimilis* may occasionally feed on litchi attacking the new soft growth of leaves and possibly flowers. They do not touch the fruit. This butterfly is found infesting litchi in such low numbers it does not cause significant damage and would not be classed as a pest (Michael Braby pers. comm. to Hancocks, B. Biosecurity Australia, pers. comm. 2007).

12 There is very little literature on this species and it is assumed to be a pest of very sporadic occurrence and minor significance. Damaged fruit would most likely be rejected at the grading stage.

13 The larvae feed on the seed by burrowing through the outer flesh. This causes the fruit to drop if young, or it makes it unmarketable (Storey & Rogers, 1980). Such fruit will be detected during grading.

14 The larvae feed on the large seeds within fruit (Herbison-Evans & Crossley 2002, Storey & Rogers 1980). It is likely that burrowing into the seed would make young fruit fall and more mature fruit unmarketable.

15 This species lays eggs singly usually in the cleft of the fruit. The larva feeds on the seed and moves to another, entering by chewing a hole approximately 2.5mm in diameter through the skin which is quite conspicuous (Hancocks, B., Biosecurity Australia, pers. comm. 2007). Pupation usually occurs inside the empty fruit and the adult emerges from the hole made by the larva. Fruits with larvae are likely to be discarded during grading.

16 The larval and pupal stages are confined to a silken foliage web feeding on the epidermis of branches, panicles and pedicels (Padmanabha-Aiyar 1944). The adults are nocturnal and remain concealed amongst leaves during the day (Mehra & Sah 1974) when litchi fruits are harvested.

17 It is likely that any damage it does to fruit will be detected during grading if young fruit do not drop due to infestation.

18 The adults are the fruit feeding life stage. They are nocturnal (Fay & Halfpapp 1999) and unlikely to be associated with the commodity during harvest.

19 *E. fullonia* is recorded as an occasional immigrant occurring throughout New Zealand (Dugdale 1988) but has not become established. The adults are the fruit feeding life stage. They are nocturnal (Fay & Halfpapp 1999) and unlikely to be associated with the commodity during harvest.

20 A large conspicuous moth; the adults feed on fruit nocturnally with larvae and pupae feeding on foliage (Fay & Halfpapp 1999). It is unlikely to be associated with the commodity during harvest.

Common name	Scientific name	In NZ?	Associated with litchi fruit?	Potential Hazard?	Hazard?
moth	(Linnaeus) (Noctuidae)		(2006)		
Fruit piercing moth	*Eudocima salaminia* (Cramer) (Noctuidae)	N	Y Menzel (2002)	N[21]	N
	Homoeosoma vagella Zeller (Pyralidae)	N	Y Storey & Rogers (1980)	N[22]	N
	Hydrillodes lentalis Guenée (Noctuidae)	N	Y Storey & Rogers (1980)	N[23]	N
Orange fruitborer	*Isotenes miserana* (Walker) (Tortricidae)	Y	Y Herbison - Evans & Crossley (2005)	N[24]	N
Flower caterpillar	*Lobesia spp.1* (Tortricidae)	N	Y Storey & Rogers (1980)	N[25]	N
Flower caterpillar	*Lobesia physophora* Lower (Tortricidae)	N	N Storey & Rogers (1980)	N	N
	Phycita leucomilta Lower	N	Y Storey & Rogers (1980)	N[26]	N
Flower caterpillar	*Prosotas dubiosa* (Semper) (Lycaenidae)	N	N Hsu & Yen (2006)	N[27]	N
Flower caterpillar	*Prosotas felderi* Murray (Lycaenidae)	N	N Dunn & Dunn (1991)	N[28]	N
	Pyroderces dendrophaga (Meyrick) (Cosmopteridgidae)	N	Y Storey & Rogers (1980)	N[29]	N
	Tirathaba rufivena Walker (Pyralidae)	N	Y Storey & Rogers (1980)	N[30]	N
Thysanoptera					
Red banded thrips	*Selenothrips rubrocinctus* Giard (Thripidae)	N	N Sanchez-Soto & Nakano (2004)	N	N
Pathogens					
Fungi					
Alternaria leaf	*Alternaria alternata* (Fries)	Y PPIN	Y Johnson	N	N

21 Larvae of *E. salaminia* feed exclusively on foliage of host plants from the Menispermaceae while adults are nocturnal fruit feeders (Sands *et al.* 1991). Neither life stage is likely to be associated with the commodity during harvest.
22 Larvae of *H. vagella* generally feed on flowers (Ironside & Giles 1981), and this species has sometimes been misidentified as *Cryptoblabes hemigypsa* (Horak 1994). It is likely that any damage it does to fruit will be detected during grading if young fruit do not drop because of attack.
23 The larvae feed on the seed by burrowing through the outer flesh. This causes the fruit to drop if young, or it makes it unmarketable (Storey & Rogers, 1980). Such fruit will be detected during grading.
24 A restricted population of *Isotenes miserana* was detected in Auckland, in 2007. There is now a permanently established population in New Zealand. The unwanted status of this moth has been removed, and it is not considered a hazard organism in this risk analysis.
25 An unidentified species of *Lobesia*, called *Lobesia* spp. 1 is reported attacking fruit (Storey & Rogers 1980). Like other fruit feeders it is likely that burrowing into the seed would make young fruit fall and more mature fruit unmarketable. There is no information on its biology and until such time as it is identified to species level is not considered further.
26 Not in the Checklist of the Lepidoptera of Australia (Nielsen *et al.* 1996). It is likely that any damage it does to fruit will be detected during grading if young fruit do not drop due to infestation.
27 Researchers in Taiwan have shown that larvae are specialised to feed on flowers and flower buds (Hsu & Yen 2006).
28 Assumed to have a similar life cycle to its congeners *P. dubiosa* and *P. nora* which occur in both Taiwan and Australia and feed on flowers and flower buds (Hsu & Yen 2006).
29 Larvae of *P. dendrophaga* are commonly seen in grain sorghum heads (Sloan 1946). Like other fruit feeders burrowing into the seed through the flesh young litchi fruit would be caused to drop and mature fruit rendered unmarketable (Storey & Rogers 1980). It is unlikely to be more than a very minor pest on litchi where it occurs.
30 The larvae feed on the seed by burrowing through the outer flesh. This causes the fruit to drop if young, or it makes it unmarketable (Storey & Rogers, 1980). Such fruit will be detected during grading.

Common name	Scientific name	In NZ?	Associated with litchi fruit?	Potential Hazard?	Hazard?
spot	Keissler (Anamorphic *Lewia*)	(2007), NZFungi (2007)	*et al.* (2002)		
Bermuda grass browning	*Bipolaris cynodontis* (Marignoni) Shoemaker (Pleosporales: Pleosporaceae)	N	Y NCOF Database (2000)	N[31]	N
Leaf spot	*Bipolaris hawaiiensis* (Ellis) Uchida & Aragaki (Pleosporales: Pleosporaceae)	N	Y NCOF Database (2000)	Y See Chapter 6.15	Y
	Colletotrichum acutatum (Simmonds) (Hyphomycetes)	Y PPIN (2007)	Y Johnson *et al*. (2002)	N	N
Leaf spot	*Curvularia pallecens* Boedijn (Pleosporales: Pleosporaceae)	N	Y Hancocks, pers. comm. (2007)	N[32]	N
	Fusarium pallidoroseum (Cooke) (Hypocreales: Nectriaceae) Synonym: *Fusarium semitectum*	Y NZFungi (2008)	Y Hancocks pers comm. (2007)	N[33]	
Anthracnose	*Glomerella acutata* (*anamorph Colletotrichum acutatum* Simmonds (Phyllachorales: Phyllachoraceae)	Y PPIN (2007)	Y NCOF Database (2000)	N	N
Leaf blight, blossom blight	*Glomerella cingulata (anamorph Colletotrichum gloeosporioides)* Penz & Sacc. (Phyllachorales: Phyllachoraceae)	Y NZFungi (2007)	Y Menzel (2002)	N	N
Sour rot	*Geotrichum candidum* Link (Anamorphic Dipodascaceae) (Teleomorph: *Galactomyces geotrichum* (Butler & Petersen) Redhead & Malloch (Saccharomycetales: Dipodascaceae)	Y NZFungi (2007)	Y Tsai & Hsieh (1999)	N	N
	Gibberella zeae (Schwein.) Petch (*anamorph Fusarium graminearum* Schwabe (Hypocreales: Hypocreomycetidae)	N	N NCOF Database (2000)	N	N
Fruit rot	*Lasiodiplodia theobromae* Patouillard (Mitosporic fungi: Coelomycetes) Teleomorph:	N	Y Coates *et al.* (2005)	N See Chapter 6.15	N

31 There is little evidence to suggest that *B. cynodontis* attacks litchi fruit. It is commonly found on burmudagrass or ryegrass leaves (Pratt 2006; Pratt 2001).

32 Typically species of *Curvularia* are considered to be secondary pathogens or saprophytes (Roberts & Tredway 2007). *C. pallescens* occurs principally on grasses and some other substrates, throughout tropical and subtropical regions (Farr *et al.* 1989). It has been recorded once from litchi fruit in northern Queensland. There was no evidence that it was a pathogen (Hancocks, B., Biosecurity Australia, pers. comm. 2007).

33 *Fusarium pallidoroseum* is now accepted as a synonym of *Fusarium semitectum* by the International Commission on the taxonomy of Fungi (ICTF) (Canon 1986). *F. semitectum* occurs in New Zealand and therefore neither synonymy of the species is considered further in this risk analysis.

Common name	Scientific name	In NZ?	Associated with litchi fruit?	Potential Hazard?	Hazard?
	Botryosphaeria rhodina				
	Nigrospora sphaerica (Sacc.) Mason (Trichosphaeriales: Trichosphaeriaceae)	Y PPIN (2007)	Y Sawada (1959)	N	N
Ripe fruit rot	*Penicillium crustosum* Thom (Eurotiales: Trichocomaceae)	Y NZFungi (2007)	N Eriksson & Yue (1985)	N	N
Leaf blight	*Pestalotiopsis mangiferae* (Hennings) Steyzaert (Xylariales: Amphisphaeriaceae)	N	Y Kang & Singh (1991)	Y	Y
Fruit rot	*Phoma glomerata* (Corda) Wollenweb & Hochapfel (mitosporic Ascomycota)	Y (Johnston 1981)	N Mirza *et al.* (2004)	N	N
Black rot	*Stemphylium globuliferum* (Vestergren) Simmons (Pleosporales: Pleosporaceae)	N	Y Hancocks, pers. comm. (2007)	N[34]	N

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