



Australian Government

Biosecurity Australia

Provisional final import risk analysis report for fresh apple fruit from the People's Republic of China



March 2010

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Cover image:

Apple fruit from a packing house in Shandong province in the People's Republic of China.

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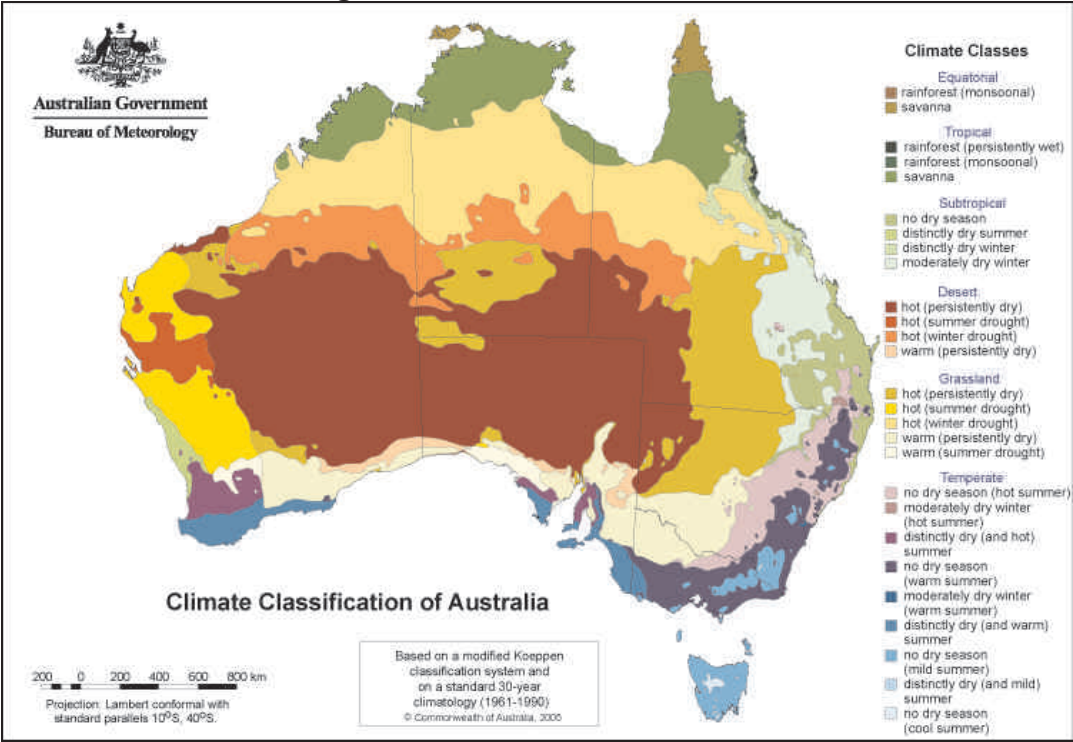
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A guide to Australia’s bio-climate zones



Acronyms and abbreviations

| Term or abbreviation | Definition |
|----------------------|--|
| ABS | Australian Bureau of Statistics |
| ALOP | appropriate level of protection |
| APAL | Apple & Pear Australia Limited |
| APPD | Australian Plant Pest Database |
| APVMA | Australian Pesticides and Veterinary Medicines Authority |
| AQIS | Australian Quarantine and Inspection Service |
| AQSIQ | General Administration for Quality Supervision, Inspection and Quarantine of the People's Republic of China (formerly CIQSA) |
| BAA | Biosecurity Australia Advice |
| BAPM | Biosecurity Australia Policy Memorandum |
| BSG | Biosecurity Services Group |
| CIQ | China Entry-Exit Inspection and Quarantine Bureau |
| CIQSA | State Administration for Entry-Exit Inspection and Quarantine of the People's Republic of China (now AQSIQ) |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| CT | concentration time |
| DAFF | Australian Government Department of Agriculture, Fisheries and Forestry |
| DAFWA | Department of Agriculture and Food, Western Australia (formerly DAWA: Department of Agriculture, Western Australia) |
| EP | existing policy |
| FAO | Food and Agriculture Organisation of the United Nations |
| FSANZ | Food Standards Australia and New Zealand |
| IDM | Integrated Disease Management |
| IPM | Integrated Pest Management |
| IPPC | International Plant Protection Convention |
| IRA | import risk analysis |
| ISPM | International Standard for Phytosanitary Measures |
| NPPO | National Plant Protection Organisation |
| NSW | New South Wales |
| NT | Northern Territory |
| NZ | New Zealand |
| PRA | pest risk analysis |
| Qld | Queensland |
| SA | South Australia |
| SPS | sanitary and phytosanitary |

| | |
|-------------|---|
| Tas. | Tasmania |
| USA | United States of America |
| USDA | United States Department of Agriculture |
| Vic. | Victoria |
| WA | Western Australia |

Abbreviations of units

| Term or abbreviation | Definition |
|----------------------|---|
| °C | degree Celsius |
| °F | degree Fahrenheit |
| kg | kilogram |
| ha | hectare |
| km | kilometre |
| kPa | kilopascal |
| m | metre |
| MT | metric tons |
| mu | unit of area used in China (one fifteenth of a hectare) |
| µm | micrometre (one millionth of a metre) |
| ml | millilitre |
| mm | millimetre |
| ppm | parts per million |
| s | second |

Summary

This import risk analysis (IRA) assesses a proposal from the People's Republic of China (China) for market access to Australia for fresh apple fruit.

Australia permits the importation of a variety of pome fruit (apples and pears) for human consumption provided they meet Australia's quarantine requirements, including pears from China, Korea and Japan, and apples from Japan and New Zealand.

This import risk analysis report recommends that the importation of fresh apple fruit from all commercial production areas of China be permitted, subject to a range of quarantine conditions, including verification of pest status in the areas nominated by China to export apple fruit to Australia. To date Biosecurity Australia has visited seven of the nine areas nominated: Beijing, Gansu, Hebei, Liaoning, Shaanxi, Shandong and Shanxi. The remaining two, Henan and Ningxia, and any additional areas nominated by China to export apple fruit to Australia in the future, will also require verification of their pest status before export can occur.

The report takes into account the stakeholders' comments on the 2008 issues paper and the 2009 draft import risk analysis report. A draft report revised after consideration of stakeholders' comments was reviewed by the Eminent Scientists Group.

The report identifies 16 pests (11 arthropods and 5 diseases) that require quarantine measures to manage risks to a very low level in order to achieve Australia's appropriate level of protection (ALOP). The arthropods include: hawthorn spider mite; flat scarlet mite; Oriental fruit fly; Comstock's mealybug; apple mealybug; summerfruit tortrix moth; peach fruit moth; codling moth; pyralid moth; Manchurian fruit moth and white fruit moth. The diseases include: Japanese apple rust; marssonina blotch; apple brown rot; European canker and apple blotch.

The recommended quarantine measures take account of regional differences. Codling moth has been identified as a quarantine pest for Western Australia.

The recommended quarantine measures are a combination of risk management measures and operational systems that will reduce the risk associated with the importation of fresh apple fruit from China into Australia to achieve Australia's ALOP, specifically:

- area freedom for Oriental fruit fly, codling moth, European canker and apple brown rot
- orchard control and surveillance, and fruit bagging for other pests
- pressurised air blasting and inspection for mealybugs and mites and remedial action if quarantine pests are detected
- a supporting operational system to maintain and verify the phytosanitary status of consignments. The Australian Quarantine and Inspection Service (AQIS) will verify that the recommended phytosanitary measures have occurred and an AQIS officer will be present under a pre-clearance arrangement to inspect and verify pest freedom prior to export.

Biosecurity Australia has made a number of changes to the risk analysis following consideration of stakeholder comments on the draft IRA report. These changes include:

- addition of 32 arthropod and 12 pathogen pests to the pest categorisation, for which seven new risk assessments have been included

- for sooty blotch and flyspeck fungal complex – a reduction in the probability of importation to ‘moderate’ and a reduction in the consequences to ‘very low’. The resulting unrestricted risk estimate of ‘very low’ now achieves Australia’s ALOP. Therefore, specific risk management measures are not required for these fungi, and the proposed disinfection treatment in the packing house has been removed
- for apple scar skin viroid – a reduction in the probability of importation to ‘moderate’ with an increase in the consequences to ‘moderate’, resulting in an unrestricted risk estimate of ‘very low’ which still achieves Australia’s ALOP
- for apple brown rot – sourcing apples from export orchards free of the disease, that is to establish pest free places of production (orchard freedom), has been recommended as a suitable measure to reduce the risk associated with latent infection
- minor changes to the rating for probability of importation, distribution, establishment, spread, or consequences for a number of other pests but resulting in no change to the unrestricted risk estimate
- for apple scab – previously identified as a regional quarantine pest for Western Australia, this pest is now recognised as present in Western Australia and the state legislation has been amended to revoke restrictions on hosts imported. Therefore, apple scab has been removed from the IRA as a regional quarantine pest.

This provisional final import risk analysis report is open to appeal. Stakeholders who believe there was a significant deviation from the import risk analysis process set out in the *Import Risk Analysis Handbook 2007 (update 2009)* that adversely affected their interests may appeal to the Import Risk Analysis Appeals Panel (IRAAP). The IRAAP has advised that written appeals must be received by 2 May 2010.

The appeals process is independent of Biosecurity Australia. The IRAAP will consider any appeal and report its findings to the appellant(s) and Australia’s Director of Animal and Plant Quarantine within 45 days of the closing date for appeals. At the conclusion of the appeal process, and after any issues arising from the appeal process have been addressed, the Chief Executive of Biosecurity Australia will provide a final report recommending a quarantine policy to the Director of Animal and Plant Quarantine for determination.

1. Introduction

1.1 Australia's biosecurity policy framework

Australia's biosecurity policies aim to protect Australia against the risks that may arise from exotic pests¹ entering, establishing and spreading in Australia, thereby threatening Australia's unique flora and fauna, as well as those agricultural industries that are relatively free from serious pests.

The import risk analysis (IRA) process is an important part of Australia's biosecurity policies. It enables the Australian government to formally consider the risks that could be associated with proposals to import new products into Australia. If the risks are found to exceed Australia's appropriate level of protection (ALOP), risk management measures are proposed to reduce the risks to an acceptable level. If it is not possible to reduce the risks to an acceptable level, then no trade will be allowed.

Successive Australian governments have maintained a conservative, but not a zero-risk, approach to the management of quarantine risks. This approach is expressed in terms of Australia's ALOP, which reflects community expectations through government policy and is currently described as providing a high level of protection aimed at reducing risk to a very low level, but not to zero.

Australia's IRAs are undertaken by Biosecurity Australia using teams of technical and scientific experts in relevant fields, and involving consultation with stakeholders at various stages during the process. Biosecurity Australia provides recommendations for animal and plant quarantine policy to Australia's Director of Animal and Plant Quarantine (the Secretary of the Australian Department of Agriculture, Fisheries and Forestry). The director or delegate is responsible for determining whether or not an importation can be permitted under the *Quarantine Act 1908*, and if so, under what conditions. The Australian Quarantine and Inspection Service (AQIS) is responsible for implementing appropriate risk management measures.

More information about Australia's biosecurity framework is provided in Appendix C of this report and in the *Import Risk Analysis Handbook 2007 (update 2009)* located on the Biosecurity Australia website www.biosecurityaustralia.gov.au.

1.2 This import risk analysis

1.2.1 Background

The State Administration for Entry–Exit Inspection and Quarantine of the People's Republic of China (CIQSA), now known as the General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (AQSIQ), requested market access to Australia for fresh apple fruit (*Malus domestica* Borkh.) in 2001.

Initially, access was sought for production areas in the provinces of Shaanxi (CIQSA 2001a) and Shandong (CIQSA 2001c). In 2004, AQSIQ requested that the production areas be

¹ A pest is any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products (FAO 2009).

extended to cover the provinces of Hebei and Laioning, and then in 2005, all commercial production areas of China (AQSIQ 2005).

1.2.2 Scope

The scope of this IRA is to consider quarantine risks associated with the importation of commercially produced individual fresh mature apple fruit, free of trash, from China into Australia as described in Section 3. This IRA pertains to all commercial apple producing provinces, and all commercially produced apple cultivars, in China.

Previous risk analyses for the importation of pears from China have been taken into account in this IRA in Sections 4 and 5.

1.2.3 Existing policy

International policy

Import policy exists for Fuji apples from Japan (AQIS 1998a). An IRA on apples from New Zealand has been completed (Biosecurity Australia 2006a). No apples have been imported into Australia under these policies.

Import policies also exist for Korean pears from South Korea (AQIS 1999a), ya pears and Asian pears from China's provinces of Hebei, Shandong and Shaanxi (AQIS 1998b) and fragrant pears from Xinjiang Uygur Autonomous Region (Biosecurity Australia 2005b).

Trade in ya pears from Hebei commenced in 1999 and from Shandong in 2000. Asian pears have been imported from Shandong since 2003, Asian pears from Hebei and fragrant pears from Xinjiang since 2005, and Asian pears from Shaanxi since 2009. Volumes of pears imported from China were 4172 tonnes in 2005, 3267 tonnes in 2006 and 3686 tonnes in 2007 (ABS 2008).

Apple juice, dried apples and apple pulp are imported from China. Imports of apple juice concentrate from China was 26 million litres in 2005, 23 million litres in 2006 and 26.6 million litres in 2007 (ABS 2008). From 2005 to 2007, the volumes of dried apple imports to Australia from China ranged from 375 to 654 tonnes per year (ABS 2008). Apple pulp is also imported from China for inclusion in processed food products.

The nature of import requirements for these commodities can be accessed at the Australian Quarantine and Inspection Service (AQIS) Import Conditions database <http://www.aqis.gov.au/icon>.

Domestic arrangements

The Commonwealth Government is responsible for regulating the movement of plants and plant products in and out of Australia. However, the state and territory governments are responsible for plant health controls within Australia. Legislation relating to resource management or plant health may be used by state or territory government agencies to control interstate movement of plants or their products.

1.2.4 Australian fresh apple fruit production and consumption

Apples are produced commercially in six states of Australia. Australian Bureau of Statistics data indicate average annual production over three years, to the summer starting in 2006, was about 291 000 tonnes (ABS 2007). It is estimated that the annual production amounts to about 1.6 billion fruit. About 17% of the fruit is processed and a small amount is exported. The majority of the remainder, approximately 1.2 billion fruit, is consumed domestically as fresh fruit. Apples are produced in summer and autumn, and a large proportion of the crop is placed in cool storage and released gradually to the market.

1.2.5 Consultation

On 17 March 2008, Biosecurity Australia Advice (BAA) 2008/05 informed stakeholders of the formal commencement of an expanded IRA for apples from China.

As part of the process for an expanded IRA, an issues paper was released on 8 July 2008 (BAA 2008/21) for a 60-day stakeholder consultation period that closed on 5 September 2008. Written submissions received from 11 stakeholders were considered and material matters raised were incorporated into, or addressed in, the draft IRA report. The submissions received were placed on the public file and the Biosecurity Australia website.

The Expert Panel for this IRA was consulted on 19-20 August, 10-11 November, 11 December 2008 and 12 January 2009 to review the draft IRA and issues raised by stakeholders.

The draft IRA report was released on 21 January 2009 (BAA 2009/1) for comment and consultation with stakeholders, for a period of 60 days that concluded on 23 March 2009. Written submissions were received from 10 stakeholders and the nine non-confidential submissions were placed on the public file and the Biosecurity Australia website.

All 10 submissions have been considered and material matters raised have been included in the present report.

Biosecurity Australia consulted informally with various stakeholders during both the preparation and the revision of the draft IRA report - steps 4 and 6 outlined in the *Import Risk Analysis Handbook 2007 (update 2009)*.

The Expert Panel was consulted on 30 July 2009 and 7 September 2009 to review the draft IRA as revised by Biosecurity Australia after consideration of the stakeholders' comments.

The draft IRA report (revised) was submitted to the Eminent Scientists Group (ESG) on 21 September 2009 for review within 60 days. The ESG reported its findings on 13 November 2009. Biosecurity Australia advised stakeholders of the ESG review report on 4 December 2009 (BAA 2009/29). The ESG report is available on the Department of Agriculture, Fisheries and Forestry (DAFF) website (http://www.daff.gov.au/about/contactus/corp-policy/eminent_scientists_group).

The Expert Panel was consulted on 22 March 2010 to review the provisional final IRA report.

State and territory governments were consulted on the outcomes of the IRA on 23 March 2010.

1.2.6 Contaminating pests

In addition to the pests of apple fruit in China identified in this IRA, there are other organisms that may arrive with the fruit. These organisms could include pests of other crops or predators and parasitoids of other arthropods. Biosecurity Australia considers these organisms to be contaminating pests that could pose sanitary and phytosanitary risks. These risks are addressed by the procedures detailed in section 5.5.

1.2.7 Next steps

The regulated timeframe for an IRA ends when a provisional final IRA report is issued.

Stakeholders who believe there was a significant deviation from the IRA process set out in the *Import Risk Analysis Handbook 2007 (update 2009)* that adversely affected their interests may appeal to the Import Risk Analysis Appeals Panel (IRAAP). Appeals must be lodged within 30 days of the publication of the provisional final IRA report.

The appeals process is independent of Biosecurity Australia. It is a non-judicial review that is not regulated under the regulations.

Further details of the appeal process may be found at Annex 6 of the IRA Handbook.

At the conclusion of the appeal process and after any issues arising from the IRAAP process have been addressed, the Chief Executive of Biosecurity Australia will provide the final IRA report and a recommendation for a policy determination to the Director of Animal and Plant Quarantine.

The Director of Animal and Plant Quarantine will then make a determination. The determination provides a policy framework for decisions on whether or not to grant an import permit and any conditions that may be attached to a permit.

A policy determination represents the completion of the IRA process.

The Director of Animal and Plant Quarantine notifies AQIS and Biosecurity Australia of the policy determination. In turn, Biosecurity Australia notifies the proposer and registered stakeholders, and the Department of Agriculture, Fisheries and Forestry notifies the WTO Secretariat, of the determination. The determination will also be placed on the public file and on the Biosecurity Australia website.

2. Method for pest risk analysis

This section sets out the method used for the pest risk analysis (PRA) in this IRA report. Biosecurity Australia has conducted this PRA in accordance with the International Standards for Phytosanitary Measures (ISPMs), including ISPM 2: *Framework for Pest Risk Analysis* (FAO 2007) and ISPM 11: *Pest Risk Analysis for Quarantine Pests, including analysis of environmental risks and living modified organisms* (FAO 2004).

A PRA is ‘the process of evaluating biological or other scientific and economic evidence to determine whether a pest should be regulated and the strength of any phytosanitary measures to be taken against it’ (FAO 2009). A pest is ‘any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products’ (FAO 2009).

Quarantine risk consists of two major components: the probability of a pest entering, establishing and spreading in Australia from imports; and the consequences should this happen. These two components are combined to give an overall estimate of the risk.

Unrestricted risk is estimated taking into account the existing commercial production practices of the exporting country and that, on arrival in Australia, AQIS will verify that the consignment received is as described on the commercial documents and its integrity has been maintained.

Restricted risk is estimated with phytosanitary measure(s) applied. A phytosanitary measure is ‘any legislation, regulation or official procedure having the purpose to prevent the introduction and spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests’ (FAO 2009).

A glossary of the terms used is provided at the back of this IRA report.

The PRA was conducted in the following three consecutive stages.

2.1 Stage 1: Initiation

Initiation identifies the pest(s) and pathway(s) that are of quarantine concern and should be considered for risk analysis in relation to the identified PRA area.

The initiation point for this PRA was the receipt of a technical submission from the National Plant Protection Organisation (NPPO) for access to the Australian market for the commodity. This submission included information on the pests associated with the production of the commodity, including the plant part affected, and the existing commercial production practices for the commodity.

The pests associated with the crop and the exported commodity were tabulated from information provided by the NPPO of the exporting country and literature and database searches. This information is set out in Appendix A.

For this PRA, the ‘PRA area’ is defined as Australia for pests that are absent or of limited distribution and under official control. For areas with regional freedom from a pest, the ‘PRA area’ may be defined on the basis of a state or territory of Australia or may be defined as a region of Australia consisting of parts of a state or territory or several states or territories.

For pests that had been considered by Biosecurity Australia in other risk assessments and for which import policies already exist, a judgement was made on the likelihood of entry of pests on the commodity and whether existing policy is adequate to manage the risks associated with its import. Where appropriate, the previous policy has been adopted.

2.2 Stage 2: Pest risk assessment

A Pest Risk Assessment (for quarantine pests) is: ‘the evaluation of the probability of the introduction and spread of a pest and of the likelihood of associated potential economic consequences’ (FAO 2009).

In this PRA, pest risk assessment was divided into the following interrelated processes:

2.2.1 Pest categorisation

Pest categorisation identifies which of the pests identified in Stage 1 require a pest risk assessment. The categorisation process examines, for each pest, whether the criteria in the definition for a quarantine pest are satisfied. A ‘quarantine pest’ is a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled, as defined in ISPM 5: *Glossary of phytosanitary terms* (FAO 2009).

The pests identified in Stage 1 were categorised using the following criteria to identify the quarantine pests for the commodity being assessed:

- identity of the pest
- presence or absence in the PRA area
- regulatory status
- potential for establishment and spread in the PRA area
- potential for economic consequences (including environmental consequences) in the PRA area.

The results of pest categorisation are set out in Appendix A. The quarantine pests identified during pest categorisation were carried forward for pest risk assessment and are listed in Table 4.1.

2.2.2 Assessment of the probability of entry, establishment and spread

Details of how to assess the ‘probability of entry’, ‘probability of establishment’ and ‘probability of spread’ of a pest are given in ISPM 11 (FAO 2004). A summary of this process is given below, followed by a description of the qualitative method used in this IRA.

Probability of entry

The probability of entry describes the probability that a quarantine pest will enter Australia as a result of trade in a given commodity, be distributed in a viable state in the PRA area and subsequently be transferred to a suitable host. It is based on pathway scenarios depicting necessary steps in the sourcing of the commodity for export, its processing, transport and storage, its utilisation in Australia and the generation and disposal of waste. In particular, the ability of the pest to survive is considered for each of these various stages.

The probability of entry estimates for the quarantine pests for a commodity are based on the use of the existing commercial production, packaging and shipping practices of the exporting country. Details of the existing commercial production practices for the commodity are set out in Section 3. These practices are taken into consideration by Biosecurity Australia when estimating the probability of entry.

For the purpose of considering the probability of entry, Biosecurity Australia divides this step of this stage of the PRA into two components:

Probability of importation: the probability that a pest will arrive in Australia when a given commodity is imported; and

Probability of distribution: the probability that the pest will be distributed, as a result of the processing, sale or disposal of the commodity, in the PRA area and subsequently transfer to a susceptible part of a host.

Factors considered in the probability of importation include:

- Distribution and incidence of the pest in the source area
- Occurrence of the pest in a life-stage that would be associated with the commodity
- Volume and frequency of movement of the commodity along each pathway
- Seasonal timing of imports
- Pest management, cultural and commercial procedures applied at the place of origin
- Speed of transport and conditions of storage compared with the duration of the life cycle of the pest
- Vulnerability of the life-stages of the pest during transport or storage
- Incidence of the pest likely to be associated with a consignment
- Commercial procedures (e.g. refrigeration) applied to consignments during transport and storage in the country of origin, and during transport to Australia.

Factors considered in the probability of distribution include:

- Commercial procedures (e.g. refrigeration) applied to consignments during distribution in Australia
- Dispersal mechanisms of the pest, including vectors, to allow movement from the pathway to a suitable host
- Whether the imported commodity is to be sent to a few or many destination points in the PRA area
- Proximity of entry, transit and destination points to suitable hosts
- Time of year at which import takes place
- Intended use of the commodity (e.g. for planting, processing or consumption)
- Risks from by-products and waste.

Probability of establishment

Establishment is defined as the ‘perpetuation for the foreseeable future, of a pest within an area after entry’ (FAO 2009). In order to estimate the probability of establishment of a pest, reliable biological information (life cycle, host range, epidemiology, survival, etc.) is obtained from the areas where the pest currently occurs. The situation in the PRA area can then be compared with that in the areas where it currently occurs and expert judgement used to assess the probability of establishment.

Factors considered in the probability of establishment in the PRA area include:

- Availability of suitable hosts, alternative hosts and vectors
- Suitability of the environment
- Reproductive strategy and potential for adaptation
- Minimum population needed for establishment
- Cultural practices and control measures.

Probability of spread

Spread is defined as ‘the expansion of the geographical distribution of a pest within an area’(FAO 2009). The probability of spread considers the factors relevant to the movement of the pest, after establishment on a host plant or plants, to other susceptible host plants of the same or different species in other areas. In order to estimate the probability of spread of the pest, reliable biological information is obtained from areas where the pest currently occurs. The situation in the PRA area is then carefully compared with that in the areas where the pest currently occurs and expert judgement used to assess the probability of spread.

Factors considered in the probability of spread include:

- Suitability of the natural and/or managed environment for natural spread of the pest
- Presence of natural barriers
- The potential for movement with commodities, conveyances or by vectors
- Intended use of the commodity
- Potential vectors of the pest in the PRA area
- Potential natural enemies of the pest in the PRA area.

Assigning qualitative likelihoods for the probability of entry, establishment and spread

In its qualitative PRAs, Biosecurity Australia uses the term ‘likelihood’ for the descriptors it uses for its estimates of probability of entry, establishment and spread. Qualitative likelihoods are assigned to each step of entry, establishment and spread. Six descriptors are used: high; moderate; low; very low; extremely low; and negligible (Table 2.1). Descriptive definitions for these descriptors and their indicative probability ranges are given in Table 2.1. The indicative probability ranges are only provided to illustrate the boundaries of the descriptors. These indicative probability ranges are not used beyond this purpose in qualitative PRAs. The standardised likelihood descriptors and the associated indicative probability ranges provide guidance to the risk analyst and promote consistency between different risk analyses.

Table 2.1: Nomenclature for qualitative likelihoods

| Likelihood | Descriptive definition | Indicative probability (P) range |
|----------------------|--|----------------------------------|
| High | The event would be very likely to occur | $0.7 < P \leq 1$ |
| Moderate | The event would occur with an even probability | $0.3 < P \leq 0.7$ |
| Low | The event would be unlikely to occur | $0.05 < P \leq 0.3$ |
| Very low | The event would be very unlikely to occur | $0.001 < P \leq 0.05$ |
| Extremely low | The event would be extremely unlikely to occur | $0.000001 < P \leq 0.001$ |
| Negligible | The event would almost certainly not occur | $0 \leq P \leq 0.000001$ |

The likelihood of entry is determined by combining the likelihood that the pest will be imported into the PRA area and the likelihood that the pest will be distributed within the PRA area, using a matrix of rules (Table 2.2). This matrix is then used to combine the likelihood of entry and the likelihood of establishment, and the likelihood of entry and establishment is then combined with the likelihood of spread to determine the overall likelihood of entry, establishment and spread.

For example, if the probability of importation is assigned a likelihood of ‘low’ and the probability of distribution is assigned a likelihood of ‘moderate’, then they are combined to give a likelihood of ‘low’ for the probability of entry. The likelihood for the probability of entry is then combined with the likelihood assigned to the probability of establishment (e.g. ‘high’) to give a likelihood for the probability of entry and establishment of ‘low’. The likelihood for the probability of entry and establishment is then combined with the likelihood assigned to the probability of spread (e.g. ‘very low’) to give the overall likelihood for the probability of entry, establishment and spread of ‘very low.’

Table 2.2: Matrix of rules for combining qualitative likelihoods

| | High | Moderate | Low | Very low | Extremely low | Negligible |
|---------------|------|----------|----------|---------------|---------------|------------|
| High | High | Moderate | Low | Very low | Extremely low | Negligible |
| Moderate | | Low | Low | Very low | Extremely low | Negligible |
| Low | | | Very low | Very low | Extremely low | Negligible |
| Very low | | | | Extremely low | Extremely low | Negligible |
| Extremely low | | | | | Negligible | Negligible |
| Negligible | | | | | | Negligible |

Time and volume of trade

One factor affecting the likelihood of entry is the volume and duration of trade. If all other conditions remain the same, the overall likelihood of entry will increase as time passes and the overall volume of trade increases.

Biosecurity Australia normally considers the likelihood of entry on the basis of the estimated volume of one year's trade. This is a convenient value for the analysis that is relatively easy to estimate and allows for expert consideration of seasonal variations in pest presence, incidence and behaviour to be taken into account. The consideration of the likelihood of entry, establishment and spread and subsequent consequences takes into account events that might happen over a number of years even though only one year's volume of trade is being considered. This difference reflects biological and ecological facts, for example where a pest or disease may establish in the year of import but spread may take many years.

The use of a one year volume of trade has been taken into account when setting up the matrix that is used to estimate the risk and therefore any policy based on this analysis does not simply apply to one year of trade. Policy decisions that are based on Biosecurity Australia's method that uses the estimated volume of one year's trade are consistent with Australia's policy on appropriate level of protection and meet the Australian Government's requirement for ongoing quarantine protection. Of course, if there are substantial changes in the volume and nature of the trade in specific commodities then Biosecurity Australia has an obligation to review the risk analysis and, if necessary, provide updated policy advice.

It is difficult to estimate the volume of trade for a commodity in the absence of existing trade. For this IRA, the volume of trade has been estimated as up to 20% of the domestic fresh apple market.

2.2.3 Assessment of potential consequences

The objective of the consequence assessment is to provide a structured and transparent analysis of the likely consequences if the pests or disease agents were to enter, establish and spread in Australia. The assessment considers direct and indirect pest effects and their economic and environmental consequences. The requirements for assessing potential consequences are given in Article 5.3 of the SPS Agreement (WTO 1995), ISPM 5 (FAO 2009) and ISPM 11 (FAO 2004).

Direct pest effects are considered in the context of the effects on:

- Plant life or health
- Other aspects of the environment.

Indirect pest effects are considered in the context of the effects on:

- Eradication, control, etc.
- Domestic trade
- International trade
- Environment.

For each of these six criteria, the consequences were estimated over four geographic levels, defined as:

Local: an aggregate of households or enterprises (a rural community, a town or a local government area).

District: a geographically or geopolitically associated collection of aggregates (generally a recognised section of a state or territory, such as ‘Far North Queensland’).

Regional: a geographically or geopolitically associated collection of districts in a geographic area (generally a state or territory, although there may be exceptions with larger states such as Western Australia).

National: Australia wide (Australian mainland states and territories and Tasmania).

For each criterion, the magnitude of the potential consequence at each of these levels was described using four categories, defined as:

Indiscernible: Pest impact unlikely to be noticeable.

Minor significance: Expected to lead to a minor increase in mortality/morbidity of hosts or a minor decrease in production but not expected to threaten the economic viability of production. Expected to decrease the value of non-commercial criteria but not threaten the criterion’s intrinsic value. Effects would generally be reversible.

Significant: Expected to threaten the economic viability of production through a moderate increase in mortality/morbidity of hosts, or a moderate decrease in production. Expected to significantly diminish or threaten the intrinsic value of non-commercial criteria. Effects may not be reversible.

Major significance: Expected to threaten the economic viability through a large increase in mortality/morbidity of hosts, or a large decrease in production. Expected to severely or irreversibly damage the intrinsic ‘value’ of non-commercial criteria.

The estimates of the magnitude of the potential consequences over the four geographic levels were translated into a qualitative impact score (A–G)² using Table 2.3³. For example, a consequence with a magnitude of ‘significant’ at the ‘district’ level will have a consequence impact score of D.

Table 2.3: Decision rules for determining the consequence impact score based on the magnitude of consequences at four geographic levels

| | | Geographic scale | | | |
|-----------|--------------------|------------------|----------|--------|--------|
| | | Local | District | Region | Nation |
| Magnitude | Indiscernible | A | A | A | A |
| | Minor significance | B | C | D | E |
| | Significant | C | D | E | F |
| | Major significance | D | E | F | G |

² In earlier qualitative IRAs, the scale for the impact scores went from A to F and did not explicitly allow for the rating ‘indiscernible’ at all four levels. This combination might be applicable for some criteria. In this report, the impact scale of A–F has changed to become B–G and a new lowest category A (‘indiscernible’ at all four levels) was added. The rules for combining impacts in Table 2.4 were adjusted accordingly.

³ The decision rules for determining the consequence impact score are presented in a simpler form in Table 2.3 from earlier IRAs, to make the table easier to use. The outcome of the decision rules is the same as the previous table and makes no difference to the final impact score.

The overall consequence for each pest is achieved by combining the qualitative impact scores (A–G) for each direct and indirect consequence using a series of decision rules (Table 2.4). These rules are mutually exclusive, and are assessed in numerical order until one applies.

Table 2.4: Decision rules for determining the overall consequence rating for each pest

| Rule | The impact scores for consequences of direct and indirect criteria | Overall consequence rating |
|------|--|----------------------------|
| 1 | Any criterion has an impact of 'G'; or more than one criterion has an impact of 'F'; or a single criterion has an impact of 'F' and each remaining criterion an 'E'. | Extreme |
| 2 | A single criterion has an impact of 'F'; or all criteria have an impact of 'E'. | High |
| 3 | One or more criteria have an impact of 'E'; or all criteria have an impact of 'D'. | Moderate |
| 4 | One or more criteria have an impact of 'D'; or all criteria have an impact of 'C'. | Low |
| 5 | One or more criteria have an impact of 'C'; or all criteria have an impact of 'B'. | Very Low |
| 6 | One or more but not all criteria have an impact of 'B', and all remaining criteria have an impact of 'A'. | Negligible |

2.2.4 Estimation of the unrestricted risk

Once the above assessments are completed, the unrestricted risk can be determined for each pest or groups of pests. This is determined by using a risk estimation matrix (Table 2.5) to combine the estimates of the probability of entry, establishment and spread and the overall consequences of pest establishment and spread. Therefore, risk is the product of likelihood and consequence.

Table 2.5: Risk estimation matrix

| | | | | | | | |
|---|----------------------|-------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| Likelihood of pest entry, establishment and spread | High | Negligible risk | Very low risk | Low risk | Moderate risk | High risk | Extreme risk |
| | Moderate | Negligible risk | Very low risk | Low risk | Moderate risk | High risk | Extreme risk |
| | Low | Negligible risk | Negligible risk | Very low risk | Low risk | Moderate risk | High risk |
| | Very low | Negligible risk | Negligible risk | Negligible risk | Very low risk | Low risk | Moderate risk |
| | Extremely low | Negligible risk | Negligible risk | Negligible risk | Negligible risk | Very low risk | Low risk |
| | Negligible | Negligible risk | Negligible risk | Negligible risk | Negligible risk | Negligible risk | Very low risk |
| | | Negligible | Very low | Low | Moderate | High | Extreme |
| Consequences of pest entry, establishment and spread | | | | | | | |

When interpreting the risk estimation matrix, note the descriptors for each axis are similar (e.g. low, moderate, high) but the vertical axis refers to likelihood and the horizontal axis refers to consequences. Accordingly, a ‘low’ likelihood combined with ‘high’ consequences, is not the same as a ‘high’ likelihood combined with ‘low’ consequences – the matrix is not symmetrical. For example, the former combination would give an unrestricted risk rating of ‘moderate’, whereas, the latter would be rated as a ‘low’ unrestricted risk.

2.2.5 Australia’s appropriate level of protection (ALOP)

The SPS Agreement defines the concept of an ‘appropriate level of sanitary or phytosanitary protection (ALOP)’ as the level of protection deemed appropriate by the WTO Member establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory.

Like many other countries, Australia expresses its ALOP in qualitative terms. Australia’s ALOP, which reflects community expectations through government policy, is currently expressed as providing a high level of sanitary or phytosanitary protection aimed at reducing risk to a very low level, but not to zero. The band of cells in Table 2.5 marked ‘very low risk’ illustrates Australia’s ALOP.

2.3 Stage 3: Pest risk management

Pest risk management describes the process of identifying and implementing phytosanitary measures to manage risks to achieve Australia's ALOP, while ensuring that any negative effects on trade are minimised.

The conclusions from pest risk assessments are used to decide whether risk management is required and if so, the appropriate measures to be used. Where the unrestricted risk estimate exceeds Australia’s ALOP, risk management measures are required to reduce this risk to a

very low level. The guiding principle for risk management is to manage risk to achieve Australia's ALOP. The effectiveness of any proposed phytosanitary measure (or combination of measures) is evaluated, using the same approach as used to evaluate the unrestricted risk, to ensure it reduces the restricted risk for the relevant pest or pests to meet Australia's ALOP.

ISPM 11 (FAO 2004) provides details on the identification and selection of appropriate risk management options and notes that the choice of measures should be based on their effectiveness in reducing the probability of entry of the pest.

Examples given of measures commonly applied to traded commodities include:

- Options for consignments – e.g. inspection or testing for freedom from pests, prohibition of parts of the host, a pre-entry or post-entry quarantine system, specified conditions on preparation of the consignment, specified treatment of the consignment, restrictions on end-use, distribution and periods of entry of the commodity.
- Options preventing or reducing infestation in the crop – e.g. treatment of the crop, restriction on the composition of a consignment so it is composed of plants belonging to resistant or less susceptible species, harvesting of plants at a certain age or specified time of the year, production in a certification scheme.
- Options ensuring that the area, place or site of production or crop is free from the pest – e.g. pest-free area, pest-free place of production or pest-free production site.
- Options for other types of pathways – e.g. consider natural spread, measures for human travellers and their baggage, cleaning or disinfestation of contaminated machinery.
- Options within the importing country – e.g. surveillance and eradication programs.
- Prohibition of commodities – if no satisfactory measure can be found.

Risk management measures are identified for each quarantine pest where the risk exceeds Australia's ALOP. These are presented in the 'Pest Risk Management' section of this report.

3. China's commercial production practices for apples

3.1 Assumptions used to estimate unrestricted risk

Biosecurity Australia considered the following information on the existing standard commercial production practices provided by China and other sources (AQSIQ 2005) when estimating the unrestricted risk of pests likely to be associated with fresh apple fruit produced in China. Where a specific practice described in Section 3.3 is not taken into account to estimate the unrestricted risk, this has been identified and explained in Section 4.

The information was verified when officers from Biosecurity Australia travelled to northern China to observe the existing commercial production practices and processing procedures for fresh apple fruit in Shandong province in July 2006; Shaanxi, Shandong and Hebei provinces in September 2008; and Shanxi, Gansu and Liaoning provinces and the Beijing region in April 2009. These visits clarified Biosecurity Australia's understanding of the cultivation and harvesting methods, pest control and management and the packing procedures proposed to produce and export fresh apple fruit to Australia.

The fruit fly pest free areas in northern China were reviewed during visits by officers from Biosecurity Australia to Hebei in September 2007; Shandong and Xinjiang in December 2007; Shaanxi in September 2008; and Shanxi, Gansu and Liaoning provinces and the Beijing region in April 2009.

Comments by stakeholders relating to the status of fire blight are discussed in Appendix D. Biosecurity Australia has reviewed available information on fire blight and visited Hebei, Shandong and Shaanxi provinces in September 2008; and Shanxi, Gansu, Liaoning and Beijing in April 2009 to confirm the absence of fire blight in the field. Verification visits to other provinces will be conducted if China nominates those provinces for export of apples to Australia.

3.2 Climate in production areas

The main apple growing provinces and regions of China include Beijing, Gansu, Hebei, Henan, Liaoning, Ningxia, Shaanxi, Shandong and Shanxi (Figure 3.1), which were nominated by China in the market access request (AQSIQ 2005).

Climate data for these provinces and regions of northern China have been presented in Figure 3.2. The climate can be described as temperate, with hot, humid and wet summers and cold wet/snowy winters. The climate in Liaoning and Shandong is considerably colder than the rest of the apple growing provinces. The number of days of snow cover is highest in Liaoning followed by Shandong and Shanxi. Mean winter temperatures are lower in the apple growing regions of China than in the commercial apple growing areas of Australia. However, while specific temperatures and rainfall levels vary between the commercial apple production regions in the two countries, the yearly weather patterns are similar. The similarity in weather patterns suggests that the pests found in the main apple producing regions in northern China would not be prevented from establishing in Australia based on climatic conditions alone.

Figure 3.1: Map of China showing the main apple production regions nominated by China for export: Beijing, Gansu, Hebei, Henan, Liaoning, Ningxia, Shaanxi, Shandong and Shanxi⁴



3.3 Commercial production and export information

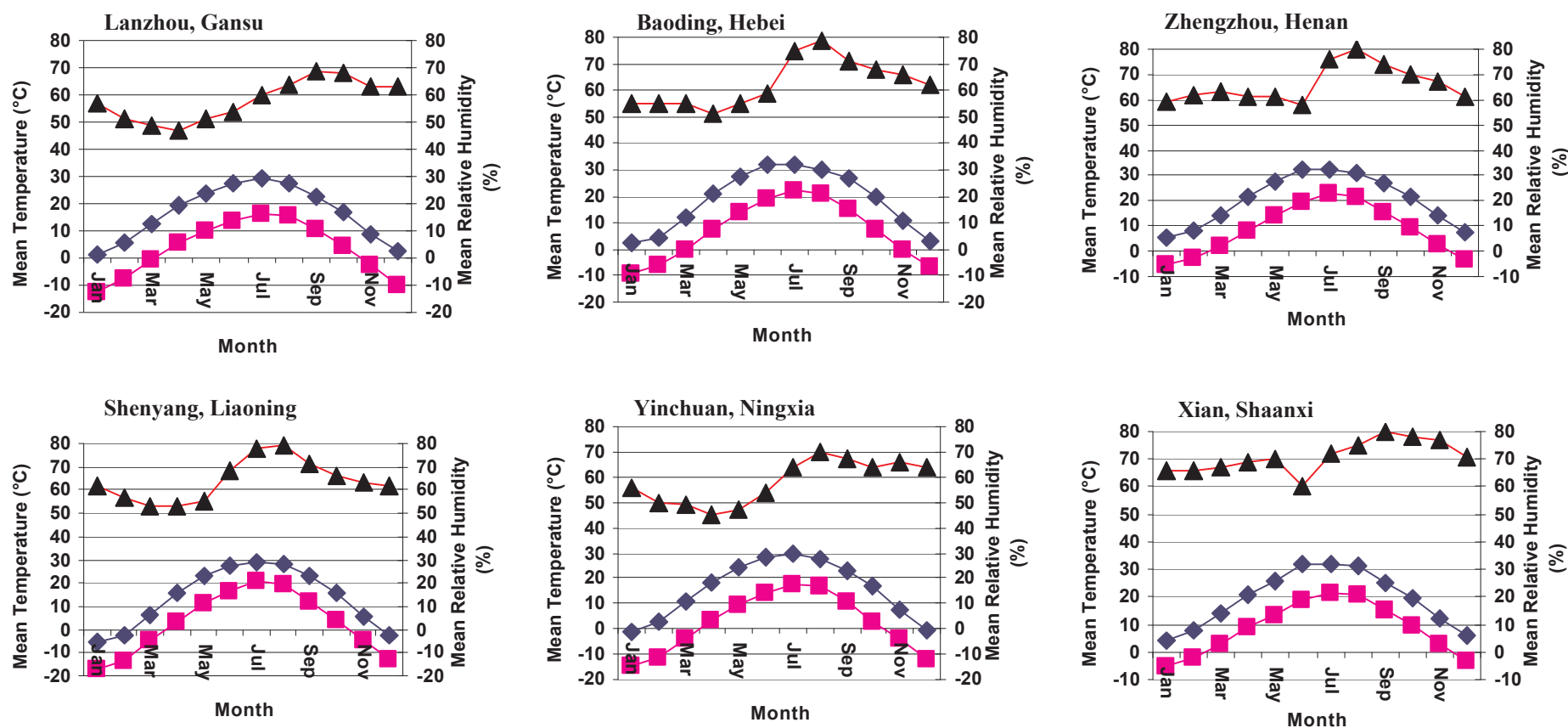
3.3.1 Production statistics

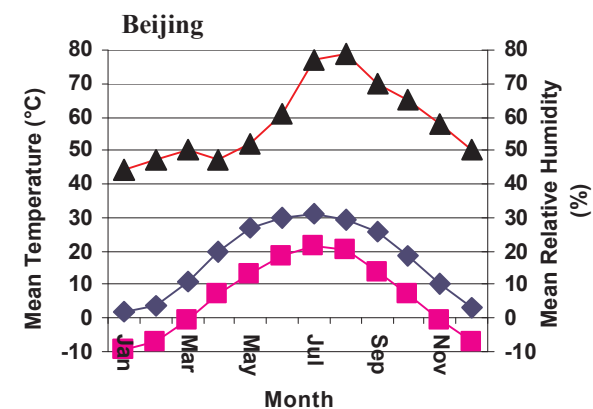
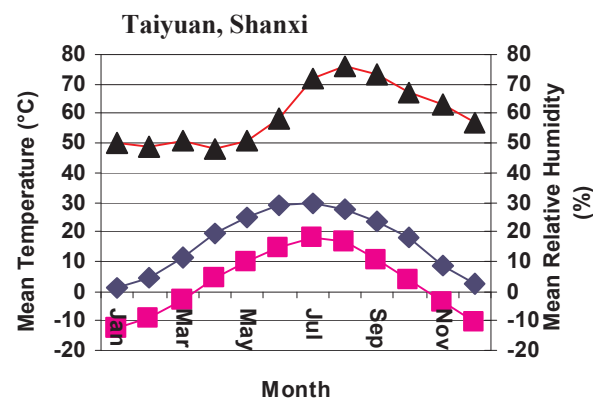
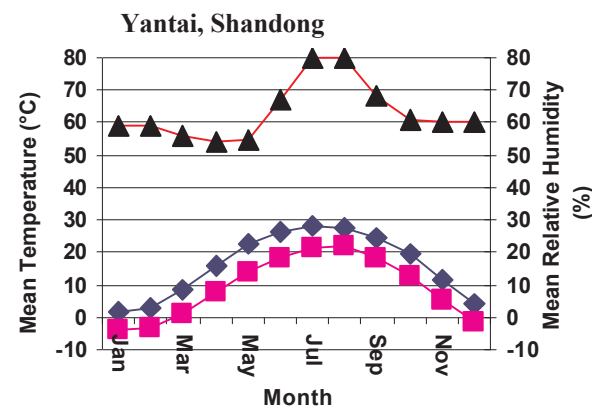
China is the world's largest producer and consumer of apples, accounting for approximately 50% of global apple production (Branson *et al.* 2004). In 2005, 25 006 500 metric tons (MT) of apples were produced from 2 200 625 ha, with an average yield of 11.36 MT/ha (FAOSTAT 2006). In 2006, China harvested a record 26 million MT of apples (Wu *et al.* 2007).

China's main deciduous fruit production areas are around the Bohai Gulf, the Northwest Loess Plateau, and the northern portion of the Yellow River Basin. Commercial apple production in Gansu, Hebei, Henan, Liaoning, Shaanxi, Shandong and Shanxi provinces accounted for 86% of the total area planted with apples and 90% of China's apple production in 2003 (Branson *et al.* 2004). Additional areas nominated by China include Beijing and Ningxia (AQSIQ 2005). The main apple production areas nominated by China for export are indicated in Figure 3.1. The provinces of Shaanxi and Shandong currently produce the majority of apples for export.

⁴ In the *Issues paper for the import risk analysis for fresh apple fruit from the People's Republic of China* (Biosecurity Australia 2008d), Jilin was incorrectly highlighted in this map but was not nominated in China's submission (AQSIQ 2005).

Figure 3.2: Mean maximum (—◆—) and minimum (—■—) temperatures and mean relative humidity (—▲—) in apple growing provinces and regions of Gansu, Hebei, Henan, Liaoning, Ningxia, Shaanxi, Shandong, Shanxi and Beijing in China, based on average monthly weather data from 1951 to 1988.





Meteorological data source: FCC (1997)

3.3.2 Cultivars

Cultivars grown in China include Red Fuji, Gala, New Red Star, Qinguan, Golden Delicious, Red General, Fuji, Red Delicious, Pink Lady and the Chinese varieties Guag and Orhin. Red Fuji made up approximately 61% of China's total apple harvest in 2003. Harvesting times for commonly cultivated varieties in China are: Gala in late August, New Red Star in late September, Qinguan in early October and Red Fuji in the middle of October (AQSIQ 2005).

3.3.3 Cultivation practices

Apple production in China is relatively labour intensive with pollination, bud thinning and pesticide and fertiliser applications commonly performed by hand (Zeitner 2006). Hand pollination and thinning and pollination by the hornfaced bee, *Osmia cornifrons* Radoszkowski, were observed by Biosecurity Australia during the visit in April 2009. Limited in-field mechanisation permits relatively high planting densities and use of sloping ground that would be unsuitable for mechanised production. Limited uptake of newer planting methods was observed by Biosecurity Australia, though demonstration orchards were being established.

Although in this IRA Biosecurity Australia will assess the risk of pests of apples on fruit that is exposed throughout all development stages, the bagging of fruit in China (Figure 3.3) is a routine practice for the production of export quality apple fruit and for some domestic production. Bagging of fruit provides protection from insects and diseases and mechanical damage. Bagging also reduces the need for agrochemical inputs and minimises chemical residues and is encouraged by local and provincial agricultural departments. Bags may be placed on young developing fruit, and are usually removed two to four weeks prior to harvest depending on the cultivar and weather and growing conditions (Zeitner 2006), to permit fruit colour development (AQSIQ 2008c). To ensure an even colour after removal of the bags each apple may be manually turned, excess leaves clipped away and reflective material placed under the trees along the rows.

Figure 3.3: Examples of double bags often used on apple fruit in China showing outer bag (left) and inner bag and apple (right)



Other commercial export apple orchard management practices include orchard hygiene, tree pruning and training, irrigation, fertiliser application and pest management. Most orchards are maintained with sweet clover or other green manure crops to retain moisture and improve soil quality (AQSIQ 2005). In denser plantings the orchard floor is kept relatively free of vegetation. In drier areas, such as in Gansu province, the orchard floor is covered by a layer of sand to maintain the moisture.

Orchards intending to export apples are required to be registered by China Entry-Exit Inspection and Quarantine Bureau (CIQ). The requirements for a registered orchard include a minimum size of 100 mu (about 6.7 hectares); freedom from contaminated sources of water in the surrounding area; use of the services of plant protection officers to monitor and control pests; and the ability to implement the approved quality management system and comply with the import conditions agreed between China and the importing country. The registration applications received from growers are assessed and accepted only after an initial and a final verification to confirm all the requirements are fulfilled. Training of plant protection officers and growers in identification and management of pests, including fruit flies, and relevant food safety issues forms an important component of the export program.

3.3.4 Pest control

The aim of the pest control program is prevention, with the emphasis on physical, biological and cultural methods; but these are supplemented with integrated pest management programs when required.

Good management of pests in the field is likely to be an important factor in reducing the number of pests associated with harvested fruit.

Biosecurity Australia visited a range of commercial apple production orchards with CIQ inspectors and plant scientists to ascertain the current pest and disease status and gain a better understanding of commercial production practices. Common pest concerns in the orchards visited included mites, mealybugs, moths, valsa canker, black spot and leaf brown spot.

While the specific practices in orchards vary according to local conditions, pest pressures and available equipment, there are common practices across the industry. These practices influence the presence of apple pests on the harvested and exported fruit.

China practices integrated pest and disease management (IPM and IDM) to manage a range of pests and diseases that affect growth and development of apple fruit in orchards. Effective but low-toxicity and low-residue pesticides are recommended. A range of effective insecticides and fungicides are used when required during the growing season to mitigate the impact of arthropod pests and disease-causing pathogens. Insect trapping devices and biological control agents are used for surveillance and monitoring and/or control. Insect trapping devices include sticky yellow cards, night light traps, fruit fly traps, tree trunk traps and pheromone traps. All these insect-trapping devices were observed during Biosecurity Australia's field verification visits.

The orchard management measures are undertaken throughout the year, beginning in December and finishing at apple harvest (August to November). They comprise eight stages and include cultural, mechanical and chemical methods (CIQSA 2001a).

1. December to early March – Orchard sanitation with removal of fallen leaves and twigs, winter pruning and management of dormant pests in the soil under the apple trees by cultivation.

2. Mid to late March – Prior to bud sprouting, fertiliser is applied to stimulate leaf growth and bud sprouting. Also, recommended pesticides are applied to prevent valsa canker, blossom blight and apple woolly aphid.
3. April – General orchard operations include fertiliser application, blossom thinning and artificial or insect pollination and removal of late shoots.
4. May – Prior to fruit bagging, orchard management practices include fruit thinning, post-blooming fertiliser application, irrigation and removal of late shoots. Also for the mitigation of arthropods (mites, aphids, Asiatic apple leaf miner, apple leaf-roller, fruit moth) and pathogens (apple rust, apple *Botryosphaeria* ring spot, *Glomerella* anthracnose, *Alternaria* leaf spot and fruit mouldy core), a range of recommended pesticides and fungicides may be applied according to the pest load.
5. June – Bordeaux mixture is commonly used before bagging and 10 days after bagging. Fruit bagging is completed by the end of June and the arthropods and pathogens (listed in May operations) are controlled if they re-appear with recommended pesticides.
6. July to August – General orchard operations include orchard draining, branch thinning and fertiliser application. After fruit-bagging, pest management measures continue for mites, cotton bollworm, peach fruit borer, leaf blister moth, *Alternaria* leaf spot, apple *Glomerella* anthracnose and leaf brown spot. Harvesting for early apple varieties commences in late August.
7. September to October – Fruit-bags are removed to expose the mature fruit to the sunlight so fruit colour develops. Pest management practices are continued for the pests identified earlier in the season, if there are re-occurrences. Withholding periods are observed to avoid potential chemical residues.
8. November – Harvesting finishes and orchard operations such as branch thinning, orchard hygiene and winter irrigation are undertaken to safeguard apple trees during the winter season.

Chemicals prohibited by China's Ministry of Agriculture are not permitted to be sold or used for control of pests on apples. Growers are allowed to purchase chemicals only from approved agents. Spraying in orchards is done under technical supervision.

Biosecurity Australia has visited seven of the nine provinces or areas nominated by China to export apples to Australia. These visits took place in 2006, 2007, 2008 and 2009 at different times of the year - blossoming and fruit set (April), fruit development (July) and fruit maturity and harvesting (October) - to observe, confirm and verify most of the practices mentioned above.

In 2000, China established a system called the National Fruit Flies Trapping Network (NFFTN) to monitor Oriental fruit fly (*Bactrocera dorsalis*) and other economically important fruit flies throughout China. No Oriental fruit fly has ever been detected in northern China where the commercial apple production is located since trapping commenced in 2000. Biosecurity Australia audited and verified the NFFTN in Hebei, Shandong, Shaanxi, Shanxi, Gansu, Lianiong, Xinjiang and Beijing, and found that the network has been well established and maintained and complies with ISPM 26 *Establishment of pest free areas for fruit flies (Tephritidae)* (FAO 2006) and *Trapping guidelines for Area-Wide Fruit Fly Programmes* (International Atomic Energy Agency 2003).

3.3.5 Post-harvest

All apples for export from China must be sourced from orchards audited and registered by CIQ in each province. Orchards must be at least 100 mu (1 ha = 15 mu) in order to be registered for export to any country.

Apples are picked carefully by hand and placed into rectangular plastic crates (about 70×40×40 cm) and transported to collection areas or to the packing house where an initial pre-sorting may take place.

In the packing house the apples are put into cold storage in plastic crates or in disinfected wooden bins that are often lined with foam to prevent bruising. Apples are stored in cold storage facilities under controlled temperature (usually 0-1°C) and high relative humidity conditions. Controlled atmosphere (CA) cold storage is used by many packing houses and storage facilities to extend the supply season. The CA cold storage is often used for long term storage prior to processing, using nitrogen gas to displace storage air to lower oxygen and carbon dioxide levels.

3.3.6 Packing house

Packing house registration – Packing houses also require registration by CIQ for export. The procedure is similar to orchard registration. Once the application is lodged, the approval of the application is subject to a verification process. During this process, consideration is given to verify general hygienic conditions of the packing house, proper functioning of the packing house machinery, availability of quality water sources to meet the specified quality requirements, cold or CA storage capacity, proper working of storage facilities, guaranteed supply of fruit from orchards, quality and management systems in place, adequacy of training and ability to meet the requirements of the agreed protocol between China and the importing country, inspection procedures for food safety aspects, including residue and pest auditing procedures.

A trace-back mechanism operates in all registered packing houses to trace both the unprocessed fruit and the packed fruit back to the specific registered orchard and/or grower.

Cleaning and/or washing – The packing houses observed by Biosecurity Australia in China followed good sanitary practices, with no evidence of any trash or contaminating material with the apples. The packing houses also followed quality assurance procedures and provided evidence of domestic and international accreditation, such as Hazard Analysis and Critical Control Points (HACCP), International Organisation for Standardisation, ISO 9001:2000, TESCO, GLOBAL GAP/EUREPGAP and British Retail Consortium (BRC) certification.

After initial cold storage, apple fruit is cleaned according to the requirements of the importing country, either through a process of washing and/or a process involving the cleaning of each individual apple with a pressurised air gun and other tools. In the washing process, the fruit is emptied into a water dump tank and then floated onto rollers. Various types of automated and semi-automated washing systems were observed; some were fitted with an overhead rinsing waterfall or pressurised spraying unit (Figure 3.4) and various rotating brushes. Apples are washed using clean potable water, usually with no additives. The water is changed regularly, at least daily. The washing and brushing assists the removal of pests and foreign material from the surface of the apple. Fruit is dried by passing through suction sponges and/or hot-air blowers.

Figure 3.4: Water cleaning facility, showing floating and rinsing of apples

For some export markets, each individual apple is manually cleaned with air pressure guns (Figure 3.5) and other tools to remove any debris or insects hidden in the calyx and stem end of the apple. This may be done instead of washing or in addition to the washing process. The individual cleaning is conducted by teams of workers over troughs or buckets of water to collect the material and prevent contamination. Either washing or pressurised air cleaning processes, or a combination of the two, were observed and used for export to countries requiring the highest level of orchard and packing house registration.

Figure 3.5: Use of pressurised air gun with a water trough (left) and examining and cleaning each fruit (right)

Sorting and grading – Apples may be manually pre-sorted to select fruit of export quality for the intended market. Any immature or damaged apple fruit is removed and loaded into plastic crates and labelled for domestic use, processing or disposal. This is followed in most packing houses by an electro-optical grading system that uses various optical methods to assess size and weight and/or colour. Fruit is automatically distributed to the appropriate packing lines or stations according to quality standards or market specifications (Figure 3.6).

Figure 3.6: Weight sizing and grading (left) and packing (right).

Packing – Graded apples are placed into soft, expandable foam net sleeves to prevent bruising. They are then placed on moulded foam separators or trays and packed in multiple layers into compressed cardboard cartons lined with plastic bags (Figure 3.6). Cartons are clearly labelled with the production unit registration code number, packing house registration code number, date and lot number for quality assurance and quarantine trace-back purposes.

Quality assurance inspection – Packed cartons of apples are randomly selected from the line on a continuous basis. The apples are checked on a designated inspection table by trained packing house staff for quality and the presence of quarantine pests identified for the importing country.

Storage – Packed and sealed cartons are palletised and put into the segregated post-processing cold storage rooms to bring the fruit temperature to 0-1 °C for short-term storage.

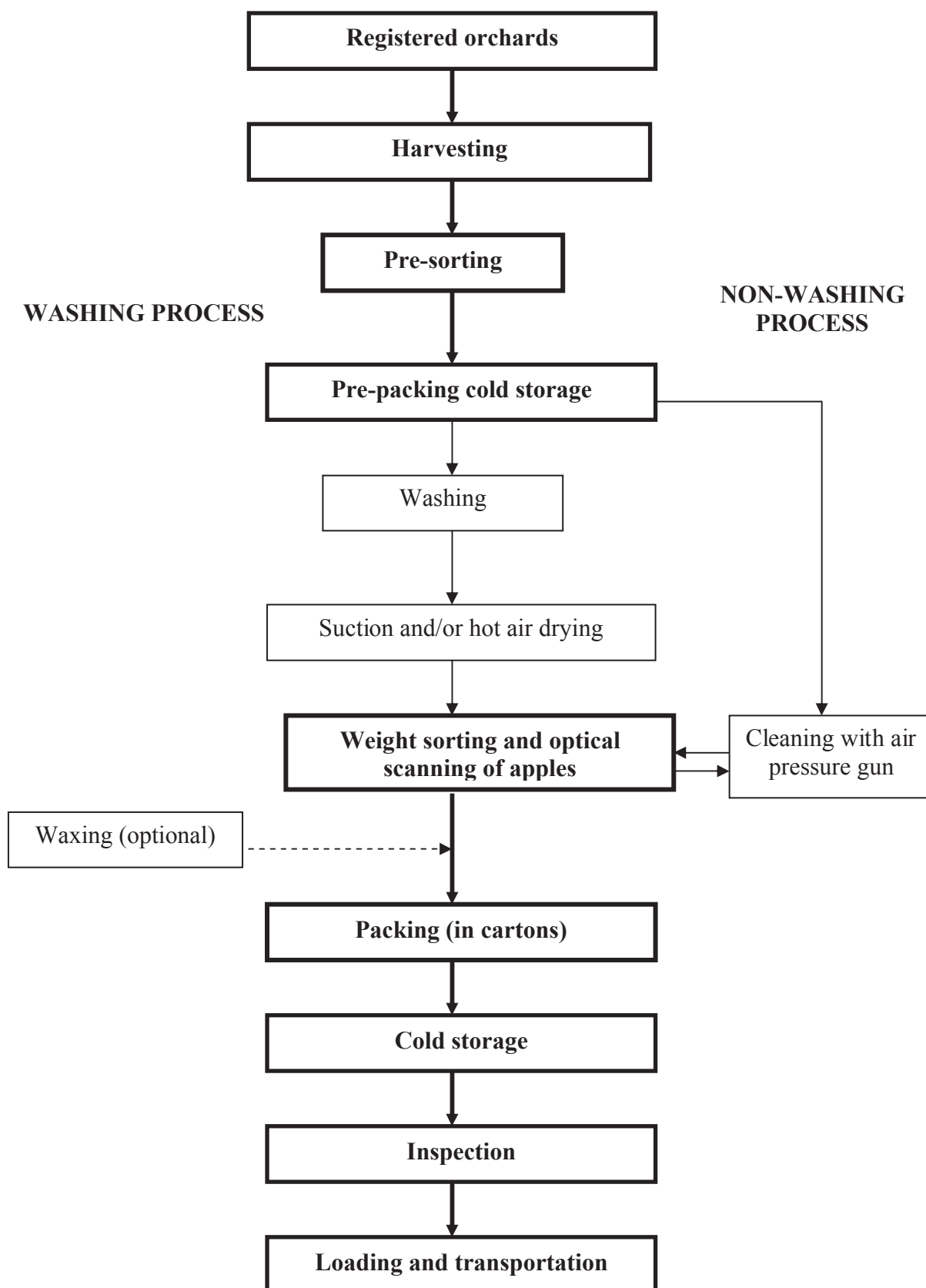
CIQ quarantine inspection – Packed apple fruit is inspected in designated equipped quarantine inspection facilities by CIQ inspectors to meet the phytosanitary requirements of the importing country.

Loading and transportation – Packed fruit is loaded from the cold storage facility into closed refrigerated trucks or containers and sealed. The loading docks have a secure docking facility to prevent insect entry and cross-contamination. Refrigerated containers are transported directly from the packing houses to shipping ports (AQSIQ 2005) such as Tianjin; Dalian in Liaoning; Qingdao and Yantai in Shandong and Shenzhen in Guangdong. The transportation of apples from China to Australia is estimated to take a minimum of 2–3 weeks by sea.

A schematic diagram summarising the processing, treatment and storage system for apples prior to export is shown in Figure 3.7.

While the unrestricted risk assessments undertaken in this IRA do not impose any mandatory measures during storage and transport, common commercial practices may impact on the survival of some pests.

Figure 3.7: Systematic processing, treatment and storage of apples in China prior to export (modified from AQSIQ (2005))



3.3.7 Export data

China exports only a small proportion of its total apple production. Over the two year period 2003/04 and 2004/05, only 3.5% of production was exported. Exports of fresh apple fruit increased from 181 000 MT in 1999 to 774 000 MT in 2004 (Zeitner 2006), 823 988 MT in 2005 and 804 318 MT in 2006 (Wu *et al.* 2007). In 2007, the volume of apple exports decreased because of tightened supplies and higher prices, coupled with more stringent control over exported fruit by AQSIQ, as predicted in Wu *et al.* (2007).

In 2004, China exported fresh apple fruit to 74 countries, with 10 countries accounting for 74% of all exports. Russia is the largest single export market with approximately 113 000 MT of apples imported from China during 2004, followed by Vietnam with 95 000 MT (Zeitner 2006). Other major export markets include Canada, Indonesia, Malaysia, the Philippines, Singapore and Thailand. More recent markets include Argentina, Chile, Peru and Mexico (AQSIQ 2005) and South Africa. Apples are also exported to many countries in the European Union.

3.3.8 Export season

Apple harvesting in apple growing provinces in China commences in late August and continues till early winter (late November) depending upon the cultivar and regional conditions. The Chinese apple export season commences primarily from late September onwards depending on the cultivar and continues from cold storage to the following September (AQSIQ 2005). Although some apples would be processed directly at harvest and exported, the majority of apples are kept in cold storage and may be processed for export up to 12 months after harvest in some years.

4. Pest risk assessments for quarantine pests

Pest risk assessments are presented in this section for the pests associated with apple fruit that were found to be quarantine pests for Australia in the categorisation process (Appendix A). Pest risk assessment was done to determine whether the risk posed by a pest exceeds Australia's ALOP and thus whether phytosanitary measures are required to manage the risk.

Pest categorisation identified 32 species as quarantine pests associated with fresh apple fruit from China; 25 species for the whole of Australia and six species of regional concern for Western Australia only (Table 4.1). Full details of pest categorisation are given in Appendix A.

Pest risk assessments already exist for some of the organisms considered here as they have been assessed previously by Biosecurity Australia.

There are three types of existing assessments for pests considered in this IRA report.

- The first type is where there is no change to the risk ratings from previous assessments (for example, European canker).
- The second is where there is a change to the likelihood of entry (importation and/or distribution) from previous assessments due to differences in the commodity and/or country assessed (for example, Oriental fruit fly, citrophilus mealybug and codling moth).
- The third is where the assessments were carried out before the introduction of Biosecurity Australia's current risk assessment method (for example, peach fruit moth, Japanese apple rust and apple scar skin). In this case, the pest is re-assessed according to the current method.

These three types of assessments are reflected in the introduction and layout of the risk assessments that follow. To highlight the pests for which previous assessments have led to the establishment of existing policy, the superscript 'EP' has been used.

Some organisms identified in this assessment have been recorded in some regions of Australia, and due to interstate quarantine regulations are considered pests of regional concern. These organisms are identified with a superscript, such as 'WA', for the state for which the regional pest status is considered.

The unrestricted risk estimate (URE) for each quarantine pest is based on the assumption that apple fruit is produced for export without fruit bagging. Biosecurity Australia considers there may be situations either currently or in the future where the practice of bagging may not be consistent, feasible or commercially viable. This approach is consistent with that taken on previous and current IRAs on apples and pears for other countries where fruit bagging is used. The URE is also based on the assumptions that washing and pressurised air blasting of apple fruit are not used in all packing houses across the apple production areas in China. This approach also ensures consistency in the assessment of similar pests on apples between IRAs. AQSIQ has confirmed that apples would be packed in cartons in China for export to Australia and not exported in bulk for packing in Australia, thus the URE is based on this assumption. In the event of China seeking to undertake bulk exports, China would need to notify Biosecurity Australia and Biosecurity Australia would reconsider the risk assessments.

Table 4.1 Quarantine pests for apple fruit from China

| Pest | Common name |
|--|---|
| Spider mites [Acarina: Tetranychidae] | |
| <i>Amphitettranychus viennensis</i> (Zacher, 1920) | Hawthorn spider mite ^{EP} |
| Flat mites [Acarina: Tenuipalpidae] | |
| <i>Cenopalpus pulcher</i> (Canestrini & Fanzago, 1876) | Flat scarlet mite |
| Weevils [Coleoptera: Rhynchitidae] | |
| <i>Rhynchites auratus</i> (Scopoli, 1763) | Apricot weevil |
| <i>Rhynchites heros</i> Roelofs, 1874 | Japanese pear weevil ^{EP} |
| Fruit flies [Diptera: Tephritidae] | |
| <i>Bactrocera dorsalis</i> (Hendel, 1912) | Oriental fruit fly ^{EP} |
| Armoured scales [Hemiptera: Diaspididae] | |
| <i>Diaspidiotus ostreaeformis</i> (Curtis, 1843) | Oystershell scale ^{WA, EP} |
| <i>Lopholeucaspis japonica</i> (Cockerell, 1897) | Pear white scale ^{EP} |
| <i>Parlatoria oleae</i> (Colvée, 1880) | Olive scale ^{WA} |
| <i>Parlatoria yanyuanensis</i> Tang, 1984 | Yanyuanen scale |
| Mealybugs [Hemiptera: Pseudococcidae] | |
| <i>Phenacoccus aceris</i> (Signoret, 1875) | Apple mealybug ^{EP} |
| <i>Pseudococcus calceolariae</i> (Maskell, 1879) | Citrophilus mealybug ^{WA, EP} |
| <i>Pseudococcus comstocki</i> (Kuwana, 1902) | Comstock's mealybug ^{EP} |
| Moths [Lepidoptera] | |
| <i>Adoxophyes orana</i> (Fisher von Roeslerstamm, 1834) | Summer fruit tortrix moth ^{EP} |
| <i>Argyresthia assimilis</i> Moriuti, 1977 | Apple fruit moth |
| <i>Carposina sasakii</i> Matsumura, 1900 | Peach fruit moth ^{EP} |
| <i>Cydia pomonella</i> Linnaeus, 1758 | Codling moth ^{WA, EP} |
| <i>Euzophera pyriella</i> Yang, 1994 | Pyralid moth ^{EP} |
| <i>Grapholita inopinata</i> (Heinrich, 1928) | Manchurian fruit moth ^{EP} |
| <i>Grapholita molesta</i> (Busck, 1916) | Oriental fruit moth ^{WA, EP} |
| <i>Spilonota albicana</i> (Motschulsky, 1866) | White fruit moth ^{EP} |
| Fungi | |
| <i>Cryptosporiopsis curvispora</i> (Peck) Gremmen | Bull's eye rot ^{EP} |
| <i>Diplocarpon mali</i> Y. Harada & Sawamura | Marssonina blotch ^{EP} |
| <i>Gymnosporangium yamadae</i> Miyade ex G. Yamada | Japanese apple rust ^{EP} |
| <i>Monilinia fructigena</i> Honey | Apple brown rot ^{EP} |
| <i>Mucor mucedo</i> Fresen. | Mucor rot |
| <i>Mucor racemosus</i> Fresen. | Mucor rot ^{WA} |
| <i>Neonectria ditissima</i> (Tul. & C. Tul.) Samuels & Rossman | European canker ^{EP} |
| <i>Phyllosticta arbutifolia</i> Ellis & G. Martin | Apple blotch ^{EP} |

| Pest | Common name |
|--|--|
| Fungi associated with sooty blotch and flyspeck disease complex | Sooty blotch and flyspeck disease complex |
| <i>Truncatella hartigii</i> (Tubef) Steyaert | Truncate leaf spot |
| Viroids | |
| <i>Apple scar skin viroid</i> | Apple scar skin and apple dapple ^{EP} |
| Virus | |
| Tobacco necrosis viruses | Tobacco necrosis virus |
| WA: Quarantine pest for the state of Western Australia EP: Species has been assessed previously and for which import policy already exists. | |

4.1 Hawthorn spider mite - *Amphitetranychus viennensis*

4.1.1 Introduction

Amphitetranychus viennensis (hawthorn spider mite) belongs to the mite family Tetranychidae, which consists of small, eight-legged arthropods, mostly living on the underside of leaves, where they spin protective silk webs (Cranshaw and Sclar 2008).

Amphitetranychus viennensis has five life stages: egg, larva, two nymph stages (protonymph, and deutonymph) and adult. Adult females are 0.54 mm long and red. Adult males are 0.43 mm long, initially light yellow-green and later becoming light green (Wang and Feng 2004). Only fertilised females overwinter (Jeppson *et al.* 1975). Eggs are laid on the under surface of the leaves. Nymphs and adults mainly feed on leaves, but can move onto fruit when mite populations are high. The mites damage plants with their stylets, penetrating into tissues and removing cell contents. *Amphitetranychus viennensis* produces from 3 to 10 generations a year in China, depending on the climatic conditions in the area of occurrence (Sun *et al.* 2004).

The risk scenario of concern for *A. viennensis* is the presence of nymphs and adults on apple fruit.

Amphitetranychus viennensis was included as *Tetranychus viennensis* in the existing import policy for pears from China (Biosecurity Australia 2005b; AQIS 1998b) and Fuji apples from Japan (AQIS 1998a). The assessment of *A. viennensis* presented here builds on these existing pest risk assessments.

4.1.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that *A. viennensis* will arrive in Australia with the importation of the commodity: **HIGH**.

- *Amphitetranychus viennensis* is widely spread throughout China including in Henan, Liaoning, Shaanxi and Shandong where China's main apple fruit production areas are located and apple is one of the main hosts (CAB International 2006; AQSIQ 2005; Sun *et al.* 2004).
- The species primarily feeds on the underside of leaves and is also found on fruit. When mite populations are high, the female mites may move into the calyx crevices and depressions on the stem-end of mature fruit (APHIS 2005).
- If the mites are present in the calyx or the stem-end of apple fruit, the grading process may not be effective in removing them from the fruit.
- The mated adults overwinter under bark or lichen (CAB International 2008) and it is likely that they can survive cold storage and transportation to Australia.

The mite's small size and the presence of nymphs and adults in the calyx or stem-end of the apple fruit support a risk rating for importation of 'high'.

Probability of distribution

The likelihood that *A. viennensis* will be distributed in Australia in a viable state as a result of the processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **MODERATE**.

- Apple fruit is intended for human consumption and viable mites may remain on the fruit during retail distribution. The calyx of infested fruit is unlikely to be consumed, and disposal of fruit waste may further aid distribution of viable mites. Disposal of infested waste fruit is likely to be via commercial or domestic rubbish systems.
- *Amphitetranychus viennensis* does not have wings and is not able to fly by itself into the environment.
- *Amphitetranychus viennensis* can enter through distribution of fruit, by crawling, dispersal on wind currents or by birds, insects, and other animals including human activities (CAB International 2008).
- *Amphitetranychus viennensis* has a wide host range. Apart from apples, it also attacks other crops such as cherry, pear, peach, plum, cotton, hawthorn, almond and raspberry (Bolland *et al.* 1998). These hosts are widely available in commercial orchards and household gardens in Australia.

The wide host range of the mite, moderated by its limited mobility, supports a risk rating for distribution of 'moderate'.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The likelihood that *A. viennensis* will enter Australia as a result of trade in the commodity and be distributed in a viable state to a suitable host: **MODERATE**.

4.1.3 Probability of establishment

The likelihood that *A. viennensis* will establish in Australia based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **HIGH**.

- *Amphitetranychus viennensis* is polyphagous. Major hosts of this species include *Arachis hypogaea* (peanut), *Cydonia oblonga* (quince), *Ficus carica* (fig), *Fragaria* (strawberry), *Gossypium* (cotton), *Malus domestica* (apple), *Prunus avium* (sweet cherry), *Prunus domestica* (plum), *Prunus persica* (peach), *Pyrus* (pears), *Pyrus communis* (European pear), *Rubus idaeus* (raspberry) (CAB International 2008; Bolland *et al.* 1998). These species are found in Australia.
- *Amphitetranychus viennensis* is found in many parts of temperate Asia and Europe (Bolland *et al.* 1998). Temperate climate conditions are present throughout south-eastern and south-western parts of Australia and this mite could establish wherever suitable hosts occur.
- *Amphitetranychus viennensis* is highly adaptable to different food plants. It may take only two to three generations to adapt to a new food plant, whereas *Tetranychus urticae* has been shown to take 10 generations to adapt (Skorupska and Boczek 1985).

- Development of *A. viennensis* from egg to adult at 22 to 25 °C takes 12-14.5 days (Jeppson *et al.* 1975), although more rapid development, 9.1 and 8.6 days in female and male individuals, respectively, has also been observed.
- Laboratory studies indicated that the population of the mites could double in 12.2 days at 15 °C and in 2.6 days at 35 °C (Ji *et al.* 2005).
- The number of generations produced per year is estimated to be 3-6 in Liaoning, 7-9 in Shandong, and 7-10 in Shaanxi and Henan (Sun *et al.* 2004).
- Control measures for the two-spotted mite in orchards in Australia may have some impact on the probability of establishment of *A. viennensis*, but pesticide resistance may be an issue if this species was introduced into Australia as it has developed resistance to organophosphate pesticides (Cranham and Helle 1985).

The wide host range of the mite, its adaptability to a wide range of climatic conditions and its high reproductive rate support a risk rating for establishment of ‘high’.

4.1.4 Probability of spread

The likelihood that *A. viennensis* will spread, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pest:

MODERATE.

- *Amphitetranychus viennensis* occurs in many temperate parts of Asia and Europe (Bolland *et al.* 1998), indicating that there would be suitable environments available for its spread in temperate regions of Australia.
- Commercial fruit crops, such as apples, pears and stone fruit, are grown in six states of Australia. However, there are geographical barriers, including arid areas between Western Australia and the eastern part of Australia. It would be difficult for the mite to disperse from one area to another unaided, because *A. viennensis* lacks active long-range dispersal mechanisms.
- Host plants such as apples and stone fruit are also grown in home gardens, parks and along roads. They could aid the dispersal of the mite.
- Crawling is the main means of dispersal on a host plant, from leaf to leaf and leading to eventual spread over the whole tree (CAB International 2008).
- Aerial dispersal by wind over longer distances involves two different launching behaviours: spinning down from the foliage on a thread until the wind breaks the thread, or facing into the wind with the forelegs upright (CAB International 2008).
- Apples would be used mostly for human consumption and would be distributed around the country. Such human assisted distribution would aid the spread of the mite.
- Natural enemies such as spiders, ladybirds, predatory mites such as *Amblyseius cucumeris* and general predators in Australia may be able to attack *A. viennensis*, but their effectiveness in limiting spread is difficult to assess.

The ready availability of hosts and the ability of first instar nymphs to be carried by wind currents, mitigated by the restricted mobility of the mite, support a risk rating for spread of ‘moderate’.

4.1.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of ‘rules’ for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *A. viennensis* will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in Australia and subsequently spread within Australia: **LOW**.

4.1.6 Consequences

The consequences of the establishment of *A. viennensis* in Australia have been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are ‘E’, the overall consequences are estimated to be **MODERATE**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|---|---|
| DIRECT | |
| Plant life or health | <p>E – Significant at the regional level</p> <p><i>Amphitetranychus viennensis</i> is an important pest in apple, peach, pear, apricot, plum, hawthorn, and cherry in a number of countries in Europe and Asia. In China, it can reduce the yield of the fruit during that current year by more than 10% and in the subsequent year up to 70-80%, due to the impact on the formation of flower buds (Sun <i>et al.</i> 2004; Cai <i>et al.</i> 1992). The mite causes a reduction in fruit size and weight, but not in the number of fruit produced (Cai <i>et al.</i> 1992).</p> <p><i>Amphitetranychus viennensis</i> may cause particular damage in dry years. Photosynthetic activity is also sensitive to mite damage. Heavy infestations of <i>A. viennensis</i> may cause water loss, premature leaf drop, impaired fruit formation, and lower the resistance of the host to winter conditions (Li <i>et al.</i> 1998).</p> |
| Other aspects of the environment | <p>B – Minor significance at the local level</p> <p>There are no known direct consequences of this species on the natural or built environment, but its introduction into a new environment may lead to competition for resources with native species.</p> |
| INDIRECT | |
| Control, eradication, etc. | <p>D – Significant at the district level</p> <p>Indirect consequences of eradication or control as a result of the introduction of hawthorn spider mite may include: (i) an increase in the use of acaricides for control of the pest due to the difficulties involved in estimating optimum times for application; (ii) disruption to Integrated Pest Management (IPM) programs because of the need to increase the use of acaricides; (iii) the development of resistance to acaricides as a result of the use of numerous acaricides to control <i>A. viennensis</i> (see (CAB International 2008)) for details); (iv) increases in control measures and impacts on existing production practices; (v) increases in costs of production due to increases in the use of acaricides may alter the economic viability of some crops; (vi) increased costs for crop monitoring and consultant services to producers.</p> |

| | |
|----------------------------|--|
| Domestic trade | <p>D – Significant at the district level</p> <p>If <i>A. viennensis</i> becomes established in areas of Australia, it is likely to result in interstate trade restrictions on many commodities such as apples, pears and cherries, potential loss of markets and significant industry adjustment.</p> |
| International trade | <p>D – Significant at the district level</p> <p>The presence of <i>A. viennensis</i> in commercial production areas of a wide range of commodities (e.g. apples, pears and cherries) may limit access to overseas markets, such as the USA, where this pest is absent.</p> |
| Environment | <p>B – Minor significance at the local level</p> <p>Pesticide applications or other control activities would be required to control this pest on susceptible crops, which would have a minor impact on the environment.</p> |

4.1.7 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for hawthorn spider mite | |
|--|----------|
| Overall probability of entry, establishment and spread | Low |
| Consequences | Moderate |
| Unrestricted risk | Low |

As indicated, the unrestricted risk for hawthorn spider mite has been assessed as ‘low’, which exceeds Australia’s ALOP. Therefore, specific risk management measures are required for this pest.

4.2 Flat scarlet mite - *Cenopalpus pulcher*

4.2.1 Introduction

Cenopalpus pulcher (flat scarlet mite) belongs to the mite family Tenuipalpidae, which consists of eight-legged arthropods. They are small but obvious due to their intense scarlet colour (Jeppson *et al.* 1975).

Cenopalpus pulcher has five life stages: egg, larval, two nymph stages (protonymphal, and deutonymphal) and adult (Zaher *et al.* 1974). Adult females are about 0.32 mm long and 0.16 mm wide (Jeppson *et al.* 1975) and deposit eggs on the striations and natural indentations of leaves and fruits. The adult male is shorter and paler than the female and its abdomen is almost transparent and curves upward. Mating occurs in August and September, after which the males die and the females go into hibernation. *Cenopalpus pulcher* prefers the lower leaf surface and may cause stippling of injured tissue, leaf and fruit drop or twig die-back (Jeppson *et al.* 1975). These mites can also feed on fruit (Bajwa and Kogan 2003). Beside adults, the nymphal stage may overwinter (Elmosa 1971). *Cenopalpus pulcher* produces from one generation a year in Europe (Dosse 1953) to three generations a year in Iran and Iraq (Elmosa 1971; Sepasgosarian 1970).

The risk scenario of concern for *C. pulcher* is that the nymphs and adults can be found on the fruit and females can also deposit their eggs on the fruit (Bajwa and Kogan 2003).

4.2.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues, respectively.

Probability of importation

The likelihood that *C. pulcher* will arrive in Australia with the importation of the commodity: **HIGH.**

- *Cenopalpus pulcher* is present in several of China's major apple production areas, including Beijing, Hebei, Liaoning, Shangdong and Shaanxi (Wang 1981).
- Apple is a major host for *C. pulcher* throughout its natural range (CAB International 2008).
- Eggs can be found on fruit and nymphs and adults can feed on fruit (Bajwa and Kogan 2003).
- *Cenopalpus pulcher* overwinters on structures remaining on trees during winter, and is known to occur on fruit (Bajwa and Kogan 2003; Elmosa 1971). A large proportion of the population of this mite would be dormant or seeking overwintering sites by the start of apple harvesting in China (Wang 1981), so it is anticipated that mites will shelter in the stem end and calyx of harvested apple fruit.
- *Cenopalpus pulcher* is unlikely to be dislodged from fruit by harvesting and grading activities because of its small size.
- A large proportion of *C. pulcher* populations in China are already dormant when apples are harvested (Wang 1981). Accordingly, dormant mites present on apples are likely to

survive cold storage during transport to Australia, as they may survive temperatures as cold as -30°C in their native habitats (Jeppson *et al.* 1975).

The small size of the mite and the presence of eggs, nymphs and adults on apple fruit support a risk rating for importation of ‘high’.

Probability of distribution

The likelihood that *C. pulcher* will be distributed in Australia in a viable state as a result of the processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **MODERATE**.

- Apple fruit is sourced for human consumption and the mites may stay on the fruit during wholesale and retail distribution in Australia. Mites present on apples are likely to occupy sheltered positions, such as the stem attachment and the calyx.
- The cores of apple fruit include the stem attachment and calyx and are not normally consumed by humans and are disposed of as waste.
- Apple waste products disposed of as municipal waste and compost is unlikely to distribute *C. pulcher* into the environment.
- Apple waste disposed of as litter may be deposited into urban, peri-urban and agricultural situations, as well as areas of natural vegetation, throughout Australia.
- *Cenopalpus pulcher* cannot fly and is unlikely to move from fruit waste to a host by crawling because of its small size. However, *C. pulcher* may be able to access hosts in the environment via air currents (Pedgley 1982).
- Most of these environments are known to contain suitable hosts, including fruit crops (apple, apricot, pear, pomegranate, prune, quince and walnut) and amenity trees (sycamore and willow), which are commonly found in southern areas of Australia (Hnatiuk 1990).

The limited mobility of the flat scarlet mite, mitigated by the wide distribution of its hosts, supports a risk rating for distribution of ‘moderate’.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The likelihood that *C. pulcher* will enter Australia as a result of trade in the commodity and be distributed in a viable state to a suitable host: **MODERATE**.

4.2.3 Probability of establishment

The likelihood that *C. pulcher* will establish in Australia based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **HIGH**.

- In China, overwintering populations of *C. pulcher* are adult females, which produce successive generations the following spring (Wang 1981). Individual *C. pulcher* distributed in Australia via apples from China are likely to be gravid females capable of establishing a new generation from very few founders.
- *Cenopalpus pulcher* is capable of feeding on a range of fruit crops and amenity trees widely planted in southern areas of Australia. Host availability, especially in urban and rural areas, is high in southern areas of Australia (Hnatiuk 1990).

- *Cenopalpus pulcher* populations occur in a range of climatic zones, including arid tropical and subtropical in north Africa, arid subtropical and warm temperate in the Middle East, and from cold temperate to subarctic in the Middle East, north Asia and eastern Europe (Wang 1981). Within Australia, *C. pulcher* may be capable of occupying a range of habitats in subtropical and temperate areas throughout southern Australia where suitable hosts also grow, often as naturalised plants (Hnatiuk 1990).
- Developmental time for a single generation of *C. pulcher* (egg to mature adult) is 38.3 days at an average temperature of 25.5 °C, and 25.8 days at an average temperature of 29.2 °C. Pairing occurs soon after adult emergence and both sexes pair more than once (Zaher *et al.* 1974).
- The number of generations completed by *C. pulcher* varies according to climate. Populations in cold temperate Europe complete one generation annually (Jeppson *et al.* 1975), while as many as three may be completed in warm temperate to subtropical climates in Iran and Iraq (Jeppson *et al.* 1975; Elmosa 1971). Populations of *C. pulcher* introduced to Australia may be capable of breeding in most months of the year, especially in subtropical areas.
- The presence of *C. pulcher*, if introduced to Australia, may not be immediately identified, as its feeding damage is similar to that produced by other agricultural pests. This is especially true of populations establishing on feral fruit trees in regional areas. This may allow populations of *C. pulcher* to rapidly reach high numbers.
- Control measures for two-spotted mite and other *Tetranychus* spp. in orchards in Australia may have some impact on the establishment of *C. pulcher*, but these measures are not commonly used in home gardens and amenity plantings.

The availability of hosts, its adaptability to a wide range of climates and its high reproductive rate support a risk rating for establishment of 'high'.

4.2.4 Probability of spread

The likelihood that *C. pulcher* will spread, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pest: **MODERATE.**

- *Cenopalpus pulcher* occurs in many subtropical and temperate parts of Asia, Europe, North America and Africa (Jeppson *et al.* 1975; Elmosa 1971). This indicates that there would be suitable environments for its spread in temperate regions of Australia.
- Host plants are widely grown in six states of Australia. The distribution of hosts on the roadside and in home gardens, parks and orchards could assist the spread of this mite.
- Geographical areas such as arid regions between the western and eastern parts of Australia could be natural barriers for the spread of *C. pulcher*.
- Crawling is the common mode of movement of the mite on host plants and this limited mobility may limit its ability to spread.
- First instar nymphs of *Cenopalpus pulcher* may be able to access hosts in the environment via air currents (Pedgley 1982). However, there is no strong evidence that the mite has been transferred over long distances by unaided dispersal mechanisms (NAPPO 2008).
- The movement of vegetative propagative material, such as nursery stock or budwood, could be a means of dispersal (NAPPO 2008).

- Apples and other fruits for human consumption would be distributed around the country. Such human assisted distribution would lead to spread of the mite.
- Known natural enemies of *C. pulcher* are predatory mites that are listed by Bajwa and Kogan (2003). Of these, only *Typhlodromus pyri* is established in Australia (Halliday 2000), where it is a biological control agent. This relative lack of natural enemies may allow populations of *C. pulcher* to increase without regulation.

The wide distribution of hosts and the ability of first instar nymphs to be carried by wind currents, mitigated by the restricted mobility of the mite and the lack of evidence of unaided dispersal over long distances support a risk rating for spread of ‘moderate’.

4.2.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of ‘rules’ for combining qualitative likelihood shown in Table 2.2.

The likelihood that *C. pulcher* will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in the PRA area and subsequently spread within Australia: **LOW**.

4.2.6 Consequences

The consequences of the establishment of *C. pulcher* in Australia have been estimated according to the methods described in Table 2.3.

Based on the decision described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are ‘E’, the overall consequences are estimated to be **MODERATE**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|---|--|
| DIRECT | |
| Plant life or health | <p>E – Significant at the regional level</p> <p><i>Cenopalpus pulcher</i> feeds on many host plants, including apple, pear, quince, loquat, walnut, oriental sycamore, apricot, prune, pomegranate and willow (USDA-APHIS 2000b). It feeds on leaves, soft twigs and fruits (Bajwa and Kogan 2003; Bajwa <i>et al.</i> 2001). Although <i>C. pulcher</i> is an occasional pest of neglected apple, pear, prune, and walnut trees in England and Europe (Jeppson <i>et al.</i> 1975) and is unlikely to become economically damaging in northern North America (Mahr 2001), it seriously damages apple, pear and other fruit trees in China (Wang 1981), is a very dangerous pest of quince trees in Georgia (Arabuli and Tskitishvili 2008), is the most dominant and economically important mite on pear trees in Egypt (Osman and Mahmoud 2008), and was included among the six most injurious mite species associated with economic plants in Iran (Rahmani <i>et al.</i> 2008).</p> |
| Other aspects of the environment | <p>B – Minor significance at the local level</p> <p>There are no known direct consequences of this species on the natural or built environment, but its introduction into a new environment may lead to competition for resources with native species (Ma 2006).</p> |
| INDIRECT | |

| | |
|----------------------------------|--|
| Eradication, control etc. | <p>D – Significant at the district level</p> <p>Indirect effects of eradication or control as a result of the introduction of flat scarlet mite may include: (i) an increase in the use of acaricides for control of the pest due to the unclear critical time of application; (ii) disruption to integrated pest management; (iii) potential to develop resistance to acaricides as a result of the use of numerous acaricides to control <i>C. pulcher</i>; (iv) use of additional control measures and impacts on existing production practices; (v) increase in cost of production could alter the economic viability of some crops; (vi) additional cost of crop monitoring and consultative advice to producers</p> |
| Domestic trade | <p>D – Significant at the district level</p> <p>If <i>C. pulcher</i> is established in Australia it is likely to result in interstate trade restrictions on many commodities such as apple, pear, quince, loquat, apricot, plum and pomegranate, and potential loss of markets. This could require significant industry adjustment.</p> |
| International trade | <p>D – Significant at the district level</p> <p>The presence of <i>C. pulcher</i> in commercial production areas of a wide range of commodities (e.g. apple, pear, quince, loquat, apricot, plum and pomegranate) may limit access to overseas markets.</p> |
| Environment | <p>B – Minor significance at the local level</p> <p>Safer pesticide applications would be required to control this pest on susceptible crops, which would have minor impact on the environment.</p> |

4.2.7 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for flat scarlet mite | |
|--|-----------------|
| Overall probability of entry, establishment and spread | Low |
| Consequences | Moderate |
| Unrestricted risk | Low |

As indicated, the unrestricted risk for flat scarlet mite has been assessed as ‘low’, which exceeds Australia’s ALOP. Therefore, specific risk management measures are required for this pest.

4.3 Apricot weevil - *Rhynchites auratus*

4.3.1 Introduction

Rhynchites auratus (apricot weevil) belongs to the weevil family Rhynchitidae which can be distinguished from other beetles by its long proboscis, called a snout, and mouth parts modified to allow it to chew into flower heads.

Rhynchites auratus has four life stages: egg, larva, pupa and adult. Adults are 5-7 mm long, hairy and gold-brown or bright red. Damage by adult weevils is visible as large holes on the fruit surface. Females deposit their eggs within the fruit pulp, where the larvae develop (Booth *et al.* 1990). Larvae are short, wide and curved and remain inside the fruit until ready to pupate. Mature larvae leave the fruit and pupate in the soil. Both the larvae and adults can overwinter (Lazarevic 1955). *Rhynchites auratus* has one generation per year (Lazarevic 1955).

The risk scenario of concern for *R. auratus* is the presence of eggs and developing larvae within apple fruit.

4.3.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that *R. auratus* will arrive in Australia with the importation of the commodity: **VERY LOW**.

- *Rhynchites auratus* has been reported only from Xinjiang Uygur Autonomous Region in China (AQSIQ 2006a) and apple is listed as one of its hosts (Booth *et al.* 1990). There is no evidence of official control measures in place to prevent its spread to other provinces.
- Females of *R. auratus* oviposit deep within the fruit pulp, where the larvae develop (Booth *et al.* 1990). Schreiner (1914) reported that *R. auratus* had a particular attraction to “the China variety” of apple, where they deposited their eggs.
- AQSIQ (2008c) advised that *R. auratus* was listed as ‘not on pathway’ by the USDA in its pest risk analysis on Chinese apples.
- In Bulgaria, Tosheva-Tsverkova (1965) found that *R. auratus* larvae fed on the fruits of stone fruit for between 16-36 days, with most of the larvae feeding for 31-33 days before entering the soil to pupate or overwinter. The average period from the entry of the larvae into the soil to the emergence of the first adults ranged from 72-105 days, and adults emerged from August to November.
- After laying eggs in the fruit, female *Rhynchites* weevils often sever the stalk, causing much of the infested fruit to drop to the ground so that the larva can enter the soil for pupation (Hanson 1963). This reduces the chance of infested fruit being harvested. However, Podleckis (2003) reports that ‘*Rhynchites* sp. was intercepted once on Chinese pear [entering the USA]; presumably, these were larvae’ but it is not clear if the interception was on a commercial consignment or from fruit carried by passengers.

AQSIQ advised Biosecurity Australia that they are unaware of this incident, which suggests this interception is unlikely to have occurred on a commercial consignment.

- Adults have chewing mouthparts and cause feeding damage to plant tissue. Damage by adult *Rhynchites* weevils is visible as large holes on the fruit surface. Fruit damaged by adults can be recognised and removed during harvest, quality inspection and packing (Podleckis 2003).
- Adults of *R. auratus* are approximately 5-7 mm long and easily visible to the naked eye (Booth *et al.* 1990), and this would increase the chance that they would be noticed and removed during harvesting, quality sorting and packing.
- Larvae and adults of *R. auratus* can overwinter in cold climates (Lazarevic 1955). It is likely that they can survive cold storage and low-temperature transportation.

The indications that, after laying their eggs, the weevils often sever the stalk of the fruit causing much of the infested fruit to drop to the ground; that damaged fruit can be removed during harvest, quality inspection and packing; and that, although this species is only reported in Xinjiang, there is no evidence of official control measures in place to prevent its spread to other provinces, support a risk rating for importation of ‘very low’.

Probability of distribution

The likelihood that *R. auratus* will be distributed in Australia in a viable state as a result of processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **MODERATE**.

- It is expected that after arrival in Australia, apples will be distributed widely throughout the country for repacking and/or retail sale.
- Because the larvae reside within the fruit, infested apples are likely to travel unnoticed to their destination.
- *Rhynchites auratus* larvae and pupae can live in soil and even if they are not distributed to a host immediately, they could still survive and be moved to a suitable host subsequently. They can also pupate in the soil and emerge as adult weevils.
- Unaided movement of the larvae to nearby hosts or soil would be limited to crawling distance. If adults are present they would be able to fly to reach new hosts (Zherikhin and Gratshev 1995).
- Apples are intended for human consumption in Australia. It is expected that during commercial transport, storage and distribution to the end destination, some apples will be discarded as waste material. Individual consumers will dispose of small quantities of discarded apples in a variety of urban, rural and wild environments. This waste may be disposed of close to soil or a suitable host. The presence of waste infested with larvae may increase the chance of dispersal of this pest.
- Two or three larvae of *R. auratus ferganensis* Nevskii have been reported in one apricot fruit (Nevskii 1928) and it is feasible that this would be the case for *R. auratus* on apple fruit. This would increase the chance of sexual reproduction, as one infested fruit may contain larvae of both sexes.
- Fruit tree hosts of *R. auratus*, such as apple and stone fruit, are widely and sporadically distributed throughout Australia in domestic, commercial and wild environments that could occur near the commodity’s transport pathway and/or end destination.

Evidence that larvae may reside unnoticed within the fruit increasing the chance of dispersal, moderated by the need to complete their development and find a mate for sexual reproduction, supports a risk rating for distribution of ‘moderate’.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The likelihood that *R. auratus* will enter Australia as a result of trade in the commodity and be distributed in a viable state to a suitable host: **VERY LOW**.

4.3.3 Probability of establishment

The likelihood that *R. auratus* will establish, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **MODERATE**.

- Hosts of *R. auratus* are mostly fruit trees such as apple and stone fruit (Booth *et al.* 1990). These hosts are distributed throughout Australia, including in domestic, commercial and wild environments where the weevils could establish.
- *Rhynchites auratus* is currently distributed throughout Xinjiang in China and in Europe (Booth *et al.* 1990). Both of these regions span a range of climate types, many of which are similar to temperate areas throughout much of Australia that would be suitable for this species’ establishment.
- *Rhynchites auratus* has one generation per year (Lazarevic 1955).
- Existing control programs in Australia, such as broad spectrum pesticide application, may be effective in preventing *R. auratus* establishing on some hosts, but these are not routinely applied to all hosts or all host habitats, or may not be applied to the hosts in the wild and on road sides.

The ready availability of host plants and the adaptability of the pest over a range of temperate climates, mitigated by its slow reproductive rate of one generation per year support a risk rating for establishment of ‘moderate’.

4.3.4 Probability of spread

The likelihood that *R. auratus* will spread, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pests: **MODERATE**.

- Adults of *R. auratus* can fly, but other natural dispersal mechanisms are limited (e.g. they have no known natural vectors) (Zherikhin and Gratshev 1995).
- Natural barriers such as arid areas, climate differences and long distances, exist in Australia and may limit the spread of *R. auratus*.
- *Rhynchites auratus* pupates in the soil and pupae may be spread with the contaminated soil on products or machinery that has not been properly cleaned.
- If infested apples and other hosts from Australian orchards where *Rhynchites auratus* become established are transported and sold on the domestic market, this could increase opportunities for the species to spread to and establish in other areas in the same manner

as the initial introduction (e.g. disposal of infested apples intended for human consumption).

- An egg-eating parasite of *R. auratus* was reported in Turkestan (Troitzky 1913), but it is most likely not present in Australia.
- Effective control of *Rhynchites* species has been achieved in Greece with organophosphate compounds (Lykouressis *et al.* 2004), and in Siberia with endosulfan (Thiodan) and pirimiphos-methyl (Actellic) (Bashkatova *et al.* 1983). Although there is the intention to phase out the use of endosulfan, this pesticide is still registered for use in Australia and is sometimes used as part of integrated pest management programs for apples (APVMA 2005). Pirimiphos-methyl is used in Australia, but not on apples (NRA 1999).

Readily available commercial hosts and winged adults but otherwise limited natural dispersal mechanisms support a risk rating for spread of ‘moderate’.

4.3.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of ‘rules’ for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *R. auratus* will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **VERY LOW**.

4.3.6 Consequences

The consequences of the establishment of *R. auratus* in Australia have been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are ‘E’, the overall consequences are estimated to be **MODERATE**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|-----------------------------|--|
| DIRECT | |
| Plant life or health | <p>E – Significant at the regional level</p> <p>Adults and larvae of <i>R. auratus</i> attack fruit crops, requiring active management during the growing season. Adults feed on plants and fruit and oviposit in the fruit. Infestation can cause considerable fruit drop (Hanson 1963).</p> <p><i>Rhynchites auratus</i> can cause great damage to host plants. It is described from the USSR as one of the most injurious insect pests of fruit trees (Lozhaunikas and Yakovishena 1978; Kharin 1916). In Kazakhstan, <i>R. auratus</i> weevils present in large numbers damaged up to 60% of apples in some trees (Khairushev 1970). <i>Rhynchites auratus</i> was reported in 1914 to reduce yearly peach orchard outputs by</p> |

nearly 90% in Turkestan (Plotnikov 1914), and is known to infest up to 98% of cherry crops in Serbia (Lazarevic 1955) and 10-85% of cherry crops in Turkey (Ozbek *et al.* 1996).

Larval *Rhynchites* feeding has also been shown to encourage infestation of the fungus *Sclerotinia fructigena* (a synonym of *Monilinia fructigena*) (INRA 2006).

Other aspects of the environment

B – Minor significance at the local level

There are no known direct consequences of *R. auratus* for the natural or built environment, but its introduction into a new environment may lead to competition for resources with native species.

INDIRECT

Eradication, control etc.

C – Significant at the local level

Programs to suppress and control *R. auratus* by insecticide applications, should this species become established, would not add significantly to grower costs of crop production. Insecticides which would also control weevils are used to control existing insect pests in Australian apple orchards.

Domestic trade

D – Significant at the district level

The presence of *R. auratus* in commercial production areas may result in interstate trade restrictions on a range of commodities such as apples, pears and stone fruit. These restrictions may lead to a loss of markets.

International trade

D – Significant at the district level

The presence of *R. auratus* in the commercial production areas of a range of commodities (apples and stone fruit) may limit access to overseas markets where this pest is absent. These restrictions may lead to a loss of international markets.

Environment

B – Minor significance at the local level

Additional pesticide application and other measures to control *R. auratus* could have additional effects on the environment. It is noted that insecticides such as synthetic pyrethroids are already registered for and used in Australian orchards to control other weevil species.

4.3.7 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for apricot weevil | |
|--|-----------------|
| Overall probability of entry, establishment and spread | Very low |
| Consequences | Moderate |
| Unrestricted risk | Very low |

As indicated, the unrestricted risk for apricot weevil has been assessed as ‘very low’, which achieves Australia’s ALOP. Therefore, specific risk management measures are not required for this pest.

4.4 Japanese pear weevil - *Rhynchites heros*

4.4.1 Introduction

Rhynchites heros (Japanese pear weevil) belongs to the weevil family Rhynchitidae which can be distinguished from other beetles by its long proboscis, called a snout, and mouth parts modified to allow it to chew into flower heads.

Rhynchites heros is widely cited as *R. foveipennis*, a synonym, in Chinese literature. It is a common and destructive pest of fruit trees in Japan, Korea and China (USDA 1958a).

Rhynchites heros has four life stages: adult, egg, larva and pupa. Adults are 10 mm long and cause feeding damage to fruits and fruiting twigs (USDA 1958a). Females deposit one to three eggs in the feeding holes or cavities created by the adults on young fruit (Hanson 1963). Larvae develop in the fruit and then exit in order to pupate in the soil. Both larvae and adults can overwinter (USDA 1958a). The species has one generation per year (USDA 1958a).

The risk scenario of concern for *R. heros* is the presence of eggs and developing larvae within apple fruit.

Rhynchites heros was included in the IRAs on ya pear from China (AQIS 1998b) and Fuji apples from Japan (AQIS 1998a). It was assessed in the final extension of policy for Chinese pears (Biosecurity Australia 2005b). The assessment of *R. heros* presented here builds on these existing pest risk assessments.

4.4.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that *R. heros* will arrive in Australia with the importation of the commodity: **VERY LOW**.

- *Rhynchites heros* is a commonly occurring pest of apple fruit in China (USDA 1958a; Schreiner 1914).
- Females of *R. heros* deposit one to three eggs in the hole or cavity created by the adults on young fruit, starting in late May (Hanson 1963). Hanson (1963) also found that *R. heros* reproduces one generation a year, the larvae feed in fruit for 18 days, then leave the fruit to enter the ground and live as prepupae in a cocoon for 80 days, and then as pupae for 28 days. Most larvae would have left the fruit by the time of fruit harvesting starting in late August. Adults emerge and then hibernate in October and November, until the next April or May.
- AQSIQ (2008c) advised that *R. heros* was listed as ‘not on pathway’ by the USDA in their pest risk analysis on Chinese apples.
- After laying eggs in the fruit, adult females of *R. heros* often sever the stalk, causing much of the infested fruit to drop to the ground so that the larva can enter the soil for pupation (Hanson 1963). This reduces the chance of infested fruit being harvested. However, Podleckis (2003) reports that “*Rhynchites* sp. was intercepted once on Chinese pear [entering the USA]; presumably, these were larvae”, but it is not clear if the

interception was on a commercial consignment or from fruit carried by passengers. AQSIQ advised Biosecurity Australia that they are unaware of this incident, which suggests this interception is unlikely to have occurred on a commercial consignment.

- Adults have chewing mouthparts and cause feeding damage to plant tissue (Hanson 1963; USDA 1958a). Damage by adult *R. heros* is visible as large holes on the fruit surface. Damaged fruit can be recognised and removed during harvest, quality inspection and packing (Podleckis 2003).
- Adult *R. heros* weevils are 10 mm long (USDA 1958a) and are easily visible to the naked eye. This increases the chance that they would be noticed and removed during harvesting, quality sorting and packing.
- Larvae and adults of *R. heros* can overwinter in cold climates (Hanson 1963; USDA 1958a). It is likely that this species can survive cold storage and low-temperature transportation.

The indication that after laying their eggs the weevils often sever the stalk of the fruit causing much of the infested fruit to drop to the ground and that most larvae would have left the fruit by the time of harvesting support a risk rating for importation of ‘very low’.

Probability of distribution

The likelihood that *R. heros* will be distributed in Australia in a viable state as a result of processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **MODERATE**.

The probability of distribution for *R. heros* was assessed as ‘low’ in the final extension of policy for importation of pears from China (Biosecurity Australia 2005b). At that time, it was stated that adults of *R. heros* are flightless. However, species of *Rhynchites* actually have wings, including hind wings (Zherikhin and Gratshev 1995) and therefore would be able to fly (Oberprieler 2006). Therefore, the probability of distribution has been reconsidered and rated as ‘moderate’ in this analysis.

- It is expected that after arrival in Australia, apples will be distributed widely throughout the country for repacking and/or retail sale.
- Because *R. heros* larvae reside within the fruit, infested apples are likely to travel unnoticed to their destination.
- Because *R. heros* larvae and pupae can live in organic matter and soil, they can survive for periods without a host (Hanson 1963). Even if not distributed to a host immediately, they could still survive if subsequently moved to a suitable host. They can also pupate in the soil and emerge as adult weevils.
- Unaided movement of *R. heros* larvae to nearby hosts or soil would be limited to crawling distance. If adults are present, they would be able to fly to reach new hosts (Zherikhin and Gratshev 1995).
- Apples are intended for human consumption in Australia. Individual consumers will distribute small quantities of apples to a variety of urban, rural and wild environments, where they will be consumed or disposed of. Disposal may be close to soil or a suitable host. Infestation with *R. heros* larvae is likely to increase the chance of fruit being discarded.
- It is expected that during commercial transport, storage and distribution to the end destination in Australia, some apples will be discarded as waste material. As larvae of

R. heros can live in decaying tissue (Hanson 1963; USDA 1958a), they may persist and develop in waste. Commercial waste could be deposited near suitable hosts or soil.

- Because there could be more than one larvae of *R. heros* present in each infested fruit (USDA 1958a), this would increase the chance of sexual reproduction, as a single infested fruit may contain both males and females.
- Fruit trees and other hosts of *R. heros* are widely and sporadically distributed throughout Australia in domestic, commercial and wild environments that could occur near the commodity's transport pathway and/or end destination.

Evidence that larvae may reside unnoticed within the fruit increasing the chance of dispersal, but moderated by the need to complete development and find a mate for sexual reproduction, supports a risk rating for distribution of 'moderate'.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The likelihood that *R. heros* will enter Australia as a result of trade in the commodity and be distributed in a viable state to a suitable host: **VERY LOW**.

4.4.3 Probability of establishment

The likelihood that *R. heros* will establish, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **MODERATE**.

- Hosts of *R. heros* are fruit trees such as apple, pear, stone fruit, fig, quince and loquat (USDA 1958a). Hosts are distributed throughout Australia, including domestic, commercial and wild environments, where the weevils could establish.
- *Rhynchites heros* is currently distributed in China, Japan and Korea (USDA 1958a), regions that span a range of climate types. Many of these are similar to temperate areas throughout much of Australia that would be suitable for their establishment.
- *Rhynchites heros* has only one generation per year. The life cycle of *R. heros* from egg to adult lasts approximately 132 days, and adults live for approximately 320 days (Hanson 1963).
- Long-lived *R. heros* females spread egg-laying over an extended period (April to June). They are reported to each produce 35-50 eggs over approximately 50 days (Hanson 1963; USDA 1958a). Between one and three eggs are deposited in each fruit (Hanson 1963). It is possible that this staggering of egg-laying over 50 days could act as a buffer mechanism for survival during infrequent extreme environmental conditions (e.g. particularly hot or cold days), thus increasing the chance of establishment.
- *Rhynchites heros* larvae living within the fruit can survive for between 18 and 50 days (Hanson 1963), feeding on and developing within the fruit (USDA 1958a). This ensures protection from rapid changes in environmental conditions, as well as a constant food source.
- Existing control programs in Australia, such as broad spectrum pesticide application, may be effective for preventing establishment of *R. heros* on some hosts, but these are not routinely applied to all hosts or all host habitats, or may not be applied to the hosts in the wild and on road sides. Effective control of *Rhynchites* species has been achieved in Greece with organophosphate compounds (Lykouressis *et al.* 2004), and in Siberia with

endosulfan (Thiodan) and pirimiphos-methyl (Actellic) (Bashkatova *et al.* 1983). Although there is the intention to phase out the use of endosulfan, this pesticide is still registered for use in Australia and is sometimes used as part of integrated pest management programs for apples (APVMA 2005). Pirimiphos-methyl is used in Australia, but not on apples (NRA 1999).

The availability of host plants, the adaptability over a range of climatic types but with only one generation per year support a risk rating for establishment of ‘moderate’.

4.4.4 Probability of spread

The likelihood that *R. heros* will spread, based on comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pests:

MODERATE.

- Adults of *R. heros* are able to fly (Zherikhin and Gratshev 1995).
- Natural barriers such as arid areas and climate differences and long distances exist in Australia and may limit the spread of *R. heros*.
- *Rhynchites heros* pupate in the soil (Hanson 1963; USDA 1958a) and pupae may be spread on products or machinery that has not been properly cleaned.
- If infested apples from Australian orchards where *R. heros* become established are transported and sold on the domestic market, this could increase chances for the species to spread to and establish in other areas in the same manner as the initial introduction (e.g. disposal of infested apples intended for human consumption).
- The potential for natural enemies in Australia to reduce the spread of *R. heros* is unknown. Although several natural enemies of *R. heros* (Liu *et al.* 1991; Hanson 1963) have been identified within its current distribution, they do not occur in Australia.

Readily available commercial hosts and winged adults but limited natural dispersal mechanisms support a risk rating for spread of ‘moderate’.

4.4.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of ‘rules’ for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *R. heros* will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **VERY LOW**.

4.4.6 Consequences

The consequences of the establishment of *R. heros* in Australia have been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are ‘E’, the overall consequences are estimated to be **MODERATE**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|---|---|
| DIRECT | |
| Plant life or health | <p>E – Significant at the regional level</p> <p><i>Rhynchites heros</i> attacks many fruit crops and other plant species, can cause great damage and requires active management during the growing season. Adults feed on plants and fruit and oviposit in the fruit. Infestation can cause considerable fruit drop (Hanson 1963; USDA 1958a).</p> <p>It is a common pest in Japan, Korea and China where destruction of the fruit and fruiting twigs of host trees has been described as practically complete in severe infestations (USDA 1958a).</p> <p>Feeding by larval <i>Rhynchites</i> has also been shown to encourage infestations of the fungus <i>Sclerotinia fructigena</i> (a synonym of <i>Monilinia fructigena</i>) (INRA 2006).</p> |
| Other aspects of the environment | <p>B – Minor significance at the local level</p> <p>There are no known direct consequences of <i>R. heros</i> for the natural environment or built environment, but its introduction into a new environment may lead to competition for resources with native species.</p> |
| INDIRECT | |
| Eradication, control etc. | <p>C – Significant at the local level</p> <p>Programs to suppress and control <i>R. heros</i> by insecticide applications, should it become established, would not add significantly to grower costs of crop production. Insecticides which would also control weevils are used to control existing insect pests in Australian apple orchards.</p> |
| Domestic trade | <p>D – Significant at the district level</p> <p>The presence of <i>R. heros</i> in commercial production areas may result in interstate trade restrictions on a range of commodities such as apples, pears and summerfruit. These restrictions may lead to a loss of markets.</p> |
| International trade | <p>D – Significant at the district level</p> <p>The presence of <i>R. heros</i> in the commercial production areas of a range of commodities (apples, pears and stone fruit) may limit access to overseas markets where this pest is absent. These restrictions may lead to a loss of markets, which in turn would be likely to require industry adjustment.</p> |
| Environment | <p>B – Minor significance at local level</p> <p>Additional pesticide application and other measures to control <i>R. heros</i> could have additional effects on the environment. It is noted that insecticides such as synthetic pyrethroids are already registered for and used in Australian orchards to control other weevil species.</p> |

4.4.7 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for Japanese pear weevil | |
|--|-----------------|
| Overall probability of entry, establishment and spread | Very low |
| Consequences | Moderate |
| Unrestricted risk | Very low |

As indicated, the unrestricted risk for Japanese pear weevil has been assessed as ‘very low’, which achieves Australia’s ALOP. Therefore, specific risk management measures are not required for this pest.

4.5 Oriental fruit fly - *Bactrocera dorsalis*

4.5.1 Introduction

Bactrocera dorsalis (Oriental fruit fly) belongs to the fruit fly family Tephritidae which is a group considered to be among the most damaging pests of horticultural crops (White and Elson-Harris 1992). *Bactrocera dorsalis* is a serious pest of most commercial fruit crops (Drew *et al.* 1982).

Bactrocera dorsalis has four life stages: egg, larva, pupa and adult. Adults are predominantly black, or black and yellow. Eggs are laid below the skin of the host fruit. Hatched larvae feed within the fruit and third instar larva are 7.5–10.0 mm long and 1.5–2.0 mm wide. Pupation occurs in the soil under the host plant. (CAB International 2008). It can produce several generations a year, depending on the temperature (CAB International 2008).

The risk scenario of concern for *B. dorsalis* is the presence of eggs and developing larvae within apple fruit.

Bactrocera dorsalis was included and/or assessed in the existing import policy for pears from China (AQIS 1998b), longan and lychees from China and Thailand (DAFF 2004a), mangosteens from Thailand (DAFF 2004b), mangoes from Taiwan (Biosecurity Australia 2006c) and mangoes from India (Biosecurity Australia 2008c). The assessment of *B. dorsalis* presented here builds on these previous assessments.

The probability of importation for *B. dorsalis* was rated as ‘high’ in the assessments for longan and lychees from China and Thailand (DAFF 2004a) and mangoes from Taiwan (Biosecurity Australia 2006c) because the species is widespread in the production regions, and as ‘very low’ in the assessment for mangosteens from Thailand (DAFF 2004b) because mangosteen is a conditional non-host of *B. dorsalis*.

The probability of distribution of *B. dorsalis* was rated ‘high’ in the assessments for longan and lychees (DAFF 2004a) and mangoes (Biosecurity Australia 2008c; Biosecurity Australia 2006c) because this species can fly and has a wide host range; and ‘moderate’ in mangosteens (DAFF 2004b) probably due to mangosteens being a conditional non-host of *B. dorsalis*.

The probability of establishment and of spread in Australia, and the consequences it may cause will be the same for any commodity in which the species is imported into Australia. Accordingly, there is no need to re-assess these components. However, differences in commodities, horticultural practices, climatic conditions and the prevalence of the pest between previous export areas (Thailand and Taiwan) and China make it necessary to re-assess the likelihood of entry of *B. dorsalis* to Australia with apples from China.

4.5.2 Reassessment of probability of importation

The likelihood that *B. dorsalis* will arrive in Australia with the importation of the commodity: **MODERATE**.

- Yang *et al.* (1994) reported that *B. dorsalis* is found on the Xisa Islands (Parcel Islands) in the South China Sea and as far north on mainland China as 26 degrees north latitude. Recent studies indicate that the northernmost border of *B. dorsalis* distribution in China is 30 +/- 2 degrees north latitude (Wu 2005; Hou and Zhang 2005). In 2003, 90% of apple

production in China occurred in seven provinces, all located north of 30 degrees latitude where *B. dorsalis* does not naturally occur because it would not survive the northern winter temperatures (Hou and Zhang 2005).

- Apples are a host of *B. dorsalis*. This fruit fly species has been reported as a serious pest of apples in Pakistan (Khan *et al.* 2003).
- *Bactrocera dorsalis* may be introduced into apple producing areas in the north of China through non-commercial movement of fruit fly-infested produce by travellers, as there are limited official control measures in place to prevent its movement from southern provinces, where *B. dorsalis* is known to occur, during the summer.
- *Bactrocera dorsalis* occurs in southern China, but also may fly into the northern provinces of China where apples are produced during the warmer months of the year.
- Females deposit eggs beneath the skin of host fruit including apples (EPPO 2005a) and larvae feed within the fruit for a few days after hatching. This location makes larvae difficult to detect pre-emergence. Infested fruit would be harvested.
- Infested fruit are unlikely to be detected during sorting, packing and quality inspection procedures in the absence of visual blemishes, bruising or damage to the skin and are likely to be present in fruit packed for export.

The evidence that larvae of *B. dorsalis* live inside the fruit and are difficult to detect but that this species would not survive the winter in the main apple production areas in China supports a risk rating for importation of ‘moderate’.

4.5.3 Reassessment of probability of distribution

The likelihood that *B. dorsalis* will be distributed in Australia in a viable state as a result of processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **HIGH**.

- Apple fruit is intended for human consumption and the larvae feed on the fruit internally. Therefore, larvae may remain in the fruit during retail distribution. Disposal of fruit waste may further aid distribution of viable insects, as an infested apple could be partially consumed and then discarded with viable larvae inside that could pupate within the remaining fruit.
- Adults can fly long distances and could enter the environment by emerging from discarded infested apple fruits. Species of *Bactrocera* have been reported to fly 50-100 km (CAB International 2008).
- *B. dorsalis* has a wide host range, including apple, pear, citrus, plum, apricot and cherry (CAB International 2008; Allwood *et al.* 1999). These host plants are grown commercially and in household gardens in Australia.

The association of larvae with fruit, combined with a wide host range and the capacity of adults to fly long distances, support a risk rating for distribution of ‘high’.

4.5.4 Probability of establishment and of spread

As indicated above, the probability of establishment and of spread for *B. dorsalis* would be the same as those assessed for longan and lychees from China and Thailand (DAFF 2004a)

and mangoes from Taiwan (Biosecurity Australia 2006c). The ratings from the previous assessments are presented below:

Probability of establishment: **HIGH**
 Probability of spread: **HIGH**

4.5.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of ‘rules’ for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *B. dorsalis* will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **MODERATE**.

4.5.6 Consequences

The consequences of the establishment of *B. dorsalis* in Australia have been estimated previously for longan and lychees from China and Thailand (DAFF 2004a) and mangoes from Taiwan (Biosecurity Australia 2006c). This estimate of impact scores is provided below expressed in the current scoring system (Table 2.3).

| | |
|--------------------------------------|----------|
| Plant life or health | E |
| Any other aspects of the environment | C |
| Eradication, control etc. | F |
| Domestic trade | E |
| International trade | E |
| Environment | D |

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are ‘F’, the overall consequences are estimated to be **HIGH**.

4.5.7 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for Oriental fruit fly | |
|--|-----------------|
| Overall probability of entry, establishment and spread | Moderate |
| Consequences | High |
| Unrestricted risk | High |

As indicated, the unrestricted risk for Oriental fruit fly has been assessed as ‘high’, which exceeds Australia’s ALOP. Therefore, specific risk management measures are required for this pest.

4.6 Oystershell scale - *Diaspidiotus ostreaeformis*

4.6.1 Introduction

Diaspidiotus ostreaeformis (oystershell scale) is not present in Western Australia and is a pest of regional quarantine concern for that state.

Diaspidiotus ostreaeformis belongs to the armoured scale insect family Diaspididae which construct a wax-like covering or ‘scale’ that encapsulates the insect (Carver *et al.* 1991) and protects it against physical damage and natural enemies (Foldi 1990). Throughout most of their life, armoured scales are sessile and are firmly affixed to their host plant by their mouthparts (Burger and Ulenberg 1990).

Females and males of *D. ostreaeformis* have a different life cycle. The female life stages include egg, nymph and adult, while the male has egg, nymph, pre-pupa, pupa and adult stages. There is no pupal stage in the female lifecycle. The adult females are approximately 1.3 mm in diameter, grey and conically shaped. The adult males are approximately 1mm in length, winged, and live only from 1 to 3 days. Hatched first instar nymphs (crawlers) are active and once they settle on the plant to feed, they become immobile and develop a protective covering. Although heavy infestations of oystershell scale are mainly found on the bark and stems of apple trees, they can also be found on fruit near the calyx or stem-end. *Diaspidiotus ostreaeformis* overwinters as diapausing second instar nymphs. There is one annual generation per year (CAB International 2008).

The risk scenario of concern for *D. ostreaeformis* is the presence of nymphs and adults on apple fruit.

Diaspidiotus ostreaeformis was assessed in the *Final Import Risk Analysis Report for Apples from New Zealand* (Biosecurity Australia 2006a) and *New Zealand stone fruit to Western Australia* (Biosecurity Australia 2006b).

The probability of importation for *D. ostreaeformis* was rated as ‘low’ in the assessments in the New Zealand apple IRA (Biosecurity Australia 2006a) because this species is only found in New Zealand’s South Island, which constitutes only a small portion of the apple export production area of New Zealand.

The probability of distribution of *D. ostreaeformis* will not differ for the same commodity (apples) after arrival in Western Australia. The probability of establishment and of spread in Western Australia, and the consequences it may cause will be the same for any commodity in which the species is imported into Western Australia. Accordingly, there is no need to re-assess these components. However, differences in commodities, horticultural practices, climatic conditions and the prevalence of the pest between previous export areas (New Zealand) and China make it necessary to re-assess the likelihood that *D. ostreaeformis* will be imported to Western Australia with apples from China.

4.6.2 Reassessment of probability of importation

The likelihood that *D. ostreaeformis* will arrive in Western Australia with the importation of the commodity: **MODERATE**.

- *Diaspidiotus ostreaeformis* is reported in the provinces of Anhui, Heilongjiang, Liaoning, Shaanxi and Shanxi, and the autonomous regions of Inner Mongolia and Xinjiang Uygur of China. Apple is one of the main hosts (Watson 2005).
- *Diaspidiotus ostreaeformis* mostly infests the bark on the stems and branches of the host trees, causing drying of the tissues (Watson 2005). It may also occur on fruit, where it causes red spots (Watson 2005). This damage may be noted during quality inspection.
- Post-harvest grading and packing procedures would not be effective in removing this pest from the fruit, because the insects settle and stick on the fruit.
- *Diaspidiotus ostreaeformis* overwinters as second instar nymphs (Watson 2005), suggesting that temporary cold storage and transportation would not be effective in killing this scale.

The widespread distribution of oystershell scale in China moderated by the removal of damaged fruit during quality inspection supports a risk rating for importation of ‘moderate’.

4.6.3 Probability of distribution, of establishment and of spread

As indicated above, the probability of distribution, of establishment and of spread for *D. ostreaeformis* in Western Australia will be the same as those assessed for apples from New Zealand (Biosecurity Australia 2006a). The ratings from the previous assessments are presented below:

| | |
|-------------------------------|-----------------|
| Probability of distribution: | LOW |
| Probability of establishment: | HIGH |
| Probability of spread: | MODERATE |

4.6.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of ‘rules’ for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *D. ostreaeformis* will enter Western Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Western Australia: **LOW**.

4.6.5 Consequences

The consequences of the establishment of *D. ostreaeformis* in Western Australia have been estimated previously for apples from New Zealand (Biosecurity Australia 2006a). This estimate of impact scores is provided below:

| | |
|--------------------------------------|----------|
| Plant life or health | D |
| Any other aspects of the environment | A |

| | |
|----------------------------|----------|
| Eradication, control, etc. | C |
| Domestic trade | B |
| International trade | C |
| Environment | B |

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are ‘**D**’, the overall consequences are estimated to be **LOW**.

4.6.6 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for oystershell scale | |
|--|-----------------|
| Overall probability of entry, establishment and spread | Low |
| Consequences | Low |
| Unrestricted risk | Very low |

As indicated, the unrestricted risk for oystershell scale has been assessed as ‘very low’, which achieves Australia’s ALOP. Therefore, specific risk management measures are not required for this pest.

4.7 Pear white scale - *Lopholeucaspis japonica*

4.7.1 Introduction

Lopholeucaspis japonica (pear white scale) belongs to the armoured scale insect family Diaspididae which construct a wax-like covering or ‘scale’ that encapsulates the insect (Carver *et al.* 1991) and protects it against physical damage and natural enemies (Foldi 1990). Throughout most of their life, armoured scales are sessile and are firmly affixed to their host plant by their mouthparts (Burger and Ulenberg 1990). *Lopholeucaspis japonica* is a major pest of *Citrus* species and also feeds on many other horticultural crops such as apple and pear and ornamental and amenity plants (CABI/EPPO 2007b; Ben-Dov *et al.* 2006a).

Females and males of *L. japonica* have a different life cycle. The female life stages include egg, nymph and adult, while the male has egg, nymph, pre-pupa, pupa and adult stages. There is no pupal stage in the female lifecycle. Adult females are pale violet, 0.9–1.1 mm long and protected by a red-brown scale cover, 1.5–2.0 mm in length. Male scales are smaller and more oblong than the female and at the final moult produce tiny winged males that slip out from beneath the scale and fly off to find females to mate. Eggs of *L. japonica* are 0.25 mm long and are laid under the scale cover of the adult female. First-instar nymphs or ‘crawlers’ are mobile; the sexes are indistinguishable at this stage. Second instar female nymphs are sessile and are protected by a dark-brown scale cover 1.5–2.0 mm long. Second instar male nymphs are similar to females but smaller with whitish scale cover (CAB International 2008). It reproduces one to two generations per year (CAB International 2008).

The risk scenario of concern for pear white scale is the presence of nymphs and/or adults on apple fruit.

Lopholeucaspis japonica (pear white scale) was included in the existing import policy for pears from China (Biosecurity Australia 2005b; AQIS 1998b) and Fuji apples from Japan (AQIS 1998a). The assessment of pear white scale presented here builds on these existing pest risk assessments.

4.7.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that *L. japonica* will arrive in Australia with the importation of the commodity: **HIGH**.

- *Lopholeucaspis japonica* is widely spread in many provinces of China, including main apple production areas such as Shanxi (CAB International 2008).
- *Lopholeucaspis japonica* also attacks apples although its main hosts of economic importance are *Citrus* species (CAB International 2008; CABI/EPPO 2007b).
- Nymphs and adults of *L. japonica* are found on leaves and also on the bark of branches and sometimes on fruit (CABI/EPPO 2007b).

- Once the first instar crawlers settle on the host, they become sessile and do not move again and subsequent nymphs and adults inside the scale covers are sessile and remain attached to their host (Beardsley and Gonzalez 1975). If they attach inside and to protected/sheltered areas, such as the calyx, the fruit sorting and packing processes may not remove them effectively.
- *Lopholeucaspis japonica* would be likely to survive cold storage and transportation because it readily overwinters at temperatures of -20 to -25 °C in the Russian Far East (CAB International 2008).
- The small size of *L. japonica* (scale cover 1.5-2 mm) makes them difficult to detect, especially at low population levels.

The small size, sessile nature of most life stages and hard external covering of almost all life stages of scales all support a risk rating for importation of ‘high’.

Probability of distribution

The likelihood that *L. japonica* will be distributed in Australia in a viable state as a result of the processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **LOW**.

- Apple fruit is intended for human consumption and nymphs and adults of *L. japonica* may remain on the fruit during retail distribution. The unconsumed parts of the fruit, especially skin and calyx of infested fruit is likely to end up in fruit waste, which may further aid distribution of viable *L. japonica*. Disposal of infested waste fruit is likely to be via commercial or domestic rubbish systems or discarded where the fruit is consumed. However, some fruit waste may be disposed of in the home garden which provides an opportunity for these pests to transfer to susceptible hosts in the vicinity.
- The ability of *L. japonica* to disperse is limited. Nymphs and adults lack active mechanisms for long range dispersal, the first-instar nymphs (crawlers) can be carried by wind. Second-instar nymphs and adult females are sessile. Adult males have wings but are fragile and short-lived.
- *Lopholeucaspis japonica* has been reported from 25 families, 43 genera and at least 58 species or subspecies of host plants (Ben-Dov *et al.* 2006a).

The limited mobility of almost all life stages of *L. japonica* supports a risk rating for distribution of ‘low’.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The likelihood that *L. japonica* will enter Australia as a result of trade in the commodity and be distributed in a viable state to a suitable host: **LOW**.

4.7.3 Probability of establishment

The likelihood that *L. japonica* will establish based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **HIGH**.

- *Lopholeucaspis japonica* feeds on a wide range of host plants including several horticultural crops such as apple, pear, citrus as well as some ornamental plants such as camellia and ficus (Ben-Dov *et al.* 2006a).
- *Lopholeucaspis japonica* has been reported from Africa, Asia, North and South Americas and Russia (Ben-Dov *et al.* 2006a). This indicates the species has the ability to adapt to new environments. Climatic conditions in many parts of Australia are similar to the areas where *L. japonica* currently occurs.
- *Lopholeucaspis japonica* has one generation per year in a cold climate such as the Far East of Russia and two generations per year in milder climates such as Maryland and Virginia in the USA and parts of Japan (CAB International 2008).
- In spring, adult females each lay 35-60 eggs under the scale cover. The first-instar larvae hatch and emerge from under the female's scale to seek feeding sites on the bark (especially in cool countries) or (in warmer conditions) on the upper leaf surface, near a vein or leaf margin. *Lopholeucaspis japonica* overwinter as second instars under the bark in the former USSR and Oita, Japan, and as mated adult females in Tokyo, Japan (CAB International 2008).
- Existing control programs may be effective for some hosts (e.g. broad spectrum pesticide application) but not all hosts, because of its wide host range.

The wide host plant range, adaptability of armoured scales over a wide climatic range and limited pesticide effectiveness to control these pests support a risk rating for establishment of 'high'.

4.7.4 Probability of spread

The likelihood that *L. japonica* will spread, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pest: **MODERATE**.

- *Lopholeucaspis japonica* occurs in many parts of Asia, Africa and North and South America, indicating the Australian environment would be suitable for its spread.
- The commercial fruit crop hosts of *L. japonica* such as apples, citrus and pears are grown in many parts of Australia. Widely distributed suitable hosts are grown in home gardens, parks and along roads, which would aid the spread of *L. japonica*.
- With natural barriers including arid areas, climatic differentials and long distances present between these areas, it would be difficult for *L. japonica* to disperse from one area to another unaided.
- The main dispersal phase of *L. japonica* is the first-instar crawler, which is probably capable of walking no more than a metre or so, within the same tree or possibly from one tree to another if the branches are touching. However, crawlers can be carried greater distances by the wind and on larger animals including people as they move around the orchard (CAB International 2008).
- Adult males have wings, but are very fragile and short lived and only travel for short distances.
- Apples and other fruit hosts have unrestricted movement around most of the country. Such movement would aid the spread of *L. japonica* on infested fruit.

- Natural enemies such as parasitoids and general predators are reported as being associated with *L. japonica* (CAB International 2008) but their potential effectiveness in Australia is difficult to assess.

The lack of a natural mechanism for long distance dispersal and the restricted mobility to first instar nymphs support a risk rating of *L. japonica* for spread of ‘moderate’.

4.7.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of ‘rules’ for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *L. japonica* will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **LOW**.

4.7.6 Consequences

The consequences of the establishment of *L. japonica* in Australia have been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are ‘D’, the overall consequences are estimated to be **LOW**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|---|---|
| DIRECT | |
| Plant life or health | <p>D – Significant at the district level</p> <p><i>Lopholeucaspis japonica</i> is a main pest of <i>Citrus</i> species and also feeds on many other horticultural crops such as apple and pear and ornamental and amenity plants (CABI/EPPO 2007b; Ben-Dov <i>et al.</i> 2006a).</p> <p><i>Lopholeucaspis japonica</i> attacks all citrus severely, multiplying rapidly to cover the trunk, branches and young shoots with dense colonies. Individual trees are killed by heavy infestations, while neighbouring trees may be virtually unaffected (CAB International 2008).</p> |
| Other aspects of the environment | <p>B – Minor significance at the local level</p> <p>There are no known direct consequences of this species on the natural or built environment, but its introduction into a new environment may lead to competition for resources with native species.</p> |

INDIRECT**Control,
eradication,
etc.****D** – Significant at the district level

Programs to minimise the impact of this pest on host plants may be costly and may include additional pesticide applications and crop monitoring.

Existing control strategies in place for other economically important armoured scales may have impacts on *L. japonica* in Australia. However, existing IPM programs may be disrupted due to possible increases in the use of insecticides. Costs for crop monitoring and consultants' advice regarding management of this pest may be incurred by the producer.

**Domestic
trade****C** – Significant at the local level

If *L. japonica* becomes established in part of Australia, it might have an effect at the local level due to resulting trade restrictions on the sale or movement of a wide range of commodities such as apples, pears and citrus between areas in Western Australia and between other states/territories.

**International
trade****C** – Significant at the local level

The presence of *L. japonica* in commercial production areas of a wide range of commodities (e.g. apples, pears and citrus) might limit access to some overseas markets which are free from these pests.

Environment**B** – Minor significance at the local level

Pesticide applications or other control activities would be required to control this pest on susceptible crops, which could have minor indirect impact on the environment.

4.7.7 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for pear white scale | |
|--|----------|
| Overall probability of entry, establishment and spread | Low |
| Consequences | Low |
| Unrestricted risk | Very low |

As indicated, the unrestricted risk for pear white scale has been assessed as 'very low', which achieves Australia's ALOP. Therefore, specific risk management measures are not required for this pest.

4.8 Olive scale - *Parlartoria oleae*

4.8.1 Introduction

Parlartoria oleae (olive scale) is not present in Western Australia and is a pest of regional quarantine concern for that state.

Parlartoria oleae belongs to the armoured scale insect family Diaspididae, which construct a wax-like covering or 'scale' that encapsulates the insect (Carver *et al.* 1991). *Parlartoria oleae* is a pest of olive (*Olea europaea*) but is also found infesting numerous fruit, nut and ornamental plant species (CAB International 2007b).

Females and males of *P. oleae* have a different life cycle. The female life stages include egg, first and second instar nymphs and adult, while the male has egg, nymph, pre-pupa, pupa and adult stages. Female scale cover is round or oval and 1.9–2.5 mm long and 1.7–1.8 mm wide. The body of the adult female is broad-oval, 1–1.3 mm long and 0.8–0.9 mm wide. The first instar nymph is oval, about 0.29 mm long and 0.19 mm wide. The second instar nymph is similar to the adult but smaller. Male scale cover is smaller than that of the female, 1.1–1.2 mm long and 0.35–0.36 mm wide (Chou 1985).

Parlartoria oleae produces two to three generations annually depending on the geographical region (CAB International 2007b).

The risk scenario of concern for *P. oleae* is the presence of nymphs and/or adults on apple fruit.

Parlartoria oleae was included in the existing import policy for pears from China (Biosecurity Australia 2005b) but was not considered further due to its presence in the eastern states of Australia. The assessment of *P. oleae* presented here is for the regional quarantine concern for Western Australia.

4.8.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that *P. oleae* will arrive in Western Australia with the importation of the commodity: **HIGH**.

- *Parlartoria oleae* is widely spread in China, including main apple production areas such as Shaanxi (Ben-Dov *et al.* 2006a).
- *Parlartoria oleae* also attacks apples although its primary host is olive (CAB International 2007b).
- Nymphs and adults of *P. oleae* are found on the bark, leaves and fruit of its hosts (CAB International 2007b).
- Adult females are present in the autumn through the winter (Ben-Dov *et al.* 2006a) and therefore will be present during the apple harvest time from late August to October.

- Once the first instar crawlers settle on the host, they become sessile and do not move again (Beardsley and Gonzalez 1975). If they settle inside protected/sheltered areas of the fruit, such as the calyx, they may not be detected during fruit sorting and packing processes and may not be removed from the pathway.
- *Parlatoria oleae* would be likely to survive cold storage and transportation because it overwinters as fertilised females (CAB International 2007a).
- The small size of *P. oleae* (scale cover 1-2 mm) makes them difficult to detect, especially at low population levels.

The small size, sessile nature of most life stages and hard external covering of almost all life stages of scales all support a risk rating for importation of 'high'.

Probability of distribution

The likelihood that *P. oleae* will be distributed in Western Australia in a viable state as a result of the processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **LOW**.

- Apple fruit is intended for human consumption and nymphs and adults of *P. oleae* may remain on the fruit during retail distribution. The unconsumed parts of the fruit, especially skin and calyx of infested fruit, is likely to end up in fruit waste, which may further aid distribution of viable *P. oleae* to the environment.
- Disposal of infested waste fruit is likely to be via commercial or domestic rubbish systems or discarded where the fruit is consumed. However, some fruit waste may be disposed of in the home garden which provides an opportunity for these pests to transfer to susceptible hosts in the vicinity.
- The ability of *P. oleae* to disperse is limited. Nymphs older than first instar and adults lack active mechanisms for long range dispersal, although the first-instar nymphs (crawlers) can be carried by wind and animal agent, and by human transport of infested material. The species overwinters as fertilised adult females or second instar females on the bark.
- *Parlatoria oleae* is highly polyphagous and attacks olive, apple, peach, plum, rose and many other host plants (Ben-Dov *et al.* 2006a). *Parlatoria oleae* has been reported to infest species over 80 genera in central Europe and has been collected from over 200 species of host plants in California, USA, although many of these host plants will not support complete development (CAB International 2007b).

The limited mobility of almost all life stages of *P. oleae* supports a risk rating for distribution of 'low'.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The likelihood that *P. oleae* will enter Western Australia as a result of trade in the commodity and be distributed in a viable state to a suitable host: **LOW**.

4.8.3 Probability of establishment

The likelihood that *P. oleae* will establish based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **HIGH**.

- *Parlatoria oleae* feeds on a wide range of host plants, including several horticultural crops such as olive, apple, plum and peach as well as some ornamental plants such as roses and *Bignonia* sp. (Ben-Dov *et al.* 2006a).
- *Parlatoria oleae* has been reported from Asia, Europe, Africa, North America and South America (CAB International 2008). This indicates that the species has the ability to adapt to new environments. Climatic conditions in many parts of Australia are similar to the areas where *P. oleae* currently occurs.
- *Parlatoria oleae* produces one to four generations annually depending on the geographical region. Overwintering occurs as fertilised adult females, although a small portion of the population may overwinter as second instars (Ben-Dov *et al.* 2006a).
- In areas where two generations occur, adult females each lay an average of 90 (8-152) eggs under the scale cover. Eggs are laid in mid April to early June in California, USA, and late April to early July in Maryland, USA (Ben-Dov *et al.* 2006a).
- *Parlatoria oleae* apparently does not do well under coastal conditions where the summer is relatively cool (CAB International 2007b; Ben-Dov *et al.* 2006a).
- Existing control programs, such as pesticide application for other scales in apple and pear orchards, may not be effective against *P. oleae* because the timing of their life cycle may differ from existing species in production areas.

The wide host plant range, adaptability of *P. oleae* over a wide climatic range and limited pesticide effectiveness to control these pests support a risk rating for establishment of 'high'.

4.8.4 Probability of spread

The likelihood that *P. oleae* will spread, based on a comparison of factors in the area of origin and in Western Australia that affect the expansion of the geographic distribution of the pest: **MODERATE**.

- *Parlatoria oleae* occurs in many parts of Asia, Africa, North and South America, and eastern Australia, indicating that the Western Australian environment would be suitable for its spread.
- The commercial fruit crop hosts of *P. oleae* such as olive, apple, plum and peach are grown in many parts of Australia. Widely distributed suitable hosts are grown in home gardens, parks and along roads, which would aid the spread of *P. oleae*.
- With natural barriers including arid areas, climatic differentials and long distances present between these areas, it would be difficult for *P. oleae* to disperse from one area to another unaided.
- The main dispersal phase of *P. oleae* is the first-instar crawler, whose range is limited by their small size. Dispersal is commonly within the same tree, or from one tree to another if the branches are touching (Beardsley and Gonzalez 1975). However, crawlers of armoured scale insects can be carried greater distances by wind, transport of infested host material (especially viable propagative stock) and on larger animals, including people (Beardsley and Gonzalez 1975).

- Adult males have wings, but are very fragile and short lived and only travel for short distances (Beardsley and Gonzalez 1975).
- Apples and other fruit hosts have unrestricted movement around most of the country. Such movement would aid the spread of *P. oleae* on infested fruit.
- Natural enemies such as parasitoids and general predators are reported as being associated with *P. oleae* (CAB International 2007b; Ben-Dov *et al.* 2006a) but their potential effectiveness in Australia is difficult to assess.

The lack of a natural mechanism for long distance dispersal and the fact that mobility is restricted to the first instar nymphs, which can be carried greater distance by wind, support a risk rating for spread of ‘moderate’.

4.8.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of ‘rules’ for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *P. oleae* will enter Western Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Western Australia: **LOW**.

4.8.6 Consequences

The consequences of the establishment of *P. oleae* in Western Australia have been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are ‘D’, the overall consequences are estimated to be **LOW**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|---|---|
| DIRECT | |
| Plant life or health | <p>D – Significant at the district level</p> <p><i>Parlatoria oleae</i> is a common pest of olives and has also been reported to be an economic pest on many other horticultural crops such as apple, peach and plum and ornamental and amenity plants (CAB International 2007b; Ben-Dov <i>et al.</i> 2006a).</p> <p><i>Parlatoria oleae</i> attacks olive, multiplying rapidly to cover the trunk, branches and young shoots with dense colonies. Individual trees are defoliated by heavy infestations, which can result in dieback of limbs (CAB International 2007b).</p> |
| Other aspects of the environment | <p>B – Minor significance at the local level</p> <p>There are no known direct consequences of this species on the natural or built environment, but its introduction into a new environment may lead to competition for resources with native species.</p> |

INDIRECT**Control,
eradication,
etc.****D** – Significant at the district level

Programs to minimise the impact of this pest on host plants may be costly and may include additional pesticide applications and crop monitoring expenses.

Existing control strategies in place for other economically important armoured scales may have impacts on *P. oleae* in Western Australia. However, existing IPM programs may be disrupted due to possible increases in the use of insecticides. Costs for crop monitoring and consultants' advice regarding management of this pest may be incurred by the producer.

**Domestic
trade****B** – Minor significance at the local level

If *P. oleae* becomes established in part of Western Australia, it might have an effect at the local level due to resulting trade restrictions on the sale or movement of a wide range of commodities such as apple, plum and peach between areas in Western Australia.

**International
trade****C** – Significant at the local level

The presence of *P. oleae* in commercial production areas of a wide range of commodities (e.g. apple, plum and peach) might limit access to some overseas markets, such as Japan, which are free from these pests.

Environment**B** – Minor significance at the local level

Pesticide applications or other control activities would be required to control this pest on susceptible crops, which could have minor indirect impact on the environment.

4.8.7 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for olive scale | |
|--|----------|
| Overall probability of entry, establishment and spread | Low |
| Consequences | Low |
| Unrestricted risk | Very low |

As indicated, the unrestricted risk for olive scale has been assessed as 'very low', which achieves Australia's ALOP. Therefore, specific risk management measures are not required for this pest.

4.9 Yanyuan scale - *Parlartoria yanyuanensis*

4.9.1 Introduction

Parlartoria yanyuanensis (yanyuan scale) belongs to the armoured scale insect family Diaspididae, which construct a wax-like covering or ‘scale’ that encapsulates the insect (Carver *et al.* 1991). *Parlartoria yanyuanensis* scale is a pest of fruit trees in Sichuan and Yunnan provinces of China (Lu and Wu 1988).

Females and males of *P. yanyuanensis* have a different life cycle. The female life stages include egg, nymph and adult, while the male has egg, nymph, pre-pupa, pupa and adult stages. Female scale cover is white, almost circular in shape and 2 mm in diameter. Adult female is pink-red, its body is oval, 1.38 mm long and 1.08 mm wide. Male scale cover is also white, elongated in shape, smaller than that of female and about 1 mm long. The adult male is 0.5–0.7 mm long with wingspan of 1.2–1.3 mm. The egg is elongate-oval, and its length to width ratio is 3:1. The newly hatched nymph is oval, about 0.2 mm long. The nymph undergoes a series of colour changes before scale cover is formed: from red-brown to rose-red, pink-red, dark-pink and eventually black.

The risk scenario of concern for *P. yanyuanensis* is the presence of nymphs and/or adults on apple fruit.

4.9.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that *P. yanyuanensis* will arrive in Australia with the importation of the commodity: **LOW**.

- *Parlartoria yanyuanensis* is present in Sichuan and Yunnan provinces of south-west China (Lu and Wu 1988), which are not the main apple production areas.
- *Parlartoria yanyuanensis* attacks apples, and its nymphs and adults are found on branches and fruit (Lu and Wu 1988).
- Once the first instar crawlers settle on the host, they become sessile and do not move again (Beardsley and Gonzalez 1975). If they settle inside protected/sheltered areas of the fruit, such as the calyx, they may not be detected during fruit sorting and packing processes and may not be removed from the pathway.
- *Parlartoria yanyuanensis* would be likely to survive cold storage and transportation because this species overwinters as adult females.
- Although the scale covers of adult females of *P. yanyuanensis* are white, their small size (2 mm) makes them difficult to be detected, especially at low population levels.

The small size, sessile nature of most life stages and hard external covering of almost all life stages of scales, moderated by its limited distribution in southwest of China – not a main apple production area – support a risk rating for importation of ‘low’.

Probability of distribution

The likelihood that *P. yanyuanensis* will be distributed in Australia in a viable state as a result of the processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **LOW**.

- Apple fruit is intended for human consumption and nymphs and adults of *P. yanyuanensis* may remain on the fruit during retail distribution. The unconsumed parts of the fruit, especially skin and calyx of infested fruit, is likely to end up in fruit waste, which may further aid distribution of viable *P. yanyuanensis*.
- Disposal of infested waste fruit is likely to be via commercial or domestic rubbish systems or discarded where the fruit is consumed. However, some fruit waste may be disposed of in the home garden, which provides an opportunity for these pests to transfer to susceptible hosts in the vicinity.
- The ability of *P. yanyuanensis* to disperse is limited. Nymphs older than first instar and adults lack active mechanisms for long range dispersal, although the first-instar nymphs (crawlers) can be carried by wind. Second-instar nymphs and adult females are sessile. Adult males have wings but are fragile and short-lived and can not produce new populations without females.
- *Parlatoria yanyuanensis* has been reported from apple, pear, paper mulberry and Chinese quince (Ben-Dov *et al.* 2006a; Lu and Wu 1988).

The limited mobility of almost all life stages supports a risk rating for distribution of ‘low’.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The likelihood that *P. yanyuanensis* will enter Australia as a result of trade in the commodity and be distributed in a viable state to a suitable host: **VERY LOW**.

4.9.3 Probability of establishment

The likelihood that *P. yanyuanensis* will establish based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **HIGH**.

- The reported host plants of *P. yanyuanensis* include apple, pear, paper mulberry and Chinese quince (Ben-Dov *et al.* 2006a; Lu and Wu 1988). Apple and pear are widely grown in Australia.
- *Parlatoria yanyuanensis* has been reported from southwest China (Lu and Wu 1988). Climatic conditions in parts of Australia are similar to the areas where *P. yanyuanensis* currently occurs.
- *Parlatoria yanyuanensis* produces one generation per year, with adult female overwintering. Adult females each lay an average of 50 (up to 108) eggs under the scale cover (Lu and Wu 1988).
- Existing control programs, such as pesticide application for other scales in apple and pear orchards, may not be effective against *P. yanyuanensis* because the timing of their life cycle may differ from existing species in production areas.

The availability of the host plants, suitability of climatic conditions and unknown effectiveness of existing control programs support a risk rating for establishment of ‘high’.

4.9.4 Probability of spread

The likelihood that *P. yanyuanensis* will spread, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pest: **MODERATE**.

- The Australian climatic environment would be suitable for the spread of *P. yanyuanensis*.
- The commercial fruit crop hosts of *P. yanyuanensis*, such as apples and pears, are grown in many parts of Australia, including in home gardens, in parks and along roads, which would aid the spread of *P. yanyuanensis*.
- With natural barriers including arid areas, climatic differentials and long distances present between these areas, it would be difficult for *P. yanyuanensis* to disperse from one area to another unaided.
- The main dispersal phase of *P. yanyuanensis* is the first-instar crawler, whose range is limited by their small size. Dispersal is commonly within the same tree, or from one tree to another if the branches are touching (Beardsley and Gonzalez 1975). However, crawlers of armoured scale insects can be carried greater distances by the wind, by transport of infested host material (especially viable propagative stock) and on larger animals, including people (Beardsley and Gonzalez 1975)(CAB International 2008)
- Adult males have wings, but are very fragile and short lived and only travel for short distances (Beardsley and Gonzalez 1975).
- Apples and pears have unrestricted movement around most of the country. Such movement would aid the spread of *P. yanyuanensis* on infested fruit and nursery stock.
- There have been no report of parasitoids or predators of *P. yanyuanensis*. Potential effectiveness of generalist natural enemies in Australia is difficult to assess.

The availability of the host plants and suitability of climatic conditions in Australia, moderated by the lack of a natural mechanism for long distance dispersal and the restricted mobility to first instar nymphs, support a risk rating for spread of ‘moderate’.

4.9.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of ‘rules’ for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *P. yanyuanensis* will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **VERY LOW**.

4.9.6 Consequences

The consequences of the establishment of *P. yanyuanensis* in Australia have been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are ‘D’, the overall consequences are estimated to be **LOW**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|---|---|
| DIRECT | |
| Plant life or health | <p>D – Significant at the district level</p> <p><i>Parlatoria yanyuanensis</i> feeds on apple, pear, paper mulberry and Chinese quince (Ben-Dov <i>et al.</i> 2006a; Lu and Wu 1988). Feeding of <i>P. yanyuanensis</i> reduces the vigour of the hosts and can cause the death of branches in severe cases. Damage results in poor quality fruit. The occurrence of <i>P. yanyuanensis</i> also causes the growth of sooty mould. This damage causes economic loss (Lu and Wu 1988).</p> |
| Other aspects of the environment | <p>B – Minor significance at the local level</p> <p>There are no known direct consequences of this species on the natural or built environment, but its introduction into a new environment may lead to competition for resources with native species.</p> |
| INDIRECT | |
| Control, eradication, etc. | <p>D – Significant at the district level</p> <p>Programs to minimise the impact of this pest on host plants may be costly and may include additional pesticide applications and crop monitoring expenses.</p> <p>Existing control strategies in place for other economically important armoured scales may have impacts on <i>P. yanyuanensis</i> in Australia. However, existing IPM programs may be disrupted due to possible increases in the use of insecticides. Costs for crop monitoring and consultants' advice regarding management of this pest may be incurred by the producer.</p> |
| Domestic trade | <p>C – Significant at the local level</p> <p>If <i>P. yanyuanensis</i> becomes established in parts of Australia, it might have an effect at the local level due to resulting trade restrictions on the sale or movement of apples and pears between states/territories.</p> |
| International trade | <p>D – Significant at the local level</p> <p>As <i>P. yanyuanensis</i> has only been reported from China, the presence of this pest in commercial production areas of apples and pears might limit access to other overseas markets.</p> |
| Environment | <p>B – Minor significance at the local level</p> <p>Pesticide applications or other control activities would be required to control this pest on susceptible crops, which could have minor indirect impact on the environment.</p> |

4.9.7 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for yanyuan scale | |
|--|-------------------|
| Overall probability of entry, establishment and spread | Very low |
| Consequences | Low |
| Unrestricted risk | Negligible |

As indicated, the unrestricted risk for yanyuan scale has been assessed as ‘negligible, which achieves Australia’s ALOP. Therefore, specific risk management measures are not required for this pest.

4.10 Mealybugs - *Phenacoccus aceris* and *Pseudococcus comstocki*

4.10.1 Introduction

Phenacoccus aceris (apple mealybug) and *Pseudococcus comstocki* (Comstock's mealybug) belong to the mealybug family Pseudococcidae which are small, oval, soft-bodied insects that are covered with a white, cottony or mealy wax secretion that is moisture repellent and protects them against desiccation (CUES 2007). Mealybugs are sucking insects that injure plants by extracting large quantities of sap. Feeding weakens and stunts plants, causing leaf distortion, premature leaf drop, dieback and even plant death (Lindquist 2000).

Females and males of mealybugs have a different life cycle. Female mealybugs develop from an egg through three nymphal (immature instar) stages before undergoing a final moult into the adult form (CAB International 2008). Adult females are 3–4 mm long, slow-moving and oval-shaped. Males develop from eggs through first and second feeding instars, and third and fourth non-feeding instars, before moulting into tiny winged adults, which possess a pair of long wax terminal filaments (CUES 2007). Although the nymphs and adults live mainly on the bark of apple trees, they can also be found on fruit and in such cases tend to live either around or in the calyx of the fruit. *Phenacoccus aceris* has one generation per year (Beers 2007) and *Pseudococcus comstocki* reproduces three generations a year in China (Liu 2004).

The risk scenario of concern for mealybugs is the presence of nymphs and/or adults on apple fruit.

Phenacoccus aceris (apple mealybug) was included in the existing import policy for pears from Korea (AQIS 1999a). *Pseudococcus comstocki* was included in the existing import policy for pears from China (Biosecurity Australia 2005b; AQIS 1998b) and Fuji apples from Japan (AQIS 1998a). The assessment of mealybugs presented here builds on these existing pest risk assessments.

4.10.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that *Phenacoccus aceris* and *Pseudococcus comstocki* will arrive in Australia with the importation of the commodity: **HIGH**.

- *Pseudococcus comstocki* is widely spread in China and apple is one of the main hosts (CAB International 2008; AQSIQ 2005).
- *Phenacoccus aceris* is reported in Shanxi (Ben-Dov 2005b) which is one of the main apple production areas in China.
- *Phenacoccus aceris* attacks various host plant parts including fruit, twigs and leaves (Beers 2007).
- In China, the first generation nymphs of *P. comstocki* usually attack the young leaves of the tree, but the second and third generation nymphs mainly attack the fruit (Liu 2004).

- As the mealybugs can be concealed within the stem end or calyx of apple fruit, the sorting and packing processes may not remove them effectively.
- No data are available as to whether *P. aceris* and *P. comstocki* will survive transportation of apples from China to Australia. However, another species of mealybug (*Pseudococcus calceolariae*) belonging to the same genus has been detected at on-arrival inspection in the USA on New Zealand apples exported to the USA (USDA-APHIS 2003) and it is feasible that *P. aceris* and *P. comstocki* would also survive during transportation.

The association of mealybugs with fruit, their inconspicuousness and the presence of a protective coating allowing them to withstand sorting and packing processing, all support a risk rating for importation of ‘high’.

Probability of distribution

The likelihood that *Phenacoccus aceris* and *Pseudococcus comstocki* will be distributed in Australia in a viable state as a result of the processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **MODERATE**.

- Apple fruit is intended for human consumption and the mealybugs may remain on the fruit during retail distribution. The unconsumed calyx of infested fruit is likely to end up in fruit waste, which may further aid distribution of viable mealybugs. Disposal of infested waste fruit is likely to be via commercial or domestic rubbish systems or discarded where the fruit is consumed.
- The ability of mealybugs to disperse is limited. Mealybugs lack active mechanisms for long range dispersal, but as shown for a similar species, *Pseudococcus longispinus* (longtailed mealybug), the first- and second-instar nymphs can be carried by wind (Barrass *et al.* 1994). Adult females are slow moving.
- Mealybugs can enter into the environment through distribution of fruit, by crawling, dispersal on wind currents or by other human activities.
- *Pseudococcus comstocki* has a wide host range. Ben-Dov (2005b) reported 39 families, 55 genera and at least 65 species or subspecies of host plants. Musaev & Bushkov (1977) found that this species infested over 300 plant species in Turkmenistan. Apart from apples, it also attacks other fruit crops such as banana, peach, pear, lemon, apricot, cherry and mulberry (Ben-Dov 2005b).
- Ben-Dov (2005b) listed 27 families and over 100 species or subspecies of host plants for *Phenacoccus aceris*.

The evidence that mealybugs have limited mobility but a wide host range supports a risk rating for distribution of ‘moderate’.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The likelihood that mealybugs will enter Australia as a result of trade in the commodity and be distributed in a viable state to a suitable host: **MODERATE**.

4.10.3 Probability of establishment

The likelihood that *Phenacoccus aceris* and *Pseudococcus comstocki* will establish based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **HIGH**.

- *Pseudococcus comstocki* feeds on many host plants including several horticultural crops such as banana, peach, pear, lemon, apricot, cherry, catalpa and mulberry. *Phenacoccus aceris* infests a broad range of host plants such as apple, cherry, pear, plum and apricot (Ben-Dov 2005b).
- *Pseudococcus comstocki* is believed to be of Asian origin, possibly indigenous to Japan, where it was initially described infesting maple (Kuwana 1902). It has been reported from a number of countries throughout both Asia and Europe (Ben-Dov 2005b). *Phenacoccus aceris* is believed to be of European origin but currently its distribution is cosmopolitan (Beers 2007). This indicates that both species have the ability to adapt to new environments. Climatic conditions in many parts of Australia are similar to these regions.
- Both mealybugs are bisexual species (meaning that both male and female are required for reproduction).
- Beers (2007) reported that *P. aceris* has one generation per year. The second instar nymphs overwinter in the bark, twigs or leaves of the host plant in the autumn and emerge in early spring. They mature, mate and begin egg-laying on twigs in mid-spring. Eggs hatch early summer and the nymphs disperse and attack host plant parts including fruit, twigs and leaves (Beers 2007).
- *Pseudococcus comstocki* has three generations a year in China (Liu 2004). Females of *P. comstocki* produce overwintering eggs in the autumn. Each female lays 100-300 yellow eggs which are protected in a wax-like sac attached to the female's abdomen. The females usually move to the bark for protection in the cracks and crevices. The eggs hatch in the spring and the young nymphs initially migrate to, and settle on, the underside of the leaves to feed.
- An integrated approach using chemicals and biological control agents resulted in the successful elimination of *P. comstocki* in orchards and vegetable fields in Russia (Nikitenko and Ponomarev 1981).

Polyphagy, adaptability over a wide climatic range and relatively high fecundity support a risk rating for establishment of 'high'.

4.10.4 Probability of spread

The likelihood that *Phenacoccus aceris* and *Pseudococcus comstocki* will spread, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pest: **HIGH**.

- *Pseudococcus comstocki* and *Phenacoccus aceris* occur in many parts of Asia, Europe, Africa and North and South America, indicating the Australian environment would be suitable for its spread.
- The commercial fruit crop hosts of these mealybug species such as apples, bananas, peach and apricot, citrus and pears are grown in many parts of Australia. Widely distributed suitable hosts grown in home gardens, parks and along roads would aid the spread of these mealybugs.

- With natural barriers such as arid areas, climatic differentials and long distances present between production areas, it would be difficult for these mealybugs to disperse from one area to another unaided. Crawling is the main means of dispersal on a host plant, from leaf to leaf and eventually spreading over the whole tree (CAB International 2008). The insect may also crawl from tree to tree, or to a neighbouring field.
- The first and second-instar nymphs of a similar species, *Pseudococcus longispinus*, can be dispersed by wind over longer distances (50 m) (Barrass *et al.* 1994). Adult males have wings, but are very fragile and shortlived and only travel for short distances.
- Apples and other fruit hosts would be distributed around the country. Such distribution would aid the spread of these mealybugs on infested fruit.
- Natural enemies such as parasitoids and general predators are reported as being associated with these mealybugs (CAB International 2008; Morimoto 1976) but their potential effectiveness in Australia is difficult to assess.

Polyphagy, dispersal of first and second instar nymphs by wind, and the past history of spread in other countries all support a risk rating for spread of ‘high’.

4.10.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of ‘rules’ for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *Phenacoccus aceris* and *Pseudococcus comstocki* will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **MODERATE**.

4.10.6 Consequences

The consequences of the establishment of *Phenacoccus aceris* and *Pseudococcus comstocki* in Australia have been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are ‘D’, the overall consequences are estimated to be **LOW**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|-----------------------------|--|
| DIRECT | |
| Plant life or health | <p>D – Significant at the district level</p> <p><i>Pseudococcus comstocki</i> is occasionally a serious pest in apple, pear and citrus orchards and is also damaging to several ornamental and shade trees (CAB International 2008). Liu (2004) indicates that, in recent years, <i>Pseudococcus comstocki</i> has become an important pest for apple orchards in China and the number of infected trees usually reaches 2.3-9.7%, but can be as high as 17.6%.</p> <p><i>Phenacoccus aceris</i> feeds on apple, cherry, pear, apricot, grape, blueberry and many</p> |

other hosts (Beers 2007). It is also reported as the vector of little cherry virus (Beers 2007).

Other aspects of the environment

B – Minor significance at the local level

There are no known direct consequences of this species on the natural or built environment, but its introduction into a new environment may lead to competition for resources with native species.

INDIRECT

Control, eradication, etc.

D – Significant at the district level

Programs to minimise the impact of this pest on host plants may be costly and may include additional pesticide applications and crop monitoring.

Existing control strategies in place for other economically important mealybug species (e.g. longtailed mealybug, *Pseudococcus longispinus*) may have impacts on apple mealybug and Comstock's mealybug in Australia. Acceptable control of *P. comstocki* and *P. aceris* may be obtained by implementing one or two chemical applications timed to coincide with each generation of immature scales (CAB International 2008). However, existing IPM programs may be disrupted due to possible increases in the use of insecticides. Costs for crop monitoring and consultants' advice regarding management of this pest may be incurred by the producer.

Domestic trade

D – Significant at the district level

If the mealybugs become established in part of Australia, it is likely to result in interstate trade restrictions on many commodities such as apples, pears and citrus, potential loss of markets and significant industry adjustment.

International trade

C – Significant at the local level

The presence of these mealybugs in commercial production areas of a wide range of commodities (e.g. apples, pears and citrus) might limit access to overseas markets which are free from these pests.

Environment

B – Minor significance at the local level

Pesticide applications or other control activities would be required to control this pest on susceptible crops, which could have minor indirect impacts on the environment.

4.10.7 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for mealybugs | |
|--|-----------------|
| Overall probability of entry, establishment and spread | Moderate |
| Consequences | Low |
| Unrestricted risk | Low |

As indicated, the unrestricted risk for mealybugs has been assessed as 'low', which exceeds Australia's ALOP. Therefore, specific risk management measures are required for this pest.

4.11 *Citrophilus mealybug* - *Pseudococcus calceolariae*

4.11.1 Introduction

Pseudococcus calceolariae (citrophilus mealybug) is not present in Western Australia and is a pest of regional quarantine concern for that state.

Pseudococcus calceolariae belongs to the mealybug family Pseudococcidae which are small, oval, soft-bodied insects that are covered with a white, cottony or mealy wax secretion that is moisture repellent and protects them against desiccation (CUES 2007). Mealybugs are sucking insects that injure plants by extracting large quantities of sap. Feeding weakens and stunts plants, causing leaf distortion, premature leaf drop, dieback and even plant death (Lindquist 2000). *Pseudococcus calceolariae* is a serious pest of citrus in South Australia (Smith *et al.* 1997)

Females and males of mealybugs have a different life cycle. Female mealybugs develop from an egg through three nymphal (immature instar) stages before undergoing a final moult into the adult form (CAB International 2008). Adult females are 3–4 mm long, slow-moving and oval-shaped. Males develop from eggs through first and second feeding instars, and third and fourth non-feeding instars, before moulting into tiny winged adults, which possess a pair of long wax terminal filaments (CUES 2007). Although the nymphs and adults live mainly on the bark of apple trees, they can also be found on fruit and tend to live either around or in the calyx of the fruit. *Pseudococcus calceolariae* reproduces three to four generations per year (CAB International 2008).

The risk scenario of concern for *P. calceolariae* is the presence of nymphs or adults on apple fruit.

Pseudococcus calceolariae was assessed in the *Final Import Risk Analysis Report for Apples from New Zealand* (Biosecurity Australia 2006a) and New Zealand stone fruit to Western Australia (Biosecurity Australia 2006b). The assessment of *P. calceolariae* presented here builds on the previous assessments.

The probability of importation for *P. calceolariae* was rated as ‘high’ in the assessments in the New Zealand apple IRA (Biosecurity Australia 2006a) because this species is widespread in New Zealand.

The probability of distribution of *P. calceolariae* will not differ for the same commodity (apples) after arrival in Australia. The probability of establishment and of spread in Australia, and the consequences it may cause will be the same for any commodity in which the species is imported into Australia. Accordingly, there is no need to re-assess these components. However, differences in commodities, horticultural practices, climatic conditions and the prevalence of the pest between previous export areas (New Zealand) and China make it necessary to re-assess the likelihood that *P. calceolariae* will be imported to Australia with apples from China.

4.11.2 Reassessment of probability of importation

The likelihood that *P. calceolariae* will arrive in Western Australia with the importation of the commodity: **MODERATE**.

- Wang (1985) reports *P. gahani* Green (a synonym of *P. calceolariae* (Ben-Dov 2005b)) in Hebei and Henan provinces although the main apple export areas of Shaanxi and Shandong are not listed.
- AQSIQ (2007; 2008c) claims that *P. calceolariae* has only been recorded in southern China from Taiwan, Yunnan and Guangxi, which are not apple production areas, and has not been reported from northern China (apple-growing area), and that there is no report of *P. calceolariae* occurring on apples in China, probably overlooking the synonymy between *P. calceolariae* and *P. gahani*.
- *Pseudococcus calceolariae* has been recorded in China on apple (Ben-Dov 2005b).
- This mealybug species usually occurs on leaves, but can also be found on fruit, including the calyx (CAB International 2008).
- As the mealybugs can be present in the calyx of apple fruit, they are likely to be overlooked during pre-export sorting and packing processes.
- *Pseudococcus calceolariae* overwinter under the bark of deciduous pipfruit trees, and on a range of other host plants associated with the crop, including shelter-belts (HortResearch 1999). It is likely that temporary cold storage may not be effective in killing this mealybug.
- *Pseudococcus calceolariae* has been detected at on-arrival inspection in the USA on New Zealand apples exported to the USA (USDA-APHIS 2003), indicating that it can survive on apples during transportation.

The distribution of this pest in Hebei and Henan but not in Shaanxi and Shandong, its association with fruit, including the calyx, and its inconspicuousness support a risk rating for importation of ‘moderate’.

4.11.3 Probability of distribution, of establishment and of spread

As indicated above, the probability of distribution, of establishment and of spread for *P. calceolariae* will be the same as those assessed for apples from New Zealand (Biosecurity Australia 2006a). The ratings from the previous assessments are presented below:

| | |
|-------------------------------|-----------------|
| Probability of distribution: | MODERATE |
| Probability of establishment: | HIGH |
| Probability of spread: | HIGH |

4.11.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of ‘rules’ for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *P. calceolariae* will enter Western Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Western Australia: **LOW**.

4.11.5 Consequences

The consequences of the establishment of *P. calceolariae* in Western Australia have been estimated previously for apples from New Zealand (Biosecurity Australia 2006a). This estimate of impact scores is provided below:

| | |
|--------------------------------------|----------|
| Plant life or health | D |
| Any other aspects of the environment | A |
| Eradication, control, etc. | C |
| Domestic trade | B |
| International trade | B |
| Environment | B |

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are ‘**D**’, the overall consequences are estimated to be **LOW**.

4.11.6 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for citrophilus mealybug | |
|--|-----------------|
| Overall probability of entry, establishment and spread | Low |
| Consequences | Low |
| Unrestricted risk | Very low |

As indicated, the unrestricted risk for citrophilus mealybug has been assessed as ‘very low’, which achieves Australia’s ALOP. Therefore, specific risk management measures are not required for this pest.

4.12 Summer fruit tortrix moth - *Adoxophyes orana*

4.12.1 Introduction

Adoxophyes orana (summer fruit tortrix moth) belongs to the insect family Tortricidae, which is an economically important group with many representatives causing major economic damage to agricultural, horticultural and forestry industries (Meijerman and Ulenberg 2000). *Adoxophyes orana* is a major pest of pome and stone fruit.

Adoxophyes orana has four life stages: egg, larva, pupa and adult (Ma 2006). Adults are yellow-brown and 6-8 mm long, with a wingspan of 15-20 mm. Eggs are about 0.7 mm, and are laid in rows, mainly on the surface of leaves, but also can be found on the back of leaves, fruit and trunks of apple and other fruit trees. Larvae are slender, 13-18 mm in length, and have soft smooth skin and fine sparse hairs. Newly hatched larvae congregate to feed on the back of leaves, or in the existing leaf rolls and then disperse to roll their own leaf. As the larvae develop, they can also move onto fruit. Pupation occurs in the feeding sites, pupae are 9-11 mm long. This species may have one to four generations per year (Ma 2006).

The risk scenario of concern for *A. orana* is that larvae may move onto and bore into apple fruit and remain undetected.

Adoxophyes orana was included in the existing import policy for pears from China (Biosecurity Australia 2005b; AQIS 1998b) and Fuji apples from Japan (AQIS 1998a). The assessment of *A. orana* presented here builds on these existing pest risk assessments.

4.12.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that *A. orana* will arrive in Australia with the importation of the commodity: **LOW**.

- *Adoxophyes orana* is a pest of apple fruit in China. Eggs are mainly laid on the surface of leaves but also can be laid on the back of leaves, fruit and trunks of apple and other fruit trees (Ma 2006; Savopoulou-Soultani *et al.* 1985; Carter 1984). Newly hatched larvae feed on young leaves and shoots close to the egg-laying sites and growing larvae can curl or roll the leaves and chew the skin of the fruit when the fruit attaches to the rolled leaves (Ma 2006). Infestations can be severe (CAB International 2008).
- Larvae and pupae of *A. orana* spin silken shelters that attach directly to apples, or under leaves or twigs stuck to the fruit (CAB International 2008). Although *A. orana* attaches itself to the fruit, these silken shelters may be disrupted and/or removed during standard harvesting, quality sorting and packing procedures.
- *Adoxophyes orana* larvae on the outside of the fruit are reported to fall to the ground on a silk or thread when disturbed. This has been described as a possible escape mechanism (CAB International 2008) and may lower the chance of larvae being harvested with the apple. In addition, fruit infested with *A. orana* may not be chosen for export because

damage to young fruit can result in premature fruit drop and damage to mature fruit may be visible, including scarring, pitting and abnormal shape (CAB International 2008), which could prevent this fruit from passing quality checks.

- *Adoxophyes orana* can cause damage to more than 50% of fruit (CAB International 2008). When attached directly to apple fruit, *A. orana* larvae can burrow into it underneath the silken shelter (CAB International 2008; Carter 1984).
- Mature larvae are 13-18 mm long and pupal length is 9-11 mm (Ma 2006). Both mature larvae and pupae can be seen with the naked eye and if externally borne, they could be detected and removed before export. However, immature larvae are smaller and both eggs and larvae are translucent yellow for part of their development (CAB International 2008), increasing the chance of overlooking their presence on the fruit surface.
- *Adoxophyes orana* overwinters as second instar larvae (Ma 2006). Larvae of *A. orana* can survive transport and cold storage by going into diapause (Milonas and Savopoulou-Soultani 2004). Diapausing *A. orana* larvae on apple from Korea were reported to be tolerant of freezing temperatures (Jo and Kim 2001).

The association of eggs, and sometimes larvae, with the fruit, combined with conspicuous fruit damage that results in removal of infested fruit, supports a risk rating for importation of 'low'.

Probability of distribution

The likelihood that *A. orana* will be distributed in Australia in a viable state as a result of processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **MODERATE**.

- *Adoxophyes orana* has a very wide host range, and fruit tree hosts including apple, apricot, peach and plum are widely distributed throughout Australia in domestic, commercial and wild environments. The polyphagous nature of *A. orana* increases the chance that it will come in contact with a suitable host.
- It is expected that once apple fruit has arrived in Australia it would be distributed widely throughout the country for repacking and/or retail sale.
- *Adoxophyes orana* residing within the fruit would not be externally visible and infested apples may travel unnoticed to their destination.
- Human consumption is the intended use for the commodity in Australia. Individual consumers will distribute small quantities of apples to a variety of urban, rural and wild environments, where infested fruit could be disposed of in close proximity to a suitable host.
- Commercial waste will also be discarded in Australia prior to retail sale for human consumption. *Adoxophyes orana* is able to survive and develop in apples and other organic material. Commercial waste material may contain *A. orana* and may be deposited near suitable hosts.
- Diapause in *A. orana* is reportedly temperature and photoperiod dependant, breaking in spring when temperatures increase (CAB International 2008; Milonas and Savopoulou-Soultani 2004). If apples are removed from cold storage, diapause is likely to be broken, leading to pupation and adult emergence (Milonas and Savopoulou-Soultani 2004).
- Reproduction requires the mating between male and female adults (Ma 2006). If adults are present they could fly to reach nearby hosts. Simultaneous breaking of diapause

would cause all *A. orana* present to emerge at the same time as adults, thus increasing the chance of mating. Female moths attract males by releasing of sex pheromone.

- If apples are kept cold in storage and transport, imported *A. orana* is likely to be in the larval or pupal life stage and development would be slow. Larvae are known to diapause and egg development stops at temperatures lower than 9 °C (CAB International 2008). The unaided movement of larvae to nearby hosts would be limited to crawling distance.

The immature life stages' association with fruit, moderated by the need to complete development and find a mate for sexual reproduction, supports a risk rating for distribution of 'moderate'.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The likelihood that *A. orana* will enter Australia as a result of trade in the commodity and be distributed in a viable state to a suitable host: **LOW**.

4.12.3 Probability of establishment

The likelihood that *A. orana* will establish, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **HIGH**.

- *Adoxophyes orana* is known to feed on a wide range of plants such as apples and stone fruit spanning many plant families (Zhou and Deng 2005; Davis *et al.* 2005; Waite and Hwang 2002). Fruit trees and other hosts of *A. orana* occur commonly throughout Australia.
- Under optimal conditions, *A. orana* can reproduce prolifically. A single female moth can lay more than 300 eggs, many of which hatch and survive to adulthood (CAB International 2008; Waite and Hwang 2002). In the laboratory, Stamenkovic and Stamenkovic (1985) found the maximum total fecundity to be 273 eggs per female at 18 °C.
- *Adoxophyes orana* generation time is temperature dependant, with warmer temperatures leading to more generations per year. Normally *A. orana* completes 2-3 generations per year in China (CAB International 2008). When reared by Milonas and Savopoulou-Soultani (2000) in the laboratory, the total development time ranged from 50.2 days at 14 °C to 20.7 days at 25 °C.
- Optimal temperatures for the survival and development of *A. orana* match those present throughout much of Australia. In addition, *A. orana* is distributed throughout both warm and cool areas of the world, and many parts of Australia have similar climates to areas where *A. orana* is currently distributed. Adult *A. orana* moths are reported to fly most actively at 23 °C, with continuous long flights reduced at temperatures under 18 °C. Suitable temperatures for female flight ranged from 20.5 to 28 °C in the Japanese species *A. honmai* (Shirai and Kosugi 2000). A rise in temperature of 2 to 3 °C can induce earlier adult emergence and lead to 1-2 more generations per year (Yamaguchi *et al.* 2001). Given this, it is likely that *A. orana* would be well suited to establishment throughout much of Australia.
- Existing control programs in Australia, such as broad spectrum pesticides (CAB International 2008; Charmillot and Brunner 1989) are unlikely to prevent establishment of *A. orana*, as they are not routinely applied to all hosts and may not be applied at the

right time. The timing of pesticide application is important, as older larvae are not easily controlled (Charmillot and Brunner 1989). Resistance to pesticides has been recorded in *Adoxophyes* spp. (Funayama and Takahashi 1995).

Polyphagy, high fecundity, the ability to adapt to a wide climatic range and the potentially limited success of control measures all support a risk rating for establishment of ‘high’.

4.12.4 Probability of spread

The likelihood that *A. orana* will spread, based on a comparison of factors in both the area of origin and Australia that affect expansion of the geographic distribution of the pests: **HIGH**.

- Many hosts of *A. orana* are distributed throughout Australia, including in suitable domestic, commercial and wild environments close to fruit production areas. This large overall number of hosts would facilitate the spread of *A. orana*.
- Several different studies have been conducted on the flying ability of adult *A. orana* moths, with flight distances ranging from 75 metres (Minks *et al.* 1971) to 400 metres (Barel 1973).
- Larvae of *A. orana* may also be able to disperse by wind, but probably for short distances. If disturbed, larvae are reported to drop down on a thread. This behaviour has also been hypothesised as being a possible mechanism for wind dispersal (CAB International 2008).
- Natural barriers such as arid areas and climatic differences in parts of Australia may limit the spread of *A. orana*.
- If infested apples from Australian orchards where *A. orana* becomes established are sold on the domestic market, this could increase opportunities for this species to spread and establish in other areas via a similar pathway to the initial introduction (e.g. disposal of infested apples intended for human consumption).
- The reported natural enemies of *A. orana* in China include egg, larval and pupal parasitoids, spiders and fungi (Ma 2006). The parasitoids include *Itopectis alternans spectabilis* (Matsumura), *Pimpla disparis* Viereck, *Trichogramma dendrolimi* Matsumura, all of which are not present in Australia. Unidentified parasitoid species of *Apanteles*, *Ascogaster*, *Goniozus* and *Trichogramma* are also reported as natural enemies of *A. orana*.

Readily available hosts and strong flight ability support a risk rating for spread of ‘high’.

4.12.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of ‘rules’ for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *A. orana* will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **LOW**.

4.12.6 Consequences

The consequences of the establishment of *A. orana* in Australia have been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are 'E', the overall consequences are estimated to be **MODERATE**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|---|--|
| DIRECT | |
| Plant life or health | <p>E – Significant at the regional level</p> <p><i>Adoxophyes orana</i> has a very wide host range, having so far been recorded on over 50 plant species spanning many plant families and including many economically important food crops such as apples, pears and stone fruit (CAB International 2008; Zhou and Deng 2005; Davis <i>et al.</i> 2005).</p> <p><i>Adoxophyes orana</i> can cause severe direct damage to plants and has been recorded as causing up to 50% losses in some fruit crops (Davis <i>et al.</i> 2005). Larvae feed on fruit, retarding the ability of plants to reproduce and causing leaf curl, holes in fruit, fruit drop, stunting of shoot growth, and delay in production of flowers and fruit, as well as a general decline in plant vigour (CAB International 2008). Severe outbreaks can cause widespread damage, for example, 33 000 hectares of apples were damaged by <i>A. orana</i> in the Netherlands during the late 1980s (Davis <i>et al.</i> 2005).</p> |
| Other aspects of the environment | <p>B – Minor significance at the local level</p> <p>[Note that <i>Adoxophyes</i> species were rated 'D' for this criteria in the Japan unshu mandarin draft IRA report because the assessment included <i>A. honmai</i> which feeds on <i>Eucalyptus</i> species.]</p> <p>It is possible that <i>A. orana</i> will compete directly for resources with native leafrollers and other species. It is also possible that <i>A. orana</i> would be able to attack some species of <i>Eucalyptus</i>, the dominant canopy plants throughout most of Australia, because a closely related species <i>Adoxophyes honmai</i> is a pest of <i>Eucalyptus</i> spp. (Nasu <i>et al.</i> 2004).</p> |
| INDIRECT | |
| Eradication, control etc. | <p>E – Significant at the regional level</p> <p>Programs to minimise the impact of <i>A. orana</i> on host plants are likely to be costly and include pesticide and pheromone applications, crop monitoring, and the possible introduction of biological control agents. Existing control programs may be effective for some, but not all hosts and success is dependant on timing relative to pest life stage.</p> <p>Resistance to pesticides has been recorded in <i>Adoxophyes</i> species and could make eradicating and controlling <i>A. orana</i> difficult (Funayama and Takahashi 1995).</p> |
| Domestic trade | <p>D – Significant at the district level</p> <p>The presence of <i>A. orana</i> in commercial production areas could result in interstate trade restrictions on a wide range of commodities. These restrictions can lead to loss of markets.</p> |

| | |
|----------------------------|--|
| International trade | <p>D – Significant at the district level</p> <p>The presence of <i>A. orana</i> in commercial production areas of a range of commodities (e.g. pome fruit, longan and lychee, stone fruit) may limit access to overseas markets where <i>A. orana</i> is not present. Additionally, existing export trade of host plant commodities may be compromised.</p> |
| Environment | <p>B – Minor significance at the local level</p> <p>Additional pesticide applications would be required to control this pest on susceptible crops, which could have minor indirect impacts on the environment.</p> |

4.12.7 Unrestricted risk

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for summer fruit tortrix moth | |
|--|-----------------|
| Overall probability of entry, establishment and spread | Low |
| Consequences | Moderate |
| Unrestricted risk | Low |

As indicated, the unrestricted risk for summer fruit tortrix moth has been assessed as ‘low’, which exceeds Australia’s ALOP. Therefore, specific risk management measures are required for this pest.

4.13 Apple fruit moth - *Argyresthia assimilis*

4.13.1 Introduction

Argyresthia assimilis (apple fruit moth) belongs to the insect family Yponomeutidae, which is commonly known as ermine moths. It is a pest of apples in Shaanxi and Gansu, China (Sun and Ma 1999).

Argyresthia assimilis has four life stages: egg, larva, pupa and adult. Adults are yellowish–white and 4–6 mm long, with a wingspan of 14–16 mm. Eggs are long-oval, 0.4–0.5 mm long and 0.2 mm wide. Newly hatched larvae bore into the fruit, eating flesh as well as seed. Larvae are slender and old larvae are 7–9 mm long. Mature larvae drop down from fruit and pupate in the soil. There is one generation per year. (Sun and Ma 1999).

The risk scenario of concern for *A. assimilis* is the presence of eggs and larvae on and/or in apple fruit.

4.13.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that *A. assimilis* will arrive in Australia with the importation of the commodity: **LOW**.

- *Argyresthia assimilis* has been reported as a pest of apple in Shaanxi and Gansu, China (Sun and Ma 1999). There is no evidence of official control measures in place to prevent its spread to other provinces.
- Each adult female lays about 50 eggs. Eggs are scattered around the hairy area of the calyx with 1–10 (maximum 20) eggs per fruit. Newly hatched larvae bore into the fruit from the calyx. Feeding damage is obvious as fruit juices seep from the entry hole and dry as white powder. Eventually, the entry point becomes a needle-hole-like black spot surrounded by a concave green ring. Larvae feed on seeds and each needs to consume two seeds to complete its development. One fruit can have 1–20 entry holes but only 4–5 larvae can complete development. Mature larvae exit the fruit mostly from the calyx or stem end. The exit hole is about 1 mm in diameter (Sun and Ma 1999).
- *Argyresthia assimilis* has one generation a year, with pupae overwintering in soil. Adults emerge from late May to late July, with a peak from early to middle June. Larvae bore into fruit with a peak in July and leave fruit from the middle of August to mid-September to pupate and overwinter in soil. Most larvae would have left the fruit when apples are harvested in October although harvesting can start in late August for the Gala variety (AQSIQ 2005).
- Packinghouse procedures are unlikely to detect larvae still feeding inside the fruit, because the entry point is small and concealed in the calyx.

The eggs laid on fruit and larvae feeding on seeds inside the fruit, moderated by the completion of egg hatching and most larvae exiting from the fruit before harvesting, support a risk rating for importation of ‘low’.

Probability of distribution

The likelihood that *Argyresthia assimilis* will be distributed in Australia in a viable state as a result of the processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **MODERATE**.

- Apple fruit is intended for human consumption and *A. assimilis* may remain on the fruit during retail distribution. The calyx of infested fruit is unlikely to be consumed, and disposal of fruit waste may further aid distribution of viable larvae. Disposal of infested waste fruit is likely to be via commercial or domestic rubbish systems, as well as directly into the environment as litter.
- *Argyresthia assimilis* can enter the environment through the flight of adults that would emerge from pupae developed from larvae coming out from the fruit. Adults are weak flyers and each flight may last for 4-5 m (Sun and Ma 1999).
- Reproduction is sexual and requires a male and female adult to be present (Sun and Ma 1999).
- The host plants of *A. assimilis* are Chinese crab apple as well as apple (Sun and Ma 1999). Apples are grown commercially and in household gardens in Australia and may also be present as feral plants in some parts of Australia.

The association of larvae with fruit, moderated by the need to complete development and find a mate for sexual reproduction and the limited host range supports a risk rating for distribution of ‘moderate’.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The likelihood that apple fruit moth will enter Australia as a result of trade in the commodity and be distributed in a viable state to a suitable host: **LOW**.

4.13.3 Probability of establishment

The likelihood that *A. assimilis* will establish based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **HIGH**.

- *Argyresthia assimilis* has been reported on apples and Chinese crab apple (Sun and Ma 1999). Apples are commonly grown in Australia.
- *Argyresthia assimilis* is found in Shaanxi and Gansu, China (Sun and Ma 1999), a temperate region. Similar climatic conditions occur in Australia and *A. assimilis* could establish in these areas if apples are present.
- *Argyresthia assimilis* reproduces sexually and has one generation per year in China (Sun and Ma 1999). Male and female moths are required for reproduction to occur.
- Existing control programs in Australian apple orchards, such as broad spectrum pesticide application, are unlikely to prevent establishment of *A. assimilis* as they are not routinely applied to other suitable habitats such as trees on roadsides or household gardens.

The availability of the host and the suitability of climatic conditions support a risk rating for establishment of ‘high’.

4.13.4 Probability of spread

The likelihood that *Argyresthia assimilis* will spread, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pest: **MODERATE**.

- *Argyresthia assimilis* occurs in the temperate area of China (Sun and Ma 1999) and similar conditions occur in Australia to support its spread.
- Apples are grown in six states of Australia; however, there are natural barriers, such as arid areas, climatic differentials and long distances between production areas.
- Apart from commercial orchards, apples are also grown in home gardens, in parks and along roads, which could add to the dispersal of *A. assimilis*.
- Adults can fly 4-5 m (Sun and Ma 1999), which would allow spread in and between adjacent orchards. Larvae may be spread over larger distances through transport of infested fruit.
- No specific natural enemies have been reported for *A. assimilis*.

The suitability of the climatic conditions, moderated by the limited hosts and weak ability of adult flight, supports a risk rating of ‘moderate’.

4.13.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of ‘rules’ for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *A. assimilis* will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **LOW**.

4.13.6 Consequences

The consequences of the establishment of *Argyresthia assimilis* in Australia have been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are ‘D’, the overall consequences are estimated to be **LOW**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|-----------------------------|---|
| DIRECT | |
| Plant life or health | <p>D – Significant at the district level</p> <p><i>Argyresthia assimilis</i> has only been reported on apple, a commercially important crop in Australia, and Chinese crab apple. It is a pest of apple in Shaanxi and Gansu</p> |

provinces of China and fruit infestation in these areas reached 30-67% in the early 1980s (Sun and Ma 1999).

| | |
|---|---|
| Other aspects of the environment | <p>B – Minor significance at the local level</p> <p>There are no known direct consequences of this species on the natural or built environment, but its introduction into a new environment may lead to competition for resources with native species.</p> |
| INDIRECT | |
| Control, eradication, etc. | <p>D – Significant at the district level</p> <p>Programs to minimise the impact of <i>A. assimilis</i> on host plants are likely to be costly and include additional pesticide applications and crop monitoring expenses.</p> <p>Indirect consequences of eradication or control programs for <i>A. assimilis</i> may include: (i) an increase in the use of pesticides for control of the pest, due to the unclear time of application; (ii) disruption to established integrated pest management; (iii) potential for other pests to develop resistance to pesticides as a result of the use of pesticides to control <i>A. assimilis</i>, (iv) use of additional measures and impacts on existing production practices; (v) increase in cost of production that could alter the economic viability of the crop; and (vi) additional cost of crop monitoring and consultative advice to producers.</p> |
| Domestic trade | <p>D – Significant at the district level</p> <p>If <i>A. assimilis</i> is established in Australia, it is likely to result in interstate trade restrictions on apples and potential loss of markets. This could require significant industry adjustment.</p> |
| International trade | <p>D – Significant at the district level</p> <p>The presence of <i>A. assimilis</i> in commercial production areas of apples might limit access to overseas markets which are free from this pest.</p> |
| Environment | <p>B – Minor significance at the local level</p> <p>Pesticide applications or other control activities would be required to control this pest on apples, which could have minor indirect impacts on the environment.</p> |

4.13.7 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for apple fruit moth | |
|--|----------|
| Overall probability of entry, establishment and spread | Low |
| Consequences | Low |
| Unrestricted risk | Very Low |

As indicated, the unrestricted risk for apple fruit moth has been assessed as ‘very low’, which achieves Australia’s ALOP. Therefore, no specific risk management measures are required for this pest.

4.14 Peach fruit moth - *Carpocapsa sasakii*

4.14.1 Introduction

Carpocapsa sasakii (peach fruit moth) belongs to the insect family Carposinidae. In this family only a few species are of minor economic importance as borers in fruits, flower buds, bark and galls. *Carpocapsa sasakii* (peach fruit moth) is a serious pest of pome fruits and peach (CAB International 2008).

Carpocapsa sasakii has four life stages: egg, larva, pupa and adult (Ma 2006). Adults are white-grey to brown-grey. Females are 7-8 mm long with a wingspan of 15-19 mm and males are 5-6 mm long with a wingspan of 13-15 mm (CAB International 2008; Ma 2006). Eggs are laid on the fruit near the calyx, and the young larvae hatch and bore into the fruit through the calyx. Larvae are peach to red and 13-16 mm long. Pupae are 6.5-8.6 mm long and pupation occurs in the soil. This species has one to three generations per year (Ma 2006).

The risk scenario of concern for *C. sasakii* is the presence of larvae within the apple fruit.

Carpocapsa sasakii was included in the existing import policy for pears from China (Biosecurity Australia 2005b; AQIS 1998b) and Fuji apples from Japan (AQIS 1998a). The assessment of *C. sasakii* presented here builds on these existing pest risk assessments.

4.14.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that *C. sasakii* will arrive in Australia with the importation of the commodity: **HIGH**.

- *Carpocapsa sasakii* is recorded as a major pest in China, where it damages apple, pear and a wide range of other fruit crops (CAB International 2008; Xu and Hua 2004; Feng *et al.* 2004).
- Females lay eggs on the fruit near the calyx and the young larvae hatch and bore into the fruit through the calyx (Ma 2006). Larvae eat the flesh, but avoid the skin, leaving no external evidence. Because the larvae reside entirely within the fruit, they may not be noticed during standard harvesting, quality sorting and packing procedures.
- *Carpocapsa sasakii* survives the winter by undergoing diapause (Lee *et al.* 1963). Diapausing *C. sasakii* larvae can survive for long periods in stored fruits (CAB International 2008; Shutova 1970).
- Adult *C. sasakii* moths have a wing span of 15-19 mm and are easily visible (CAB International 2008). Adults are not documented as feeding on apple fruit and may also fly away when disturbed by harvesting and packing. This reduces the chance that *C. sasakii* will be imported to Australia as adults.
- Interceptions of *C. sasakii* are known to occur on internationally traded fresh fruit. For example, *C. sasakii* is found by the United States Department of Agriculture inspectors almost every year on fresh fruit from Japan and Korea (CAB International 2008).

Eggs laid on the fruit, larvae developing inside the fruit, leaving no external evidence, and the interception of peach fruit moth on internationally traded fresh fruit, all support a risk rating for importation of ‘high’.

Probability of distribution

The likelihood that *C. sasakii* will be distributed in Australia in a viable state as a result of processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **HIGH**.

- *Carposina sasakii* has a wide range of hosts, mainly within the Rosaceae, but also other families (CAB International 2008) which increases the chances that *C. sasakii* will contact a suitable host.
- Hosts such as apples, pears and stone fruit are widely distributed throughout Australia in domestic, commercial and wild environments.
- It is expected that once the apple fruit has arrived in Australia it would be distributed widely throughout the country for repacking and/or retail sale.
- On average, female adults live for 13 days and male adults 16 days at 23 °C in laboratory conditions (Ishiguri and Shirai 2004). The adults would be able to fly to reach nearby hosts up to 225 metres away (Sun *et al.* 1987).
- Human consumption is the intended end use for the commodity in Australia. Individual consumers will distribute small quantities of apples to a variety of urban, rural and wild environments, where infested fruit could be disposed of in close proximity to a suitable host.
- Commercial waste will also be discarded in Australia prior to retail sale of imported apples for human consumption, at various points along the distribution pathway. As larvae can develop within and move between fruit, spoilt apples and other waste material may contain *C. sasakii*. Commercial waste could be deposited near suitable hosts or pupation sites.
- *Carposina sasakii* larvae and pupae can live in the soil. Even if the larvae and pupae are not distributed to a host immediately, they could still survive and subsequently be moved to a suitable host. Late instar larvae need only be distributed to soil suitable for pupation and from there emergent adults could fly to reach new hosts.

The ability of larvae and pupae to live in soil, combined with a wide host range and the capacity of adults to fly, supports a risk rating for distribution of ‘high’.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The likelihood that *C. sasakii* will enter Australia as a result of trade in the commodity and be distributed in a viable state to a suitable host: **HIGH**.

4.14.3 Probability of establishment

The likelihood that *C. sasakii* will establish based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **HIGH**.

- *Carposina sasakii* is known to feed on a wide range of cultivated fruit trees, such as apple, pear and stone fruit, especially the Rosaceae, but also other families (CAB International 2008).

- *Carposina sasakii* is able to survive in both warm and cool areas of Asia and the former USSR (CAB International 2008) that have climatic conditions similar to parts of Australia. Most of Australia's fruit growing regions have a warm temperate climate where *C. sasakii* could not only survive, but flourish.
- Although *C. sasakii* might only complete one generation per year in temperate climates (CAB International 2008), there are reports of three annual generations in Shandong, Jiangsu and Henan provinces in China (Ma 2006).
- *Carposina sasakii* generations are known to overlap (CAB International 2007a; Ma 2006), ensuring a long period of susceptibility to exposure for fruit.
- *Carposina sasakii* appears to adapt both genetically and behaviourally in response to the characteristics of its host and geographic locality (Xu and Hua 2004). The emergence of the first generation of moths in Hokkaido (Japan) has been found to be well synchronised with the growth of the main apple cultivars there (Kajino and Nakao 1977). In China, different biotypes emerge at different times according to the host plant (CAB International 2007a; Hua and Hua 1995). This type of adaptation may also occur in Australia, enhancing the ability of *C. sasakii* to establish a viable population.
- Up to 13 larvae have been recorded in a single fruit (Yago and Ishikawa 1936). Because many larvae can inhabit each infested fruit, this increases the chance for both male and female to be present within a single fruit to establish a population.
- Existing control programs in Australian orchards, such as broad spectrum pesticide application would be unlikely to prevent establishment of *C. sasakii* as they are not routinely applied to all hosts, or all suitable habitats. Specific systems approaches, such as a combination of pheromone monitoring (Kang 1995; Lee *et al.* 1994; Jiang *et al.* 1986), chemical application to the soil, foliar sprays and the mechanical removal of fallen fruit (Feng 1997) are generally required to control *C. sasakii* in its current distribution.

Polyphagy, the wide climatic range distribution and the potentially limited success of control measures all support a risk rating for establishment of 'high'.

4.14.4 Probability of spread

The likelihood that *C. sasakii* will spread based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pests: **HIGH**.

- Fruit trees such as apple, pear, stone fruit and other hosts of *C. sasakii* are distributed widely throughout Australia, including in suitable domestic, commercial and wild environments close to fruit production areas.
- Although *C. sasakii* moths can fly, they can normally only travel short distances. In a study conducted in China, 80% of marked adults dispersed randomly within a radius of 100 m and the furthest distance an adult dispersed was 225 m (CAB International 2007a; Sun *et al.* 1987).
- If infested apples from Australian orchards where *C. sasakii* becomes established are sold on the domestic market, this could increase opportunities for the species to spread and establish in other areas via a similar pathway to the initial introduction (e.g. disposal of infested apples intended for human consumption).
- Natural barriers such as arid areas and climate differences may limit the natural spread of *C. sasakii* between eastern and western Australia.

- Although some larvae may overwinter in fruit in storage, *C. sasakii* mostly overwinters by hibernating in the soil near fruit trees (CAB International 2007a) and may be spread on soil-contaminated produce and/or machinery.
- The potential for natural enemies in Australia to reduce the spread of *C. sasakii* is unknown. Although several natural enemies of *C. sasakii* have been recorded within its current distribution (CAB International 2007a; Lu *et al.* 1993; Yaginuma and Takagi 1987; Pschorn-Walcher 1964; Sekiguchi 1960), it is unknown whether they limit this pest's geographical range.

Readily available hosts and the ability of adults to fly support a risk rating for spread of 'high'.

4.14.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of 'rules' for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *C. sasakii* will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **HIGH**.

4.14.6 Consequences

The consequences of the establishment of *C. sasakii* in Australia have been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are 'E', the overall consequences are estimated to be **MODERATE**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|---|--|
| DIRECT | |
| Plant life or health | <p>E – Significant at the regional level</p> <p><i>Carposina sasakii</i> is a serious pest of pome fruit and peach (CAB International 2007a). It is considered one of the most important fruit pests in the Far East (CAB International 2007a). On apples in Japan, Korea Republic and China, it may cause heavy losses if not controlled (USDA 1958b). In China, together with <i>Grapholita inopinata</i>, it is recorded as destroying about one-third of the apple crop in Liaoning province (Hwang and Woo 1958). It is also damaging to <i>Ziziphus jujube</i> (Chinese jujube) crops.</p> <p>In the Primor'e territory of Russia, <i>C. sasakii</i> is the most damaging fruit moth. Damage to apples and pears can reach 100% in some cases; apricots and plums are also attacked (Gibanov and Sanin 1971; Sytenko 1960).</p> |
| Other aspects of the environment | <p>B – Minor significance at the local level</p> <p>There are no known direct consequences of <i>C. sasakii</i> for the natural environment, but its introduction into a new environment may lead to competition for resources with native species.</p> |

INDIRECT**Eradication,
control etc.****E** – Significant at the regional level

Programs to contain, eradicate and/or minimise the impact of this pest are likely to be costly and include pesticide application as well as crop monitoring. Existing controls (e.g. specific integrated pest management or organic systems) for other pests in Australia may be ineffective against *C. sasakii*.

Control of *C. sasakii* can be compared to methods used for codling moth (*Cydia pomonella*).

In China, a range of chemicals including diazinon, fenitrothion, parathion, fenvalerate, deltamethrin, betacyfluthrin, bifenthrin, chlorpyrifos and cypermethrin (CAB International 2007a; Huan *et al.* 1987) have been employed to control *C. sasakii*. Most of these are broad spectrum insecticides and some are available for use in Australia, however they are not suitable for use in all *C. sasakii* habitats. In addition, chemical spraying alone is unlikely to control *C. sasakii* and a specific systems approach is needed, including sex pheromone monitoring of males to decide when to spray (CAB International 2007a; Li *et al.* 1993; Li *et al.* 1993; Li *et al.* 1986), together with chemicals being applied to the soil and the mechanical removal of infected and fallen fruit (CAB International 2007a).

**Domestic
trade****D** – Significant at the district level

The impact of outbreaks of *C. sasakii* in Australian fruit growing areas would be potential loss of a wide range of Rosaceous fruit crops and reduced trade due to internal quarantine restrictions.

Within-country quarantine measures would be necessary to restrict the spread of *C. sasakii*. If *C. sasakii* becomes established in Australia, internal quarantine measures such as treatment and inspection may be mandatory for fruit trade between states, subsequently increasing the cost of production and domestic quarantine.

**International
trade****E** – Significant at the regional level

Carposina sasakii is regarded worldwide as a severe pest of quarantine concern. It is a risk to production of Rosaceous tree fruits in most parts of the world and the introduction of *C. sasakii* into other regions could have a severe economic impact on fruit-growing (CAB International 2007a).

Carposina sasakii is an A1 quarantine pest for Europe (CABI/EPPO 2007a) and it is also a pest of concern for other trading partners such as Taiwan, Canada and USA.

The presence of *C. sasakii* in commercial production areas of a wide range of commodities (e.g. apple, pear, and stone fruit) would limit access to overseas markets in countries, such as USA, Europe and Taiwan, where *C. sasakii* is not present. Additionally, existing export trade of host plant commodities may be compromised.

Environment**B** – Minor significance at the local level

Additional pesticide applications required to control these pests on susceptible crops, and are likely to be applied via foliar spraying or in granular form to the soil. Recommended insecticides are broad spectrum and affect many arthropods as well as other animals.

Wind dispersal of dry orchard soil containing broad spectrum chemicals in order to control *C. sasakii* larvae and pupae may also have other impacts on the local environment.

4.14.7 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for peach fruit moth | |
|--|-----------------|
| Overall probability of entry, establishment and spread | High |
| Consequences | Moderate |
| Unrestricted risk | Moderate |

As indicated, the unrestricted risk for peach fruit moth has been assessed as ‘moderate’, which exceeds Australia’s ALOP. Therefore, specific risk management measures are required for this pest.

4.15 Codling moth - *Cydia pomonella*

4.15.1 Introduction

Cydia pomonella (codling moth) is not present in Western Australia and is a pest of regional quarantine concern for that state.

Cydia pomonella belongs to the insect family Tortricidae which is an economically important group with many representatives causing major economic damage to agricultural, horticultural and forestry industries (Meijerman and Ulenberg 2000). *Cydia pomonella* is one of the most damaging pests of apple and pear worldwide (CAB International 2008).

Cydia pomonella has four life stages: egg, larva, pupa and adult (Ma 2006). Adults are grey-brown and 8 mm long, with a wingspan of 15-19 mm. Eggs are laid singly on developing fruits and nearby foliage. After hatching, the larva burrows immediately into a fruitlet. Larvae pass through five instars while feeding within the fruit, and then vacate it. Larvae pupate within cracks in the tree trunk, under loose pieces of bark or among debris on the ground. The number of generations per year varies from 1 to 4, depending on the climate and on the host plant (Ma 2006).

The risk scenario of concern for *C. pomonella* is the presence of larvae inside apple fruit.

Cydia pomonella was assessed in the *Final Import Risk Analysis Report for Apples from New Zealand* (Biosecurity Australia 2006a). The assessment of *C. pomonella* presented here builds on the previous assessment.

The probability of importation for *C. pomonella* was rated as ‘moderate’ in the assessments in the New Zealand apple IRA (Biosecurity Australia 2006a).

The probability of distribution of *C. pomonella* will not differ for the same commodity (apples) after arrival in Australia. The probability of establishment and of spread in Australia, and the consequences it may cause will be the same for any commodity in which the species is imported into Australia. Accordingly, there is no need to re-assess these components. However, differences in commodities, horticultural practices, climatic conditions and the prevalence of the pest between previous export areas (New Zealand) and China make it necessary to re-assess the likelihood that *C. pomonella* will be imported to Australia with apples from China.

4.15.2 Reassessment of probability of importation

The likelihood that *C. pomonella* will arrive in Western Australia with the importation of the commodity: **LOW**.

- *Cydia pomonella* has been recorded only in Xinjiang Uygur Autonomous Region and some areas in neighbouring Gansu province, and it is an international and domestic quarantine pest for China (CAAS 1992) under official control.
- Xinjiang is not a major export apple production area. However, Gansu has been nominated by China as one of the nine apple production areas that would export apples to Australia. *Cydia pomonella* has been reported in Denghuang in west Gansu, about 1500 km west of Gansu’s major apple production areas such as Pingliang. Official control measures have been imposed by Gansu to prevent its spread eastward, including

setting up 1300 monitoring points, carrying out surveys, delimiting pest areas, establishing 10 checkpoints, conducting control campaigns and cutting apple trees in unmanaged yards (Wang and Wang 2009).

- *Cydia pomonella* is essentially a pest of pome fruit (Hely *et al.* 1982), and apple is one of its main host plants (AQSIQ 2005).
- On pome fruit, the larvae often enter through the calyx and bore down to the core of the fruit, leaving a prominent entry hole. *Cydia pomonella* feeding causes premature fall of infested fruit (Hely *et al.* 1982).
- As the larvae of *C. pomonella* feed internally within apple fruit, grading and packing processes would not effectively detect and remove all fruit with larvae. However, quality inspection in the packing house is likely to remove at least some infested fruit, as the entrance hole and frass deposited by developing larvae can be easily detected (CAB International 2007a).
- Diapausing *C. pomonella* larvae are cold hardy and can survive exposure to -20 °C for 3 days (Neven 1998). Larvae inside the fruit would be able to survive the packing, quality inspection, containerisation and refrigerated transport to Australia.

The presence of larvae inside the fruit, moderated by its distribution restricted to Xinjiang Uygur Autonomous Region and some areas in neighbouring Gansu province in China, support a risk rating for importation of ‘low’.

4.15.3 Probability of distribution, of establishment and of spread

As indicated above, the probability of distribution, of establishment and of spread for *C. pomonella* will be the same as those assessed for apples from New Zealand (Biosecurity Australia 2006a). The ratings from the previous assessments are presented below:

| | |
|-------------------------------|-----------------|
| Probability of distribution: | MODERATE |
| Probability of establishment: | HIGH |
| Probability of spread: | HIGH |

4.15.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of ‘rules’ for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *C. pomonella* will enter Western Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Western Australia: **LOW**.

4.15.5 Consequences

The consequences of the establishment of *C. pomonella* in Western Australia have been estimated previously for apples from New Zealand (Biosecurity Australia 2006a). This estimate of impact scores is provided below:

| | |
|--------------------------------------|----------|
| Plant life or health | D |
| Any other aspects of the environment | A |
| Eradication, control, etc. | E |

| | |
|---------------------|----------|
| Domestic trade | B |
| International trade | D |
| Environment | B |

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are ‘E’, the overall consequences are estimated to be **MODERATE**.

4.15.6 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for codling moth | |
|--|-----------------|
| Overall probability of entry, establishment and spread | Low |
| Consequences | Moderate |
| Unrestricted risk | Low |

As indicated, the unrestricted risk for codling moth has been assessed as ‘low’, which exceeds Australia’s ALOP. Therefore, specific risk management measures are required for this pest.

4.16 Pyralid moth - *Euzophera pyriella*

4.16.1 Introduction

Euzophera pyriella (pyralid moth) belongs to the insect family Pyralidae. *Euzophera pyriella* was formally described in 1994 (Yang 1994). The species damages the fruit, branches and stems of host trees (Song *et al.* 1994). The larvae feed between the phloem and xylem tissues, and damage the skin, flesh and seeds of fruit (Lu 2004).

Euzophera pyriella has four life stages: egg, larva, pupa and adult (Song *et al.* 1994). Adults are 7-8 mm long with a wingspan of 15-20 mm. Eggs are 0.55-0.6 mm. Larvae are grey-black, 8-15 mm long. Pupae are 7 mm long and pupation occurs in the feeding sites. This species has three generations per year in Xinjiang (Song *et al.* 1994).

The risk scenario of concern for *E. pyriella* is that sometimes the larvae bore into apple fruit.

Euzophera pyriella was included in the existing import policy for pears from China (Biosecurity Australia 2005b; AQIS 1998b). The assessment of *E. pyriella* presented here builds on these existing pest risk assessments.

4.16.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that *E. pyriella* will arrive in Australia with the importation of the commodity: **LOW**.

- *Euzophera pyriella* was first formally described in 1994 from Korla, Xinjiang Uygur Autonomous Region on fragrant pear (Yang 1994) and its host plants include apple (Song *et al.* 1994). AQSIQ (2008a) claims that apple is not a host of *E. pyriella*. However, Song *et al.* (1994) clearly states that apple is a host as well as pear.
- To date, this species has only been reported from Xinjiang (AQSIQ 2008a; AQSIQ 2006a). However, there is no evidence of official control measures in place to prevent its spread to other provinces.
- Larvae are mostly 8-15 mm long (Lu and Deng 2003; Song *et al.* 1994). On fragrant pear, larvae can bore into fruit, feeding on skin, pulp, core and occasionally seeds (Song *et al.* 1994).
- One fruit usually has one larva, but up to five larvae of the same or different instars can feed inside a single fruit at any one time (Song *et al.* 1994). Sometimes, one fruit can contain the larvae of both *E. pyriella* and *Cydia pomonella* (Lu and Deng 2003).
- Larvae of *E. pyriella* can pupate inside the fruit as well as in the stem (Lu and Deng 2003).
- There is a clear relationship between the occurrence of *E. pyriella* and rot disease (Lu and Deng 2003). Larvae prefer to bore into stems where rot disease occurs (Lu and Deng 2003). Larval damage to the host may also result in infection with rot disease.

- Packing house procedures are unlikely to detect larvae feeding inside the fruit but externally damaged fruit would be picked up.
- Mature larvae overwinter in loose bark and sutures of the stem. They also can overwinter in large branches or fruit of apple and pear in Xinjiang (Song *et al.* 1994) where winter temperatures are severe. This indicates that this pest species would be able to survive the low temperature storage and transportation of apple fruit from China to Australia.

The evidence that larvae of the pyralid moth can bore into and pupate undetected in the fruit as well as cause external damage that can be easily detected, and that this species is only reported from Xinjiang, support a risk rating for importation of ‘low’.

Probability of distribution

The likelihood that *E. pyriella* will be distributed in Australia in a viable state as a result of the processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **MODERATE**.

- Apple fruit is intended for human consumption and the larvae feed on the fruit internally. Therefore, larvae may remain in the fruit during retail distribution. Disposal of fruit waste may further aid distribution of viable insects, as an infested apple could be partially consumed and then discarded, with viable larvae inside that could pupate within the remaining fruit.
- Sexual reproduction is essential for this species (Song *et al.* 1994). Adults can fly and could enter the environment by emerging from discarded infested apple fruits. Up to five moths could emerge from a single fruit because it can harbour up to five larvae at any one time (Song *et al.* 1994) and females can mate on the same day after emergence. Larvae can also bore into and pupate in stems of host plants (Song *et al.* 1994).
- The host plants of *E. pyriella* include apple, pear, fig, Chinese dates and poplar (Song *et al.* 1994). Apples and pears are grown commercially and in household gardens in Australia.

The association of larvae with fruit, moderated by the need to complete development and find a mate for sexual reproduction, in turn facilitated by the emergence of up to five moths from a single fruit, supports a risk rating for distribution of ‘moderate’.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The likelihood that *E. pyriella* will enter Australia as a result of trade in the commodity and be distributed in a viable state to a suitable host: **LOW**.

4.16.3 Probability of establishment

The likelihood that *E. pyriella* will establish, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **HIGH**.

- The host plants of *E. pyriella* include apple, pear, fig, Chinese dates and poplar (Song *et al.* 1994). All these hosts are available in Australia.

- *Euzophera pyriella* has only been reported from Xinjiang to date (AQSIQ 2008a; AQSIQ 2006a). At least part of temperate regions of Australia could provide this species with a suitable habitat in which to live and reproduce.
- The genetic adaptability of this species is not known.
- This species reproduces sexually and female moths are fertile from emergence.

Widely available hosts and a suitable temperate climatic condition in Australia support a risk rating for establishment of 'high'.

4.16.4 Probability of spread

The likelihood that *E. pyriella* will spread, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pest: **HIGH**.

- *Euzophera pyriella* was described in Xinjiang in 1994 (Yang 1994) and it has apparently not been found in other parts of China, or outside this country. However, some temperate regions in Australia would be suitable for its spread.
- Commercial fruit crops of apples and pears are grown in six states of Australia; however, there are natural barriers, such as arid areas, climatic differentials and long distances present between production areas.
- Widely distributed suitable hosts in Australia, including apple, pear, fig and poplar trees grown in home gardens, parks and along roads would aid the spread of *E. pyriella*.
- Apples would be used mostly for human consumption and be distributed around the country. Such human-assisted distribution would aid the spread of the larvae on fruit.
- *Euzophera pyriella* adults can fly. Larvae may spread through transport of infested fruit.
- An undescribed parasitoid was reported attacking 17-20% of *E. pyriella* in Xinjiang (Song *et al.* 1994), but it is not likely to be present in Australia.

Readily available hosts and the ability of adults to fly support a risk rating for spread of 'high'.

4.16.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of 'rules' for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *E. pyriella* will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **LOW**.

4.16.6 Consequences

The consequences of the establishment of *E. pyriella* in Australia have been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are 'E', the overall consequences are estimated to be **MODERATE**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|---|--|
| DIRECT | |
| Plant life or health | <p>E – Significant at the regional level</p> <p><i>Euzophera pyriella</i> can cause direct harm to fruit, branches and stems of apple, pear, fig and poplar trees (Song <i>et al.</i> 1994).</p> <p><i>Euzophera pyriella</i> is an important pest for Xiang pear grown in the Korla area of the Xinjiang Autonomous Region, China. It attacks young trees, damages trunks and branches and causes canker development. Infection levels in orchards reach 70-85%. The larvae feed on areas between the phloem and xylem, and damage fruit skin, flesh and seeds (Lu 2004).</p> |
| Other aspects of the environment | <p>B – Minor significance at the local level</p> <p>There are no known consequences of this species on other aspects of the environment, but its introduction into a new environment may lead to competition for resources with native species.</p> |
| INDIRECT | |
| Eradication, control etc. | <p>D – Significant at the district level</p> <p>Programs to minimise the impact of this pest on host plants are likely to be costly and include pesticide applications and crop monitoring.</p> <p>According to Lu (2004) the control measures in China include the following:</p> <ul style="list-style-type: none"> • Scraping and spraying of bark with a sugar-vinegar liquid to control adults. • Chemical control with cypermethrin and Kung Fu [lambda-cyhalothrin]. • Painting bark with 500x solution of 80% dichlorvos and then wrapping stems with film resulted in total control (Lu 2004). <p>These methods are labour intensive and would be expensive to adopt in Australia. In addition, the chemicals used are not approved for use in Australia.</p> |
| Domestic trade | <p>D – Significant at the district level</p> <p>The presence of <i>E. pyriella</i> in commercial production areas would cause interstate trade restrictions on a range of commodities. Apples and pears are grown in several Australian states. If <i>E. pyriella</i> became established in one of these states, then interstate trade would be disrupted.</p> |
| International trade | <p>D – Significant at the district level</p> <p>The major consequence for Australian horticultural industries would be the negative effect the establishment of this pest species may have on gaining and maintaining export markets for apples and pears. The current distribution of <i>E. pyriella</i> is limited to China (Yang 1994; Song <i>et al.</i> 1994).</p> |
| Environment | <p>B – Minor significance at the local level</p> <p>Pesticide applications or other control activities would be required to control this pest on susceptible crops, which could have minor indirect impact on the environment.</p> |

4.16.7 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for pyralid moth | |
|--|-----------------|
| Overall probability of entry, establishment and spread | Low |
| Consequences | Moderate |
| Unrestricted risk | Low |

As indicated, the unrestricted risk for pyralid moth has been assessed as ‘low’, which exceeds Australia’s ALOP. Therefore, specific risk management measures are required for this pest.

4.17 Manchurian fruit moth - *Grapholita inopinata*

4.17.1 Introduction

Grapholita inopinata belongs to the insect family Tortricidae. The larvae damage host fruits by boring under the skin before penetrating the core (Meijerman and Ulenberg 2000).

Grapholita inopinata has four life stages: egg, larva, pupa and adult (Ma 2006). Adults are dark-brown and 4.4-4.8 mm long with a wingspan of 10-11 mm. Eggs are 0.7 mm in diameter, white darkening to pinkish-brown and are laid on leaves and the surface of the fruit (Meijerman and Ulenberg 2000). Larvae are 6-10 mm long and, upon hatching, bore into the fruit. Larvae come out of fruit and search for protected sites along stem and branch to pupate. Pupae are 4.5-5.6 mm long. This species has two generations per year (Ma 2006).

The risk scenario of concern for *G. inopinata* is the presence of eggs on, and larvae inside, apple fruit.

Grapholita inopinata was included in the existing import policy for pears from China (Biosecurity Australia 2005b; AQIS 1998b) and Fuji apples from Japan (AQIS 1998a). The assessment of *G. inopinata* presented here builds on these existing pest risk assessments.

4.17.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that *G. inopinata* will arrive in Australia with the importation of the commodity: **MODERATE**.

- *Grapholita inopinata* is reported in at least 16 provinces in China, including Heilongjiang, Hebei, Henan, Liaoning, Shaanxi and Shandong, and apple is one of its main hosts (Ma 2006).
- Eggs are usually laid on leaves and less often, particularly later in the season, on the fruit (CABI/EPPO 2005). Conversely, Ma (2006) suggested that eggs are mostly laid on the surface of the fruit.
- Larvae bore into fruit and feed under the skin, causing a visible black-brown spot about 1 cm in diameter on the surface of the fruit (Ma 2006). Larvae can also bore into the core of small fruit. Normally there is only one larva present in each infested fruit, but up to five have been recorded (CABI/EPPO 2005).
- There are two generations per year in China (Ma 2006). The first generation occurs from late May to August and larvae occur from mid-June to mid-July. Larvae of the second generation occur from early August to late September and they feed in fruit for about 20 days and leave fruit from late August to late September to search for overwintering sites (Ma 2006). This suggests that the second generation larvae would still be in the fruit of apples harvested in late August and September such as the cultivar Gala (AQSIQ 2005).

- If the larvae are inside apple fruit, the sorting and packing processes would not be effective in detecting and removing them. However, if the black-brown spots on the surface of the fruit caused by the larvae are still visible, this may lead to the removal of some infested fruit.
- In China, mature larvae overwinter in the bark sutures of stems, branches and the root crown, and under dry bark around the pruning cut surface (Ma 2006). This suggests that larvae inside the fruit would be able to survive the storage and transportation of the fruit at low temperatures.

The association of eggs with the fruit, and of larvae boring into the fruit but causing visible black-brown spots on the surface of the fruit that may lead to the removal of some infested fruit during harvesting and packaging, support a risk rating for importation of 'moderate'.

Probability of distribution

The likelihood that *G. inopinata* will be distributed in Australia in a viable state as a result of the processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **MODERATE**.

- Apple fruit is intended for human consumption and the larvae may remain in the fruit during retail distribution. The calyx of infested fruit is unlikely to be consumed, and disposal of fruit waste may further aid distribution of viable insects. Disposal of infested fruit waste is likely to be via commercial or domestic rubbish systems or discarded where it is consumed.
- *Grapholita inopinata* can enter the environment through flight of adults that would emerge from pupae developed from larvae.
- Reproduction requires the mating between male and female adults (Ma 2006).
- The main host plant of Manchurian fruit moth is apple and it has also been recorded attacking quince, European pear and Oriental pear (CAB International 2007a), as well as peach and crab apple (Ma 2006). These plants are grown in Australia.

The association of immature life stages with fruit, moderated by the need to complete development and find a mate for sexual reproduction, supports a risk rating for distribution of 'moderate'.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The likelihood that *G. inopinata* will enter Australia as a result of trade in the commodity and be distributed in a viable state to a suitable host: **LOW**.

4.17.3 Probability of establishment

The likelihood that *G. inopinata* will establish, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **HIGH**.

- The recorded host plants of Manchurian fruit moth include *Malus domestica* (apple), *Malus pallasiana* (apple species native to Russia), *Cydonia oblonga* (quince), *Pyrus communis* (European pear), *Pyrus pyrifolia* (nashi pear) and *Prunus persica* (peach).

Grapholita inopinata has also been reared artificially on some Russian species of *Prunus*. Host plants such as apples, pears and peaches are available in Australia.

- Manchurian fruit moth is found in China ranging from Guangdong in the south to Jilin in the north, and also in Japan, Korea and Russia (CAB International 2007a; Ma 2006). This distribution covers a wide range of climatic conditions, which are similar to those in many parts of Australia.
- There are two generations per year in China (Ma 2006) but only one generation per year in the Primor'e territory of Russia and the area east of Lake Baikal (CABI/EPPO 2005).
- In China, larvae of the first generation live in fruit for 20-30 days and emerge in late June and July to pupate. Larvae of the second generation stay in the fruit for about 20 days and leave the fruit in late August to late September to search for suitable sites to overwinter (Ma 2006).
- Integrated Pest Management (IPM) programmes are practiced in the production of apples in Australia. It is not known if the measures taken against codling moth (*Cydia pomonella*) and light brown apple moth (*Epiphyas postvittana*) in commercial orchards in Australia could have some impact on the establishment of this pest.

Readily available hosts and a wide climatic range distribution support a risk rating for establishment of 'high'.

4.17.4 Probability of spread

The likelihood that *G. inopinata* will spread, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pest:

HIGH.

- Manchurian fruit moth occurs in the temperate regions from Southern China to the far east of Russia, indicating that temperate regions of the Australian environment would be suitable for its spread.
- Commercial fruit crops of apples and pears are grown in six states of Australia; however, there are natural barriers such as arid areas, climatic differentials and long distances present between production areas.
- Widely distributed hosts, apple, pear and quince would aid the spread of *G. inopinata*.
- This moth can fly from tree to tree, or to neighbouring orchards. However, it would be difficult for the moth to disperse from one area to another unaided.
- Larvae can crawl to different parts of the same host plant.
- Apples would be used mostly for human consumption and would be distributed around the country. Such distribution would aid the spread of the larvae in fruit.
- Two parasitoids, *Phaedrotonus* sp. and *Mesochorus* sp. have been reported as the natural enemies of Manchurian fruit moth (Ma 2006), but they are not present in Australia.

Readily available hosts and the ability of adults to fly support a risk rating for spread of 'high'.

4.17.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of 'rules' for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *G. inopinata* will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **LOW**.

4.17.6 Consequences

The consequences of the establishment of *G. inopinata* in Australia have been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are 'E', the overall consequences are estimated to be **MODERATE**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|---|---|
| DIRECT | |
| Plant life or health | <p>D – Significant at the district level</p> <p><i>Grapholita inopinata</i> is rather similar as a pest to the widely distributed <i>Cydia pomonella</i>. Both species occur in the far east of Russia, where <i>C. pomonella</i> damages a larger proportion of apples than does <i>C. inopinata</i>, though the latter remains a significant pest, damaging up to 11% of the apple crop. Damage from <i>G. inopinata</i> can reach 100% on apples in the area east of Lake Baikal (CABI/EPPO 2005). Based on this information, the impact of Manchurian fruit moth on plant life or health is rated as the same as codling moth.</p> |
| Other aspects of the environment | <p>B – Minor significance at the local level</p> <p>There are no known direct consequences of this species on the natural or built environment, but its introduction into a new environment may lead to competition for resources with native species.</p> |
| INDIRECT | |
| Control, eradication, etc. | <p>E – Significant at the regional level</p> <p>Programs to minimise the impact of the pest on host plants may be costly and may include additional pesticide applications and crop monitoring.</p> <p>Specific information on control is not readily available in the literature. It is presumed that measures taken against <i>Cydia pomonella</i> would be effective (CABI/EPPO 2005).</p> <p>Existing IPM programs may be disrupted due to the possible increase in the use of insecticides. However, the measures taken against the codling moth and light brown apple moth (<i>Epiphyas postvittana</i>) in commercial orchards in Australia may have some impact on the establishment of this pest. Costs for crop monitoring of the pest may be incurred by the producer.</p> <p>The impact score for control, eradication, etc. was rated as 'E', the same as that for <i>C. pomonella</i>, due to the similarity of these two pests.</p> |
| Domestic trade | <p>D – Significant at the district level</p> <p>The presence of <i>G. inopinata</i> in commercial production areas would cause interstate trade restrictions on a range of commodities. Apples and pears are grown in several</p> |

Australian states. If *G. inopinata* became established in one of these states then interstate trade would be disrupted.

International trade

D – Significant at the district level

Grapholita inopinata was recently added to the EPPO A1 list of quarantine pests (CABI/EPPO 2005) and is also a pest of concern for other trading partners such as Canada and USA. The presence of *G. inopinata* in commercial production areas of a wide range of commodities (e.g. apples, pears and cherries) may limit access to overseas markets of countries where this pest is absent.

Environment

B – Minor significance at the local level

Pesticide applications or other control activities would be required to control this pest on susceptible crops, these could have minor indirect impact on the environment.

4.17.7 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for Manchurian fruit moth | |
|--|-----------------|
| Overall probability of entry, establishment and spread | Low |
| Consequences | Moderate |
| Unrestricted risk | Low |

As indicated, the unrestricted risk for Manchurian fruit moth has been assessed as ‘low’, which exceeds Australia’s ALOP. Therefore, specific risk management measures are required for this pest.

4.18 Oriental fruit moth - *Grapholita molesta*

4.18.1 Introduction

Grapholita molesta (Oriental fruit moth) is not present in Western Australia and is a pest of regional quarantine concern for that state.

Grapholita molesta belongs to the insect family Tortricidae which is an economically important group with many representatives causing major economic damage to agricultural, horticultural and forestry industries (Meijerman and Ulenberg 2000). *Grapholita molesta* is not a primary pest of apples but is a serious pest of stone fruit in Europe, eastern Australia and North America (Murrell and Lo 1998). It occurs as a pest of apple fruit where these fruits are grown adjacent to peaches (Rothschild and Vickers 1991).

Grapholita molesta has four life stages: egg, larva, pupa and adult (Ma 2006). Adults are dark-brown or grey-brown, 6-7 mm long with a wingspan of 11-14 mm. Eggs are 0.5-0.8 mm and laid on the underside of leaves near the growing tips. Larvae are 10-14 mm long and can bore into fruit. Pupae are 6-7 mm long and pupation occurs in protected sites. This species has 4-6 generations per year (CAB International 2008).

The risk scenario of concern for *G. molesta* is the presence of larvae inside apple fruit.

Grapholita molesta was assessed in the *Final Import Risk Analysis Report for Apples from New Zealand* (Biosecurity Australia 2006a). The assessment of *G. molesta* presented here builds on this existing pest risk assessment.

The probability of distribution of *G. molesta* will not differ for the same commodity (apples) after arrival in Australia. The probability of establishment and of spread in Australia, and the consequences it may cause will be the same for any commodity in which the species is imported into Australia. Accordingly, there is no need to re-assess these components. However, differences in commodities, horticultural practices, climatic conditions and the prevalence of the pest between previous export areas (New Zealand) and China make it necessary to re-assess the likelihood that *G. molesta* will be imported to Australia with apples from China.

4.18.2 Reassessment of probability of importation

The likelihood that *G. molesta* will arrive in Western Australia with the importation of the commodity: **VERY LOW**.

- *Grapholita molesta* has been reported in 19 provinces in China, including the major apple production regions of Liaoning, Hebei, Henan, Shangdong, and Shaanxi (Ma 2006).
- *Grapholita molesta* is not a primary pest of apple, but is a serious pest of stone fruit in Europe, Australia and North America (Murrell and Lo 1998). It mainly occurs as a pest of apple fruit where these fruits are grown adjacent to peaches (Rothschild and Vickers 1991).
- It has been reported that *G. molesta* has become an important pest of apple in the mid-Atlantic region of the USA since the late 1990s (Myers *et al.* 2006). But there is no

evidence to suggest this is the case elsewhere such as other parts of the USA, New Zealand or China.

- *Grapholita molesta* caterpillars feed by boring into the centre of shoots and young stems of fruit trees, particularly stone fruit. This damage is rare in apple trees, where the caterpillars feed more commonly on ripe fruit (HortResearch 1999).
- Gum and frass protrude from the wound area as the larvae bore into the fruit (Polk *et al.* 2003). As the gum ages, a sooty mould may form on it, turning the wound area black. Such infested fruit would be rejected during routine quality inspection. However, if gum and frass are not attached to the fruit, infested fruit would escape detection during quality inspection.
- Mature larvae overwinter in northern China in sutures of the branches and crown, or in soil (Ma 2006). This indicates that this species would be able to survive the low temperature transportation of apple fruit from China to Australia.

Presence of visible gum and frass on infested fruit and apple trees not being the main host support a risk rating for importation of 'very low'.

4.18.3 Probability of distribution, of establishment and of spread

As indicated above, the probability of distribution, of establishment and of spread for *G. molesta* will be the same as those assessed for apples from New Zealand (Biosecurity Australia 2006a). The ratings from the previous assessments are presented below:

| | |
|-------------------------------|-----------------|
| Probability of distribution: | MODERATE |
| Probability of establishment: | HIGH |
| Probability of spread: | HIGH |

4.18.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of 'rules' for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *G. molesta* will enter Western Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Western Australia: **VERY LOW**.

4.18.5 Consequences

The consequences of the establishment of *G. molesta* in Western Australia have been estimated previously for apples from New Zealand (Biosecurity Australia 2006a). This estimate of impact scores is provided below:

| | |
|--------------------------------------|----------|
| Plant life or health | E |
| Any other aspects of the environment | A |
| Eradication, control, etc. | E |
| Domestic trade | B |
| International trade | D |
| Environment | B |

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are ‘E’, the overall consequences are estimated to be **MODERATE**.

4.18.6 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for Oriental fruit moth | |
|--|-----------------|
| Overall probability of entry, establishment and spread | Very low |
| Consequences | Moderate |
| Unrestricted risk | Very low |

As indicated, the unrestricted risk for Oriental fruit moth has been assessed as ‘very low’, which achieves Australia’s ALOP. Therefore, specific risk management measures are not required for this pest.

4.19 White fruit moth - *Spilonota albicana*

4.19.1 Introduction

Spilonota albicana (white fruit moth) belongs to the insect family Tortricidae which is an economically important group with many representatives causing major economic damage to agricultural, horticultural and forestry industries (Meijerman and Ulenberg 2000).

Spilonota albicana has four life stages: egg, larva, pupa and adult (CAAS 1992). Adults are white-grey and 6.5 mm long with a wingspan of 15 mm. Eggs are laid on the surface or calyx of fruit and hatched larvae bore into fruit (CAAS 1992). Larvae are 10-12 mm long. Pupae are 8 mm long and pupation occurs in the feeding sites. This species has two generations per year (CAAS 1992).

The risk scenario of concern for *S. albicana* is the presence of eggs on, and larvae inside, apple fruit.

Spilonota albicana was included in the existing import policy for pears from China (Biosecurity Australia 2005b; AQIS 1998b) and Fuji apples from Japan (AQIS 1998a). The assessment of *S. albicana* presented here builds on these existing pest risk assessments.

4.19.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that *S. albicana* will arrive in Australia with the importation of the commodity: **MODERATE**.

- *Spilonota albicana* is widespread in China and reported from regions in the southwest to northeast. It is a pest of apples as well as hawthorn, pears and stone fruit (Hua and Wang 2006).
- *Spilonota albicana* is a fruit boring insect (Wan *et al.* 2006). Adult females lay their eggs on the surface or calyx of fruit and hatched larvae bore into fruit from the calyx or stem end (CAAS 1992).
- *Spilonota albicana* has two generations per year in the apple production areas of Liaoning, Hebei and Shandong. The first-generation larvae appear in June and July. The surface of damaged areas is covered with silk-connected frass and the larvae pupate in the damaged area. The second-generation larvae appear from July to September, feed on fruit for a short while and then leave the fruit for overwintering sites (Hua and Wang 2006). Apple fruit can be harvested from late August (AQSIQ 2005) and some eggs and larvae may still be inside these earlier harvested apples.
- If larvae are present inside apple fruit at harvest, the sorting and packing processes would not be effective in detecting and removing them.

- Mature larvae of *S. albicana* are able to overwinter in China (Hua and Wang 2006) and this suggests that larvae inside the fruit would be able to survive the storage and transportation of the fruit at low temperatures.

The evidence that apples harvested in October would not harbour the eggs and larvae of white fruit moth because the larvae would have already left the fruit for overwintering and that only apples harvested in late August and September may have eggs and larvae, supports a risk rating for importation of ‘moderate’.

Probability of distribution

The likelihood that *S. albicana* will be distributed in Australia in a viable state as a result of the processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **MODERATE**.

- Apple fruit is intended for human consumption and the eggs or larvae may remain on/in the fruit during retail distribution. Disposal of fruit waste may further aid distribution of viable insects. Disposal of infested fruitwaste is likely to be via commercial or domestic rubbish systems.
- *Spilonota albicana* can enter the environment through flight of adults that would emerge from pupae developed from larvae.
- Reproduction requires the mating between male and female adults (CAAS 1992).
- *Spilonota albicana* has been recorded from 20 species of host plants in three families (Zhang and Li 2005), which include apples, pears, hawthorn, peaches, plums, apricots and cherries. These plants are grown in suburban and rural areas in Australia.

The immature life stage’s association with fruit, moderated by the need to complete development and find a mate for sexual reproduction, supports a risk rating for distribution of ‘moderate’.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The likelihood that *S. albicana* will enter Australia as a result of trade in the commodity and be distributed in a viable state to a suitable host: **LOW**.

4.19.3 Probability of establishment

The likelihood that *S. albicana* will establish, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **HIGH**.

- The recorded host plants are *Cerasus pseudocerasus*, *C. tomentose*, *Corylus heterophylla*, *Cotoneaster melanocarpus*, *Crataegus pinnatifida* (hawthorn), *C. dahurica*, *C. maximowiczii*, *Larix leptolepis*, *L. gmelini*, *Malus pumila* (apple), *M. sieboldii*, *M. mandshurica*, *M. pallasiana*, *Photinia glabra*, *Pyrus* sp. (pear), *Prunus armeniaca* (apricot), *Prunus persica* (peach), *Prunus salicina* (plum), *P. serrulate* var. *sponanea* and *Sorbus amurensis* (Hua and Wang 2006; Zhang and Li 2005).

- White fruit moth is widespread across China, and also in Japan, Korea and Russia (Ma 2006; Hua and Wang 2006) and this distribution covers a wide range of climatic conditions. Climatic conditions in many parts of Australia are similar to these areas.
- There are two generations per year in the apple production areas of Liaoning, Hebei and Shandong (Hua and Wang 2006). The first-generation larvae appear in June and July and the second-generation larvae appear from July to September. Mature larvae leave the fruit in September and October to overwinter (Hua and Wang 2006). It is expected that a similar life cycle would occur in Australia if the species is introduced.
- Integrated Pest Management (IPM) programs are practiced in the production of apples in Australia. The measures taken against codling moth (*Cydia pomonella*) and light brown apple moth (*Epiphyas postvittana* (Walker)) in Australian commercial orchards may have some impact on the establishment of this pest. However, there are no control measures in place for potential hosts in the wild and on road sides.

Readily available hosts and a wide climatic range distribution support a risk rating for establishment of 'high'.

4.19.4 Probability of spread

The likelihood that *S. albicana* will spread, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pest: **HIGH**.

- *Spilonota albicana* occurs in Japan, Korea, and Russia as well as China, indicating that parts of the Australian environment would be suitable for its spread.
- Commercial fruit crops such as apples and pears are grown in six states of Australia, however there are natural barriers including arid areas, climatic differentials and long distances present between these areas.
- Widely distributed hosts in the wild and in gardens would aid the spread of *S. albicana*.
- Although *S. albicana* can disperse locally from tree to tree or to neighbouring orchards by adult flight, it would be difficult for the moth to disperse from one production area to another unaided.
- Crawling by larvae enables dispersal on the same host plant.
- Apples would be used mostly for human consumption and would be distributed around the country. Such distribution would aid the spread of the larvae in fruit.
- Apparently, there have been no studies on the natural enemies of *S. albicana*.

Readily available hosts and the ability of adults to fly support a risk rating for spread of 'high'.

4.19.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of 'rules' for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *S. albicana* will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **LOW**.

4.19.6 Consequences

The consequences of the establishment of *S. albicana* in Australia have been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are 'E', the overall consequences are estimated to be **MODERATE**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|---|--|
| DIRECT | |
| Plant life or health | <p>E – Significant at the regional level</p> <p><i>Spilonota albicana</i> has been recorded from 20 species of host plants in three families (Zhang and Li 2005) and is a pest of apples, pears, hawthorn, peaches, plums, apricots and cherries etc. (Hua and Wang 2006).</p> <p>In China, it was a serious pest in northern apple production areas in the 1950s and 1960s. Since then, it has rarely occurred because of the control measures applied to this pest and other leafrollers. However, in the last 10 years, it has become an important pest again in uncontrolled orchards because of the planting of large numbers of hawthorn plants around the orchards (Hua and Wang 2006). In such orchards, up to 50% of fruit were reported as infested.</p> |
| Other aspects of the environment | <p>B – Minor significance at the local level</p> <p>There are no known direct consequences of this species on the natural or built environment, but its introduction into a new environment may lead to competition for resources with native species.</p> |
| INDIRECT | |
| Control, eradication, etc. | <p>D – Significant at the district level</p> <p>Programs to minimise the impact of this pest on host plants may be costly and may include additional pesticide applications and crop monitoring.</p> <p>In China, the recommended control measures include cleaning the orchard floor and removing old bark on the trees, and burying or burning the waste in August to eliminate overwintering larvae (Hua and Wang 2006). This method is very labour intensive. Another recommended measure is chemical control. Existing IPM programs may be disrupted due to the possible increase in the use of insecticides.</p> <p>The measures taken against codling moth (<i>Cydia pomonella</i>) and light brown apple moth (<i>Epiphyas postvittana</i> (Walker)) in commercial orchards in Australia may have some impact on this pest. Costs for crop monitoring of this pest may be incurred by the producer.</p> |
| Domestic trade | <p>D – Significant at the district level</p> <p>The presence of <i>S. albicana</i> in commercial production areas would cause interstate trade restrictions. Apples, pears and stone fruit are grown in several Australian states. If <i>S. albicana</i> became established in one of these states then interstate trade would be disrupted.</p> |

| | |
|----------------------------|---|
| International trade | <p>D – Significant at the district level</p> <p>The presence of <i>S. albicana</i> in commercial production areas of a wide range of commodities (e.g. apples, pears and stone fruit) may limit access to overseas markets.</p> |
| Environment | <p>B – Minor significance at the local level</p> <p>Pesticide applications or other control activities would be required to control this pest on susceptible crops, which could have minor indirect impact on the environment.</p> |

4.19.7 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for white fruit moth | |
|--|-----------------|
| Overall probability of entry, establishment and spread | Low |
| Consequences | Moderate |
| Unrestricted risk | Low |

As indicated, the unrestricted risk for white fruit moth has been assessed as ‘low’, which exceeds Australia’s ALOP. Therefore, specific risk management measures are required for this pest.

4.20 Bull's eye rot - *Cryptosporiopsis curvispora*

4.20.1 Introduction

Cryptosporiopsis curvispora is the anamorph of the ascomycete *Neofabraea malicorticis* (Landcare Research 2009). On apple fruit, this fungus expresses as a fruit rot called bull's eye rot. On trees, it causes tree cankers. The canker caused by *C. curvispora* is known as anthracnose canker (Dugan *et al.* 1993).

Cryptosporiopsis curvispora has been reported in China as *Neofabraea malicorticis* and *Pezicula malicorticis* (Ma 2006). However, it is a quarantine pest of concern to China. A recent molecular analysis of herbarium specimens has revealed that *C. curvispora* is absent from Australia (Cunnington 2004).

Cryptosporiopsis curvispora economically affects apple and pear orchards (Garipey *et al.* 2005; Spotts 1990a; Grove 1990a). It also occurs on a number of other rosaceous hosts (Grove 1990a). While the cankers may reduce the growth and bearing capacity of the tree (Andrews *et al.* 2008), they rarely kill trees or branches (Grove 1990a). Cankers serve as a source of conidial inoculum for the infection of fruit. Conidia are dispersed by rain or irrigation and can infect lenticels or wounds at any time between petal fall and harvest (Spotts 1990a), with infection becoming more likely closer to harvest (Henriquez *et al.* 2008). Fruit mummies on the orchard floor may provide an alternative source of inoculum (Grove *et al.* 1992).

Symptoms usually do not appear in the field, but show after several months of storage (Spotts 1990a). Symptoms present as brown, depressed, round spots. Acervuli, fruiting bodies containing conidia, develop in concentric rings, causing a 'bull's eye' pattern (Andrews *et al.* 2008; Spotts 1990a). Cold storage does not eliminate the fungus, but can delay the onset of symptoms (Edney 1956).

Bull's eye rot may open the way for secondary decay fungi to complete the rotting process (Ogawa and English 1991). In orchards, conidia are the infectious and dispersal agents (Grove 1990a). Conidia of *C. curvispora* can affect sound wood. The role of ascospores in dispersal is unclear.

The risk scenario of concern for *C. curvispora* is that apple fruit may be infected yet show no symptoms of disease at the time of importation.

Cryptosporiopsis curvispora was included in the existing policy for apple from New Zealand (Biosecurity Australia 2006a). The assessment of bull's eye rot presented here builds on this existing pest risk assessment.

4.20.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that *C. curvispora* will arrive in Australia with the importation of the commodity: **LOW**.

- *Cryptosporiopsis curvispora* has been reported in apple orchards in China (Ma 2006). However, the distribution of this fungus in China is limited and localised and it is a quarantine pest of concern to China.
- Cankers produce conidia which serve as inoculum for apple fruit. Fruit infection can occur anytime between petal fall and harvest (Spotts 1990a).
- Usually, symptoms only develop after several months in storage (Spotts 1990a; Pierson *et al.* 1971). Spotts (1990a) suggested that fruit-to-fruit spread does not occur in storage. Many of the most common apple cultivars, such as Gala, Golden Delicious and Granny Smith, are susceptible to anthracnose (Grove 1990a).
- Post-harvest fungicide application may provide partial control for bull's eye rot, but may not reach fungal cells deep inside the lenticels of the apple (Spotts 1990a).
- Cold temperatures, such as those in cold storage, delay the onset of symptoms of bull's eye rot (Spotts 1990a; Pierson *et al.* 1971; Edney 1956).

The asymptomatic nature of fruit at harvest, development of the disease in storage and the ability of the pathogens to survive cold storage, moderated by the limited distribution and the quarantine status of this pathogen in China, support a risk rating for importation of 'low'.

Probability of distribution

The likelihood that *C. curvispora* will be distributed in Australia in a viable state as a result of the processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **HIGH**.

- Imported apple fruit is intended for human consumption in Australia. It is expected that once the apple fruit has arrived in Australia, it will be distributed throughout Australia for wholesale or retail sale. Any infected fruit present will be distributed during these procedures.
- Apple waste disposed of as litter may be deposited into urban, peri-urban and agricultural situations, as well as areas of natural vegetations, throughout Australia.
- Some of the fruit might go into long term storage facilities before distribution. Infected fruit can remain for several months in storage before development of symptoms (Spotts 1990a). The asymptomatic fruit will be distributed to retail outlets and may finally reach areas where host plants are grown.
- If bull's eye rot develops after purchase by the consumer, rotten fruit may be disposed of into the environment.
- *Cryptosporiopsis curvispora* has a variety of rosaceous hosts, including *Amelanchier pallida*, *Chaenomeles* sp., *Crataegus* spp., *Cydonia oblonga*, *Malus* spp., *Prunus* spp., *Pyrus* spp., *Rosa* spp. and *Sorbus* spp. (de Jong *et al.* 2001; Kienholz 1939). However, apple and pear appear to be the preferred hosts.

The ready availability of the hosts and spore and symptom development during or after storage support a risk rating for distribution of 'high'.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The

likelihood that *C. curviformis* will enter Australia as a result of trade in the commodity and be distributed in a viable state to a suitable host: **LOW**.

4.20.3 Probability of establishment

The likelihood that *C. curviformis* will establish, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **MODERATE**.

- *Cryptosporiopsis curviformis* has a variety of rosaceous hosts, including *Amelanchier pallida*, *Chaenomeles* sp., *Crataegus* spp., *Cydonia oblonga*, *Malus* spp., *Prunus* spp., *Pyrus* spp., *Rosa* spp. and *Sorbus* spp. (de Jong *et al.* 2001; Kienholz 1939). Many of these are planted as commercial fruit trees or as ornamentals in home gardens or amenity plantings, or have become naturalised in the wild in many areas of Australia.
- *Cryptosporiopsis curviformis* occurs in Canada, China, New Zealand, UK and continental Europe and the USA (de Jong *et al.* 2001; Grove 1990a). Similar climates in cool-temperate Australia, such as Tasmania and parts of NSW and Victoria, would be climatically suitable for the establishment of this fungus.
- *Cryptosporiopsis perennans* and *Neofabraea alba*, closely related species, have already established in some parts of Australia (Cunnington 2004).
- Conidia of both *C. curvispora* and *C. perennans* are dispersed by the impact of water droplets from rain or irrigation (Spotts 1990a; Grove 1990a).
- Usually, cankers, rather than fruit, provide the inoculum for fruit infection (Grove 1990a). There are no records of fruit-borne conidia infecting wood and producing canker growths.
- The susceptibility of branches to infection with *C. perennans* varies with season. Apple branches are most susceptible during autumn and winter (Grove *et al.* 1992).

The range of hosts and the infectivity of apples with bull's eye rot, moderated by the limited opportunity for host infection, support a risk rating for establishment of 'moderate'.

4.20.4 Probability of spread

The likelihood that that *C. curviformis* will spread, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pest: **MODERATE**.

- *Cryptosporiopsis curviformis* has a variety of rosaceous hosts, including *Amelanchier pallida*, *Chaenomeles* sp., *Crataegus* spp., *Cydonia oblonga*, *Malus* spp., *Prunus* spp., *Pyrus* spp., *Rosa* spp. and *Sorbus* spp. (de Jong *et al.* 2001; Kienholz 1939). Many of these are planted as commercial fruit trees or as ornamentals in home gardens or amenity plantings, or have become naturalised in the wild in many areas of Australia.
- *Cryptosporiopsis curviformis* occurs in Canada, China, New Zealand, UK, the USA and continental Europe (de Jong *et al.* 2001; Grove 1990a). Similar climates in cool-temperate Australia, such as Tasmania and parts of NSW and Victoria, would be climatically suitable for the spread of this fungus.
- On apple and pear trees, *C. curviformis* produces cankers on branches and twigs and develops saprophytically on dead wood, from which spores are produced and distributed (Henriquez *et al.* 2008; Grove *et al.* 1992).

- Conidia produced on cankers caused by *C. curvispora* are dispersed by the impact of water droplets from rain or irrigation (Spotts 1990a; Grove 1990a). This limits the potential of long distance spread of spores.
- Although Grove (1990a) considered the sexual stage of *C. curvispora* insignificant for the spread of the disease, it is possible that wind-dispersed ascospores produced by the sexual stage play a role in long-distance spread (Ogawa and English 1991).

The range of hosts, and the ability of the pathogen to infect fruit, branches, twigs and dead wood, to survive in dead cankers and to survive in stored apple fruit, moderated by the limited long distance spread potential for conidia and the limited opportunity for host infection, support a risk rating for spread of 'moderate'.

4.20.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of 'rules' for combining qualitative likelihood shown in Table 2.2.

The likelihood that *C. curvispora* will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **LOW**.

4.20.6 Consequences

The consequences of the establishment of *C. curvispora* in Australia have been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are 'D', the overall consequences are estimated to be **LOW**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|---|--|
| DIRECT | |
| Plant life or health | <p>D – Significant at the district level</p> <p>Bull's eye rot caused by <i>C. curvispora</i> is a serious post-harvest disease in apples and pears in the Pacific Northwest of the USA and British Columbia (Garipey <i>et al.</i> 2005; Sholberg and Haag 1996; Grove <i>et al.</i> 1992). The disease can cause crop losses in storage from approximately 5-50% (Garipey <i>et al.</i> 2005; Edney 1956). Cankers produced by this fungus rarely kill trees, but serve as inoculum for bull's eye rot (Grove 1990a).</p> |
| Other aspects of the environment | <p>A – Indiscernible at the local level</p> <p>There are no known direct consequences of these species on other aspects of the environment.</p> |
| INDIRECT | |
| Eradication, control etc. | <p>C – Significant at the local level</p> <p>Programs to minimise the impact of these pathogens on host plants may be costly</p> |

and may include additional pesticide applications and crop monitoring.

Control of the disease involves increased orchard hygiene, including removal of cankers (Andrews *et al.* 2008; Spotts 1990a; Grove 1990a). Fungicide treatments of trees and post-harvest fungicide applications for fruit may be necessary (Andrews *et al.* 2008; Spotts 1990a).

Change of irrigation methods to reduce spread of conidia may result in a subsequent increase in the cost of production.

| | |
|----------------------------|--|
| Domestic trade | <p>B – Minor significance at the local level</p> <p>If <i>C. curvispora</i> established in parts of Australia, it may result in some interstate trade restriction on commodities such as apples and pears. The movement and trade of nursery stock could be affected in areas of bull's eye rot outbreak.</p> |
| International trade | <p>D – Significant at the district level</p> <p>The presence of <i>C. curvispora</i> in commercial production areas of apples and pears may limit access to overseas markets which are free from this pest.</p> |
| Environment | <p>B – Minor significance at the local level</p> <p>Fungicide applications or other control activities would be required to control this pest on susceptible crops, which could have minor indirect impact on the environment.</p> |

4.20.7 Unrestricted risk

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for bull's eye rot | |
|--|----------|
| Overall probability of entry, establishment and spread | Low |
| Consequences | Low |
| Unrestricted risk | Very low |

As indicated, the unrestricted risk estimate for bull's eye rot has been assessed as 'very low', which achieves Australia's ALOP. Therefore, no specific risk management measures are required for this pest.

4.21 *Marssonina blotch – Diplocarpon mali*

4.21.1 Introduction

Marssonina blotch is a fungal disease caused by *Diplocarpon mali*. This disease usually occurs on leaves. It was reported on fruit and stem of pome fruits (Lee *et al.* 2006; Yukita 2003; Takahashi and Sawamura 1990). Primary infections are initiated by ascospores produced in apothecia on overwintered leaves (Sharma *et al.* 2004; Harada *et al.* 1974). Mature ascospores are found just before the bloom stage of bud development. Ascospore discharge usually lasts 3-4 weeks. Rain is required for spore release (Sharma *et al.* 2004). Primary symptoms appear in the middle of June in China, Japan and Korea, usually on mature leaves. The pathogenic fungus was found to persist in the overwintering leaf litter in the form of conidia, which showed up to 20 percent viability in the next season (Sharma *et al.* 2004). Infection of leaves by conidia occurs most frequently at 20-25 °C. Defoliation begins about 2 weeks after the appearance of leaf symptoms (Takahashi and Sawamura 1990). Infection of the fruit is rare and restricted to trees with serious leaf infections (Takahashi and Sawamura 1990).

The risk scenario of particular relevance to *D. mali* is infected fruit with viable inoculum.

Diplocarpon mali was included in the existing import policy for Fuji apples from Japan and pears from China (AQIS 1998b; AQIS 1998a). The assessment of *D. mali* presented here builds on these existing pest risk assessments.

4.21.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that *Diplocarpon mali* will arrive in Australia with the importation of the commodity: **MODERATE**.

- *Marssonina blotch* caused by *D. mali* occurs commonly in Shandong province (CIQSA 2001c) and is also reported on apples in Gansu (Zhuang 2005).
- In recent years, the disease has become the most important disease in apple growing areas in Korea (Lee *et al.* 2006). It is also an important apple leaf disease in Canada, Italy, Japan and Rumania (Takahashi and Sawamura 1990).
- This disease usually occurs on leaves and causes defoliation (Lee *et al.* 2006; Yukita 2003; Takahashi and Sawamura 1990). This disease is favoured by high rainfall and moderate temperatures ranging from 20-25 °C. Primary infections are initiated by ascospores produced in apothecia on overwintering leaves. Mature ascospores are found just before the bloom stage of bud development. Ascospore discharge usually lasts 3-4 weeks (Takahashi and Sawamura 1990).
- Infection of the fruit is rare and restricted to trees with serious leaf infections (Takahashi and Sawamura 1990). However, Verma and Sharma (1999) reported that fruit infection is not uncommon in orchards with high level leaf infections in India.

- The pathogenic fungus was found to persist in the overwintering leaf litter in the form of conidia, which showed up to 20 percent viability in the next season (Sharma *et al.* 2004). Infection of leaves by conidia occurs most frequently at 20-25 °C.
- This disease also attacks mature fruit, causing 3-5 mm diameter circular spots. The spots become oval, depressed, and dark brown with age and are almost black at harvest time. The surface of the fruit is somewhat indented, and small, black acervuli are visible in the lesions (Sharma *et al.* 2004). So the infected fruit with visible symptoms would be easily observed and rejected during the packing house processes.
- However, incipient infections, caused by conidia released from infected leaves, are likely to be carried on apparently healthy fruit and become evident only after some days in transit and storage (Sharma *et al.* 2004). This suggests that latent infection by *D. mali* may occur on mature apple fruit.

The limited distribution of this fungus in China and the low potential for fruit infection, moderated by the potential of symptomless infected fruit passing through packing house processes, support a risk rating for importation of ‘moderate’.

Probability of distribution

The likelihood that *D. mali* will be distributed in Australia in a viable state as a result of processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **MODERATE**.

- Imported apple fruit is intended for human consumption in Australia. It is expected that once the apple fruit has arrived in Australia it will be distributed throughout Australia for repacking and/or retail sale. Any infected fruit present may be distributed during these processes. Disposal of infected unsaleable fruit near susceptible hosts may aid distribution of the pathogen.
- Individual consumers will distribute small quantities of apples to a variety of urban, rural and wild environments, where they will be consumed, or disposed of, in close proximity to a suitable host plant.
- Natural hosts of *D. mali* are limited to *Malus* and *Chaenomeles* (Farr *et al.* 2008). These host plants are grown in Australia.
- Primary infections are initiated by ascospores produced in apothecia on overwintered leaves. Mature ascospores are found just before the bloom stage of bud development. Ascospores discharge usually lasts 3-4 weeks. Rain is required for spore release (Takahashi and Sawamura 1990).
- The pathogenic fungus was found to persist in the overwintering leaf litter in the form of conidia, which showed up to 20 percent viability in the next season (Sharma *et al.* 2004). Infection of leaves by conidia occurs most frequently at 20-25 °C.

The potential distribution of infected fruit throughout Australia, the disposal of fruit waste in the environment and the ability of wind and water droplets to transfer spores from the fruit waste to a host, moderated by the limited number of hosts in Australia, support a risk rating for distribution of ‘moderate’.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The

likelihood that *D. mali* will enter Australia as a result of trade in fresh apple fruit from China and be distributed in a viable state to a suitable host: **LOW**.

4.21.3 Probability of establishment

The likelihood that *D. mali* will establish, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **MODERATE**.

- Natural hosts of *D. mali* are limited to *Malus* and *Chaenomeles* (Farr *et al.* 2008). These host plants are grown in Australia.
- Marssonina blotch caused by *D. mali* occurs commonly in Shandong province (CIQSA 2001c) and is also reported on apples in Gansu (Zhuang 2005). In recent years, the disease has become the most important disease in apple growing areas in Korea (Lee *et al.* 2006). It is also an important apple leaf disease in Canada, Italy, Japan and Rumania (Takahashi and Sawamura 1990). Environments with climates similar to these areas exist in various parts of Australia suggesting that *D. mali* has the potential to establish here.
- The pathogenic fungus was found to persist in the overwintering leaf litter in the form of conidia, which showed up to 20 percent viability in the next season (Sharma *et al.* 2004).
- Marssonina blotch is a disease of warm and wet weather. Heavy rains and extended wetting periods promote exudation, dissemination, and germination of spores (Sharma *et al.* 2004). Temperature and humidity conditions in some parts of Australia are suitable for this pathogen's survival and establishment.

The occurrence of suitable temperature and moisture conditions for spore germination and infection in some parts of Australia, moderated by the limited number of hosts, support a risk rating for establishment of 'moderate'.

4.21.4 Probability of spread

The likelihood that *D. mali* will spread, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of *D. mali*:

MODERATE.

- Marssonina blotch caused by *D. mali* occurs commonly in Shandong province (CIQSA 2001c) and is also reported on apples in Gansu (Zhuang 2005).
- In recent years, the disease has become the most important disease in apple growing areas in Korea (Lee *et al.* 2006). It is also an important apple leaf disease in Canada, Italy, Japan and Rumania (Takahashi and Sawamura 1990), suggesting that it tolerates a wide range of climates. Environments with climates similar to these areas exist in various parts of Australia suggesting that *D. mali* has the potential to spread.
- The pathogenic fungus was found to persist in the overwintering leaf litter in the form of conidia, which showed up to 20 percent viability in the next season (Sharma *et al.* 2004).
- Natural hosts of *D. mali* are limited to *Malus* and *Chaenomeles* (Farr *et al.* 2008). These host plants are grown in Australia.
- Disposal of infected fruit via commercial or domestic rubbish systems may aid the spread of the pathogen.
- Transport of infected planting material may aid the long distance movement of *D. mali* to uninfected orchards.

- The disease is usually controlled by orchard sanitation, pruning, and the use of fungicides (Sharma *et al.* 2004; Takahashi and Sawamura 1990). However, it was found that *D. mali* has relatively low sensitivity to copper fungicides which are permitted for organic sustainable orchards (Jiang *et al.* 1997).
- Rain is required for spore release (Sharma *et al.* 2004). Spores disperse to nearby plants with rain and wind.

The potential movement of symptomless infected planting material, moderated by the limited ability of long distance dispersal, support a risk rating for distribution of ‘moderate’.

4.21.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of ‘rules’ for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *D. mali* will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **LOW**.

4.21.6 Consequences

The consequences of the establishment of *D. mali* in Australia have been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are ‘E’, the overall consequences are estimated to be **MODERATE**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|---|---|
| DIRECT | |
| Plant life or health | <p>E – Significant at the regional level</p> <p>Marssonina blotch is an important leaf disease of apple in India, Italy, Korea and Japan. It also is a common leaf disease of apple in Shandong province in China (CIQSA 2001c). In India, it caused up to 50 percent defoliation of apple trees from July to September, when fruits were still hanging on the defoliated branches and rendered the trees barren in the following years (Sharma <i>et al.</i> 2004). In Korea, during a survey on the occurrence of apple diseases from 1992 to 2000, it was found that marssonina blotch caused by <i>D. mali</i> was the most serious disease causing considerable damage every year. A severe epidemic broke out for the first time, and was repeated every year since. In recent years, it has become the most important disease in apple growing areas in Korea (Lee <i>et al.</i> 2006).</p> <p>The disease is usually controlled by orchard sanitation, pruning, and the use of fungicides (Sharma <i>et al.</i> 2004; Takahashi and Sawamura 1990). However, it was found that <i>D. mali</i> has relatively low sensitivity to copper fungicides which are permitted for organic sustainable orchards (Jiang <i>et al.</i> 1997).</p> |
| Other aspects of the environment | <p>A – Indiscernible at the local level</p> <p>There are no known direct consequences of <i>D. mali</i> on the natural or built environment.</p> |

INDIRECT

| | |
|----------------------------------|---|
| Eradication, control etc. | <p>D – Significant at the district level</p> <p>The disease is usually controlled by orchard sanitation, pruning, and the use of fungicides (Sharma <i>et al.</i> 2004; Takahashi and Sawamura 1990). Removal of overwintered leaves on the ground may reduce the inoculum level. Spraying with 5% urea on the leaf litter might also be helpful in reducing the primary inoculum by enhanced decomposition. Proper pruning allows adequate air circulation in the canopy, thereby modifying the microclimate and reducing disease development (Sharma <i>et al.</i> 2004). Protective sprays of mancozeb, carbendazim, propineb, dodine, ziram and fluquinconazole are effective in controlling the disease (Sharma <i>et al.</i> 2004).</p> <p>Existing IPM programs may be disrupted due to possible increases in the use of fungicides as most of the anti-scab sterol inhibitor fungicides are not effective (Sharma <i>et al.</i> 2004). Costs for crop monitoring, orchard sanitation, pruning, and fungicides may be incurred by the producer.</p> |
| Domestic trade | <p>D – Significant at the district level</p> <p>Presence of <i>D. mali</i> in apple commercial production areas would result in the implementation of interstate quarantine measures, causing loss of markets and subsequent significant industry adjustment at district level.</p> |
| International trade | <p>E – Significant at the regional level</p> <p>The presence of <i>D. mali</i> in apple production areas of Australia would have impacts on the export of Australia's fresh apples and pears to countries where this pathogen is not present.</p> |
| Environment | <p>B – Minor significance at the local level</p> <p>Additional fungicide applications or other control activities would be required to control this disease on susceptible crops and these may have minor impact on the environment. However, it was found that <i>D. mali</i> has relatively low sensitivity to copper fungicides which are permitted for organic sustainable orchards (Jiang <i>et al.</i> 1997).</p> |

4.21.7 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for marssonina blotch | |
|--|-----------------|
| Overall probability of entry, establishment and spread | Low |
| Consequences | Moderate |
| Unrestricted risk | Low |

As indicated, the unrestricted risk for marssonina blotch has been assessed as 'low', which exceeds Australia's ALOP. Therefore, specific risk management measures are required for this pest.

4.22 Japanese apple rust - *Gymnosporangium yamadae*

4.22.1 Introduction

Japanese apple rust is a fungal disease caused by *Gymnosporangium yamadae*. *Gymnosporangium yamadae* is heteroecious in that it requires both telial hosts (*Juniperus* spp.) and aecial hosts (*Malus* spp.) to complete its life cycle (Farr *et al.* 2008). Telia are produced on the stems of *Juniperus* spp. during spring. Basidiospores produced from the germinated telia are wind-dispersed and are able to infect nearby apple trees (Guo 1994). Infection from basidiospores on apples gives rise to pycnia borne in groups on the upper surface of apple leaves (Aldwinckle 1990). Later, aeciospores are produced in pycnia on the lower leaf surface, which are subsequently released and capable of being wind borne to infect the telial hosts (*Juniperus* spp.) (Laundon 1998; Wang and Guo 1985). After germinating on telial hosts (*Juniperus* spp.), an overwintering latent mycelium is produced. The telial state appears on *Juniperus* spp. in spring to begin the life cycle again (Ma 2006; Wang and Guo 1985).

The risk scenario of particular relevance to *G. yamadae* is that infected fruit may be picked and exported.

Gymnosporangium yamadae was included in the existing import policy for Fuji apples from Japan (AQIS 1998a). The assessment of *G. yamadae* presented here builds on this existing pest risk assessment.

4.22.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that *Gymnosporangium yamadae* will arrive in Australia with the importation of the commodity: **MODERATE**.

AQSIQ (2007b) suggests that the probability of importation should be rated as ‘very low’, because it is almost impossible for traded apples to carry the pathogen due to the rare incidence of infection on mature apples. However, Biosecurity Australia believes that the ‘moderate’ rating is appropriate, given the evidence provided below.

- Apple rust caused by *G. yamadae* is a common disease of apple in China and is widely distributed across major apple production areas (CIQSA 2001b; CIQSA 2001a; Guo 1994).
- The fungus requires telial hosts (*Juniperus* spp.) to complete its life cycle (Farr *et al.* 2008; Aldwinckle 1990) and these hosts are usually removed from orchard areas for control of *G. yamadae* in China (CIQSA 2001c; CIQSA 2001a; Guo 1994).
- Leaves, young shoots and fruit of apple can become infected by basidiospores produced by teliospores from telial hosts (Aldwinckle 1990).
- Infection of fruit is rare (Aldwinckle 1990). Young infected fruit develops yellow lesions initially, and then the lesions turn dark brown (Guo 1994; Fukushi 1925). Infected fruit is

usually abnormal in shape at maturity (Guo 1994). Mature apple fruit is more resistant to infection by basidiospores (AQSIQ 2007b).

- Fruit showing symptoms of Japanese apple rust is likely to be rejected during harvesting and commercial grading operations. However, recently infected fruit and fruit with small lesions may not be detected during these operations.
- Teliospores are produced by telia hosts in spring (Guo 1994) and are unlikely to contaminate apple fruit after removal of bags in autumn.
- Aeciospores dispersed from aecia on apple trees by wind may contaminate the surface of fruit after bags are removed. However, spores on the fruit surface may be eliminated during packing house operations (AQSIQ 2006a).
- Aeciospores on the surface of fruit would survive the cold storage conditions with temperatures of 0-1 °C and high relative humidities (Guo 1994; Fukushi 1925).

The wide distribution of this fungus in China, moderated by the limited potential for infected fruit and fruit with small lesions to pass through the grading process without being detected, supports a risk rating for importation of ‘moderate’.

Probability of distribution

The likelihood that *G. yamadae* will be distributed in Australia in a viable state as a result of processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **MODERATE**.

- Imported apple fruit is intended for human consumption in Australia. It is expected that once the apple fruit has arrived in Australia it will be distributed throughout Australia for repacking and/or retail sale. Any infected fruit or fruit contaminated with aeciospores may be distributed during these processes.
- Water films are likely to develop on fruit as it is brought up to room temperature, leading to the germination and death of any aeciospores present on the surface of fruit.
- Individual consumers will distribute apples to a variety of urban, rural and wild environments, where most fruit will be consumed. However, some infected fruit waste may be discarded in close proximity to telial hosts (*Juniperus* spp.), which are required for the life cycle of this pathogen to be completed (Wang and Guo 1985).
- Aeciospores produced on infected fruit waste may be dispersed to telial hosts (*Juniperus* spp.) by wind or rain splash.
- Telial hosts (*Juniperus* spp.) are grown in home gardens, parks, along roadsides, in commercial orchard districts and as bonsai plants in Australia.
-

The potential distribution of infected fruit throughout Australia, the disposal of fruit waste in the environment and the ability of wind and water droplets to transfer rust spores from the fruit waste to a host, moderated by the limited number of telial hosts grown in Australia, support a risk rating for distribution of ‘moderate’.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The

likelihood that *G. yamadae* will enter Australia as a result of trade in fresh apple fruit from China and be distributed in a viable state to a suitable host: **LOW**.

4.22.3 Probability of establishment

The likelihood that *G. yamadae* will establish, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **MODERATE**.

- *Gymnosporangium yamadae* is established in China, Japan, South Korea and North Korea (Farr *et al.* 2008; CAB International 2008). Environments with climates similar to these countries exist in various parts of Australia where apples are produced.
- A period of conditioning at 0 °C for 10 days is required for aeciospores of *G. yamadae* to germinate (Fukushi 1925) and be able to initiate infections on *Juniperus* spp. The period apple fruit is in cold storage during storage and transport to Australia would provide this period of cold conditioning.
- *Gymnosporangium yamadae* has a restricted host range including aecial hosts (*Malus* spp.) and telial hosts (*Juniperus* spp.) (Farr *et al.* 2008; CAB International 2008). These host plants are grown in Australia, in commercial orchard districts, suburban and rural areas.
- On the apple host, aecia develop after dikaryotisation of spermatia produced in pycnia. The aecia form aeciospores which infect the telial hosts. The fungus overwinters on telial hosts and forms teliospores in spring. The basidiospores released from the germinated teliospores infect apples (OEPP/EPPO 2006).
- The temperature range for germination of basidiospores of *G. yamadae* is 7-30 °C with an optimum of 16-20 °C (Guo 1994; Fukushi 1925). These temperatures are found across the apple growing regions of temperate Australia for much of the year.

The occurrence of suitable temperature and moisture conditions for spore germination and infection in some parts of Australia, moderated by the need for proximity of telial and aecial hosts, support a risk rating for establishment of ‘moderate’.

4.22.4 Probability of spread

The likelihood that *G. yamadae* will spread, based on comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pests: **HIGH**.

- *Gymnosporangium yamadae* is a serious disease of apple in China and Japan (Guo 1994; Aldwinckle 1990), and it tolerates a wide range of climates.
- Hosts of *G. yamadae* are present in Australia in commercial orchard districts, suburban and rural areas.
- No species of *Gymnosporangium* is known to be endemic to Australia or associated with native *Cupressaceae*.
- Under natural conditions, basidiospores (from telial hosts to aecial hosts) and aeciospores (from aecial hosts to telial hosts) are dispersed by wind (CAB International 2008). The basidiospores can be wind dispersed for distances of 2.5–5 km (CAAS 1992). Wind dispersal will promote rapid spread of this pathogen (Guo 1994).

- In addition, aeciospores of *G. yamadae* can be carried on fruit, stems and leaves of infected apple plants during trade and transport (CAAS 1992). Spread by humans may also occur by transporting infected plants of *Juniperus* spp. (Ma 2006). However, infection of apple trees does not persist after infected leaves or fruits have fallen in the dormant stage (CAB International 2008).
- On telial hosts (*Juniperus* spp.), *G. yamadae* can be latent during winter and may not be detectable on inspection of nursery stock. However, infection of apple trees does not persist in the tree after infected leaves or fruits have fallen in the dormant stage (CAB International 2008).

The long distance dispersal of spores by wind, and the potential movement of symptomless infected planting materials support a risk rating for distribution of ‘high’.

4.22.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of ‘rules’ for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *G. yamadae* will enter Australia as a result of trade in apple fruit from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **LOW**.

4.22.6 Consequences

The consequences of the establishment of *G. yamadae* in Australia have been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are ‘E’, the overall consequences are estimated to be **MODERATE**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|-----------------------------|--|
| DIRECT | |
| Plant life or health | <p>E – Significant at the regional level</p> <p><i>Gymnosporangium yamadae</i> is considered a serious disease of apples in China and Japan (Aldwinckle 1990).</p> <p><i>Gymnosporangium yamadae</i> infects leaves and stems of telial hosts (<i>Juniperus</i> spp.), and leaves, stems and immature fruit of apples (Ma 2006; Guo 1994).</p> <p><i>Gymnosporangium yamadae</i> causes damage by defoliation (Guo 1994; Aldwinckle 1990). Infection of young fruit causes fruit drop and a reduction in apple fruit yield and quality (Guo 1994).</p> <p><i>Gymnosporangium yamadae</i> would be detrimental to ornamental <i>Juniperus</i> spp. No species of <i>Gymnosporangium</i> is known to be endemic to Australia or associated with native <i>Cupressaceae</i>.</p> |

| | |
|---|--|
| Other aspects of the environment | <p>A – Indiscernible at the local level</p> <p>There are no known direct consequences of <i>G. yamadae</i> on natural or built environments.</p> |
| INDIRECT | |
| Eradication, control etc. | <p>D – Significant at the district level</p> <p>Programs to monitor and eradicate <i>G. yamadae</i>, should it reach Australia, would be costly. Existing Integrated Disease Management (IDM) programs may be disrupted due to possible increases in the use of fungicides. Costs for crop monitoring and consultants' advice regarding management of this pathogen may also be incurred by the producers.</p> <p>Removal of telial hosts (<i>Juniperus</i> spp.) has been recommended as the most important Integrated Disease Management (IDM) measure for <i>G. yamadae</i> management. In Liaoning province of China, no <i>Juniperus</i> spp. plants were allowed to be planted within 5 km of apple orchards (Guo 1994). However, this measure may be not practical in Australia as <i>Juniperus</i> spp. plants are often grown in private gardens and public parks.</p> |
| Domestic trade | <p>D – Significant at the district level</p> <p>The presence of <i>G. yamadae</i> in commercial apple production areas in Australia would result in the implementation of interstate quarantine measures and potential loss of markets.</p> |
| International trade | <p>E – Significant at the regional level.</p> <p><i>Gymnosporangium yamadae</i> is one of the non-European <i>Gymnosporangium</i> spp. listed as A1 quarantine organisms by EPPO (EPPO 2005b). It is also listed as a quarantine pest by the Interafrican Phytosanitary Council. Its presence in commercial apple production areas in Australia would limit market access for Australian apples to overseas markets which lack this pest.</p> |
| Environment | <p>B – Minor significance at the local level</p> <p>Additional fungicide applications or other control activities would be required to control this disease on susceptible crops. These may have minor impact on the environment.</p> |

4.22.7 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for Japanese apple rust | |
|--|----------|
| Overall probability of entry, establishment and spread | Low |
| Consequences | Moderate |
| Unrestricted risk | Low |

As indicated, the unrestricted risk for Japanese apple rust has been assessed as 'low', which exceeds Australia's ALOP. Therefore, specific risk management measures are required for this pest.

4.23 Apple brown rot - *Monilinia fructigena*

4.23.1 Introduction

Apple brown rot is a fungal disease caused by the pathogen *Monilinia fructigena*. *Monilinia fructigena* is a pathogen favoured by moist conditions, rain, fog and other factors that increase humidity, especially at the beginning of the host's growth period. This fungus overwinters mainly in or on infected mummified fruit, either attached to the tree or on the ground (Byrde and Willetts 1977). Other infected tissues on trees, such as peduncles and cankers on twigs or branches, could also serve as primary inocula. The mycelia survive long periods of adverse environmental conditions within mummified fruits, twigs, cankers and other infected tissues. In the spring or early summer when temperature, day length and relative humidity are suitable for sporulation, tufts of conidiophores form sporodochia on the surface of the mummified fruit and infected tissues bear chains of asexual spores (conidia) (Jones 1990). The anamorph of this fungus is referred to as the *Monilia* state. The conidia of *M. fructigena* are dry air-borne spores, transported by wind, water or insects to young fruit (Jones 1990; Batra 1979). Initial infection is always via wounds, usually scab lesions or sites of insect damage, but subsequent spread by contact between adjacent fruit is possible. Any infected tissue in which the moisture content is sufficient for sporulation may serve as a source of inoculum for secondary infection. Thus a new cycle of infection is started that coincides with early spring growth of host plants (Batra 1979).

Apothecia are produced in spring on mummified fruit that have overwintered on the ground. The liberation of ascospores normally coincides with the emergence of young shoots and blossoms of plants.

The risk scenario of particular relevance to *M. fructigena* is that latent infections may occur and remain undetected on fruit.

Monilinia fructigena was included in the existing import policy for pears from China (Biosecurity Australia 2005b; AQIS 1998b) and Fuji apples from Japan (AQIS 1998a). The assessment of *M. fructigena* presented here builds on these existing pest risk assessments.

4.23.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that *Monilinia fructigena* will arrive in Australia with the importation of the commodity: **HIGH**.

- Apple brown rot caused by *M. fructigena* is a significant disease causing damage to apple trees and fruit in Shandong, Shaanxi, Liaoning and other major apple growing areas in China (Ma 2006; AQSIQ 2005; CIQSA 2001c; CIQSA 2001a).
- *Monilinia fructigena* overwinters in infected fruit, peduncles and twig cankers on branches. Conidia produced on infected blossoms and twigs infect wounded apple fruit as they mature (Jones 1990).

- At harvest, apparently healthy fruit can be contaminated with conidia (Ma 2006). Wounded fruit may also be contaminated by conidia during packing house processes. Fruit rots develop during the postharvest period.
- The mycelia survive long periods of adverse environmental conditions within mummified fruit, infected twigs, cankers and the other diseased tissues, suggesting that the fungus may survive the cold storage and transportation processes (Jones 1990).
- *Monilinia fructigena* has the ability to cause latent infection in fruit. The infected fruit do not produce symptoms of disease until the fruit begins to ripen during storage and transport, on the market shelf, or as the fruit senesces (Byrde and Willetts 1977).

The wide distribution of this fungus in major apple production areas in China, the potential for latent infection and symptomless infected fruit passing through packing house processes, support a risk rating for importation of ‘high’.

Probability of distribution

The likelihood that *M. fructigena* will be distributed in Australia in a viable state as a result of processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **HIGH**.

- Imported apple fruit is intended for human consumption in Australia. It is expected that once the apple fruit has arrived in Australia it will be distributed throughout Australia for repacking and/or retail sale. The infected fruit may be distributed during these processes. Disposal of infected fruit near susceptible hosts may aid distribution of this pathogen.
- Spores are disseminated by air currents and water splash (Byrde and Willetts 1977).
- The dry, air-borne spores can easily be dispersed when packaging is opened.
- Individual consumers will distribute small quantities of apples to a variety of urban, rural and wild environments where they will be consumed, or disposed of in close proximity to a suitable host plant.
- *Monilinia fructigena* has a wide range of hosts, including apple, pear, plum, quince, peach, apricot, nectarine, grape, and hazel (Farr *et al.* 2008; Byrde and Willetts 1977). These host plants are common in parks, home gardens, nurseries and in commercial orchards in Australia.
- *Monilinia fructigena* has the ability to cause latent infection in fruit, and also to develop during storage and transport, or as the fruit senesces (Byrde and Willetts 1977). Cross contamination may occur during storage and transportation. The infected fruit may be distributed to various areas during retail distribution.
- The mycelia survive long periods of adverse environmental conditions within mummified fruit, twigs, cankers and the other infected tissues, suggesting that the pathogen may survive the cold storage and transportation processes (Jones 1990).

The wide range and distribution of hosts, the disposal of fruit waste in the environment and the ability of wind and water droplets to transfer spores from the fruit waste to a host, support a risk rating for distribution of ‘high’.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The

likelihood that *M. fructigena* will enter Australia as a result of trade in the commodity and be distributed in a viable state to a suitable host: **HIGH**.

4.23.3 Probability of establishment

The likelihood that *M. fructigena* will establish, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **HIGH**.

- *Monilinia fructigena* is a pathogen of moist conditions, favoured by rain, fog and other factors that increase humidity especially at the beginning of the host growth period. *Monilinia fructigena* is widely distributed throughout Europe, the Middle East, China, India, North Africa and South America. In China, *M. fructigena* is established in all major apple production areas including Shandong, Shaanxi and Liaoning provinces (Ma 2006). This indicates that *M. fructigena* has the ability to survive and establish in a wide range of environments.
- *Monilinia fructigena* can infect many fruit crops including apple, pear, plum, quince, peach, apricot, nectarine, grape, and hazel (Farr *et al.* 2008; Byrde and Willetts 1977). These host plants are widely available in parks, home gardens, nurseries, along roadsides and in commercial orchards in Australia.
- Both conidia and ascospores are the sources of primary inoculum (Batra and Harada 1986; Willetts and Harada 1984).
- Transport by air is the most important way that spores of this pathogen reach hosts. Aerial dispersal of spores results in spread over a wide area, whilst water splash dispersal brings about only short-range dissemination, mainly to other parts of the same tree or between adjacent trees.
- Any infected tissue in which the moisture content is sufficient for sporulation may serve as a source of inoculum for secondary infection (Ma 2006).
- The mycelia are able to survive long periods of adverse environmental conditions within mummified fruit, twigs, cankers and other infected tissues. When conditions become favourable (after a dormant period), spores are produced on infected tissues (Jones 1990) and a new cycle of infection is started, coinciding with spring growth. Spores are disseminated by air currents and water splash (Byrde and Willetts 1977).
- Wounds on the fruit surface caused by birds, insects or other pathogens provide a pathway for this pathogen to infect apple fruit and aid the spread of *M. fructigena* (Byrde and Willetts 1977).
- Protective fungicide treatments provide the best control of fruit rot. Other control measures include cultural control and sanitary methods, control of vectors, postharvest control and biological control (Byrde and Willetts 1977). A recent survey of Australian stone fruit growers showed that brown rot (caused by *Monilinia fructicola* and *M. laxa*) was the disease that they had most difficulty controlling (Hetherington 2005).

The occurrence of suitable temperature and moisture conditions for spore germination and infection in fruit production areas of Australia and the wide range of hosts, support a risk rating for establishment of 'high'.

4.23.4 Probability of spread

The likelihood that *M. fructigena* will spread, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pest: **HIGH**.

- *Monilinia fructigena* has a wide range of hosts including apple, pear, plum, quince, peach, apricot, nectarine, grape and hazel (Farr *et al.* 2008; Byrde and Willetts 1977), which are common in parks, home gardens, nurseries and in commercial orchards in Australia.
- *Monilinia fructigena* can be passed from one fruit to others in contact with it during packing, storage and distribution (Wormald 1954), allowing for the spread of *M. fructigena* during these processes.
- The dissemination of conidia of *M. fructigena* is promoted by wind at high temperatures and low relative humidity (Jones 1990). Many regions across Australia have climates which are favourable for the spread of *M. fructigena*, especially in southern Australia.
- Transport by air is the most important way that spores of this pathogen reach hosts. Under suitable conditions, the introduction of *M. fructigena* has the potential to result in an epidemic, as aerial dispersal of its spores can be spread over a wide area and from one orchard to another (Ma 2006; Jones 1990).
- The spores can also be transported by water. There is potential for the spread of spores from infected trees to healthy trees by irrigation water and rain (Jones 1990). High humidity is favourable for germination (Ma 2006).
- Animals and insects (birds, wasps, beetles, flies) are important vectors of this fungus (Lack 1989).
- Movement of infected planting material would aid the spread of this pathogen.

The long distance dispersal of spores by wind and vectors and the potential movement of symptomless infected planting material, support a risk rating for spread of ‘high’.

4.23.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of ‘rules’ for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *M. fructigena* will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **HIGH**.

4.23.6 Consequences

The consequences of the establishment of *M. fructigena* in Australia have been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are ‘E’, the overall consequences are estimated to be **MODERATE**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|---|---|
| DIRECT | |
| Plant life or health | <p>E – Significant at the regional level</p> <p><i>Monilinia fructigena</i> can affect leaves (wilting, yellowing or death), growing points (dead heart), stems (internal discoloration, canker, abnormal exudates or dieback) and fruit (brown rot), causing reduced vigour and loss of yield (Ma 2006).</p> <p><i>Monilinia fructigena</i> causes significant yield losses both before and after harvest. In Europe, losses of 7-36% were reported in individual orchards (Jones 1990). Losses are highly visible to the grower, although it is not easy to assess the overall losses it causes in a country, or on a worldwide scale (Jones 1990).</p> <p>In addition to apple, <i>M. fructigena</i> also causes fruit rot on pear, plum, sweet cherry, peach, nectarine, apricot and quince (Batra 1991).</p> |
| Other aspects of the environment | <p>B – Minor significance at the local level</p> <p><i>Monilinia fructigena</i> can infect a wide range of fruit crops (Ma 2006). However, it is not known if <i>M. fructigena</i> will infect native plant species or endangered species.</p> |
| INDIRECT | |
| Eradication, control etc. | <p>E – Significant at the regional level</p> <p>Any attempts to eradicate <i>M. fructigena</i>, should it reach Australia, would be difficult, costly and would be unlikely to occur. <i>Monilinia fructigena</i> also infects stone fruit and may be unable to be differentiated from <i>M. fructicola</i> and <i>M. laxa</i> under field conditions. Therefore, eradication would have to encompass all three <i>Monilinia</i> species from apples, stone fruit and pears. Diverse measures would be necessary, including chemical control, biological control, control of vectors, cultural measures, postharvest control and breeding resistant varieties to control or eradicate the fungus (Ma 2006).</p> <p>Fungicides used for the routine control of other diseases, such as apple scab, powdery mildew, apple rust and grey mould are effective for reducing the amount of overwintering inoculum and subsequent sporulation formed on the infected tissue (CAB International 2007a; Ma 2006).</p> <p>Control of insects that serve as vectors and/or provide wounds for subsequent infection is essential for effective control of <i>M. fructigena</i>. Applying a protectant fungicide without delay when significant injuries, caused by weather conditions such as hail storms, occur is an important measure (Byrde and Willetts 1977). Measures such as cooling, a combination of cooling and fungicides, and other postharvest treatments have been suggested to control <i>M. fructigena</i> (Ma 2006).</p> |
| Domestic trade | <p>E – Significant at the regional level</p> <p><i>Monilinia fructigena</i> causes significant losses both before harvest and postharvest (Byrde and Willetts 1977) and this pathogen poses a high potential for establishment and spread from infected orchards to uninfected orchards. Therefore, the presence of <i>M. fructigena</i> in commercial production areas is likely to result in interstate trade restrictions on apples, pears and stonefruit, and potential loss of markets.</p> |
| International trade | <p>E – Significant at the regional level</p> <p>Its presence in pome and stone fruit production areas of Australia would have impacts on the export of Australia's fresh pome and stone fruit to countries where this pathogen is not present such as NZ and the USA.</p> |
| Environment | <p>B – Minor significance at the local level</p> <p>Additional fungicide applications or other control activities would be required to control this disease on susceptible crops and these may have minor impact on the environment.</p> |

4.23.7 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for apple brown rot | |
|--|----------|
| Overall probability of entry, establishment and spread | High |
| Consequences | Moderate |
| Unrestricted risk | Moderate |

As indicated, the unrestricted risk for apple brown rot has been assessed as ‘moderate’, which exceeds Australia’s ALOP. Therefore, specific risk management measures are required for this pest.

4.24 *Mucor rot – Mucor mucedo and Mucor racemosus*

4.24.1 Introduction

Mucor racemosus is not present in Western Australia and is a pest of regional quarantine concern for that state.

Mucor rot is a fungal post-harvest disease of apple and pear primarily caused by *Mucor piriformis*, *Mucor mucedo* and *Mucor racemosus* (Spotts 1990b). Infection usually occurs through stem wounds (Washington State University 2005), turning the tissue soft, watery and light brown. Measurable lesions on fruit are detectable after 10 days at -1°C (Bertrand and Saulie-Carter 1980). After about two months in cold storage at 0°C, infected fruit completely decay and release juice containing sporangiospores. Secondary spread in cold storage is uncommon in apples (Spotts 1990b; Michailides and Spotts 1990; Bertrand and Saulie-Carter 1980). Serious losses due to mucor rot have occurred in the USA (Spotts 1990b).

Mucor mucedo and *M. piriformis* are closely related species forming sporangiospores and zygospores (Schipper 1975). *Mucor racemosus* is a member of a different clade (Jacobs and Botha 2008; Schipper 1976). All these species may be associated with decaying fruit, soil and dung (Jacobs and Botha 2008; Schipper 1976).

Mucor mucedo and *M. racemosus* have been recorded in China (Bi *et al.* 2007; Bi *et al.* 2003; Teng 1996; Cheng *et al.* 1988). Although *Mucor piriformis* has been used in laboratory research in China, it has not been recorded in China. *Mucor mucedo* has not been recorded in Australia. *Mucor piriformis* and *M. racemosus* have been recorded in some parts of Australia (*M. piriformis* in Queensland and Victoria; *M. racemosus* in the Australian Capital Territory, New South Wales and Victoria) but not in Tasmania or Western Australia (APPD 2009).

The risk scenario of concern for mucor rot fungi is that symptomless infected fruit may be exported and result in the establishment of these pathogens in Australia or regions of Australia.

Not much scientific information on *Mucor mucedo* and *M. racemosus* is available. The assessment of *Mucor mucedo* and *M. racemosus* has been largely based on the scientific information on *M. piriformis* because of their related biology and taxonomy, and are predicted to pose a similar risk and to require similar mitigation measures. Unless explicitly stated, the information presented is considered as applicable to all three species. In this section, the common name mucor rot will be used to refer to all three species. The scientific name will be used when the information is about a specific species.

4.24.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that mucor rot fungi will arrive in Australia with the importation of the commodity: **VERY LOW**.

- *Mucor mucedo* and *M. racemosus* have been recorded on plant species other than apples in China (Bi *et al.* 2007; Bi *et al.* 2003; Teng 1996; Cheng *et al.* 1988). *Mucor piriformis* has been used in laboratory research, but has not been recorded in China.
- Serious losses due to mucor rot have occurred in the USA, both in the eastern and the western states (Spotts 1990b).
- Michailides and Spotts (1990b) claimed that mucor rot of pears and apples in the USA Pacific Northwest states (PNW) and of stone fruit in California, USA were caused only by *M. piriformis*. However, Michailides (1991) demonstrated the pathogenicity of *M. racemosus* isolates from stone fruit in California. All three assessed mucor species have been reported from the PNW, and it must be assumed that all three can contribute to mucor rot.
- During harvest, the underside of harvest bins can be covered with soil and debris. In Oregon, USA, as many as 8333 propagules (mycelia and spores) of *M. piriformis* have been recovered per gram of dry soil sampled from harvest bins in pear orchards (Michailides and Spotts 1990).
- In packing houses in the USA, apple fruit is commonly removed from field bins by immersion dumping (Bertrand and Saulie-Carter 1979). Dump-tank water is thus contaminated with the soil and debris brought in with the bin. Studies conducted in 1975 and 1978 showed that dump-tank water samples collected from packing houses in Oregon commonly contained spores of *M. piriformis* (Bertrand and Saulie-Carter 1979). *Mucor piriformis* was also isolated from dump-tank water in 1981 to 1983 from apple and pear packing houses, even though the water contained chlorine. The levels of *M. piriformis* increased as the packing season progressed (Spotts and Cervantes 1986).
- Infection of apple fruit occurs during harvest or in the dump-tank during processing in the packing house. Late harvested, overmature or injured apples are particularly susceptible to infection (Washington and Holmes 2006; Spotts 1990b; Michailides and Spotts 1990).
- *Mucor piriformis* can grow well at temperatures used for cold storage of apples (Bertrand and Saulie-Carter 1980; Smith *et al.* 1979). It can cause post-harvest fruit decay at 0–20°C (Smith *et al.* 1979).
- Infected fruit completely decay after about two months in cold storage at 0 °C and release juice containing sporangiospores. Secondary spread in cold storage is uncommon in apples (Spotts 1990b; Michailides and Spotts 1990; Bertrand and Saulie-Carter 1980).

The lack of evidence of these fungi on apples in China supports a risk rating for importation of ‘very low’.

Probability of distribution

The likelihood that mucor rot fungi will be distributed in Australia in a viable state as a result of the processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **HIGH**.

- Imported apple fruit is intended for human consumption in Australia. It is expected that once the apple fruit has arrived in Australia, it will be distributed throughout Australia for wholesale or retail sale. Any infected fruit present may be distributed during these procedures. However, infected fruit with obvious signs of rot are expected to be

disposed of rather than distributed further. Measurable lesions on fruit are detectable after 10 days at -1 °C (Bertrand and Saulie-Carter 1980).

- If fruit purchased by consumers are found to be rotten, they will be disposed of into garden compost bins, possibly near host plants, or into landfills. Individual consumers will distribute small quantities of apples to a variety of urban, rural and wild environments, where they will be consumed or disposed of in close proximity to a suitable host plant.
- Infected fruit disposed of near suitable hosts may serve as a source of inoculum.
- Sporangiospores of *M. piriformis* are primarily dispersed by rain, insects and birds. Experiments have shown that, on peach, nitidulid beetles (*Carpophilus hemipterus* and *C. freemani*) and vinegar flies (*Drosophila melanogaster*) can spread the fungus from fruit to fruit. In orchards with high incidence of decayed, infected fruit contamination by vinegar flies can be expected to be very high (Michailides and Spotts 1990). Vinegar flies are very common in pome fruit orchards.
- It is likely that if infected fruit is eaten by wild animals, spores will survive passage through the gut and germinate and grow on dung (Jacobs and Botha 2008; Schipper 1976; Schipper 1975).
- Sporangiospores of *M. piriformis* are not dispersed by wind (Spotts 1990b), but those of *M. racemosus* are (Sarbhoy 1966). *Mucor racemosus* forms abundant chlamydospores in the aerial mycelium (Sarbhoy 1966) which probably function as long-lived survival propagules. *Mucor piriformis* and *M. mucedo* do not form chlamydospores.
- If zygospores are present, they may serve as a long-lived source of inoculum.
- All three *Mucor* species occur in a wide range of environments, suggesting that the climate in most parts of Australia is likely to be suitable for the survival of these species. *Mucor piriformis* has already been recorded in Queensland and Victoria, and *M. racemosus* in the Australian Capital Territory, New South Wales and Victoria (APPD 2009).

The potential distribution of infected fruit throughout Australia, the disposal of fruit waste in the environment and the ability of rodents, birds and insects to transfer spores from the fruit waste to a host, support a risk rating for distribution of ‘high’.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The likelihood that mucor rot fungi will enter Australia as a result of trade in the commodity and be distributed in a viable state to a suitable host: **VERY LOW**.

4.24.3 Probability of establishment

The likelihood that mucor rot fungi will establish, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **HIGH**.

- The mucor rot fungi assessed have a wide host range. Hosts of *M. piriformis* include apple, carrot, gooseberry, orange, pear, plum, stone fruit, strawberry, sweet potato and tomato (Kirk 1997; Smith *et al.* 1979). Hosts of *M. racemosus* include sweet potato,

potato and citrus (Lunn 1977). Hosts of *M. mucedo* include tomato and strawberry (Moline and Kuti 1984).

- Suitable hosts are widely present in Australia. The three species of *Mucor* are widely distributed overseas (Kirk 1997; Schipper 1976; Sarbhoy 1966).
- *Mucor piriformis* is a soilborne fungus that survives primarily as sporangiospores. The spores are associated with organic matter, such as fallen fruit, in the top layer of the soil (Spotts 1990b). Species of *Mucor* can survive as saprotrophs (Kirk 1997).
- *Mucor piriformis* survives well in cool, dry soil. Sporangiospores of *M. piriformis* do not survive well at soil temperatures of 27 °C or above. Soil temperatures of 33 °C and above lead to a rapid decline in spore viability (Michailides and Ogawa 1987).
- Sporangiospores of *M. piriformis* are able to survive in soil for up to one year if average weekly soil temperatures are below 27 °C (Michailides and Ogawa 1987).
- Under experimental conditions, optimal growth and sporulation of *M. piriformis* occurs at 10-15 °C. No growth was observed at 30 °C, both for *M. mucedo* and *M. piriformis* (Schipper 1975). The optimum temperature for growth and sporulation of *M. racemosus* is higher, 5-30 °C (Schipper 1976).
- Under experimental conditions, spore germination of *M. piriformis* occurs at temperatures of 1-20 °C. Optimal germination occurs at 20 °C. Germination at 25 °C was abnormal and no germination was observed at 30 °C (Bertrand and Saulie-Carter 1980).
- Viability of sporangiospores decreases rapidly in wet soils, but soil temperature is more important than soil moisture (Michailides and Ogawa 1987). Clamydospores in mycelium of *M. racemosus* would permit it to persist in soil.
- *Mucor piriformis* cannot compete effectively with other soil microbes at 20 °C and above (Michailides and Spotts 1990).
- To be able to propagate, the fungus requires a nutrient base of fallen fruit or other organic matter, low temperatures and a high moisture level in the soil (Spotts 1990b; Michailides and Spotts 1990).

The wide distribution of hosts, the occurrence of suitable temperature and moisture conditions for spore germination and infection in some parts of Australia, support a risk rating for establishment of 'high'. *Mucor racemosus* has been recorded in the Australian Capital Territory, New South Wales and Victoria, further supporting the risk rating for establishment of 'high' for these fungi.

4.24.4 Probability of spread

The likelihood that mucor rot fungi will spread, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pest: **HIGH**.

- Spores of *M. piriformis* are primarily dispersed by rain, insects and birds (Michailides and Spotts 1990). In the orchard, fallen fruit is infected by direct contact with infected soil or by spores dispersed by rodents, birds and insects from decaying fruit. Rain washes spores from decaying fruit into the soil. Sporangiospores can also be dispersed as a result of mowing, which scatters pieces of infected fruit (Spotts 1990b). The fungus

can persist as a saprotroph (Kirk 1997). Sporangiospores of *M. racemosus* are wind dispersed (Sarbhoy 1966).

- The fungus can be dispersed via movement of infected soil (e.g. with harvest bins or machinery) or via water borne dispersal of sporangiospores (Kirk 1997). It enters the packing house in soil adhering to harvest bins. Infection of apple fruit occurs during harvest or in the dump tank during processing in the packing house. Late harvested, overmature or injured apples are particularly susceptible to infection (Washington and Holmes 2006; Spotts 1990b; Michailides and Spotts 1990).
- Spores of *M. piriformis* are not dispersed by wind (Spotts 1990b), but may be splash dispersed (Kirk 1997).
- Hosts of the mucor rot fungi assessed are present in Australia in commercial orchard districts, suburban and rural areas.
- All three *Mucor* species occur in a wide range of environments, suggesting that the climate in most parts of Australia is likely to be suitable for the survival of these species. *Mucor piriformis* has already been recorded in Queensland and Victoria, and *M. racemosus* in the Australian Capital Territory, New South Wales and Victoria.
- *Mucor piriformis* survives well in cool, dry soil. Soil temperatures of 33 °C and above lead to a rapid decline in spore viability (Spotts 1990b).
- Sporangiospores of *M. piriformis* are able to survive in soil for up to one year if average weekly soil temperatures are below 27 °C (Michailides and Ogawa 1987).
- To be able to propagate, the fungus requires a nutrient base of fallen fruit, low temperatures and a high moisture level in the soil (Spotts 1990b; Michailides and Spotts 1990).

The dispersal of spores with infected soil, by animals or rain, and in the case of *M. racemosus* by wind, support a risk rating for spread of 'high'. *Mucor racemosus* has been recorded in the Australian Capital Territory, New South Wales and Victoria, further supporting the risk rating for spread of 'high' for these fungi.

4.24.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of 'rules' for combining qualitative likelihood shown in Table 2.2.

The likelihood that mucor rot fungi will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **VERY LOW**.

4.24.6 Consequences

The consequences of the establishment of mucor rot fungi in Australia has been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are 'D', the overall consequences are estimated to be **LOW**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|---|---|
| DIRECT | |
| Plant life or health | <p>D – Significant at the district level</p> <p><i>Mucor rot</i> is a post-harvest disease and does not affect life or health of the plant or of the fruit pre-harvest. Infection of apple fruit occurs during harvest or during processing in the packing house. Infected tissue is soft, watery and light brown, and infected fruit completely decay after about two months in cold storage at 0°C (Spotts 1990b). Secondary spread in cold storage is uncommon in apples (Spotts 1990b; Michailides and Spotts 1990; Bertrand and Saulie-Carter 1980).</p> <p>Serious losses due to this disease have occurred in the USA, but it occurs less consistently than blue mould (caused by <i>Penicillium</i> spp.) or grey mould (caused by <i>Botrytis cinerea</i>) (Spotts 1990b). In some seasons considerable losses have occurred in areas of Australia where <i>mucor rot</i> is present (Washington and Holmes 2006). It is not known if the assessed <i>Mucor</i> spp. would have any effects on native plants.</p> |
| Other aspects of the environment | <p>A – Indiscernible at the local level</p> <p>There are no known direct consequences of these species on other aspects of the environment.</p> |
| INDIRECT | |
| Control, eradication, etc. | <p>D – Significant at the district level</p> <p>No fungicides are registered for the control of <i>Mucor</i> on apples in Australia (Washington and Holmes 2006).</p> <p>Recommended measures for the control of <i>M. piriformis</i> in the orchard include: cleaning of fruit bins before harvest; harvesting in dry weather; avoiding fruit injury; minimising the collection of soil and debris on the underside of fruit bins; avoiding the movement of infected soil with machinery; avoiding putting fruit that has fallen to the ground during harvest into bins with harvested fruit; removing fallen fruit from the orchard floor (Washington and Holmes 2006; Spotts 1990b). Some of these measures are very labour-intensive and not always practicable. Implementation of these control measures would result in an increase in the cost of production. Additionally, costs for crop monitoring and consultants' advice to manage these pests may be incurred by the producer.</p> |
| Domestic trade | <p>B – Minor at the local level</p> <p>Apple fruit infected with <i>Mucor</i> spp. completely decay after about two months in cold storage at 0 °C. Measurable lesions on fruit are already detectable after 10 days at 1 °C (Bertrand and Saulie-Carter 1980). Secondary spread in cold storage is uncommon in apples (Spotts 1990b; Michailides and Spotts 1990; Bertrand and Saulie-Carter 1980). Serious losses due to this disease have occurred in the US (Spotts 1990b). The <i>Mucor</i> species assessed also infect fruit of other commercial species, including <i>Fragaria X ananassa</i> Duch. (strawberry), <i>Prunus</i> spp., <i>Rubus idaeus</i> (raspberry) and <i>Solanum lycopersicum</i> var. <i>lycopersicum</i> (tomato) (Kirk 1997; Moline and Kuti 1984; Dennis and Mountford 1975).</p> <p><i>Mucor mucedo</i> has not been recorded in Australia. <i>Mucor racemosus</i> has been recorded in some parts of Australia, but not in Western Australia (APPD 2009).</p> <p>The presence of these species of <i>Mucor</i> in commercial production areas could result in the implementation of interstate quarantine measures, causing loss of market and subsequent industry adjustment.</p> |

| | |
|----------------------------|---|
| International trade | <p>D – Significant at the district level</p> <p>The presence of these mucor rot fungi in commercial production areas of a range of commodities, including apple, raspberry, stone fruit, strawberry and tomato, would have a significant effect at the district level due to potential limitations of accessing international markets where these pests are absent, such as New Zealand. <i>Mucor rot</i> is already present in the USA, Canada, South Africa and Europe</p> |
| Environment | <p>A – Indiscernible at the local level</p> <p>Additional fungicide applications are unlikely because, currently, no fungicides are registered for the control of <i>Mucor rot</i> in Australia (Washington and Holmes 2006). Other control activities would be required to control these pathogens on susceptible crops.</p> |

4.24.7 Unrestricted risk

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for mucor rot | |
|--|-------------------|
| Overall probability of entry, establishment and spread | Very low |
| Consequences | Low |
| Unrestricted risk | Negligible |

As indicated, the unrestricted risk estimate for mucor rot fungi has been assessed as ‘negligible’, which achieves Australia's ALOP. Therefore, no specific risk management measures are required for these pests.

4.25 European canker - *Neonectria ditissima*

4.25.1 Introduction

European canker caused by the fungus *Neonectria ditissima*, is an important disease affecting apples, pears and many species of hardwood forest trees (Swinburne 1975). The disease mostly affects branches and trunks of trees, causing cankers. Infection is initiated through leaf and bud scars, bark disruptions such as pruning cuts and wounds, or woolly aphid galls (Swinburne 1975). In apple and pear species, fruit is also infected and develops rot. Foliage is not affected (Butler 1949). Typically, infection of fruit occurs at the blossom end, through either the open calyx, lenticels, scab lesions or wounds caused by insects (Swinburne 1975; McCartney 1967; Swinburne 1964). Sometimes the rot can develop at the stem-end (Bondoux and Bulit, 1959; Swinburne, 1964) or rarely on the surface of the fruit when the skin is damaged (Bondoux and Bulit 1959). Apple varieties vary greatly in their susceptibility to the disease, but no variety is immune (McKay 1947).

The fungus produces two types of spores: conidia in spring and summer, and ascospores in autumn and winter. Spores are dispersed by rain splash and wind, and possibly by insects and birds (Butler 1949). Spores germinate over a range of temperatures between 2 °C and 30 °C, the optimum being 20–25 °C (Munson 1939).

The risk scenario of particular relevance to *N. ditissima* is primarily any latent infection in fruit that would not have been detected during harvesting and grading operations.

Neonectria ditissima (as *Nectria galligena*) was assessed in the *Final Import Risk Analysis Report for Apples from New Zealand* (Biosecurity Australia 2006a). In that assessment, the overall probability of entry, establishment and spread was assessed to be ‘low’ using a semi-quantitative method and the consequences assessed to be ‘moderate’. As a result the unrestricted risk was assessed to be ‘low’ and specific risk management measures were determined to be necessary.

Neonectria ditissima occurs sporadically in parts of Shaanxi, Gansu, Shanxi, Hebei and Nenan (Ma 2006). The likelihood of *N. ditissima* occurring on apple fruit in China is considered to be comparable to that from New Zealand. Transport of apple fruit from China will normally take longer than from New Zealand. However, *N. ditissima* can readily survive extended cold storage (Biosecurity Australia 2006a). For these reasons, Biosecurity Australia considers that the probability of importation of *N. ditissima* on apple fruit from China would be in the same range as that for apple fruit from New Zealand. Factors affecting the distribution of the commodity (and with it the pathogen) in Australia are similar for both countries. The probability of establishment and of spread of *N. ditissima* in Australia, and the consequences it may cause will be the same for any commodity with which the species is imported into Australia. Therefore, the existing pest risk assessment for *N. ditissima* for fresh apple fruit from New Zealand is proposed for the importation of apple fruit from China as the unrestricted risk estimate is considered to be in the same range.

4.25.2 Unrestricted risk

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

Biosecurity Australia considers the unrestricted risk of *N. ditissima* through the importation of apple fruit from China is the same as the risk of this pathogen through the importation of apple fruit from New Zealand. Therefore, the existing policy for *N. ditissima* has been adopted for the importation of apple fruit from China.

| Unrestricted risk estimate for European canker | |
|--|-----------------|
| Overall probability of entry, establishment and spread | Low |
| Consequences | Moderate |
| Unrestricted risk | Low |

As indicated, the unrestricted risk for European canker has been assessed as ‘low’, which exceeds Australia’s ALOP. Therefore, specific risk management measures are required for this pest.

4.26 Apple blotch - *Phyllosticta arbutifolia*

4.26.1 Introduction

Apple blotch is a fungal disease caused by *Phyllosticta arbutifolia* (previously known as *P. solitaria*), which is native to North America. Primary infection occurs about 2-3 weeks after blossom fall. Overwintered cankers are probably the exclusive source of primary inoculum. The rainsplash-dispersed pycnidiospores infect the current year's growth, with new cankers appearing in August. Lesions also occur on the leaves and fruit. Primary lesions on fruit and foliage are important inoculum sources for summer infections. On fruit in the autumn, pycnidia function, release, fill up and become typical pycnosclerotia, in which stage they overwinter. However, the overwintering pycnosclerotia on infected fruit and fallen leaves give rise to pycnidiospores in the spring, but their role as inoculum is probably minor; many overwintering pycnosclerotia become sterile (Ma 2006; Gardner 1923). Spores are also produced each spring from cankers, leaves and fruits (Ma 2006; Yoder 1990). These spores may germinate at temperatures from 5-39 °C (Gardner 1923). The ascigerous stage of this pathogen has not been found, but possibly occurs in the spring as one of the final stages of the pycnosclerotium.

The risk scenario of particular relevance to *P. arbutifolia* is infected fruit with viable inoculum.

Phyllosticta arbutifolia (as *P. solitaria*) was included in the existing import policy for Fuji apples from Japan (AQIS 1998a). The assessment of *P. arbutifolia* presented here builds on this existing pest risk assessment.

4.26.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that *Phyllosticta arbutifolia* will arrive in Australia with the importation of the commodity: **MODERATE**.

- Apple fruit blotch caused by *P. arbutifolia* occurs widely across all major apple production areas in China (Ma 2006; CIQSA 2001c).
- Leaves, fruits and stems of susceptible apple cultivars can become infected. Lesions occur on the leaves and fruit (Ma 2006; Yoder 1990). Primary lesions on fruit and foliage are important inoculum sources for summer infections (Yoder 1990). Both disease incidence and severity are directly correlated with rainfall. For example, in years with frequent rain, 50% or more of the fruit in many orchards may be infected (Ma 2006).
- Infection on fruit can occur from petal fall up to about 4 weeks after petal fall. Lesions on the infected fruit gradually enlarge and develop fringed but distinct margins, with a star-like appearance. Lesions often crack as the fruit enlarges (Yoder 1990). Therefore, the infected fruit are likely to be rejected during hand harvesting and routine grading and sorting operations (Ma 2006; Yoder 1990).

- *Phyllosticta arbutifolia* is able to survive long periods (at least 6-9 months) of cold storage at 1-2 °C (McClintock 1930). Spores may germinate at a wide range of temperatures from 5-39 °C with an optimum germination temperature range of 21-27 °C (Gardner 1923).
- On fruit, pycnidia, which have already functioned in the season, fill up and become typical pycnosclerotia in the autumn, in which stage they overwinter. However, the overwintering pycnosclerotia on mummified fruit and fallen leaves give rise to pycnidiospores in the spring, but their role as inoculum is probably minor; many overwintering pycnosclerotia become sterile (Ma 2006; Gardner 1923).

The wide distribution of this fungus in China and the strong capacity to survive the cold storage and transportation, moderated by a limited potential of infected fruit passing through packing house processes support a risk rating for importation of ‘moderate’.

Probability of distribution

The likelihood that *P. arbutifolia* will be distributed in Australia in a viable state as a result of processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **MODERATE**.

- Imported apple fruit is intended for human consumption in Australia. It is expected that once the apple fruit has arrived in Australia it will be distributed throughout Australia for repacking and/or retail sale. Any infected fruit present may be distributed during these processes. Disposal of infected fruit near susceptible hosts may aid distribution of the pathogen.
- Individual consumers will distribute small quantities of apples to a variety of urban, rural and wild environments, where they will be consumed, or disposed of, in close proximity to a suitable host plant.
- Natural hosts – apple, pear and hawthorn (*Crataegus* spp.) – are present in Australia, in commercial orchard districts, and suburban and rural areas.
- *Phyllosticta arbutifolia* is able to survive long periods (at least 9 months) of cold storage at 1-2 °C (McClintock 1930).
- Primary lesions on fruit and foliage are important inoculum sources for summer infections by producing conidia (Yoder 1990). Infected fruit may be distributed throughout Australia during retail distribution.
- On fruit, pycnidia, which have already functioned in the season, fill up and become typical pycnosclerotia in the autumn, in which stage they overwinter. The overwintering pycnosclerotia on mummified fruit and fallen leaves give rise to pycnidiospores in the spring, but their role as inoculum is probably minor; many overwintering pycnosclerotia become sterile (Ma 2006; Gardner 1923).

The disposal of fruit waste in the environment and the ability of wind and water droplets to transfer spores from the fruit waste to a host, moderated by the limited number of hosts in Australia, support a risk rating for distribution of ‘moderate’.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The

likelihood that *P. arbutifolia* will enter Australia as a result of trade in fresh apple fruit from China and be distributed in a viable state to a suitable host: **LOW**.

4.26.3 Probability of establishment

The likelihood that *P. arbutifolia* will establish, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **MODERATE**.

- The hosts of *P. arbutifolia* are restricted to apples, pears, and hawthorns (*Crataegus* spp.) (Farr *et al.* 2008; CAB International 2007a; Ma 2006; Yoder 1990). However, these hosts are widely available in Australia, in commercial orchard districts, as well as suburban and rural areas.
- *Phyllosticta arbutifolia* is established in all apple production areas in China, and has also been reported in Brazil, Canada, Denmark, India, Japan, South Africa and USA (CAB International 2007a). Environments with climates similar to these areas exist in various parts of Australia suggesting that *P. arbutifolia* has the potential to establish here.
- Apple blotch is a disease of warm and wet weather, but spores of *P. arbutifolia* can germinate under a wide range of temperatures from 5-39 °C, with the optimum temperatures for mycelial growth and spore germination being 25-30 °C and 30 °C, respectively (Ma 2006; Yoder 1990). Temperature and humidity conditions in some parts of Australia are suitable for this pathogen's survival and establishment.
- Heavy rains and extended wetting periods promote exudation, dissemination, and germination of conidia. The radius of infection in wind-blown rain from a 10 m tree was estimated to be 80 m, with 100% infection occurring within 12 m from the infected trees (CAB International 2007a), suggesting that this pathogen has the potential to rapidly establish and spread.

The occurrence of suitable temperature and moisture conditions for spore germination and infection in some parts of Australia, moderated by the limited number of hosts, support a risk rating for establishment of 'moderate'.

4.26.4 Probability of spread

The likelihood that *P. arbutifolia* will spread, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of *P. arbutifolia*: **MODERATE**.

- *Phyllosticta arbutifolia* is a common disease of apples across all apple production areas in China (Ma 2006), suggesting that it tolerates a wide range of climates.
- The host range of *P. arbutifolia* is restricted to apples, pears and *Crataegus* spp. (Farr *et al.* 2008; CAB International 2007a; Ma 2006; Yoder 1990). These hosts are available in Australia, both in commercial orchard districts, suburban and rural areas.
- The ability to cause infection of apple trees within 80 m from an infected tree by wind-blown rain (CAB International 2007a) provides the potential for this pathogen to be spread from one orchard to nearby orchards (Ma 2006).
- Disposal of infected fruit via commercial or domestic rubbish systems may aid the spread of the pathogen.
- On fruit, pycnidia, which have already functioned in the season, fill up and become typical pycnosclerotia in the autumn, in which stage they overwinter. However, the

overwintering pycnosclerotia on mummified fruit and fallen leaves give rise to pycnidiospores in the spring, but their role as inoculum is probably minor; many overwintering pycnosclerotia become sterile (Ma 2006; Gardner 1923).

- Heavy rains and extended wetting periods promote exudation, dissemination, and germination of conidia. The radius of infection in wind-blown rain from a 10 m tree was estimated to be 80 m, with 100% infection occurring within 12 m from the infected trees (CAB International 2007a), suggesting that this pathogen has the potential to rapidly establish and spread.
- Transport of infected plant seedlings and other planting materials with cankers may aid the long distance movement of *P. arbutifolia* (CAB International 2007a) to uninfected orchards.

The potential movement of symptomless infected planting materials, moderated by the requirement of rain and an extended wetting period for spore exudation, dissemination, and germination, support a risk rating for distribution of ‘moderate’.

4.26.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of ‘rules’ for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that *P. arbutifolia* will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **LOW**.

4.26.6 Consequences

The consequences of the establishment of *P. arbutifolia* in Australia have been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are ‘E’, the overall consequences are estimated to be **MODERATE**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|-----------------------------|--|
| DIRECT | |
| Plant life or health | <p>D – Significant at the district level</p> <p><i>Phyllosticta arbutifolia</i> affects apple trees at both the vegetative growth and fruiting stages. <i>Phyllosticta arbutifolia</i> causes a serious blotching of apples which reduces fruit quality and yield (Ma 2006). In the USA, losses caused by <i>P. arbutifolia</i> were reported in the past to vary between 5 and 10%. However, the economic importance of <i>P. arbutifolia</i> has declined, probably due to the regular fungicide treatment of apple and pear orchards against diseases such as apple scab (<i>Venturia inaequalis</i>) (CAB International 2007a).</p> <p>The disease also causes damage on leaves, buds, twigs, and branches of susceptible apple cultivars (Yoder 1990), causing defoliation and development of cankers on twigs and branches (Ma 2006).</p> |
| Other | A – Indiscernible at the local level |

| | |
|-----------------------------------|--|
| aspects of the environment | There are no known direct consequences of <i>P. arbutifolia</i> on the natural or built environment. |
| INDIRECT | |
| Eradication, control etc. | <p>D – Significant at the district level</p> <p>Programs to monitor and eradicate <i>P. arbutifolia</i>, should it reach Australia, would be costly. The disease is usually controlled by planting disease free nursery stock or using resistant cultivars (Ma 2006) and following a regular fungicide program for summer disease control (Yoder 1990). Eradication of cankers formed on branches and twigs by using fungicides can be costly (Yoder 1990).</p> <p>Existing IDM programs may be disrupted due to possible increases in the use of fungicides. Costs for crop monitoring and consultants' advice regarding management of the pest may be incurred by the producer.</p> |
| Domestic trade | <p>D – Significant at the district level</p> <p>Presence of <i>P. arbutifolia</i> in apple commercial production areas would result in the implementation of interstate quarantine measures, causing loss of market and subsequent significant industry adjustment at district level.</p> |
| International trade | <p>E – Significant at the regional level</p> <p><i>Phyllosticta arbutifolia</i> has been listed as an A1 quarantine pathogen by EPPO (EPPO 2005b) and is also of quarantine significance for Comité de Sanidad Vegetal Del Cono Sur (COSAVE). Its presence in apple production areas of Australia would make it more difficult for Australia to access these markets.</p> |
| Environment | <p>B – Minor significance at the local level</p> <p>Additional fungicide applications or other control activities would be required to control this disease on susceptible crops and these may have minor impact on the environment.</p> |

4.26.7 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for apple blotch | |
|--|-----------------|
| Overall probability of entry, establishment and spread | Low |
| Consequences | Moderate |
| Unrestricted risk | Low |

As indicated, the unrestricted risk for apple blotch has been assessed as 'low', which exceeds Australia's ALOP. Therefore, specific risk management measures are required for this pest.

4.27 Sooty blotch and flyspeck complex

4.27.1 Introduction

Sooty blotch and flyspeck (SBFS) are diseases caused by a complex of fungi that colonise the wax on the cuticle of apple fruit (Batzer *et al.* 2005). Sooty blotch appears as dark smudges and flyspeck appears as groups of tiny black spots on the surface of fruit. Although these fungi do not affect the growth and development of the fruit, they cause economic loss to growers because of reduced fruit quality, and market value can be reduced by more than 90 per cent (Batzer *et al.* 2002; Williamson and Sutton 2000).

Colby (1920) determined that sooty blotch was caused by *Gloeodes pomigena* (Schwein.) Colby and flyspeck was caused by *Schizothyrium pomi* (Mont. & Fr.) Arx. Johnson and Sutton (1994) and Johnson *et al.* (1997) found sooty blotch was caused by three fungi, *Geastrum polystigmatis* Batista & M.L. Farr, *Peltaster fructicola* Eric M. Johnson, T.B. Sutton & Hodges and *Leptodontidium elatius* (de Hoog) de Hoog. Subsequently, recent studies have found that a range of fungi can cause SBFS. Batzer *et al.* (2005) using molecular methods to identify the fungi from samples from the midwest of the United States, found 30 species caused SBFS lesions on apple fruit in inoculation field trials.

In two recent studies conducted in China, a range of fungi were isolated from apples with SBFS symptoms from orchards in Shaanxi, Shandong, Liaoning, Henan and Yunnan provinces (Zhang 2007; Zhang 2006). These fungi included the following groups:

Dissoconium mali G.Y. Sun, Z. Zhang & R. Zhang and *Dissoconium multiseptatae* G.Y. Sun & Z. Zhang [Anamorphic Mycosphaerellaceae]

Paraconiothyrium sp. [Anamorphic Montagnulaceae]

Passalora sp. [Anamorphic Mycosphaerellaceae]

Peltaster sp. [Dothidiales: Dothioraceae]

Pseudocercospora sp. [Anamorphic Mycosphaerellaceae]

Pseudocercospora sp. [Anamorphic Mycosphaerellaceae]

Stenella sp. [Anamorphic Mycosphaerellaceae]

Strelitziana mali G.Y. Sun & Z. Zhang [Anamorphic Chaetothyriales]

Stomiopeltis spp. [Anamorphic Micropeltidaceae]

Wallemia longxianensis, *Wallemia qiangyangensis* and *Wallemia sebi* (Fr.) Arx [Wallemiales]

Xenostigmata sp. [Anamorphic Mycosphaerellaceae]

Zygophiala liquanensis and *Zygophiala taiyuensis* [Anamorphic Schizothyriaceae]

In the 2006 study, 18 isolates from apples, in the genera *Zygophiala*, *Wallemia*, *Dissoconium*, *Peltaster* and *Pseudocercospora*, were able to cause SBFS (Zhang 2006). Of the fungi listed above for China, *Dissoconium* spp., *Passalora* sp., *Peltaster* spp., *Pseudocercospora* spp., *Pseudocercospora* spp., *Xenostigmata* spp. and *Zygophiala* spp. have been shown to cause SBFS in the USA. Members of the SBFS complex can vary between orchards and geographic regions (Batzer *et al.* 2005).

The fungi associated with SBFS in China are anamorphic fungi that disperse by means of conidia. SBFS fungi apparently overwinter on reservoir hosts and apple twigs and fruit in the USA and conidia are spread by wind and rain to developing fruit and new tissues of reservoir hosts in the spring and early summer (Williamson and Sutton 2000). SBFS fungi grow on a wide range of reservoir hosts, including trees, shrubs and vines that are near or bordering orchards (Williamson and Sutton 2000).

Warm and moist or humid conditions are needed for the development of SBFS (Williamson and Sutton 2000). The duration of leaf wetness was related to the appearance of symptoms (Brown and Sutton 1995) and more than 100 h of relative humidity of 95% or above were required for disease development (Sharp and Yoder 1985).

Researches in the USA demonstrated that fruit bagging significantly reduces the incidence of the SBFS complex and has been used to control these diseases (Zhang 2007; Zhang 2006; Smigell and Hartman 1998; Smigell and Hartman 1997b; Smigell and Hartman 1997a).

Because the fungi that are associated with SBFS in China are not known to be present in Australia, they will be assessed in this pest risk assessment.

The risk scenario of particular relevance to the SBFS complex is fruit carrying viable inoculum.

4.27.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that SBFS fungi will arrive in Australia with the importation of the commodity: **MODERATE**.

- The fungi causing SBFS occur widely in China, being collected in Henan, Liaoning, Shaanxi, Shandong and Yunnan provinces (Zhang 2007; Zhang 2006).
- The development of SBFS diseases during the summer months occurs at relative humidities above 95% (Williamson and Sutton 2000).
- High incidences of the SBFS complex are reported to occur in Yunnan province, which has a hot and humid summer. Infection rates of 72–86% of apple fruit have been recorded, with losses from SBFS of 92–95% in some orchards in extreme years (Zhang 2006). However, Yunnan is not an export production area and fruit is unlikely to be exported to Australia from this province.
- The general incidence of SBFS in the main apple production areas in Beijing, Gansu, Hebei, Henan, Liaoning, Ningxia, Shaanxi, Shandong and Shanxi provinces in China is not published. However, the relative humidities of the main production areas of China are 60–80% during the summer months (Figure 3.2), which are below those required for the development of these fungi on the surface of the fruit.
- Sooty blotch and flyspeck produce obvious symptoms on apple fruit. Colonies vary from discrete circular colonies to large colonies with diffuse margins (Sutton 1990). Apples with obvious SBFS symptoms will be detected and discarded during the grading operations in the packing house. However, fruit in the early stages of infection or with small colonies may escape detection. Once apples are infected with SBFS fungi, it takes

about 20–28 days for symptoms to develop, but they may become visible in 8–12 days under optimal conditions (Sutton *et al.* 1988).

- Sooty blotch and flyspeck can develop in storage and transport. Drake (1974; 1972; 1970) found that when symptomless fruit was stored for 6 months at 0–1 °C, extensive sooty blotch and flyspeck developed when the last fungicide spray was made 8–10 weeks before harvest.

The occurrence of SBFS fungi in provinces exporting apple fruit, mitigated by the relative humidities being below those required for disease development in the export areas and the standard practice of fruit bagging in the export orchards, support a risk rating for importation of ‘moderate’.

Probability of distribution

The likelihood that SBFS fungi will be distributed in Australia in a viable state as a result of processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **HIGH**.

- Imported apple fruit is intended for human consumption in Australia. It is expected that once the apple fruit has arrived in Australia it will be distributed throughout Australia for repacking and/or retail sale. Any infected fruit present may be distributed during these processes.
- Individual consumers will distribute small quantities of apples to a variety of urban, rural and wild environments.
- SBFS fungi will survive distribution in Australia, as they can develop in storage at 0–1 °C (Drake 1974; Drake 1972; Drake 1970).
- Fruit waste, that may include the skin of apple fruit with SBFS colonies, may be disposed of in close proximity to a suitable host plant.
- SBFS fungi grow on a wide range of reservoir hosts, including trees, shrubs and vines that are near or bordering orchards (Williamson and Sutton 2000). For example, the host plants of *Zygophiala jamaicensis* include 120 species in 44 families of seed plants, including *Malus*, that are found throughout temperate and tropical regions (Zhang 2007; Zhang 2006). These host plants are widely distributed throughout Australia.
- The fungi associated with SBFS in China are anamorphic fungi that disperse by means of conidia (Williamson and Sutton 2000). Conidia of these fungi on the surface of SBFS colonies could be spread by wind and wind-blown rain to new tissues of hosts in close proximity to discarded apple waste.

The disposal of fruit waste in the environment, the ability of wind and water droplets to transfer spores from the fruit waste to a host and the wide range and distribution of hosts support a risk rating for distribution of ‘high’.

Probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The likelihood that SBFS fungi will enter Australia as a result of trade in fresh apple fruit from China and be distributed in a viable state to a suitable host: **MODERATE**.

4.27.3 Probability of establishment

The likelihood that SBFS fungi will establish in Australia based on a comparison of factors in the source and destination areas considered pertinent to their survival and reproduction:

HIGH.

- The development of SBFS is favoured by warm temperatures, high rainfall and high humidity (Batzer *et al.* 2008; Zhang 2007; Zhang 2006).
- The effects of temperature and relative humidity have been studied in vitro for a number of the fungi that cause SBFS. Conidia of *Peltaster fructicola* germinated from 12 to 24 °C at relative humidities of 95% or above, conidia of *Leptodontium elatius* germinated from 12 to 32 °C at relative humidities of 97% or above and conidia of *Zygophiala jamaicensis* germinated from 8 to 28 °C at relative humidities of 96% or above (Williamson and Sutton 2000).
- Conditions that would allow the establishment of SBFS fungi on host plants would occur in parts of Australia, especially during periods of wet weather in coastal areas in the warmer months of the year.
- Sooty blotch caused by *Gloeodes pomigena* and flyspeck caused by *Schizothyrium pomi* have been recorded in New South Wales and Western Australia (APPD 2008; Shivas 1989), which suggests that other SBFS fungi have the potential to establish in Australia.

The occurrence of sooty blotch caused by *Gloeodes pomigena* and flyspeck caused by *Schizothyrium pomi* in New South Wales and Western Australia and the wide range and distribution of hosts, support a risk rating for establishment of ‘high’.

4.27.4 Probability of spread

The likelihood that SBFS fungi will spread based on a comparison of the factors in the source and destination areas considered pertinent to the expansion of the geographic distribution of SBFS: **HIGH.**

- SBFS fungi have a wide range of hosts. For example, the hosts of *Z. jamaicensis* include 120 species in 44 families of seed plants, including *Malus*, throughout temperate and tropical regions (Zhang 2007; Zhang 2006). These host plants are widely distributed throughout Australia.
- The fungi associated with SBFS in China are anamorphic fungi that disperse by means of conidia (Williamson and Sutton 2000). Conidia of these fungi on the surface of SBFS colonies could be spread by wind and wind-blown rain to new tissues of hosts.
- SBFS diseases are favoured by warm temperatures, high rainfall and high humidity (Batzer *et al.* 2008; Zhang 2007; Zhang 2006).
- Conditions that would allow the development and spread of SBFS fungi on host plants would occur in parts of Australia, especially during periods of wet weather in coastal areas in the warmer months of the year.
- Sooty blotch, caused by *Gloeodes pomigena*, and flyspeck, caused by *Schizothyrium pomi*, have been recorded in New South Wales and Western Australia (APPD 2008; Shivas 1989), which suggests that other SBFS fungi have the potential to spread in Australia.
- Distribution of infected fruit via commercial or domestic movement may aid the spread of the SBFS pathogens.

- Distribution of infected nursery stock may aid the long distance movement of SBFS fungi to new areas.

The dispersal of spores by wind and wind-blown rain, the potential movement of symptomless infected planting materials and the wide range and distribution of hosts, support a risk rating for spread of 'high'.

4.27.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of 'rules' for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that SBFS fungi will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **MODERATE**.

4.27.6 Consequences

The consequences of the establishment of the SBFS fungi recorded on apple fruit in China in Australia have been estimated using the decision rules described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are 'C', the overall consequences are estimated to be **VERY LOW**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|-----------------------------|--|
| DIRECT | |
| Plant life or health | <p>C – Minor significance at the district level</p> <p>SBFS are common diseases of pome fruits in many moist, temperate growing regions of the world (Williamson and Sutton 2000). They cause considerable economic loss to growers of fresh market fruit because of reduced fruit quality (Williamson and Sutton 2000; Sutton 1990). In regions with warm, wet and humid conditions in summer when fruit is developing, such as the south-east of the USA and Yunnan Province in China, up to 95% of the crop can be affected by these diseases (Batzer <i>et al.</i> 2008; Zhang 2007; Zhang 2006).</p> <p>In Australia, SBFS are minor diseases. There are limited records of these diseases, probably due to the drier climates in Australian fruit production areas and the regular application of fungicides to control other diseases. Sooty blotch, caused by <i>Gloeodes pomigena</i>, has been recorded in New South Wales on apple, peach and orange and in Western Australia on apple (APPD 2008)(Shivas 1989). Flyspeck, caused by <i>Schizothyrium pomi</i>, has been recorded in New South Wales on apple, peach and persimmon (APPD 2008) and in Western Australia on apple (Shivas 1989). There have been no molecular studies to confirm the identity of the fungi causing SBFS in Australia.</p> <p>Although SBFS fungi have a wide range of host plants, they are unlikely to affect the health of native flora, because they are a complex of fungi that grow on the waxy cuticle of plants (Williamson and Sutton 2000)</p> |

Other aspects of the environment

A – Indiscernible at the local level

There are no known direct consequences of the SBFS complex on the natural environment.

INDIRECT

Eradication, control etc.

C – Minor significance at the district level

It is unlikely that eradication of additional species of SBFS fungi would be possible, due to their wide host range and the difficulty in identifying infected hosts.

SBFS are only recorded in NSW and WA (APPD 2008) and are minor diseases in Australia. This may be due to a combination of the unfavourable climates for disease development in the commercial fruit producing areas and the fungicide spray programs applied for the control of other diseases. It is unlikely that additional control measures would be required should additional species of the SBFS complex establish and spread in Australia.

Domestic trade

A – Indiscernible at the local level

It is unlikely that the entry, establishment and spread of additional SBFS fungi in commercial apple production areas in Australia would result in the implementation of interstate quarantine measures. Sooty blotch and flyspeck have been recorded in New South Wales and Western Australia and no interstate quarantine measures have been put in place for these diseases.

International trade

A – Indiscernible at the local level

It is unlikely that the entry, establishment and spread of additional SBFS fungi in commercial apple production areas in Australia would result in the introduction of international quarantine measures. Sooty blotch and flyspeck already occur in Australia and there are no restrictions on the export of Australian fruit because of these diseases. In addition, these diseases are widespread around the world.

Environment

A – Indiscernible at the local level

Should additional species of the SBFS complex establish and spread in Australia, it is unlikely that any additional control measures would be required that would impact on the environment.

4.27.7 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for sooty blotch and flyspeck disease complex | |
|--|-----------------|
| Overall probability of entry, establishment and spread | Moderate |
| Consequences | Very low |
| Unrestricted risk | Very low |

As indicated, the unrestricted risk for sooty blotch and flyspeck disease complex has been assessed as ‘very low’, which achieves Australia’s ALOP. Therefore, specific risk management measures are not required for the SBFS complex.

4.28 Truncate leaf spot - *Truncatella hartigii*

4.28.1 Introduction

The ascomycete *Truncatella hartigii* (syn. *Pestalotia hartigii*) belongs to the family Amphisphaeriaceae in the order Xylariales. Amphisphaeriaceae contain a number of plant pathogenic genera such as *Seiridium* and *Pestalotiopsis* (Jeewon *et al.* 2003). Many amphisphaeriaceous species are endophytes (Jeewon *et al.* 2003). They usually cause no obvious disease symptoms in plant tissues but may be latent pathogens.

Truncatella hartigii has a wide range of hosts across several unrelated plant families and including Asteraceae: *Lactuca*; Fagaceae: *Fagus*; Oleaceae: *Fraxinus*, *Olea*; Pinaceae: *Abies*, *Picea*, *Pinus*, *Pseudotsuga*; Restionaceae: *Cannomois*, *Rhodocoma* and Rosaceae: *Malus*, *Pyrus* (Farr and Rossman 2009; Lee *et al.* 2006; Vujanovic *et al.* 2000; Spaulding 1956). The fungus has only been recorded on *Pinus* in China (Farr and Rossman 2009). *Truncatella hartigii* has been recorded on *Malus* and *Pyrus* (Glawe 2009; Pierson *et al.* 1971; Zeller 1929) in the Pacific Northwest of the USA. On these species, it causes leaf spots (Chaudhary *et al.* 1987) and post-harvest decay of fruit (Rosenberger 1990b).

Truncatella hartigii has been associated with damage to many coniferous species. It has been reported to destroy the bark and stem-girdle of *Abies* and *Picea* spp. (Cooke 1906), and has been associated with damaged cones of many *Pinus* spp. (Vujanovic *et al.* 2000). However, while commonly found in *Pinus* spp. showing dieback symptoms, a clear association between the fungus and the symptoms could not be established (Dogmus-Lehtijärvi *et al.* 2007).

The risk scenario of concern for *Truncatella hartigii* is that apple fruit, including seed, may be infected yet show no obvious symptoms of the disease.

4.28.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that *T. hartigii* will arrive in Australia with the importation of the commodity: **VERY LOW**.

- *Truncatella hartigii* has been reported on *Pinus massoniana* in China (Farr and Rossman 2009). No records of *Truncatella hartigii* on fruit trees in China have been found.
- *Truncatella hartigii* is present in the Pacific Northwest of the USA on apples and pears (Glawe 2009; Pierson *et al.* 1971; Zeller 1929).
- *Truncatella hartigii* has been reported as a post-harvest decay pathogen on apple fruit (Rosenberger 1990b; Pierson *et al.* 1971) and in apple seeds (Chaudhary *et al.* 1987).
- *Truncatella hartigii* may not be symptomatic when kept in cold storage (Rosenberger 1990b; Pierson *et al.* 1971), and it is possible for infected fruit to escape visual detection (Spotts 1990a; Pierson *et al.* 1971).

The lack of evidence of the presence of *T. hartigii* on fruit trees in China supports a risk rating for importation of ‘very low’.

Probability of distribution

The likelihood that *T. hartigii* will be distributed in Australia in a viable state as a result of the processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **HIGH**.

- Imported apple fruit is intended for human consumption in Australia. It is expected that once the apple fruit has arrived in Australia, it will be distributed throughout Australia for wholesale or retail sale. Any infected fruit present may be distributed during these procedures.
- The cores of apple fruit, including seeds, are not normally consumed by humans and are disposed of as waste.
- Apple waste products disposed of as municipal waste and compost are unlikely to distribute *T. hartigii* into the environment.
- Apple waste disposed of as litter may be deposited into urban, peri-urban and agricultural situations, as well as areas of natural vegetation, throughout Australia.
- The mode of infection by *T. hartigii* is not clearly known. However, *T. hartigii* can be seed-borne (Chaudhary *et al.* 1987). Discarded apple cores may give rise to infected seedlings.
- *Truncatella hartigii* has many potential hosts in addition to *Malus* and *Pyrus* spp., including *Abies* spp., *Fagus sylvatica*, *Fraxinus excelsior*, *Larix occidentalis*, *Olea laurifolia*, *Picea* spp., *Pinus* spp. (Farr and Rossman 2009) and some South African Restionaceae (Lee *et al.* 2006).

The potential distribution of infected fruit throughout Australia, the disposal of fruit waste in the environment and the seed-borne nature of the fungus, support a risk rating for distribution of ‘high’.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The likelihood that *T. hartigii* will enter Australia as a result of trade in the commodity and be distributed in a viable state to a suitable host: **VERY LOW**.

4.28.3 Probability of establishment

The likelihood that *T. hartigii* will establish, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **HIGH**.

- There are numerous potential host species (Farr and Rossman 2009; Dogmus-Lehtijärvi *et al.* 2007; Vujanovic *et al.* 2000), many of them coniferous. Records of *T. hartigii* are from Europe, Turkey, India, Pakistan, South Africa, and North America and include a range of climates from temperate to subtropical and mediterranean (Farr and Rossman 2009). Within Australia, *T. hartigii* may be capable of occupying a range of habitats in temperate, subtropical and mediterranean areas throughout southern Australia, where

suitable hosts grow in commercial plantations and often as naturalised plants (Hnatiuk 1990).

- Species of Restionaceae are widespread in Australia. Some of these are probably susceptible to *T. hartigii* (Lee *et al.* 2006).
- In commercial apple and pear orchards, *T. hartigii* may be controlled by frequent fungicide applications. This is less likely in commercial plantations of conifers such as *Pinus radiata*, or for naturalised pome fruit trees and conifers.
- The cryptic nature of *T. hartigii* would make early detection of the fungus in Australia difficult.

The number and wide distribution of hosts support a risk rating for establishment of ‘high’.

4.28.4 Probability of spread

The likelihood that that *T. hartigii* will spread, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pest:

HIGH.

- There are numerous potential host species, many of them coniferous (Farr and Rossman 2009; Dogmus-Lehtijärvi *et al.* 2007; Vujanovic *et al.* 2000). Records of *T. hartigii* are from Europe, Turkey, India, Pakistan, South Africa, and North America and include a range of climates from temperate to subtropical and mediterranean. Within Australia, *T. hartigii* may be capable of occupying a range of habitats in temperate, subtropical and mediterranean areas throughout southern Australia where suitable hosts also grow, in commercial plantations and often as naturalised plants (Hnatiuk 1990). Native species of Restionaceae may be susceptible to *T. hartigii* (Lee *et al.* 2006).
- Geographical areas such as arid regions between the western and eastern parts of Australia could be natural barriers for the spread of *T. hartigii*.
- There are no reports on the mechanism of spread for *T. hartigii*, but is probably by splash and wind.

The number and wide distribution of hosts support a risk rating for spread of ‘high’.

4.28.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of ‘rules’ for combining qualitative likelihood shown in Table 2.2.

The likelihood that *T. hartigii* will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **VERY LOW.**

4.28.6 Consequences

The consequences of the establishment of *T. hartigii* in Australia has been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are ‘D’, the overall consequences are estimated to be **LOW**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|---|---|
| DIRECT | |
| Plant life or health | <p>D – Significant at the district level</p> <p><i>Truncatella hartigii</i> is considered a minor pest for apples and pears (Pierson <i>et al.</i> 1971). It causes leaf spots (Chaudhary <i>et al.</i> 1987) and post-harvest decay of fruit (Rosenberger 1990b). As a pathogen of conifers, it attacks the bark of seedlings, stem-girdling young plants of <i>Picea</i>, <i>Abies</i>, and <i>Pseudotsuga</i> spp. (Spaulding 1956; Cooke 1906). It has also been associated with seed and cone damage in <i>Pinus sylvestris</i> (Vujanovic <i>et al.</i> 2000). The fungus has the potential to affect the Australian softwood timber industry, although records on the impact of <i>T. hartigii</i> internationally are inconsistent.</p> <p><i>Truncatella hartigii</i> is a pathogen of some Rationaceae in South Africa (Lee <i>et al.</i> 2006). The introduction of <i>T. hartigii</i> may affect some native species in susceptible families such as Rosaceae, Oleaceae or Restionaceae.</p> |
| Other aspects of the environment | <p>A – Indiscernible at the local level</p> <p>There are no known direct consequences of this species on other aspects of the environment.</p> |
| INDIRECT | |
| Control, eradication, etc. | <p>B – Minor significance at the local level</p> <p>Once introduced, it would be difficult to eradicate or control <i>T. hartigii</i>. In pome fruit orchards, it is not expected to play a major role and could be controlled in the course of routine fungicide applications. For other trees, screening of nursery material could provide pathogen-free seedlings.</p> |
| Domestic trade | <p>B – Minor significance at the local level</p> <p>If <i>T. hartigii</i> is established in Australia, it is not likely to affect interstate trade in pomefruit or timber. It may affect the domestic trade in pine nursery stock.</p> |
| International trade | <p>A – Indiscernible at the local level</p> <p>If <i>T. hartigii</i> is established in Australia, it is not likely to affect international trade.</p> |
| Environment | <p>B – Minor significance at the local level</p> <p>As a post-harvest pathogen of apples, <i>T. hartigii</i> may affect the quality of apples for the consumer if rot symptoms become apparent. This may be especially significant in a home orchard situation with no or irregular fungicide applications.</p> |

4.28.7 Unrestricted risk

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for truncatella leaf spot | |
|--|------------|
| Overall probability of entry, establishment and spread | Very low |
| Consequences | Low |
| Unrestricted risk | Negligible |

As indicated, the unrestricted risk estimate for truncatella leaf spot has been assessed as ‘negligible’, which achieves Australia's ALOP. Therefore, no specific risk management measures are required for this pest.

4.29 Apple scar skin and apple dapple – *Apple scar skin viroid*

4.29.1 Introduction

Apple scar skin and apple dapple are diseases caused by *Apple scar skin viroid* (ASSVd), which is sometimes called the apple dapple viroid or the pear rusty skin viroid. The diseases deface the fruit and the fruit may remain small and hard and develop an unpleasant flavour. The severity of disease depends on the cultivar and the duration of infection. In severe cases in susceptible cultivars, the fruit is affected by scarring, necrosis and cracking. Some apple cultivars may develop leaf roll or leaf epinasty symptoms (Koganezawa *et al.* 2003).

ASSVd is a small circular nucleic acid molecule. ASSVd also infects pears and apricots (Zhao and Niu 2008; Koganezawa *et al.* 2003) and it spreads systemically through trees. Latent symptomless infection of pear by ASSVd is common in China and pear trees are considered to be a source of inoculum for apple trees (Kyriakopoulou *et al.* 2003; Koganezawa *et al.* 2003). The viroid is persistent and may have a long incubation (latency) period. Pears and apples may be infected for several years before symptoms become apparent, with symptoms increasing each year after onset in susceptible cultivars (Desvignes *et al.* 1999).

ASSVd has been found in apple fruit, seed, anthers, petals, receptacles, leaves, bark and roots (Hadidi *et al.* 1991). Viroid nucleic acids have been found in seeds from apples in the seed coat, subcoat, cotyledon and embryo (Kim *et al.* 2006). ASSVd is spread by grafting and budding, infected rootstocks and contaminated equipment and tools (Grove *et al.* 2003; Hadidi *et al.* 1991). It is also transmitted naturally between trees by an unknown mechanism (Koganezawa *et al.* 2003; Kyriakopoulou and Hadidi 1998). Transmission by root to root contact has been proposed and may involve natural root grafting (Desvignes *et al.* 1999).

The possibility of the importation and establishment of ASSVd was considered in an IRA for pears from China and the potential for establishment and spread from the fruit pathway was assessed as not feasible (Biosecurity Australia 2005b) because seed transmission had not been reported at the time. However, seed transmission was recently shown to occur (Kim *et al.* 2006). The new findings indicate that the viroid can be transmitted through the infected seeds of fruit from infected trees.

The risk scenario of particular relevance to apple scar skin viroid is infected seeds in symptomless fruit.

The assessment of the apple scar skin viroid presented here builds on the existing pest risk assessment and takes into account information on seed transmission.

4.29.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that ASSVd will arrive in Australia with the importation of the commodity: **MODERATE**.

- ASSVd caused one of the most damaging apple diseases in China in the 1950s and 1960s (Han *et al.* 2003). It was present in Hebei, Liaoning, Shaanxi and Shanxi provinces. In the 1950s, more than 50% of apple trees were infected with the viroid in some parts of China (Koganezawa *et al.* 2003).
- Recent advice indicates that ASSVd rarely occurs in modern apple orchards in China (AQSIQ 2008b) and most commercial orchard tree stocks in China have been replaced in the past few decades. Reviews suggest that the viroid may still be widespread in pears in China (Hammond and Owens 2006).
- ASSVd spreads systemically through apple trees and is present in fruit and seed from infected trees (Hadidi *et al.* 1991).
- In susceptible apple cultivars, the symptoms are usually found at the calyx end of the fruit and include skin scarring, cracking and dappling. Infected fruit may remain small and hard and may develop an unpleasant flavour. Almost all fruit on an infected tree of a susceptible cultivar will show symptoms and is unmarketable (Koganezawa *et al.* 2003).
- Infected fruit from susceptible cultivars is likely to be removed in the grading process.
- Tolerant cultivars may produce fruit that is normal, even though the trees are infected (Di Serio *et al.* 2001; Desvignes *et al.* 1999).
- A percentage of the fruit of slightly sensitive cultivars may have dappled skin (Di Serio *et al.* 2001; Desvignes *et al.* 1999) with other fruit from the same trees being symptomless.
- The commonly grown cultivars Golden Delicious, Granny Smith, Pink Lady, Fuji and Gala are tolerant or slightly sensitive to the viroid (Di Serio *et al.* 2001; Desvignes *et al.* 1999).
- Trees may not express symptoms for some years after infection by the viroid (Desvignes *et al.* 1999) and continue to produce normal fruit.
- Symptomless fruit infected with the viroid would not be removed in the grading process and could be exported to Australia.

The previous high levels of infection of AASVd in apple trees in China, the unknown status of ASSVd in tolerant apple cultivars in China at present, and the ability of normal fruit from recently infected trees or tolerant or slightly sensitive cultivars to carry the viroid support a risk rating for importation of ‘moderate’.

Probability of distribution

The likelihood that ASSVd will be distributed in Australia in a viable state as a result of processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **HIGH**.

- Imported apple fruit is intended for human consumption in Australia. It is expected that imported apples will be distributed throughout Australia for retail sale.
- Infected fruit could be distributed by wholesale and retail trade.
- Wholesalers and retailers will dispose of some fruit that may be infected and this waste will be sent to municipal tips.
- Individual consumers will carry small quantities of apples to urban, rural and natural locations.
- Apple cores are not usually consumed and are discarded with the seed.
- Some of the apple waste containing seed will be sent to municipal tips and some of it will be disposed of in contained compost.

- A relatively small number of apple cores with seed will be not be disposed of through a managed waste process but will instead be discarded into the environment in urban, rural and natural locations.
- A small number of apple cores with viable infected seeds may be discarded into the environment in apple growing regions.
- Imported apple fruit might be consumed by orchard workers.

The distribution of imported apples widely throughout Australia and the disposal of some fruit or fruit waste containing seed into the environment support a risk rating for distribution of 'high'.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The likelihood that apple scar skin viroid will enter Australia as a result of trade in fresh apple fruit from China and be distributed in a viable state to a suitable host: **MODERATE**.

4.29.3 Probability of establishment

The likelihood that ASSVd will become established, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **MODERATE**.

- No seed transmission of ASSVd was detected in experiments in the 1990s (Desvignes *et al.* 1999; Howell *et al.* 1995).
- It was recently reported that 7.7% of apple seedlings germinated from ASSVd-positive fruit were infected (Kim *et al.* 2006), indicating that seed transmission occurs under some conditions.
- ASSVd nucleic acids have been detected in the cotyledons and embryos of seed from infected plants (Kim *et al.* 2006), supporting the finding of seed-transmission.
- Although the cultivation of pome fruit is limited by climatic conditions, there are no reports of climatic conditions affecting the distribution of the viroid in apples and pears. ASSVd occurs in apples and pears in Asia, Europe and North America, although the level of infection varies widely (Kyriakopoulou *et al.* 2003; Koganezawa *et al.* 2003).
- Volunteer apple trees are commonly observed along roadsides in southern Australia, presumably arising from seed in discarded apple cores that have germinated after winter chilling.
- Some volunteer apple trees will grow from seed from imported apples.
- Apple seeds normally only germinate after moist winter chilling and apple trees are unlikely to grow from discarded seed in many areas of northern Australia where minimum winter temperatures usually exceed 5 °C (BOM 2009).
- Apple trees are unlikely to grow from seed in municipal waste because such waste is covered.
- Cores with seed from imported apples will be discarded in environments in southern Australia where apple trees can grow. These environments will include poorly managed compost heaps and uncontained areas such as roadsides, including roadsides in apple growing regions.

- Orchard workers might contaminate orchard equipment if they consume imported fruit while working, although this is unlikely.

The small number of apple trees that will grow from seed in discarded imported fruit or fruit residues and the report of ASSVd seed transmission experiments support a risk rating for establishment of ‘moderate’.

4.29.4 Probability of spread

The likelihood that ASSVd will spread, based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of ASSVd: **LOW**.

- ASSVd infects most *Malus* and *Pyrus* species and cultivars (Kyriakopoulou *et al.* 2003; Koganezawa *et al.* 2003; Kyriakopoulou and Hadidi 1998). Natural infections are found in apple, apricot, peach, pear and sweet cherry. ASSVd also infects experimentally *Chaenomeles*, *Cydonia*, *Pyronia* and *Sorbus* species (Koganezawa *et al.* 2003). These host plants are grown in Australia.
- Although volunteer apple trees from seed from imported apples will establish in fruit growing areas in Australia, few if any of the volunteer trees are likely to be infected with ASSVd.
- ASSVd has no known natural vectors but knowledge of transmission is incomplete (Koganezawa *et al.* 2003).
- ASSVd is transmitted by grafting and budding, infected rootstocks and on contaminated equipment and tools (Grove *et al.* 2003; Hadidi *et al.* 1991).
- Fruit growers will not use volunteer plants for grafting or budding, nor are they likely to use orchard equipment on volunteer plants.
- ASSVd is naturally transmitted between neighbouring trees by an unknown mechanism (Koganezawa *et al.* 2003; Desvignes *et al.* 1999). This natural transmission is slow, taking several years. Transmission by root to root contact has been proposed and may involve natural root grafting.
- ASSVd has been found in wild pear in isolated areas, suggesting natural transmission by some unknown means (Kyriakopoulou *et al.* 2003; Kyriakopoulou and Hadidi 1998). Some other viroids are transmitted by aphids or pollen (Singh *et al.* 2003), but no evidence has been reported of ASSVd transmission by aphids or pollen. Mechanical transmission of some viroids by grazing animals has also been suggested, based on experiments in Greece where orchards are commonly grazed (Cohen *et al.* 2005). In Australia, commercial orchards are rarely grazed.
- Seed transmission was recently shown to occur (Kim *et al.* 2006). The new findings indicate that the viroid can be transmitted through the infected seeds of fruit from infected trees.
- If trees in commercial orchards become infected, some fruit with infected seed may be distributed and give rise to new infected volunteer apple trees.
- ASSVd can be controlled by removing infected trees from orchards, avoiding spread to neighbouring trees, and by propagating nursery stock from ASSVd-indexed mother trees. ASSVd is eliminated from most infected apple plants when plants are subjected to a dormant stage followed by thermotherapy (Koganezawa *et al.* 2003).

The small number of infected volunteer apple trees likely to grow in fruit growing regions, the very limited opportunity for transmission from volunteer trees to cultivated host plants and its slow natural transmission, support a risk rating for spread of ‘low’.

4.29.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of ‘rules’ for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that ASSVd will enter Australia as a result of trade in the commodity from the ‘country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **VERY LOW**.

4.29.6 Consequences

The consequences of the establishment of ASSVd in Australia have been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are ‘E’, the overall consequences are estimated to be **MODERATE**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|-----------------------------|--|
| DIRECT | |
| Plant life or health | <p>E – Major significance at the district level</p> <p>ASSVd infects a wide range of apple and pear cultivars as well as cultivars of apricot, peach and sweet cherry (Kyriakopoulou <i>et al.</i> 2003; Koganezawa <i>et al.</i> 2003; Kyriakopoulou and Hadidi 1998). The viroid causes a range of symptoms in apple, depending on the cultivar (Desvignes <i>et al.</i> 1999). It causes pear rusty skin disease, although it is often symptomless in pear (Kyriakopoulou <i>et al.</i> 2003). No report of symptoms in other natural hosts has been found.</p> <p>There may be no marketable yield from infected susceptible apple and pear cultivars (i.e. 100% loss) as all the fruit may be blemished (Kyriakopoulou <i>et al.</i> 2003; Koganezawa <i>et al.</i> 2003). Yield may be reduced by 10-20% in symptomless apple cultivars (Lemoine and Cathala 2006).</p> <p>ASSVd caused one of the most damaging apple diseases in China and Japan in the 1950s to 1960s and 1970s, respectively (Han <i>et al.</i> 2003)(Koganezawa <i>et al.</i> 2003). In some counties in China more than 50% of apple trees were affected in the 1950s to 1960s (Koganezawa <i>et al.</i> 2003). By contrast, the viroid was relatively rare in North America and Europe over the same period.</p> <p>ASSVd is transmitted by horticultural activity including grafting and budding and the use of contaminated equipment (Grove <i>et al.</i> 2003; Hadidi <i>et al.</i> 1991). Natural transmission is slow (Desvignes <i>et al.</i> 1999). The spread of ASSVd between trees in orchards is considered to be likely but slow and limited in range.</p> <p>In Australia, pathogen tested scion material and clonal root stocks are used to establish most orchards, which would limit the potential for ASSVd to cause production losses. In addition, some of the apple cultivars grown in Australia, such as Golden Delicious, Granny Smith and Pink Lady are tolerant to the viroid (Desvignes <i>et al.</i> 1999).</p> |

| | |
|---|--|
| Other aspects of the environment | A – Indiscernible at the local level There are no known direct consequences of this viroid on other aspects of the environment. |
| INDIRECT | |
| Eradication, control etc. | D – Significant at the district level The major local control measures for the viroid are to remove the infected trees from orchards and to propagate nursery stock from ASSVd-indexed mother trees. ASSVd is eliminated from most infected apple plants when plants are subjected to a dormant stage followed by thermotherapy (Koganezawa <i>et al.</i> 2003). |
| Domestic trade | D – Significant at the district level. Presence of ASSVd in commercial pome and stone fruit orchards could result in the implementation of interstate quarantine measures, causing loss of markets and subsequent significant industry adjustment at the district level. |
| International trade | D – Significant at the district level The presence of ASSVd in production areas of Australia could have impacts on the export of Australia's fresh fruit and planting material of apple, apricot, peach, pear and sweet cherry to countries where this pathogen is not present. |
| Environment | A – Indiscernible at the local level Control activities for ASSVd on susceptible crops are not considered to impact on the environment. |

4.29.7 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for apple scar skin | |
|--|-----------------|
| Overall probability of entry, establishment and spread | Very Low |
| Consequences | Moderate |
| Unrestricted risk | Very Low |

As indicated, the unrestricted risk for apple scar skin has been assessed as 'very low', which achieves Australia's ALOP. Therefore, specific risk management measures are not required for this pest.

4.30 Tobacco necrosis viruses

Tobacco necrosis virus A, *Tobacco necrosis virus D*, tobacco necrosis virus Nebraska isolate and related viruses.

4.30.1 Introduction

The taxonomy of ‘tobacco necrosis virus’ (TNV) has been revised. *Tobacco necrosis virus A* (TNV-A) and *Tobacco necrosis virus D* (TNV-D) have been recognised as distinct species in the *Necrovirus* genus (Coutts *et al.* 1991; Meulewaeter *et al.* 1990), as have *Chenopodium necrosis virus* (ChNV) and *Olive mild mosaic virus* (OMMV), which were previously considered TNV isolates (Tomlinson *et al.* 1983). TNV isolates from Nebraska and Toyama (TNV-NE and TNV-Toyama) represent another species in the genus, as yet not officially recognised (Saeki *et al.* 2001; Zhang *et al.* 1993) and molecular sequence data indicates that some other necroviruses called ‘tobacco necrosis virus’ are also distinct species (NCBI 2009).

Necroviruses are transmitted through soil. ChNV, TNV-A and TNV-D are transmitted by the root-infecting chytrid fungus *Olpidium brassicae* (Wor.) Dang (Rochon *et al.* 2004) and at least one TNV strain is transmitted by the related chytrid *Olpidium virulentus* (Sasaya and Koganezawa 2006). Virus particles released from roots and other plant matter are acquired in soil water by fungal zoospores and transmitted when the spores infect the roots of a suitable host. TNV particles are stable and relatively long lived. Transmission probably only occurs when there is sufficient soil water for *Olpidium* zoospore activity (Spence 2001; Uyemoto 1981). TNVs cause sporadic disease in some vegetable crops, strawberry, tulip and soybean. TNVs have been detected in apple causing symptomless systemic infections (Uyemoto and Gilmer 1972). The necrovirus species involved in these infections of apple were not identified.

TNVs have been reported in Qld and Vic. (Teakle 1988; Finlay and Teakle 1969) but it is not known if the species or strains that infect apple are present in Australia. TNV was thought to be ubiquitous and have a worldwide distribution (Brunt and Teakle 1996; Uyemoto 1981), but this status has not been reviewed since the taxonomic revision of the viruses. A satellite virus replicates with some strains of TNV.

A pathway is considered where the particles of foreign TNV species or strains are released from fruit waste, acquired in soil by a vector and transmitted to suitable host plants. TNVs may enter Australia in hyacinth (*Hyacinthus* sp.), lily (*Lilium* sp.) and tulip (*Tulipa* sp.) bulbs imported for planting under current conditions (ICON 2009). It is not known if the species and strains infecting these monocots are the same as those infecting apple.

4.30.2 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues respectively.

Probability of importation

The likelihood that tobacco necrosis viruses will arrive in Australia with the importation of the commodity: **MODERATE**.

- TNVs are probably widely prevalent in China. TNVs have been isolated from melon in Xinjiang and soybean in Jiangsu (Xi *et al.* 2008; Huang *et al.* 1984). TNVs have also been isolated from mulberry, potato and tobacco growing in China (Xi *et al.* 2008).
- Strains of TNV were found naturally infecting several apple cultivars in the USA and Europe (Uyemoto and Gilmer 1972; Kegler *et al.* 1969). The taxonomy, incidence and global distribution of the apple-infecting TNVs are not known. No recent reports of testing of apples for TNV have been found.
- Apple trees are systemically infected and virus particles are present in fruit (Uyemoto and Gilmer 1972).
- Some TNV species and strains may not infect apple systemically and may not be in apple fruit. Detectable systemic infection only occurs with certain combinations of host species and TNV species or strains (Brunt and Teakle 1996; Uyemoto 1981).
- Infected apple trees and their fruit are symptomless (Uyemoto and Gilmer 1972).

The prevalence of TNVs in China and the likelihood of symptomless systemic infection of apple, moderated by uncertainty about the incidence and distribution of infections of apple, support a risk rating for importation of ‘moderate’.

Probability of distribution

The likelihood that tobacco necrosis viruses will be distributed in Australia in a viable state as a result of the processing, sale or disposal of the commodity and subsequently transfer to a susceptible part of a host: **MODERATE**.

- Imported apple fruit is intended for human consumption. Fruit will be distributed to many localities by wholesale and retail trade and by individual consumers. Apple fruit may be distributed to all states in unrestricted trade.
- Most apple fruit waste will be discarded into managed waste systems and will be disposed of in municipal tips. Consumers will discard small quantities of apple waste in urban, rural and natural localities. Small amounts of apple waste will be discarded in domestic compost.
- Fruit waste may be discarded near host plants.
- TNV particles are present in low concentrations in infected apple fruit and their distribution in apple tissue may be erratic (Uyemoto and Gilmer 1972).
- TNV particles are moderately to highly stable and survive for long periods in plant debris. TNV particles survive in soil containing infected roots for up to 130 days (18.5 weeks) and remain viable *in vitro* at 20 °C for one to eight weeks, depending on the strain, and up to several years *in vitro* at 20 °C (Brunt and Teakle 1996; Nemeth 1986; Gibbs and Harrison 1976; Kassanis 1970; Smith *et al.* 1969).
- TNV particles tolerate temperatures as high as 95 °C (Brunt and Teakle 1996), so the temperatures achieved by composting and soil pasteurisation may not eliminate the viruses.
- Virus particles are released from roots and plant debris (CAB International 2009).
- TNVs are transmitted by the zoospores of the chytrid fungi *Olpidium brassicae* and *Olpidium virulentus* (Sasaya and Koganezawa 2006; Rochon *et al.* 2004). The chytrids probably occur throughout Australia. *Olpidium brassicae* has been recorded in NSW and

WA (APPD 2009). *Olpidium virulentus* has been recorded in WA (Maccarone *et al.* 2008).

- *Olpidium brassicae* is an efficient vector of TNV-D and can acquire particles from very dilute solutions and transmit the virus to susceptible hosts in short time periods (Kassanis and MacFarlane 1964). If infected fruit waste is discarded in areas where *Olpidium* zoospores are active, then zoospores may acquire particles and transmit the virus.
- Species of *Olpidium* form resting spores through sexual reproduction (Spence 2001). Resting spores resist dessication, are long lived and may be distributed in dust, soil and roots. They germinate to produce zoospores.
- Zoospores need water to germinate and move and they are only active when there is sufficient soil moisture (Spence 2001). During drought and dry weather, zoospores are unlikely to be active in some areas because of dry conditions.
- Only certain *Olpidium brassicae* biotypes will transmit particular TNV strains (Uyemoto 1981). Some isolates of *Olpidium brassicae* will parasitise a wide range of host plants whereas others are more specific (Campbell 1996).
- TNV strains typically have wide experimental host ranges (Uyemoto 1981). TNVs have been found collectively to naturally infect apple (*Malus pumila*), apricot (*Prunus armeniaca*), adzuki bean (*Vigna angularis*), beetroot (*Beta vulgaris*), cabbage (*Brassica oleracea*), carrot (*Daucus carota*), citrus (*Citrus* spp.), common bean (*Phaseolus vulgaris*), crab apple (*Malus sylvestris*), cucumber (*Cucumis sativus*), European pear (*Pyrus communis*), grapevine (*Vitis vinifera*), hyacinth (*Hyacinthus* sp.), lettuce (*Lactuca sativa*), lily (*Lilium* sp.), melon (*Cucumis melo*), mulberry (*Morus* sp.), olive (*Olea europaea*), passionfruit (*Passiflora edulis*), pea (*Pisum sativum*), plum (*Prunus domestica*), potato (*Solanum tuberosum*), sour cherry (*Prunus cerasus*), soybean (*Glycine max*), strawberry (*Fragaria* × *ananassa*), tomato (*Solanum esculentum*) tulip (*Tulipa gesneriana*) and zucchini (*Cucurbita pepo*) (Zitikaitė and Staniulis 2009; CAB International 2009; Xi *et al.* 2008; Pham *et al.* 2007b; Pham *et al.* 2007a; Brunt and Teakle 1996; Kassanis 1970). Commercial crops of some of these plants are grown in every Australian state and territory and others are grown commercially in several states (SAI 2009; HAL 2004). Many of the plants are grown in domestic gardens and tulip is grown as an ornamental in Tas., Vic. and parts of NSW.
- TNVs are also found in some wild plants, weeds and forest trees including birch (*Betula* spp.), European ash (*Fraxinus excelsior*), European beech (*Fagus sylvatica*), Norway spruce (*Picea abies*), pedunculate oak (*Quercus robur*), poplar (*Populus* spp.) and potato weed (*Galinsoga parviflora*) (Bos 1999; Nienhaus and Castello 1989; Teakle 1988; Hibben *et al.* 1979).
- It is unlikely that the TNV strains that infect apple will also infect all of the species recorded as hosts of TNVs collectively. The host ranges of many strains and the newly recognised species are largely unknown. The TNVs were considered to be a single species when most host range studies were done (Brunt and Teakle 1996).

The presence of efficient vectors in Australia, moderated by the low concentration of TNV particles in apple fruit flesh and the chance that infected fruit waste will be discarded near a plant host while vector chytrids are active, supports a risk rating for distribution of 'moderate'.

Overall probability of entry (importation × distribution)

The overall probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2. The likelihood that tobacco necrosis viruses will enter Australia as a result of trade in the commodity and be distributed in a viable state to a suitable host: **LOW**.

4.30.3 Probability of establishment

The likelihood that tobacco necrosis viruses will establish, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction: **HIGH**.

- The presence of TNVs in many countries (CAB International 2009) suggests that these viruses can become established in places with widely differing conditions.
- TNV-NE and its close relative TNV-Toyama were isolated in Nebraska and Japan (Saeki *et al.* 2001; Zhang *et al.* 1993) and a closely related TNV has been detected in Europe (Zitikaitė and Staniulis 2009).
- Viruses likely to be strains of TNV-A and TNV-D have been recorded in Vic. and in three sites in Qld (Teakle 1988; Finlay and Teakle 1969). TNV incidence in Qld varies from year to year depending on rainfall (Teakle 1988). Conditions exist in Australia that will suit other necrovirus species and strains.
- In the UK, TNVs produce greater levels of disease in glasshouse grown plants in winter than in summer (Bawden 1956). The infectivity of TNVs present in the United Kingdom, as measured by mechanical inoculation of leaves, is reduced when plants are exposed to higher light intensities (Bawden 1956).
- Commercial crop, ornamental plant and fruit tree hosts of TNVs are common throughout Australia.
- In general, plants that are growing vigorously are more likely to be infected by viruses (Gibbs and Harrison 1976; Bawden 1956). In Australia, potential hosts of TNVs will be growing during most of the year, depending on temperature and rainfall.
- *Olpidium brassicae* and *Olpidium virulentus*, the vectors of TNVs, probably occur throughout Australia. Evidence of the widespread nature of *Olpidium virulentus* comes from knowledge of lettuce big-vein disease that occurs throughout Australia and is caused by *Mirafiori Lettuce Big-Vein Virus* (MLBVV) which is transmitted by *Olpidium virulentus* (Maccarone *et al.* 2008; McDougall 2006).
- *Olpidium* zoospores acquire TNV particles within a few minutes of mixing *in vitro* in solution (Gibbs and Harrison 1976; Kassanis and MacFarlane 1964). Zoospores can drift and swim in films of soil water to a root surface, where they form a cyst and then penetrate the root epidermal cells and infect the plant (Gibbs and Harrison 1976).
- Transmission only occurs when there is sufficient soil water for *Olpidium* activity (Spence 2001; Uyemoto 1981). Drought and long dry spells may limit the opportunity for TNVs to establish by limiting zoospore activity, whereas high rainfall may favour TNVs as it favours zoospore activity.
- When infected by TNVs many plant species appear symptomless (Uyemoto 1981). Many hosts of TNVs appear not to be systemically infected (Bawden 1956). TNV infections may not be detected.

The distribution of hosts and the presence of two TNV strains in Australia support an establishment risk rating of ‘High’.

4.30.4 Probability of spread

The likelihood that tobacco necrosis viruses will spread based on a comparison of those factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pest: **HIGH**.

- TNVs are transmitted by the zoospores of *Olpidium brassicae* and *Olpidium virulentus*. These chytrids probably occur throughout Australia. (APPD 2009; Maccarone *et al.* 2008; Sasaya and Koganezawa 2006; McDougall 2006; Rochon *et al.* 2004).
- The viruses are transmitted to the roots of susceptible plants and to leaves that are touching the ground (Uyemoto 1981; Bawden 1956).
- Climatic conditions that favour plant growth may increase the chance of a TNV spreading in Australia. Rainfall will favour zoospore activity, as may cool conditions because of reduced evaporation.
- No measurements of the rate at which TNV spreads through fields have been found.
- In moist soil and without physical assistance, zoospores only move very short distances (10-20 mm) (Dixon 2009). Rain splash will disperse the fungus. Sporangia and zoospores will be dispersed in runoff water, irrigation channels and waterways.
- It is not known how long *Olpidium* zoospores remain infective, but the zoospores may only live for a few days (Spence 2001; Gibbs and Harrison 1976).
- TNVs spread through soil with the movement of soil water (Smith 1988) and can be found in waterways (Tomlinson *et al.* 1983). Drainage water from contaminated soil contains infectious TNV particles as does runoff. However, a report of TNV spreading from waterways has not been found.
- TNVs are spread in a glasshouse if an irrigation source is contaminated with the virus (Harrison 1960; Bawden 1956) or viruliferous zoospores.
- *Olive latent virus 1*, another necrovirus, is probably transmitted through soil water without the aid of a vector (Lommel *et al.* 2005) and it is possible that some TNVs may be transmitted in this way.
- TNV particles are probably spread in dust by wind (Harrison 1960), although drying prevents transmission. They are probably also spread by splashing.
- Root-infecting viruses are spread to new sites by movement of soil, root fragments and drainage water and by transplanting infected plants (Harrison 1977). Soil-borne viruses may be spread to new localities by the transfer of soil on agricultural implements and possibly also on the boots of farm workers (Harrison 1960).

The presence of chytrid vectors in Australia and the likely spread of TNVs in soil and water support a spread risk rating of ‘high’.

4.30.5 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread using the matrix of ‘rules’ for combining qualitative likelihood shown in Table 2.2.

The overall likelihood that tobacco necrosis viruses will enter Australia as a result of trade in the commodity from the country of origin, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **LOW**.

4.30.6 Consequences

The consequences of the establishment of tobacco necrosis viruses in Australia have been estimated according to the methods described in Table 2.3.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are ‘C’, the overall consequences are estimated to be **VERY LOW**.

Reasoning for these ratings is provided below:

| Criterion | Estimate |
|-----------------------------|--|
| DIRECT | |
| Plant life or health | <p>C – minor significance at the district level</p> <p>Among the hosts in which TNVs cause disease, carrot, potato and strawberry are the most economically important in Australia, with the estimated value in 2002 of the carrot crop being \$198.5 million, the potato crop being \$485.4 million and the strawberry crop being \$107.7 million (HAL 2004).</p> <p>The sporadic diseases caused by TNVs are economically important in some vegetable and ornamental crops in some years (Zitikaitė and Staniulis 2009; Smith <i>et al.</i> 1988; Nemeth 1986; Uyemoto 1981; Kassanis 1970). No reports of adverse effects on fruit trees have been found (Nemeth 1986). A deterioration disease in trembling aspen (<i>Populus tremuloides</i>) may be caused by TNVs (Hibben <i>et al.</i> 1979).</p> <p>TNVs cause rusty root disease of carrot, Augusta disease of tulip, stipple streak disease of common bean, necrosis diseases of cabbage, cucumber, soybean and zucchini and ABC disease of potato (Zitikaitė and Staniulis 2009; Xi <i>et al.</i> 2008; Smith <i>et al.</i> 1988; Uyemoto 1981).</p> <p>Losses as high as 50% have been recorded in tulips and glasshouse grown cucumbers (CAB International 2009). No estimates of losses in carrot, potato and strawberry have been found. Symptomless viral infections of plants, in general, may cause no yield loss, but they may cause yield losses as high as 15% (Bos 1999; Gibbs and Harrison 1976).</p> <p>Naturally infected vegetable crops show a range of symptoms, including spots, flecks, streaks, necrosis and stunting. In strawberry in the Czech Republic, TNV has caused dwarfing and leaf and root necrosis (Martin and Tzanetakis 2006).</p> <p>Stipple streak disease has been reported in Qld causing small yield losses (Teakle 1988), but no reports of TNVs causing other diseases in Australia have been found, suggesting that the combinations of virus strain, vector biotype and host plant cultivar that result in disease have not occurred in Australia.</p> <p>Strains have been distinguished by various characteristics, including the symptoms they cause, their host ranges and genetic sequences (Kassanis 1970). The diseases recorded in common bean and cucumber are probably caused by distinct TNV strains (Zitikaitė and Staniulis 2009; Brunt and Teakle 1996). The</p> |

TNV strains detected in apple caused lesions in tests with cowpea (*Vigna sinensis*) and *Chenopodium quinoa* (Uyemoto and Gilmer 1972), but no report of further investigation of their disease causing potential was found.

A satellite virus replicates with some strains of TNV (Uyemoto 1981; Kassanis 1970) but no report has been found indicating greater disease when the satellite virus is present.

Because the wide host range of TNVs and their chytrid vectors it is likely that some native plants will be susceptible, although no supporting evidence was found.

Other aspects of the environment

A – Indiscernible at the local level

There are no known direct consequences of these species on other aspects of the environment.

INDIRECT

Eradication, control etc.

C – significant at the local level

Virus control measures in fields are limited and eradication may not be possible unless an outbreak is detected at an early stage. Resistant cultivars may be planted, if they are available, and crop rotations may be altered to reduce incidence (CAB International 2009). Establishment and spread in a glasshouse may be controlled by reducing or eliminating *Olpidium* infestation of soil by chemical treatment or by heating by composting or soil pasteurisation (CAB International 2009; Asjes and Blom-Barnhoorn 2002). This may add significantly to costs. TNVs tolerate temperatures as high as 95 °C (Brunt and Teakle 1996), so the temperatures achieved by composting and pasteurisation may not eliminate the viruses. Propagation of virus free plants and careful sanitation may reduce the chance of outbreaks (CAB International 2009; Smith *et al.* 1988).

Domestic trade

C – minor significance at the district level

Australian states are unlikely to set up restrictions on interstate trade if a foreign TNV becomes established unless it causes significant disease, which is unlikely.

International trade

C – minor significance at the district level

If a damaging foreign TNV became established in Australia, additional restrictions might be introduced on the international trade of some vegetables or ornamentals that might lead to the loss of markets and some industry adjustment.

Environment

A – Indiscernible at the local level

There are no known indirect consequences of these species on the environment.

4.30.7 Unrestricted risk

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the estimate of consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

| Unrestricted risk estimate for tobacco necrosis viruses | |
|---|------------|
| Overall probability of entry, establishment and spread | Low |
| Consequences | Very low |
| Unrestricted risk | Negligible |

As indicated, the unrestricted risk for tobacco necrosis viruses has been assessed as ‘negligible’, which achieves Australia’s ALOP. Therefore, specific risk management measures are not required for this pest.

4.31 Risk assessment conclusion

Conclusions drawn from the detailed risk assessments for the quarantine pests are presented in Table 4.2, which provides the unrestricted risk estimates for the quarantine pests that are considered to be associated with fresh apple fruit for human consumption, from China.

Any pest with an unrestricted risk estimated as ‘low’, ‘moderate’ ‘high’ or ‘extreme’ does not meet Australia’s ALOP and requires risk management measures in addition to China’s standard commercial production and post-harvest processing practices.

Key to summary table 4.2

Genus species^{EP}
pests for which policy already exists. The outcomes of previous assessments and/or reassessments in this IRA are presented in Table 4.2

Genus species^{state/territory}
state/territory in which regional quarantine pests have been identified

Likelihoods for entry, establishment and spread

| | |
|--------|--|
| N | negligible |
| EL | extremely low |
| VL | very low |
| L | low |
| M | moderate |
| H | high |
| P[EES] | overall probability of entry, establishment and spread |

Assessment of consequences from pest entry, establishment and spread

| | |
|-----|---|
| PLH | plant life or health |
| OE | other aspects of the environment |
| EC | eradication control etc |
| DT | domestic trade |
| IT | international trade |
| ENC | environmental and non-commercial |
| A-G | consequence impact scores are detailed in section 2.2.3 |
| URE | unrestricted risk estimate. This is expressed on an ascending scale from negligible to extreme. |

Table 4.2: Summary of unrestricted risk estimates for quarantine pests associated with apple fruit from China

| Pest name | Likelihood of | | | | | | Consequences | | | | | | | URE |
|---|---------------|--------------|---------|---------------|--------|--------|--------------|----------|----|----|----|-----|---------|-----|
| | Entry | | | Establishment | Spread | P[EES] | | | | | | | | |
| | importation | distribution | Overall | | | | direct | indirect | | | | | Overall | |
| | | | | | | | PLH | OE | EC | DT | IT | ENC | | |
| Spider mite [Acari: Tetranychidae] | | | | | | | | | | | | | | |
| <i>Amphitetranynchus viennensis</i> ^{EP} | H | M | M | H | M | L | E | B | D | D | D | B | M | L |
| Flat scarlet mite [Acari: Tenuipalpidae] | | | | | | | | | | | | | | |
| <i>Cenopalpus pulcher</i> | H | M | M | H | M | L | E | B | D | D | D | B | M | L |
| Weevils [Coleoptera: Rhynchitidae] | | | | | | | | | | | | | | |
| <i>Rhynchites auratus</i> | VL | M | VL | M | M | VL | E | B | C | D | D | B | M | VL |
| <i>Rhynchites heros</i> ^{EP} | VL | M | VL | M | M | VL | E | B | C | D | D | B | M | VL |
| Fruit flies [Diptera: Tephritidae] | | | | | | | | | | | | | | |
| <i>Bactrocera dorsalis</i> ^{EP} | M | H | M | H | H | M | E | C | F | E | E | D | H | H |
| Armoured scales [Hemiptera: Diaspididae] | | | | | | | | | | | | | | |
| <i>Diaspidiotus ostreaeformis</i> ^{WA, EP} | M | L | L | H | M | L | D | A | C | B | C | B | L | VL |
| <i>Lopholeucaspis japonica</i> ^{EP} | H | L | L | H | M | L | D | B | D | C | C | B | L | VL |
| <i>Parlatoria oleae</i> ^{WA} | H | L | L | H | M | L | D | B | D | B | C | B | L | VL |
| <i>Parlatoria yanyuanensis</i> | L | L | VL | H | M | VL | D | B | D | C | D | B | L | N |
| Mealybugs [Hemiptera: Pseudococcidae] | | | | | | | | | | | | | | |
| <i>Phenacoccus aceris</i> ^{EP} | H | M | M | H | H | M | D | B | D | D | C | B | L | L |
| <i>Pseudococcus comstocki</i> ^{EP} | | | | | | | | | | | | | | |

| Pest name | Likelihood of | | | | | | Consequences | | | | | | | | URE |
|--|---------------|--------------|---------|---------------|--------|--------|--------------|----------|----|----|---------|-----|---|----|-----|
| | Entry | | | Establishment | Spread | P[EES] | | | | | | | | | |
| | importation | distribution | Overall | | | | direct | indirect | | | Overall | | | | |
| | | | | | | | PLH | OE | EC | DT | IT | ENC | | | |
| <i>Pseudococcus calceolariae</i> ^{WA, EP} | M | M | L | H | H | L | D | A | C | B | B | B | L | VL | |
| Moths [Lepidoptera] | | | | | | | | | | | | | | | |
| <i>Adoxophyes orana</i> ^{EP} | L | M | L | H | H | L | E | B | E | D | D | B | M | L | |
| <i>Argyresthia assimilis</i> | L | M | L | H | M | L | D | B | D | D | D | B | L | VL | |
| <i>Carposina sasakii</i> ^{EP} | H | H | H | H | H | H | E | B | E | D | E | B | M | M | |
| <i>Cydia pomonella</i> ^{WA, EP} | L | M | L | H | H | L | D | A | E | B | D | B | M | L | |
| <i>Euzophera pyriella</i> ^{EP} | L | M | L | H | H | L | E | B | D | D | D | B | M | L | |
| <i>Grapholita inopinata</i> ^{EP} | M | M | L | H | H | L | D | B | E | D | D | B | M | L | |
| <i>Grapholita molesta</i> ^{WA, EP} | VL | M | VL | H | H | VL | E | A | E | B | D | B | M | VL | |
| <i>Spilonota albicana</i> ^{EP} | M | M | L | H | H | L | E | B | D | D | D | B | M | L | |
| Fungi | | | | | | | | | | | | | | | |
| <i>Cryptosporiopsis curvispora</i> ^{EP} | L | H | L | M | M | L | D | A | C | B | D | B | L | VL | |
| <i>Diplocarpon mali</i> ^{EP} | M | M | L | M | M | L | E | A | D | D | E | B | M | L | |
| <i>Gymnosporangium yamadae</i> ^{EP} | M | M | L | M | H | L | E | A | D | D | E | B | M | L | |
| <i>Monilinia fructigena</i> ^{EP} | H | H | H | H | H | H | E | B | E | E | E | B | M | M | |
| <i>Mucor mucedo</i> | VL | H | VL | H | H | VL | D | A | D | B | D | A | L | N | |
| <i>Mucor racemosus</i> ^{WA} | | | | | | | | | | | | | | | |
| <i>Neonectria ditissima</i> ^{EP 5} | - | - | - | - | - | L | - | - | - | - | - | - | M | L | |

⁵ Semi-quantitative method used in the previous assessment.

| Pest name | Likelihood of | | | | | | Consequences | | | | | | | | URE |
|---|---------------|--------------|---------|---------------|--------|--------|--------------|----------|----|----|----|-----|---------|----|-----|
| | Entry | | | Establishment | Spread | P[EES] | | | | | | | | | |
| | importation | distribution | Overall | | | | direct | indirect | | | | | Overall | | |
| | | | | | | | PLH | OE | EC | DT | IT | ENC | | | |
| <i>Phyllosticta arbutifolia</i> ^{EP} | M | M | L | M | M | L | D | A | D | D | E | B | M | L | |
| Sooty blotch and flyspeck complex | M | H | M | H | H | M | C | A | C | A | A | A | VL | VL | |
| <i>Truncatella hartigii</i> | VL | H | VL | H | H | VL | D | A | B | B | A | B | L | N | |
| Viroids [Pospiviroidae] | | | | | | | | | | | | | | | |
| <i>Apple scar skin viroid</i> | M | H | M | M | L | VL | E | A | D | D | D | A | M | VL | |
| Virus | | | | | | | | | | | | | | | |
| Tobacco necrosis viruses | M | M | L | H | H | L | C | A | C | C | C | A | VL | N | |

EP: Species has been assessed previously and for which import policy already exists.

Regional quarantine pests

Regional quarantine pests have the endangered area in superscript text (e.g., ^{WA} = Western Australia).

Likelihoods for entry, establishment and spread

N = Negligible

EL = Extremely low

VL = Very low

L = Low

M = Moderate

H = High

P[EES] = Overall probability of entry, establishment and spread

Consequences

Consequences from pest entry, establishment and spread are on an ascending scale from A to G (see method section 4).

PLH = Plant life or health

OE = Other aspects of the environment

EC = Eradication, control etc.

DT = Domestic trade

IT = International trade

ENC = Environmental and non-commercial

URE = Unrestricted risk estimate

5. Pest risk management

5.1 Pest risk management measures and phytosanitary procedures

In addition to China's existing commercial production practices for the production of fresh apple fruit and minimum border procedures in Australia, specific pest risk management measures, including operational systems, are recommended to achieve Australia's ALOP.

In 2008, China proposed the following general framework to be considered by Australia for the management of pests and procedures for production of fresh apples for export to Australia:

- *Registration*: Apples for export to Australia must originate from orchards and packing houses registered by China Entry-Exit Inspection and Quarantine Bureau (CIQ).
- *Personnel training*: CIQ will supervise the training of personnel working in registered orchards and packing houses in the monitoring and control of pests, fruit bagging, sanitation and identification of pests.
- *Pest control and monitoring*: Quarantine pests of concern to Australia are to be monitored and controlled in export orchards. The general pest control measures are: (i) orchard sanitation measures including timely clearance of orchard during both the off season and the growing season; (ii) pest management measures including cultivation, fruit bagging, pest trapping and application of chemicals.
- *Fruit fly monitoring*: AQSIQ has established a national fruit fly trapping system in China to monitor for fruit flies of quarantine concern.
- *Pre-harvesting auditing and supervision*: Before fruit is harvested, CIQ will periodically examine the records for pest monitoring, control, spraying, fertilising and fruit bagging. Ten to 20 days before harvesting, CIQ will send technicians to undertake orchard inspections to ensure the effectiveness of field control measures.
- *Packing house management*: A sanitation program is to be carried out in packing houses to ensure they are kept clean. Windows and doors are to be insect-proof. The waste fruit is to be collected regularly for disinfection treatment. The processing line is specifically used to grade export fruit. Fruit for export to different countries and for the domestic market are prohibited for processing in the same packing house at the same time.
- *Labelling*: New and clean cartons must be used for packing fruit. Plant derived packing materials (such as straw) must not be used. For the convenience of tracing the origin of any problem, all the cartons must be labelled with 'For Australia', with the registration number of orchards and packing house, the lot number, the number of cartons in each lot, and date.
- *Storage and transport*: The storage facilities should be clean and hygienic. Fruit for different export markets should be stored separately. The packing houses are to ensure that the relevant records are kept up to date.
- *Pre-export inspection and certification*: CIQ will conduct the on-site phytosanitary inspection, and if the lot meets the requirements, issue the Phytosanitary Certificate.

Biosecurity Australia has considered the components of China's proposed general framework. Biosecurity Australia has also conducted many visits to apple production areas in China and observed and collected information related to the framework proposed by China for registration and management of orchards and packing houses, and pest management, including fruit fly monitoring and storage and transport. There are specific requirements to be fulfilled for apple orchards and packing houses to be eligible to register for export, as detailed in Section 3. The requirements for orchard registration include a minimum size of 100 mu, good water quality, service of a plant protection officer to monitor and control pests, capacity for implementing quality management and complying with conditions of export protocols. Requirements for packing houses include good general hygiene, adequate machinery functioning and maintenance, cold or CA storage capacity and capability for personnel training in quarantine and food safety issues. The registration applications received are assessed and accepted after an initial and a final verification to confirm that all the requirements are fulfilled. Fruit sourced from specific orchards and packing houses can be traced back through labelling and other trace back mechanisms.

The pest risk management measures are based on the mandatory requirement for China to adhere to existing commercial practices (refer to Section 3) and the general framework of management measures and procedures for production proposed by China, detailed on the previous page.

The following recommended pest risk management measures will apply to all the apple production areas from which China intends to export apples to Australia. Nominated areas or provinces must be visited and their pest status verified by Biosecurity Australia before the commencement of trade from that area. Among the nine areas nominated by China for export of fresh apple fruit to Australia, Biosecurity Australia has already visited seven: Beijing, Gansu, Hebei, Liaoning, Shaanxi, Shandong and Shanxi. The remaining two, Henan and Ningxia, and any additional areas to be nominated by China in the future, will also be visited and their pest status verified before export can occur.

In this IRA report, discussion of the management options is divided into two parts. Risk management measures are evaluated for quarantine pests for the whole of Australia (including Western Australia) where the unrestricted risks exceed Australia's ALOP. Following this, risk management options are discussed for the quarantine pests for Western Australia only, because these pests occur in other parts of Australia but are absent from Western Australia.

5.2 Risk management measures for quarantine pests for the whole of Australia

The pest risk analysis identified the quarantine pests for the whole of Australia listed in Table 5.1 as having an unrestricted risk above Australia's ALOP.

This IRA builds on the existing policy for the import of pears from China, Fuji apples from Japan and apples from New Zealand, which include most of the pests identified in Table 5.1. The policy for pears from China (AQIS 1998b) was reviewed and extended in 2003 (AFFA 2003b; AFFA 2003a) and 2005 (Biosecurity Australia 2005b). Considerable trade in pears from China has taken place since 1999. No apples have been imported under the policy for Fuji apples from Japan (AQIS 1998a) or apples from New Zealand (Biosecurity Australia 2006a). The same or equivalent management measures have been considered and recommended in this IRA. Thus, the management options recommended are consistent with these existing policies, although combinations of the measures may differ. They include:

- area freedom for fruit flies
- a systems approach for other arthropod pests
- other potential measures for arthropod pests
- area freedom for European canker and apple brown rot
- a systems approach for other disease pests
- consideration of alternative measures.

Table 5.1 Phytosanitary measures recommended for quarantine pests for the whole of Australia for fresh apple fruit from China

| Pest | Common name | Measures |
|---|-----------------------|---|
| Arthropods | | |
| <i>Bactrocera dorsalis</i> ^{EP} | Oriental fruit fly | Area freedom* |
| <i>Adoxophyes orana</i> ^{EP} | Summerfruit tortrix | Systems approach: <ul style="list-style-type: none">• Orchard control and surveillance• Fruit bagging• Visual inspection and remedial action⁶ |
| <i>Carposina sasakii</i> ^{EP} | Peach fruit moth | |
| <i>Euzophera pyriella</i> ^{EP} | Pyralid moth | |
| <i>Grapholita inopinata</i> ^{EP} | Manchurian fruit moth | |
| <i>Spilonota albicana</i> ^{EP} | White fruit moth | |
| <i>Amphitetranynchus viennensis</i> ^{EP} | Hawthorn spider mite | Systems approach: <ul style="list-style-type: none">• Orchard control and surveillance• Fruit bagging• Pressurised air blasting• Visual inspection and remedial action |
| <i>Cenopalpus pulcher</i> | Flat scarlet mite | |
| <i>Phenacoccus aceris</i> ^{EP} | Apple mealybug | Systems approach: <ul style="list-style-type: none">• Orchard control and surveillance• Pressurised air blasting• Visual inspection and remedial action |
| <i>Pseudococcus comstocki</i> ^{EP} | Comstock's mealybug | |
| Pathogens | | |
| <i>Monilinia fructigena</i> ^{EP} | Apple brown rot | Area freedom* |
| <i>Neonectria ditissima</i> ^{EP} | European canker | |
| <i>Diplocarpon mali</i> ^{EP} | Marssonina blotch | Systems approach: <ul style="list-style-type: none">• Orchard control and surveillance |
| <i>Gymnosporangium yamadae</i> ^{EP} | Japanese apple rust | |

⁶ Remedial action (depending on the location of the inspection) may include: treatment of the consignment to ensure that the pest is no longer viable; withdrawing the consignment from export to Australia; re-export of the consignment from Australia; or destruction of the consignment.

| | | |
|---|--------------|---|
| <i>Phyllosticta arbutifolia</i> ^{EP} | Apple blotch | <ul style="list-style-type: none"> • Fruit bagging • Post-harvest processing • Visual inspection and remedial action |
| <p>^{EP}: Species has been assessed previously and for which import policies already exist.</p> <p>*: Area freedom may include pest free areas, pest free places of production or pest free production sites.</p> | | |

5.2.1 Management of *Bactrocera dorsalis*

Bactrocera dorsalis (Oriental fruit fly) was assessed to have an unrestricted risk estimate that exceeds Australia's ALOP. Measures are therefore required to manage this risk.

Area freedom

Area freedom is a measure that might be applied to manage the risk posed by Oriental fruit fly. The requirements for establishing pest free areas or pest free places of production are set out in ISPM 4: *Establishment of pest free areas* (FAO 1996) and ISPM 10: *Requirements for the establishment of pest free places of production and pest free production sites* (FAO 1999) and more specifically in ISPM 26: *Establishment of pest free areas for fruit flies (Tephritidae)* (FAO 2006).

Current requirements for the import of pears from China include monitoring and trapping of fruit flies in export orchards and packing houses. Monitoring and trapping of fruit flies in the specific apple export orchards and packing houses (as for current pear export) would be required.

Biosecurity Australia is currently considering China's request for recognition of northern China, where the main pear and apple production areas are located, for area freedom for Oriental fruit fly and other economically significant fruit flies. The current assessment is based on China's National Fruit Flies Trapping Network and associated *National Fruit Flies Trapping Guide* which includes emergency action plans. If area freedom for Oriental fruit fly and other economically significant fruit flies is accepted by Biosecurity Australia for northern China, China's National Fruit Flies Trapping Network would be required to be maintained in all areas including production areas where apples are to be sourced for export to Australia. However, additional monitoring and trapping of fruit flies in the specific export orchards and packing houses may not be required.

Under either of the two area freedom situations (i.e. monitoring and trapping of export orchards or based on the National Fruit Flies Trapping Network), AQSIQ would be required to notify the Australian Government Department of Agriculture, Fisheries and Forestry (DAFF) of the detection of any fruit fly species of economic importance in the regions within 48 hours. DAFF would then assess the species and number of individual flies detected and the circumstances of the detection, before advising AQSIQ of the action to be taken. If fruit flies are detected at pre-clearance inspection, trade would stop immediately, pending the outcome of an investigation.

The objective of this measure is to reduce the likelihood of importation for Oriental fruit fly to at least 'very low'. The restricted risk would then be reduced to at least 'very low', which would achieve Australia's ALOP.

Other potential mitigation measures for Oriental fruit fly could include cold treatment, chemical treatment, fumigation or irradiation subject to suitable efficacy data.

5.2.2 Management of *Adoxophyes orana*, *Amphitetranychus viennensis*, *Carposina sasakii*, *Cenopalpus pulcher*, *Euzophera pyriella*, *Grapholita inopinata*, *Phenacoccus aceris*, *Pseudococcus comstocki* and *Spilonota albicana*

Adoxophyes orana (summer fruit tortrix moth), *Amphitetranychus viennensis* (hawthorn spider mite), *Carposina sasakii* (peach fruit borer), *Cenopalpus pulcher* (flat scarlet mite), *Euzophera pyriella* (pyralid moth), *Grapholita inopinata* (Manchurian fruit moth), *Phenacoccus aceris* (apple mealybug), *Pseudococcus comstocki* (Comstock's mealybug) and *Spilonota albicana* (white fruit moth) were assessed to have an unrestricted risk estimate that exceeds Australia's ALOP. Measures are therefore required to manage this risk.

Biosecurity Australia recommends the following systems approaches based on orchard control and surveillance, fruit bagging, pressurised air blasting of fruit and visual inspection to reduce the risk associated with these arthropod pests to meet Australia's ALOP.

Orchard control and surveillance

Registered growers would implement an orchard control program (i.e. good agricultural practice/integrated pest management (IPM) programs for export apples). Programs would be approved by AQSIQ, and incorporate field sanitation and appropriate pesticide applications for the management of quarantine arthropod pests.

AQSIQ/CIQ would be responsible for ensuring that export apple growers are aware of pests of quarantine concern to Australia and that the export orchards are subject to field sanitation and control measures. Registered growers would be required to keep records of control measures for auditing. Details of the arthropod pest control program would need to be provided to DAFF by AQSIQ before trade commences.

Monitoring/detection surveys for pests and diseases that require orchard management measures must be conducted regularly by AQSIQ/CIQ in orchards registered for export to verify the effectiveness of the measures. AQSIQ/CIQ will maintain annual survey results using a standard reporting format. These results will be made available to DAFF if requested.

Fruit bagging

AQSIQ has indicated that apples produced in China for export are individually bagged on the tree (AQSIQ 2005). However, as previously indicated, the unrestricted risk for each pest in the pest risk assessments has been based on apple fruit that has not been bagged. Fruit bagging has been shown in China to be effective in providing some protection to the developing apple fruit and reducing damage by arthropod pests.

Biosecurity Australia proposes mandatory fruit bagging as a risk management measure (as part of the systems approach) for *Adoxophyes orana* (summer fruit tortrix moth), *Amphitetranychus viennensis* (hawthorn spider mite), *Carposina sasakii* (peach fruit moth), *Cenopalpus pulcher* (flat scarlet mite), *Euzophera pyriella* (pyralid moth), *Grapholita inopinata* (Manchurian fruit moth) and *Spilonota albicana* (white fruit moth). These pests can bore into fruit or lay their eggs in fruit and may not present clear external signs of infestation and therefore visual inspection of fruit alone is not considered to be an appropriate measure.

Fruit bagging is also part of the systems approach for managing arthropod pests in pears from China. However, the bagging practice for most of the *Pyrus* spp. (pears) currently exported from China to Australia differs from apples. With pears the bags remain on the fruit until after they are harvested and transported to the packing house to protect fruit from mechanical and pest damage and discoloration. The exception is *Pyrus* sp. nr. *communis* (fragrant pear) from Xinjiang which is not bagged due to the small size of the fruit, climatic conditions and absence of key quarantine pests (Biosecurity Australia 2005b).

Apple fruit bagging is also practised and included as a requirement for the importation of Fuji apples from Japan (AQIS 1998a).

For apples from China, double bags would be required to be placed over individual apple fruit when the fruit is no more than 2.5 cm in diameter (AQSIQ 2008c), to minimise the risk of early exposure to these pests. Pest control measures are applied immediately prior to bagging to ensure that the orchards in general and the developing fruit in particular, are free from pests when bagged.

During field visits in July 2006 and September 2008 to Shandong, Shaanxi and Hebei provinces, Biosecurity Australia was advised that the process of bagging varied in different areas. Apple fruit observed in Shandong was double bagged before the third week in June, for apples harvested in early October. AQSIQ advised that depending on the variety and weather and orchard conditions, the outer bags are removed approximately three to four weeks before harvesting to allow gradual exposure of apple fruit to the sun, and the inner bag removed two to three weeks before harvesting to allow the fruit to develop colour. In some areas, both bags may be removed at once about two weeks before harvesting.

AQSIQ (2005) states that the maturity time for apple fruit is late August for Gala, late September for New Red Star, early October for Qinguan and middle and late October for Fuji, indicating that apples can be harvested from late August to late October depending on the variety and production area. This means that the bags would be removed starting from early August to early October. It is possible that pests, if present in the orchard, could infest the exposed physiologically mature fruit during the two to four week period (AQSIQ 2008c) between complete removal of the bags and the harvest of the fruit.

The life cycle of each quarantine pest was examined to determine whether or not it would be present during this period after bag removal to attack the mature fruit. The results indicate that larvae of *Adoxophyes orana* (summer fruit tortrix) and *Carposina sasakii* (peach fruit moth), *Euzophera pyriella* (pyralid moth), and nymphs and adults of *Amphitetranychus viennensis* (hawthorn spider mite) and *Cenopalpus pulcher* (flat scarlet mite) are still likely to be present in orchards in late August-October (Sun *et al.* 2004; USDA-APHIS 2000b; Song *et al.* 1994) and could infest the recently exposed fruit of all apple varieties.

However, there is less chance for *Grapholita inopinata* (Manchurian fruit moth) or *Spilonota albicana* (white fruit moth) to attack the exposed fruit of Fuji, Qinguan and New Red Star varieties which are harvested from late September to late October (AQSIQ 2005) but they may attack mature Gala fruit which is harvested in late August. Larvae of *Grapholita inopinata* begin moving out of the fruit to start overwintering in late August to late September (Ma 2006; Hanson 1963). Second generation larvae of *Spilonota albicana* leave the fruit during September and October to overwinter (Hua and Wang 2006).

Prior to the removal of bags, AQSIQ/CIQ would need to ensure that the level of pests in registered export orchards is reduced so that the risk of fruit being infested after the removal

of bags is minimised, especially for *Adoxophyes orana* (summer fruit tortrix), *Carposina sasakii* (peach fruit borer), *Euzophera pyriella* (pyralid moth), *Amphitetranychus viennensis* (hawthorn spider mite) and *Cenopalpus pulcher* (flat scarlet mite). This may be achieved through monitoring and inspecting the orchards before removing the bags, and maintaining the pest status during the period from when the bags are removed and the fruit is harvested. AQSIQ/CIQ would develop the monitoring and inspection procedures to demonstrate effective management of these pests is achieved during this period. These procedures would be documented and provided to DAFF before trade commences. The results of monitoring and inspection along with the recorded dates of initial bagging of fruit and the staged removal of bags must also be made available to DAFF for auditing purposes.

For *Pseudococcus comstocki* (Comstock's mealybug) fruit bagging is not considered an appropriate measure. This may also apply to *Phenacoccus aceris* (apple mealybug).

Pressurised air blasting for mealybugs and mites

Pressurised air blasting is recommended to mitigate the risk of *P. comstocki* (Comstock's mealybug) because recent studies indicate that bagging actually encourages rather than prevents this pest from feeding on apple fruit (Liu 2004; Li *et al.* 2004). *Phenacoccus aceris* (apple mealybug) may be affected by fruit bagging in a similar way as *Pseudococcus comstocki*, although there is no information available. Pressurised air blasting of the calyx and stem end of each apple would dislodge and remove the mealybugs from the fruit. This measure would also be effective to reduce the risk of *Amphitetranychus viennensis* (hawthorn spider mite) and *Cenopalpus pulcher* (flat scarlet mite). Pressurised air blasting is a commercial practice used in a number of countries for the removal of surface pests.

Pressurised air blasting (300-400 kPa) was introduced by China to clean individual apples as a consequence of a detection of *Amphitetranychus viennensis* in a shipment of apples from Shaanxi to an international market in 2001. Since its introduction this measure has been shown to be effective in the removal of mites and mealybugs from apple fruit in subsequent trade.

Similarly, pressurised air blasting has also been used as a packing house practice for pears exported from China to Australia, as advised by AQSIQ. Pears from China have been exported to Australia since 1999 and AQIS pre-clearance officers have been inspecting these consignments every year and no mites or mealybugs have been detected.

The effectiveness of this measure can be verified by visual inspection of fruit.

Visual inspection and remedial action

The objective of visual inspection is to ensure that consignments of apples from China infested with these pests are identified and subjected to appropriate remedial action. The remedial action will reduce the risk associated with these pests to a very low level.

Pseudococcus comstocki (Comstock's mealybug), *Phenacoccus aceris* (apple mealybug), *Amphitetranychus viennensis* (hawthorn spider mite) and *Cenopalpus pulcher* (flat scarlet mite) are external pests and can be visually detected by trained quarantine inspectors using optical enhancement where necessary. Therefore, the standard 600 unit quarantine inspection undertaken by AQIS would be effective in identifying consignments infested with these pests.

Remedial action, if required, would be any treatment known to be effective against the target pests. Currently, standard methyl bromide fumigation rates for external pests are recognised.

However, Biosecurity Australia would also consider any other treatment that AQSIQ may propose, providing that it provides an equivalent level of protection.

The consignment would not be released from quarantine until the remedial action has been undertaken.

The objective of all these measures (a systems approach) is to reduce the likelihood of importation for these arthropod pests to at least 'very low'. The restricted risk would then be reduced to at least 'very low', which would achieve Australia's ALOP.

Other potential measures for arthropod pests

Other potential mitigation measures for arthropod pests could include area freedom (pest free areas or pest free production sites), areas of low pest prevalence, cold treatment, fumigation or irradiation, or a combination of these measures.

However, development of final import conditions will be dependant on AQSIQ providing additional scientific information supporting the establishment of pest free areas, pest free production sites or areas of low pest prevalence, or efficacy of treatments against the arthropod pests that reduce the level of risk in line with Australia's ALOP.

The use of ionising treatments, such as gamma rays and x-rays for quarantine purposes is recognised as a potential mitigation measure for all arthropod pests. The ISPM 18: *Guidelines for the use of irradiation as a phytosanitary measure* (FAO 2003) outlines a number of considerations that can be made in accepting irradiation as a phytosanitary measures.

The arthropod pests identified in this IRA include: *Bactrocera dorsalis* (Oriental fruit fly); two mites *Amphitetranychus viennensis* (hawthorn spider mite) and *Cenopalpus pulcher* (flat scarlet mite); two mealybugs *Pseudococcus comstocki* (Comstock's mealybug) and *Phenacoccus aceris* (apple mealybug); and five lepidopteran borers *Adoxophes orana* (summer fruit tortrix moth), *Carpocapsa sasakii* (peach fruit borer), *Euzophera pyriella* (pyralid moth), *Grapholita inopinata* (Manchurian fruit moth), and *Spilota albicans* (white fruit moth). FAO (2003) provides an estimated minimum absorbed dose for certain responses for selected pest groups including fruit flies, spider mites and lepidopteran borers but not mealybugs. The minimum absorbed doses for these pests would need to be confirmed and/or determined before irradiation is accepted as the treatment against these species.

Currently, irradiated apples are not permitted to be sold in Australia due to regulations managed by the Food Standards Australia New Zealand (FSANZ). However, application may be made to FSANZ by any interested stakeholder to change the *Australia New Zealand Food Standards Code* to allow apples or other fruits treated with irradiation for phytosanitary purposes to be sold in Australia. Information on these applications can be viewed at the FSANZ web site⁷.

5.2.3 Management of *Neonectria ditissima*

The unrestricted risk of *Neonectria ditissima* (European canker) has been assessed as 'low' when the overall probability of entry, establishment and spread was combined with consequence in the *Final import risk analysis report for apples from New Zealand* (NZ apple IRA) (Biosecurity Australia 2006a). This exceeds Australia's ALOP and risk mitigation measures are recommended to lower this rating to achieve the ALOP. The risk pathway of

⁷ <http://www.foodstandards.gov.au/standardsdevelopment/>

greatest concern to export with regard to European canker is symptomless infection of fruit that cannot be detected by inspection. Under suitable conditions the fungus could develop to produce spores that transmit the disease.

Inspection of fruit cannot detect symptomless infection. Therefore, the following three options were evaluated in the New Zealand apple IRA in detail with a view to mitigating the unrestricted risk by reducing the probability of importation by sourcing fruit from: (i) pest free areas, (ii) pest free places of production and (iii) areas of low pest prevalence. These options can equally be applied to apples from China.

Option 1: Pest free areas

A pest free area, as described in ISPM 4: *Requirements for the establishment of pest free areas* (FAO 1996) and ISPM 10: *Requirements for the establishment of pest free places of production and pest free production sites* (FAO 1999), would require systems to be put in place by AQSIQ to establish, maintain and verify that *N. ditissima* does not occur within that area. Freedom from *N. ditissima* in an area would reduce the overall probability of entry to 'very low'. Subsequently, the overall probability of entry, establishment and spread would be reduced to 'very low'. When this was combined with the 'moderate' estimate of consequences for European canker, the restricted risk for European canker achieved Australia's ALOP. While the option of a pest free area is available, *Neonectria ditissima* (as *Nectria galligena*) occurs sporadically in part of Gansu, Hebei, Henan, Hubei, Shaanxi and Shanxi provinces (Ma 2006). AQSIQ claimed that *N. ditissima* is a quarantine pest for China and it is not on the pest list provided by AQSIQ (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a). Extensive detection and delineating surveys, including inspection of alternative host plants would be required to confirm pest free areas. Similarly, the establishment and maintenance of pest free areas would need to be relevant to the biology of *N. ditissima*, including its means of spread. Infected nursery stock presents a pathway for establishment and spread of European canker in New Zealand. China would need to provide the detailed measures controlling the movement of fruit and planting materials within China. If there are no restrictions on the movement of planting stock within China, maintenance of pest free areas may not be technically feasible.

Option 2: Pest free places of production

A second option to mitigate the annual risk is to source apples from export orchards free of the disease, that is to establish pest free places of production, ISPM 10: *Requirements for the establishment of pest free places of production and pest free production sites* (FAO 1999). This measure would require the place of production, under the supervision of CIQ and responsibility of AQSIQ, to establish, maintain and verify freedom from European canker supported by the appropriate documentation.

Orchard inspection

Risk management for European canker is based on establishing that export orchards/blocks are pest-free places of production. The requirements are:

- Orchards/blocks are inspected for symptoms of European canker after leaf fall and before winter pruning.
- Orchards/blocks in areas less conducive for the disease are inspected for symptoms by walking down every row and visually examining all trees on both sides of each row.
- Areas more conducive for the disease are inspected using the procedure above, combined with inspection of the upper limbs of each tree using ladders (if needed).

- Detection of European canker would result in suspension of exports in that orchard/block for the season. Reinstatement would require eradication of the disease, confirmed by inspection.

Option 3: Areas of low pest prevalence

A third option to mitigate the annual risk is to source apples from areas of low pest prevalence (ALPP) as specified in ISPM 22: *Requirements for the establishment of areas of low pest prevalence* (FAO 2005). When establishing an ALPP, the exporting country is required to meet a number of requirements including establishing the specified level of the relevant pest to sufficient precision, recording and maintaining surveillance and control activities for a sufficient number of years and identifying and regulating pathways of entry. The exporting country should also describe the ALPP with supporting maps demonstrating the boundaries of the area. China would need to provide such information for this option to be considered by Biosecurity Australia. Further it is not known if specific surveillance targeted at this pest is being done in China and if there is evidence of regulation of entry to new areas through pathways such as nursery plants or control activities recorded for a sufficient number of years. This means it is not possible to consider the option of ALPP as a risk mitigation measure for this pest at this stage.

The objective of these measures is to reduce the probability of entry, establishment and spread for *N. ditissima* (European canker) to at least 'very low'. The restricted risk would then be reduced to at least 'very low', which would achieve Australia's ALOP.

5.2.4 Management of *Monilinia fructigena*

The unrestricted risk of *Monilinia fructigena* (apple brown rot) was assessed to have an unrestricted risk estimate that does not achieve Australia's ALOP. Measures are therefore required to manage this risk.

Visual inspection of fruit alone is not considered to be an appropriate management option for this pathogen, as external signs of infection are not always present and there can be latent infections on symptomless fruit. Fruit bagging has been shown in China to be effective in providing some protection to the developing apple fruit and in reducing damage from diseases. If *M. fructigena* were present in the orchard, infected blossoms or twigs could infect young fruit prior to bagging and infected fruit would develop symptoms before the removal of the bags. However, maturing fruit exposed to conidial infection in the orchard in the two to three weeks before harvest (after the removal of the bags) may remain symptomless yet could harbour latent infection.

Monilinia fructigena is present in a range of provinces across China, including the major apple production areas. No pest free areas for this disease have been identified by China. A measure to manage the risk is to source apples from export orchards free of the disease; that is to establish pest free places of production, ISPM 10: *Requirements for the establishment of pest free places of production and pest free production sites* (FAO 1999). Biosecurity Australia recommends pest free places of production (orchard freedom) as a suitable measure to reduce the risk associated with this pathogen to an acceptable level by reducing the probability of importation.

Pest free places of production (Orchard freedom)

Apple fruit for export to Australia would need to be sourced from export orchards free of the disease. This measure would require systems to be put in place for the establishment, maintenance and verification of orchard freedom from *M. fructigena* under the supervision of CIQ and the responsibility of AQSIQ. The inspection and monitoring of trees in the export orchard at appropriate times to detect evidence of the pathogen must be undertaken and supported by appropriate documentation. The inspection method appropriate for this disease, including details of the timing and size of the sampling to be undertaken for each orchard, would be developed by AQSIQ and subject to approval by DAFF. Results of the inspections would subsequently be made available to DAFF for auditing purposes.

If *M. fructigena* is detected in any export orchard, fruit from that export orchard will not be eligible for the export program to Australia.

To prevent any potential contamination from the processing of fruit destined to domestic or other export markets, processing equipment in packing houses must be suitably cleaned prior to the commencement of processing fruit for export to Australia.

The objective of this measure is to reduce the likelihood of importation for *M. fructigena* (apple brown rot) to at least 'very low'. The restricted risk would then be reduced to at least 'very low', which would achieve Australia's ALOP.

Other potential measures for apple brown rot

Consistent with the principle of equivalence detailed in ISPM 11: *Pest risk analysis for quarantine pests including analysis of environmental risks and living modified organisms* (FAO 2004), Biosecurity Australia will consider any alternative measure proposed by AQSIQ, providing that it achieves an equivalent level of quarantine protection. Evaluation of such measures or treatments will require a technical submission from AQSIQ that details the proposed treatment and includes data from suitable treatment trials.

5.2.5 Management of *Diplocarpon mali*, *Gymnosporangium yamadae* and *Phyllosticta arbutifolia*

Diplocarpon mali (marssonina blotch), *Gymnosporangium yamadae* (Japanese apple rust) and *Phyllosticta arbutifolia* (apple blotch) were assessed to have an unrestricted risk estimate that does not achieve Australia's ALOP. Measures are therefore required to manage this risk.

Visual inspection of fruit alone is not considered to be an appropriate management option for these pathogens as external signs of infection are not always present and there may be latent infections. Biosecurity Australia proposes the following systems approach based on orchard control and surveillance, fruit bagging, and post-harvest processing in the packing house, in addition to visual inspection to reduce the risk associated with these pathogens to an acceptable level.

Orchard control and surveillance

Registered growers would implement an orchard control program (i.e. acceptable agricultural practice and integrated disease management (IDM) program for export apples). Programs would need to be approved by AQSIQ, and incorporate field sanitation and appropriate fungicide applications for the management of pathogens of quarantine concern to Australia.

AQSIQ/CIQ would be responsible for ensuring that export apple growers are aware of diseases of quarantine concern to Australia, field sanitation and control measures. Registered growers would be required to keep records of control measures for auditing purposes. Details of the pathogen control program would need to be provided to DAFF by AQSIQ before trade commenced.

Orchard control and surveillance for these pathogens would include:

- Monitoring/detection surveys for diseases that require orchard management measures must be conducted regularly by AQSIQ/CIQ in orchards registered for export to verify the effectiveness of the measures. AQSIQ/CIQ will maintain annual survey results using a standard reporting format. These results must be made available to DAFF if requested.
- AQSIQ would be required to inspect all export orchards prior to removal of bags and harvest for *D. mali* (marssonina blotch), *G. yamadae* (Japanese apple rust) and *P. arbutifolia* (apple blotch) to ensure that they are free from symptoms of the diseases. The inspection method, including details of the timing and size of the sampling to be undertaken for each orchard, appropriate for these diseases would be developed by AQSIQ. Results of the inspections would subsequently be made available to DAFF for auditing purposes.
- For *G. yamadae* (Japanese apple rust), Australia proposes the removal of the telial hosts (*Juniperus* spp.) of the telial stage located within 2 km of orchards registered for export to Australia. This is consistent with the requirements for *G. asiaticum* (Japanese pear rust) and *G. sabinae* (European pear rust) for pears from China (Biosecurity Australia 2005b). AQSIQ has already implemented this requirement in pear production areas of Hebei, Shandong and Shaanxi as a requirement for the import of Chinese pears into Australia. AQSIQ has expressed concern at removing old *Juniperus* spp. amenity trees (AQSIQ 2006a). AQSIQ expressed a preference for alternative measures such as controlling the diseases on the telial host and/or adding the washing of fruit into the process, as suggested below.

Rather than removal of the telial hosts (*Juniperus* spp.), an alternative approach is for AQSIQ to ensure a chemical control program is in place to combat the disease in both the apple orchards as well as any surrounding telial hosts within 2 km. Documented evidence of effective control (i.e. spraying of telial hosts (*Juniperus* spp.) in spring in addition to orchard trees) would be required. This approach was recommended for management of *G. yamadae*, for the import of apples from Japan (AQIS 1998a).

Fruit bagging

AQSIQ has indicated that apples produced in China for export are individually bagged (AQSIQ 2005). Fruit bagging has been shown in China to be effective in providing some protection to the developing apple fruit and in reducing damage from diseases. For example, it has been successfully used to control apple sooty blotch and flyspeck diseases (Zhang 2007; Zhang 2006). Apple fruit bagging is also practised in Japan and is included as a requirement for the importation of Fuji apples from Japan (AQIS 1998a). Fruit bagging is also part of the systems approach for managing pathogens in pears from China with the exception of *Pyrus* sp. nr. *communis* (fragrant pear) from Xinjiang. With pears, the bags remain on the fruit until after harvest and transport to the packing house to protect fruit from mechanical and pest damage and discoloration (Biosecurity Australia 2005b).

Biosecurity Australia proposes fruit bagging as a risk management measure (as part of the systems approach) for *D. mali* (marssonina blotch), *G. yamadae* (Japanese apple rust) and *P. arbutifolia* (apple blotch).

As stated previously, double bags would be required to be placed over individual apple fruit when the fruit is no more than 2.5 cm in diameter (AQSIQ 2008c), to minimise the risk of early exposure to these pests. Biosecurity Australia was advised that apple fruit observed in Shandong Province was double bagged before the third week in June, for apples harvested in early October. Disease control measures, including fungicide sprays, would need to be applied at the appropriate time to manage each of the quarantine pathogens prior to bagging to ensure that the orchards in general, and the developing fruit in particular, are free from these pathogens. This is particularly important as bagging of young fruitlets may not limit infection by *Diplocarpon mali* and *Phyllosticta arbutifolia*, as fruit is already highly susceptible from petal fall up to four weeks after petal fall (Gardner 1923).

AQSIQ has advised that the outer bags are usually removed approximately three to four weeks before harvesting to allow gradual exposure of apple fruit to the sun, and the inner bag removed two to three weeks before harvesting to allow the fruit to develop the desired colour. Variations in these practices have been observed in different provinces however this advice indicates the maximum length of time that the apple fruit would be exposed after bag removal. AQSIQ (2005) states that the maturity time for apple fruit is late August for Gala, late September for New Red Star, early October for Qinguan and middle and late October for Fuji, indicating that apples can be harvested from late August to late October depending on the cultivars. This means that the bags would be removed starting from early August to early October. It is possible that pathogens, if present in the orchard could infect the exposed physiologically mature fruit during the two to four week period (AQSIQ 2008c) between complete removal of the bags and harvesting the fruit.

The disease cycle of each pathogen was examined to determine whether or not it would be present and could infect mature fruit during the period after bag removal. Basidiospores of *G. yamadae* (Japanese apple rust) from the telial hosts (*Juniper*) may infect apple fruit, although infection of mature fruit is rare (Guo 1994).

Prior to the removal of bags, AQSIQ/CIQ would need to ensure that the level of pests in registered export orchards is reduced so that the risk of fruit being infected after the removal of bags is minimised, especially for *G. yamadae* (Japanese apple rust) on aecial hosts (apple). This may be achieved through monitoring and inspecting the orchards before removing the bags, and maintaining the pest status during the period from when the bags are removed and the fruit is harvested. AQSIQ/CIQ would develop the monitoring and inspection procedures to demonstrate effective management of these pests is achieved during this period. These procedures would be documented and provided to DAFF before trade commences. The results of monitoring and inspection along with the recorded dates of initial bagging of fruit and staged removal of bags must also be made available to DAFF for auditing purposes.

Post-harvest processing

Infection may also occur on fruit wounded during the harvest and post-harvest handling processes. Protective measures, such as the practice of putting each individual apple into an expandable foam sleeve or ‘sock’, would minimise fruit damage.

Preliminary sorting after harvest, to remove damaged, spoilt or badly blemished fruit, prior to storage will minimise any cross-contamination in the fruit during the pre-processing cold storage period.

To prevent any potential contamination from the processing of fruit destined to domestic or other export markets, processing equipment in packing houses must be suitably cleaned prior to the commencement of processing fruit for export to Australia.

When fruit for export to Australia is removed from cold storage for processing, any damaged, spoilt, or badly blemished fruit must be removed during the early stages of processing (i.e. cleaning, sorting and grading).

The objective of all these measures (a systems approach) is to reduce the likelihood of importation for these pathogens to at least ‘very low’. The restricted risk would then be reduced to at least ‘very low’, which would achieve Australia’s ALOP.

Other potential measures for pathogens

Consistent with the principle of equivalence detailed in ISPM 11: *Pest risk analysis for quarantine pests including analysis of environmental risks and living modified organisms* (FAO 2004), Biosecurity Australia will consider any alternative measure proposed by AQSIQ, providing that it achieves an equivalent level of quarantine protection. Evaluation of such measures or treatments will require a technical submission from AQSIQ that details the proposed treatment and includes data from suitable treatment trials.

5.3 Risk management measures for quarantine pests for Western Australia only

One arthropod pest was assessed as having an unrestricted risk that does not meet Australia’s ALOP (Table 5.2).

Table 5.2: Pest identified for Western Australia only

| Pest | Common Name | Measures |
|---|--------------|--|
| Arthropods | | |
| <i>Cydia pomonella</i> ^{WA, EP} | Codling moth | Option 1: Area freedom (pest free areas or pest free places of production or production sites) Option 2: Areas of low pest prevalence Option 3: Fruit bagging and an orchard management program Option 4: Methyl bromide fumigation |
| ^{WA} : Quarantine pest for the State of Western Australia ^{EP} : Species has been assessed previously and for which import policies already exist. | | |

The same pest *Cydia pomonella* (codling moth) has also been identified as requiring management measures for Western Australia only, in the *Final Import Risk Analysis Report for Apples from New Zealand* (Biosecurity Australia 2006a). The risk management options recommended for apples from New Zealand can be adopted for apples from China.

However, there are some differences between export apples produced in China and in New Zealand. Apples produced for export in China are bagged individually during the development on the tree. Fruit bagging has therefore been recommended as part of the systems approach for specific arthropod and pathogen pests on apples from China, as described under pests for the whole of Australia (Section 5.2). The impact of fruit bagging is discussed in relation to this pest for Western Australia.

5.3.1 Management for *Cydia pomonella*

Biosecurity Australia has considered that visual inspection of fruit alone may not be an appropriate risk management measure for *Cydia pomonella* (codling moth), because signs of infestation may not be visible. Other identified options to manage risks associated with codling moth, if fruit is to be imported into Western Australia, are (i) sourcing fruit from pest free areas, (ii) sourcing fruit from areas of low pest prevalence, (iii) fruit bagging and (iv) methyl bromide fumigation. The objective of these options is to provide measures that will reduce the risk of the importation of the codling moth to a level that will achieve Australia's ALOP.

Option 1: Area freedom

Area freedom is a measure that might be applied to manage the risk posed by codling moth. If AQSIQ wishes to consider pest free areas or pest free places of production or pest free production sites as a potential management measure for codling moth, Biosecurity Australia will assess any proposal from China.

The requirements for establishing pest free areas are set out in ISPM 4: *Establishment of pest free areas* (FAO 1996) and ISPM 10: *Requirements for the establishment of pest free places of production and pest free production sites* (FAO 1999).

AQSIQ (2008c) indicated that *C. pomonella* (codling moth) is only reported from Xinjiang and parts of Gansu, which are not China's main apple production areas. If this option is to be adopted, AQSIQ would be responsible for the establishment of pest free areas or production area pest freedom, by carrying out verification of pest free places of production through official surveys and monitoring. These survey results would need to be submitted to DAFF before access could be considered.

Option 2: Areas of low pest prevalence

Low pest prevalence is a measure that might be applied to manage the risk posed by codling moth to Western Australia. The requirements for establishing areas of low pest prevalence are set out in ISPM 22: *Requirements for the establishment of areas of low pest prevalence* (FAO 2005). Components of such a program could include:

- registration of grower designated production sites
- monitoring and trapping for codling moth
- specific codling moth control requirements

- specific requirements for submission of fruit to packing houses
- grower compliance agreement.

AQSIQ would be responsible for the establishment of areas of low pest prevalence by official surveys and monitoring. These survey results must be submitted to DAFF before access could be considered.

Option 3: Fruit bagging and an orchard management program

The requirement for fruit bagging as part of a systems approach to manage arthropod pests has been described previously. As mentioned, there are about two to four weeks of exposure of the mature fruit to possible pest attack after the bags are removed and before the fruit is harvested, starting in late August (AQSIQ 2005). *Cydia pomonella* larvae of the third generation may still be present in orchards during August-October (CAB International 2007a; CAAS 1992) and would have the opportunity to attack the exposed fruit. However, the requirement for ongoing orchard management, including monitoring and trapping to ensure freedom from codling moth in orchards during this limited exposure period will mitigate the risk of fruit being attacked. Thus, fruit bagging and an orchard management program together would be effective to reduce the risk of *C. pomonella* to an acceptable level.

Option 4: Methyl bromide fumigation

It is recommended that the methyl bromide fumigation treatment could be performed for consignments where fruit can not be sourced under Option 1, Option 2 or Option 3, and when codling moth is detected at either pre-clearance in China or on-arrival inspection in Australia.

Where fumigation with methyl bromide is utilised as the measure for codling moth, it must be carried out for 2 hours according to the specifications below:

- 32 g/m³ at a pulp temperature of 21 °C or greater – minimum concentration time (CT) product of 47 g.h/m³; or
- 40 g/m³ at a pulp temperature of 16 °C or greater – minimum CT product of 58 g.h/m³; or
- 48 g/m³ at a pulp temperature of 10 °C or greater – minimum CT product of 70 g.h/m³.

It is recommended that fruit should not be fumigated if the pulp temperature is below 10 °C and that fumigations should be carried out in accordance with AQIS fumigation standards.

All pre-shipment (off-shore) fumigation certificates would need to contain the following fumigation details:

- the name of the fumigation facility
- the date of fumigation
- rate of methyl bromide used, that is initial dosage (g/m³)
- CT product of methyl bromide achieved by the fumigation (g.h /m³)
- the fumigation duration (hours)
- ambient air temperature during fumigation (°C)

- minimum fruit pulp temperature during fumigation (°C).

The objective of these measures is to reduce the likelihood of importation for codling moth to at least ‘very low’. The restricted risk would then be reduced to at least ‘very low’, which would achieve Australia’s ALOP.

5.4 Operational systems for maintenance and verification of phytosanitary status

A system of operational procedures is necessary to maintain and verify the phytosanitary status of fresh apple fruit from China. This is to ensure that the recommended risk management measures have been met and are maintained.

It is recommended that China’s AQSIQ or other relevant agency such as CIQ nominated by AQSIQ, prepare a documented work plan for approval by Biosecurity Australia/AQIS that describes the phytosanitary procedures for the pests of quarantine concern for Australia and the various responsibilities of all parties involved in meeting this requirement.

Details of the operational system, or equivalent, will be determined by agreement between Biosecurity Australia and AQSIQ.

5.4.1 Recognition of the competent authority

The General Administration of Quality Supervision, Inspection and Quarantine of the People’s Republic of China (AQSIQ) is the competent authority for China.

The objectives of the competent authority are to ensure that:

- recommended service and certification standards, and recommended work plan procedures, are met by all relevant agencies participating in this program
- recommended administrative processes are established that provide assurance that the recommended requirements of the program are being met.

5.4.2 Audit and verification

The objectives of the recommended requirement for audit and verification are to ensure that:

- an effective approved documented system is in operation for the orchard, the packing house and during transport.

The phytosanitary system for apple export production, certification of export orchards, pre-export inspection and certification is subject to audit by AQIS. Audits may be conducted at the discretion of AQIS during the entire production cycle and as a component of any pre-clearance arrangement.

AQIS orchard audits will measure compliance with orchard registration and identification, pest/disease management including maintenance of a spray diary/monitoring, record management, the administration and verification of area freedom status of the export areas for Oriental fruit fly, apple brown rot, European canker, codling moth and any other relevant pests if accepted by Australia.

AQIS packing house audits of participants involved in pre-clearance arrangements will include the verification of compliance with packing house responsibilities, traceability, labelling, segregation and product security, and the AQSIQ/agency certification processes.

5.4.3 Registration of export orchards

The objectives of this recommended procedure are to ensure that:

- apple fruit is sourced from AQSIQ registered export orchards producing export quality fruit, as the pest risk assessments are based on existing commercial production practices
- export orchards from which apple fruit is sourced can be identified so investigation and corrective action can be targeted rather than applying it to all contributing export orchards in the event that live pests are regularly intercepted during pre-clearance inspection.

5.4.4 Registration of packing houses and treatment facilities and auditing of procedures

The objectives of this recommended procedure are to ensure that:

- apple fruit is sourced only from AQSIQ registered packing houses, processing export quality fruit, as the pest risk assessments are based on existing commercial packing activities
- reference to the packing house and the orchard source (by name or a number code) are clearly stated on cartons destined for export of fresh apple fruit to Australia for trace back and auditing purposes.

It is recommended that AQSIQ registers the packing houses before commencement of harvest each season. The list of registered packing houses must be kept by AQSIQ and provided to AQIS prior to exports commencing with updates provided if packing houses are added or removed from the list.

Registration of packing houses and treatment facilities in the initial export season would include an audit program conducted jointly by AQIS and AQSIQ before exports commence. After the initial approval, AQSIQ would be required to audit facilities at the beginning of each season to ensure that packing houses and treatment facilities are suitably equipped to carry out the specified phytosanitary tasks and treatments. Records of AQSIQ audits would be made available to AQIS on request.

Packing houses will be required to identify individual orchards with a unique identifying system and identify fruit from individual orchards by marking cartons or pallets (i.e. one orchard per pallet) with a unique orchard number or identification provided by AQSIQ.

Where apple fruit is cold treated and/or fumigated prior to export, this process could only be undertaken in facilities that have been registered with and audited by AQSIQ for that purpose. AQSIQ would be required to register all export fumigators, as well as fumigation and cold treatment facilities before export activity commences. Registered fumigators would need to comply with the current AQSIQ standards for export grade facilities, and also comply with Australian Fumigation Accreditation Scheme (AFAS) standards. Copies of registration and fumigation chamber test records would need to be made available to AQIS if requested.

5.4.5 Packaging and labelling

The objectives of this recommended procedure are to ensure that:

- apple fruit recommended for export to Australia is not contaminated by quarantine pests or regulated articles (e.g. trash, soil and weed seeds)
- unprocessed packing material (which may vector pests not identified as being on the pathway) is not imported with fresh apple fruit
- all wood material used in packaging of the commodity complies with AQIS conditions (see AQIS publication *Cargo Containers: Quarantine aspects and procedures*)
- secure packaging is used if consignments are not transported in sealed containers directly to Australia
- the packaged apple fruit is labelled with the orchard registration number for the purposes of trace back to registered orchards
- the pre-cleared status of apple fruit is clearly identified.

5.4.6 Specific conditions for storage and movement

The objectives of this recommended procedure are to ensure that:

- product for export to Australia is secure by segregation from non-precleared product and to prevent mixing or cross-contamination with produce destined elsewhere
- the quarantine integrity of the commodity during storage and movement is maintained.

5.4.7 Freedom from trash

All apples for export must be free from trash, foreign matter and pests of quarantine concern to Australia. Freedom from trash will be confirmed by the inspection procedures. AQSIQ/CIQ must provide details of how inspection for trash will occur before trade commences.

5.4.8 Pre-export phytosanitary inspection and certification by Chinese authorities

The objectives of this recommended procedure are to ensure that:

- all consignments are inspected by CIQ in accordance with official procedures for all visually detectable quarantine pests and other regulated articles (including soil, animal and plant debris) at a standard 600 unit sampling rate per lot whereby one unit is one apple fruit
- an international phytosanitary certificate (IPC) is issued for each consignment upon completion of pre-export inspection and treatment to verify that the relevant measures have been undertaken offshore
- each IPC includes:
 - a description of the consignment (including orchard number and packing house details)
 and

- an additional declaration that *‘The fruit in this consignment has been produced in China in accordance with the conditions governing entry of fresh apple fruit to Australia and inspected and found free of quarantine pests’*.

5.4.9 Requirement for pre-clearance

The objectives of the recommended requirement for pre-clearance are to ensure that:

- the recommended quarantine measures, including orchard control and surveillance, product identification, AQIS inspection requirements, product security and documentation are met
- all lots are inspected by AQIS and CIQ in accordance with official procedures for all visually detectable quarantine pests and other regulated articles (including soil, animal and plant debris) at a standard 600 unit sampling rate per lot whereby one unit is one apple fruit
- the detection of live quarantine pests will result in the rejection of the inspection lot and remedial action may be required.

Under pre-clearance arrangements, AQIS officers would be involved in orchard inspections for pests of quarantine concern to Australia, in the direct verification of packing house procedures, and in joint fruit inspection. It would further include their involvement in auditing of other arrangements including registration procedures, existing commercial practice, traceability, and handling of export fruit in a secure manner.

The pre-clearance arrangement is to be used at least for initial trade. Subsequently, subject to a review of the trade and agreement by DAFF and AQSIQ on a region by region basis, pre-clearance of lots in China may not be undertaken in the future and in this case AQIS will conduct the quarantine inspection on arrival in Australia.

5.4.10 On-arrival clearance for pre-cleared consignments by AQIS

The objectives of this recommended procedure are to ensure that:

- the required pre-clearance arrangement has been undertaken.

Consignments inspected under pre-clearance arrangements in China would generally only undergo on-arrival verification in Australia. AQIS would examine documents for compliance and verification that the consignments received were those pre-cleared, and that the integrity of the consignments had been maintained, prior to their release from quarantine. AQIS may open the containers to verify the contents but does not usually carry out on-arrival quarantine inspection of the fruit. However, Australia maintains the right to select containers for random quarantine inspection.

Any ‘consignment’ with incomplete documentation, certification that does not conform to specifications, or with seals on the containers that are damaged or missing, would be held pending clarification by AQSIQ and determination by AQIS, which would include the options of re-export, destruction or treatment. AQIS would inform AQSIQ of action taken including any intention to suspend importation.

5.4.11 On-arrival quarantine inspection for consignments where pre-clearance is not used

The objectives of this recommended procedure are to ensure that:

- consignments that have not been inspected under pre-clearance arrangements undergo appropriate quarantine inspection on arrival in Australia.

As recommended in Section 5.4.9 *Requirement for pre-clearance* the pre-clearance arrangement is to be used at least for initial trade. If the requirement for the pre-clearance is removed, AQIS will undertake a documentation compliance examination for consignment verification purposes, followed by quarantine inspection before release from quarantine on arrival in Australia.

5.4.12 Remedial action(s) for non-compliance

The objectives of the recommended requirements for remedial action(s) for non-compliance are to ensure that:

- any quarantine risk is addressed by remedial action, as appropriate
- non-compliance with import requirements is addressed, as appropriate.

5.5 Uncategorized and other pests

If an organism, including contaminating pests, is detected on apple fruit, either in China or on-arrival in Australia, that has not been categorised, it will require assessment by Biosecurity Australia to determine its quarantine status and if phytosanitary action is required.

Assessment is also required if the detected species was categorised as not likely to be on the import pathway. If the detected species was categorised as on the pathway but assessed as having an unrestricted risk that achieves Australia's ALOP due to the rating for likelihood of importation, then it would require reassessment. The detection of any pests of quarantine concern not already identified in the analysis may result in remedial action and/or temporary suspension of trade while a review is conducted to ensure that existing measures continue to provide the appropriate level of protection for Australia.

5.6 Audit of protocol

Prior to the first season of trade, a representative from Biosecurity Australia and AQIS will visit areas in China that produce apples for export to Australia. They will audit the implementation of agreed import conditions and measures including registration, operational procedures and fumigation facilities.

5.7 Review of policy

Biosecurity Australia reserves the right to review the import policy after the first year of trade or when there is reason to believe that the pest and phytosanitary status in China has changed. The pre-clearance arrangement requirement may be reviewed after initial substantial trade.

AQSIQ must inform Biosecurity Australia/AQIS immediately on detection in China of any new pests of apples that are of potential quarantine concern to Australia. For example, fire

blight (caused by the bacterium *Erwinia amylovora*) has not been detected in China. Should fire blight be detected in China, AQSIQ must immediately advise Biosecurity Australia and AQIS of the changed pest status. Similarly, should area freedom from Oriental fruit fly (*Bactrocera dorsalis*) and economically significant fruit flies be recognised for the areas exporting apples to Australia, AQSIQ must immediately advise Biosecurity Australia and AQIS if any economically significant fruit flies are detected in the exporting provinces.

Appendixes

Appendix A. Initiation and pest categorisation

Appendix A1: Organisms associated with production of apples in China, their status in Australia and their association with fresh apple fruit ⁸.

Note: Species in **bold text** are additional to those included in the pest categorisation of the draft IRA report (Biosecurity Australia 2009a)

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|---------------------------------------|---|-----------------------------------|--|---|-------------------|
| ARTHROPODS | | | | | | |
| ACARI | | | | | | |
| <i>Aculus schlechtendali</i> (Nalepa, 1890) [Acari : Eriophyidae] | apple rust mite | Yes (Li and Cai 1996) | Yes (Halliday 2000) | Yes (AQIS 1998a) | | No |
| <i>Amphitetranynchus viennensis</i> (Zacher, 1920) <i>As Tetranychus viennensis</i> in AQSIQ (2005) [Acari: Tetranychidae] | hawthorn spider mite | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No (Halliday 2000; AQIS 1998b) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Likely Hawthorn spider mites primarily feed on the underside of leaves; preferentially cherry leaves. Female mites over-winter in cracks and under the bark of stems and branches. When mite populations are high, female mites may over-winter in the calyx crevices, or in the depression on the stem-end of mature apple fruit (APHIS 2005). This species is listed as a 'commonly occurring insect' in China (CIQSA 2001c; CIQSA 2001a). It was assessed as on pathway in the Fuji apple IRA (AQIS 1998a). | Yes |
| <i>Bryobia rubrioculus</i> (Scheuten, 1857) [Acari: Tetranychidae] | <i>Bryobia</i> mite; brown apple mite | Yes (CIQSA 2001c) | Yes (Halliday 2000) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | | No |
| <i>Cenopalpus pulcher</i> (Canestrini & Fanzago, 1876) [Acari: Tenuipalpidae] | flat scarlet mite | Yes (Wang 1981) | No (Halliday 2000) | No | Likely This mite feeds on leaves of host plants, causing them to become grey-brown in colour (Wang 1981). Bajwa and Kogan (2003) found that <i>Cenopalpus pulcher</i> deposits eggs on the striation and natural indentations of leaves and fruits and feeds on leaves, soft twigs and fruits. | Yes |

⁸ This pest categorisation table does not represent a comprehensive list of all the pests associated with the entire plant of an imported commodity. Reference to soilborne nematodes, soilborne pathogens, wood borer pests, root pests or pathogens, and secondary pests have not been listed or have been deleted from the table, as they are not directly related to the export pathway of fresh apple fruit and would be addressed by Australia's current approach to contaminating pests.

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|------------------------|---|------------------------------------|--------------------------------------|--|-------------------|
| <i>Eotetranychus pruni</i> (Oudemans, 1931) [Acari: Tetranychidae] | spider mite | Yes (Wang 1981) | No (Halliday 2000) | No | Unlikely This mite feeds on the underside of leaves, mainly around the midvein and causes both sides of leaves to turn pale yellow. Leaves may also curl and dry out (Wang 1981). | No |
| <i>Eotetranychus</i> sp. [Acari :Tetranychidae] | spider mite | Yes (Chai <i>et al.</i> 1990) | Uncertain | No | Unlikely Nymphs and adults of <i>Eotetranychus</i> sp. damage flower bud, leaves and young shoots (Chai <i>et al.</i> 1990). | No |
| <i>Galendromus occidentalis</i> (Nesbitt, 1951) <i>As Metaseiulus occidentalis</i> (Nesbitt) [Acari: Phytoseiidae] | apple mite | Yes (Deng <i>et al.</i> 1990) | Yes (Poole 2008; Halliday 2000) | No | | No |
| <i>Panonychus ulmi</i> (Koch, 1836) [Acari: Tetranychidae] | European red mite | Yes (CAB International 2007a) | Yes (Halliday 2000) | Yes (AQIS 1998a) | | No |
| <i>Tarsonemus confusus</i> Ewing, 1939 [Acari: Tarsonemidae] | mushroom mite | Yes (Hao <i>et al.</i> 2007) | No (Halliday 2000) | Yes (Biosecurity Australia 2005c) | Likely <i>Tarsonemus confusus</i> was the dominant population found in the bagged apples in China (Hao <i>et al.</i> 2007). The presence of this pest caused the appearance of damage symptoms (black-dot disease) on apples (Hao <i>et al.</i> 2007). | Yes |
| <i>Tetranychus kanzawai</i> Kishida Synonym: <i>Tetranychus hydrangeae</i> Pritchard & Baker 1955 [Acari: Tetranychidae] | Kanzawa spider mite | Yes (CAB International 2007a) | No records found | No | Unlikely <i>Tetranychus kanzawai</i> is often found on the under surface of the leaves; damaged leaves have yellowish spots; heavily infested leaves may become yellow and dry (CAB International 2007a). | No |
| <i>Tetranychus turkestanii</i> (Ugarov & Nikolskii, 1937) Synonym: <i>Tetranychus atlanticus</i> McGregor, 1941 [Acari: Tetranychidae] | strawberry spider mite | Yes In China (CAB International 2007a) on apple (Migeon and Dorkeld 2006; Gutierrez 1994) | No (Halliday 2000) | Yes (Biosecurity Australia 2005b) | Unlikely Apple is listed as the host of <i>Tetranychus turkestanii</i> by Pritchard and Baker (1955). There have been no reports of <i>Tetranychus turkestanii</i> on apple trees in China, although the species is recorded from Xinjiang, China on cotton (Gutierrez 1994; Wang 1981). <i>Tetranychus turkestanii</i> feeds on a wide range of low-growing plant species but seldom is found on shrubs and trees (Mellott and Krantz 2007). It is considered that they are not likely to be on the pathway. | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|---|---|-----------------------------------|--|---|-------------------|
| <i>Tetranychus urticae</i> Koch, 1836 [Acari: Tetranychidae] | two-spotted spider mite | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | Yes (Halliday 2000) | Yes (AQIS 1998a) | | No |
| COLEOPTERA | | | | | | |
| <i>Adoretus puberulus</i> Motschulsky, 1854 [Coleoptera: Scarabaeidae] | scarab beetle | Yes (CHNZX-Farming 2008a) | No (Cassis <i>et al.</i> 1992) | No | Unlikely Adults feed on leaves and larvae feed on underground parts of host (CHNZX-Farming 2008a). | No |
| <i>Adoretus tenuimaculatus</i> Waterhouse, 1875 [Coleoptera: Scarabaeidae] | rose beetle | Yes (CHNZX-Farming 2008b) | No (Cassis <i>et al.</i> 1992) | Yes (DAFF 2004a; AQIS 1999a; AQIS 1998a){#162}{#1645} | Unlikely Adults feed on leaves and larvae feed on underground parts of host (CHNZX-Farming 2008b). | No |
| <i>Aegosoma sinica</i> White, 1953 <i>As Megopis sinica</i> (White, 1853) [Coleoptera: Cerambycidae] | long-horned beetle | Yes (CHNZX-Farming 2008n) | No records found | Yes (AQIS 1999a; AQIS 1998a) | Unlikely Larvae bore into the stem of some living broad-leaved trees and dead conifers and feed on epidermis and xylem (CHNZX-Farming 2008n; Kojima 1931). | No |
| <i>Agrilus mali</i> Matsumura, 1924 [Coleoptera: Buprestidae] | apple wood borer | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a; Muramarsu 1924) | No (Bellamy 2001) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Unlikely This beetle species damages twigs and branches of apple trees in China (CIQSA 2001a). Larval buprestids generally occur in the soil and feed on roots. At night, some species ascend the plant to feed on the leaves and flowers (CAB International 2007a). | No |
| <i>Anomala corpulenta</i> Motschulsky, 1854 [Coleoptera: Scarabaeidae] | scarab beetle | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No (Cassis <i>et al.</i> 1992) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Unlikely This beetle species rolls and eats leaves of apple trees in China (CIQSA 2001a). Adults feed on leaves and larvae feed on roots of apple and crab apple trees in China (Kuoh and Chang 1959). Scarab adults and larvae have chewing mouthparts. Generally, larvae feed on roots of hosts and adults feed on flowers and leaves (CAB International 2007a). Adult scarabs are large enough to be visually identified during packing house procedures. | No |
| <i>Anoplophora chinensis</i> (Forster, 1771) [Coleoptera: Cerambycidae] | star longicorn beetle; citrus longhorn beetle | Yes (CIQSA 2001c) | No records found | No | Unlikely Larvae of <i>Anoplophora</i> species develop in the phloem and xylem of living host tree trunks and branches (Lingafelter and Hoebeke 2002). | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|--|---|-----------------------------------|--|---|-------------------|
| <i>Anoplophora glabripennis</i> (Motschulsky, 1853) Synonym: <i>Anoplophora nobilis</i> (Ganglbauer, 1890), also listed in issues paper (Biosecurity Australia 2008d) [Coleoptera: Cerambycidae] | Asian long-horned beetle | Yes (Shang <i>et al.</i> 2000) | No (CAB International 2007a) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Unlikely This beetle species damages trees of apple, pear, peach, apricot, plum and Chinese date along with grapevines in China. Eggs are laid, larvae hatch and adults emerge on apple and pear trees (Shang <i>et al.</i> 2000). Larvae of <i>Anoplophora</i> species develop in the phloem and xylem of living host tree trunks and branches (Lingafelter and Hoebeke 2002). | No |
| <i>Anthribus niveovariegatus</i> (Reolofs, 1879) [Coleoptera: Anthribidae] | anthribid beetle, fungus weevil | Yes (Deng 1985) | No records found | No | Unlikely <i>Anthribus niveovariegatus</i> is a parasite of the coccids <i>Ericerus pela</i> and <i>Eulecanium excrescens</i> (Deng 1985). <i>Ericerus pela</i> is not a pest of apples (Ben-Dov 2005a). <i>Eulecanium excrescens</i> feeds on leaves and bark (Central Science Laboratory (CSL) 2005). | No |
| <i>Apriona germari</i> (Hope, 1831) [Coleoptera: Cerambycidae] | long-horned stem borer | Yes (Yang <i>et al.</i> 2005a; AQSIQ 2005; Qin <i>et al.</i> 1994) | No records found | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Unlikely This beetle species attacks trunk and branches of apple trees in China (Yang <i>et al.</i> 2005a; CIQSA 2001a). | No |
| <i>Asias halodendri</i> (Pallas, 1776) [Coleoptera: Cerambycidae] | red-lined beetle | Yes (CHNZX-Farming 2008e) | No (Cassis <i>et al.</i> 1992) | Yes (AQIS 1998b) | Unlikely Larvae bore into branches and feed on epidermis and xylem, mainly attacking branches of 1-3 cm in diameter (CHNZX-Farming 2008e). | No |
| <i>Aulacophora femoralis</i> (Motschulsky, 1857) [Coleoptera: Chrysomelidae] | cucurbit leaf beetle | Yes (Liang <i>et al.</i> 2007) | No (Martin and Gillespie 2001) | Yes (AQIS 1999a) | Unlikely <i>Aulacophora femoralis</i> feeds on seedlings and young leaves of host plants (Liang <i>et al.</i> 2007). | No |
| <i>Bacchisa fortunei</i> (Thomson, 1857) [Coleoptera: Cerambycidae] | blue pear twig borer; pear borer | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No records found | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Unlikely This beetle species damages twigs and branches of apple trees in China (Qiang <i>et al.</i> 2002; CIQSA 2001a; Wei 1990). | No |
| <i>Chilocorus rubidus</i> Hope, 1831 [Coleoptera: Coccinellidae] | coccinellid predator, lady bird beetle | Yes (Li 1988) | No records found | No | Unlikely <i>Chilocorus rubidus</i> is a predator of the nymphs of apple leafhopper <i>Pyramidotettix mali</i> (Li 1988). The coccinellid predator also feed on the nymphs of Korean lecanium, <i>Didesmococcus koreanus</i> (Liu 1993). | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|-------------------------------|--|-----------------------------------|--|---|-------------------|
| <i>Gametis jucunda</i> (Faldermann, 1835) <i>As Oxycetonia jucunda</i> (Faldermann, 1835) in Li <i>et al.</i> (2005) <i>As Gametis forticula kotoensis</i> Nomura, 1959 in DAFWA (2009) [Coleoptera: Cetoniidae] | citrus flower chafer | Yes (Li <i>et al.</i> 2005; CIQSA 2001c) | No (Cassis <i>et al.</i> 1992) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Unlikely This beetle species visits flowers and attacks buds of apple trees in China (Wan <i>et al.</i> 2006; Nishino <i>et al.</i> 1970; Matsuo 1969). Usually attacks flowers and buds, causing a much reduced fruit set rate (Li <i>et al.</i> 2005). Scarab adults and larvae have chewing mouthparts. Generally, larvae feed on roots of hosts and adults feed on flowers and leaves (CAB International 2007a). | No |
| <i>Harmonia axyridis</i> (Pallas, 1773) [Coleoptera: Coccinellidae] | Harlequin ladybird | Yes (Li <i>et al.</i> 2008; CAB International 2008) | No records found | No | Unlikely <i>Harmonia axyridis</i> is one of the important predatory insects for controlling <i>Eriosoma lanigerum</i> in apple orchards in China (Li <i>et al.</i> 2008). There have been no reports of <i>Harmonia axyridis</i> damaging apple fruit. In the USA, <i>Harmonia axyridis</i> adults feed on damaged grapes when their primary food source, soybean aphids, are scarce. They usually cluster and contaminate and taint wine grapes (CAB International 2008). | No |
| <i>Holotrichia diomphalia</i> (Bates, 1888) [Coleoptera: Scarabaeidae] | scarab beetle | Yes (CHNZX-Farming 2008I) | No (Cassis <i>et al.</i> 1992) | No | Unlikely Adults feed on young leaves, shoots and flowers, larvae feed on underground parts of plants (CHNZX-Farming 2008I). | No |
| <i>Holotrichia parallela</i> (Motschulsky, 1854) [Coleoptera: Scarabaeidae] | large black chafer | Yes (CIQSA 2001a) | No (Cassis <i>et al.</i> 1992) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Unlikely The adults feed on leaves of host plants and larvae damage the underground parts of the plants (Anonymous 2008). This species was assessed as associated with fruit in the IRA for ya pear from China (AQIS 1998b). However the above information indicates that it is unlikely on pathway. | No |
| <i>Holotrichia scrobiculata</i> Kiesenwetter, 1857 [Coleoptera: Scarabaeidae] | chafer | Yes (AQSIQ 2005; CIQSA 2001a) | No (Cassis <i>et al.</i> 1992) | No | Unlikely Scarab adults and larvae have chewing mouthparts. Generally, larvae feed on roots of hosts and adults feed on flowers and leaves (CAB International 2007a). | No |
| <i>Lamprodila limbata</i> (Gebler, 1832) [Coleoptera: Buprestidae] | golden jewel beetle | Yes (AQSIQ 2005; CIQSA 2001c) | No (Bellamy 2001) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Unlikely Larval buprestids generally occur in the soil feeding on roots. At night, some species ascend the plant to feed on the leaves and flowers (CAB International 2007a). | No |
| <i>Linda fraterna</i> (Chevrolat, 1852) [Coleoptera: Cerambycidae] | apple branch longicorn beetle | Yes (CIQSA 2001c; CIQSA 2001a) | No records found | Yes (AQIS 1998a) | Unlikely Larvae are found in twigs of apple trees in China (Shen and Chang 1964). Damage occurs to young branches (Savio 1929). | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|-------------------------------------|--|-----------------------------------|--|---|-------------------|
| <i>Maladera orientalis</i> (Motschulsky, 1857) [Coleoptera: Scarabaeidae] | smaller velvety chafer | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No (Cassis <i>et al.</i> 1992) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Unlikely This beetle species rolls and eats leaves of apple trees in China (CIQSA 2001a). Scarab adults and larvae have chewing mouthparts. Generally, larvae feed on roots of hosts and adults feed on flowers and leaves (CAB International 2007a). | No |
| <i>Mesosa myops</i> (Dalman, 1817) [Coleoptera: Cerambycidae] | capricon beetle | Yes (CHNZX-Farming 2008o) | No records found | Yes (AQIS 1999a) | Unlikely Adults feed on young epidermis and larvae feed on epidermis and xylem (CHNZX-Farming 2008o). | No |
| <i>Metabolus flavescens</i> Brenske [Coleoptera: Scarabaeidae] | scarab beetle | Yes (Yang 1991) | No records found | No | Unlikely The scarabaeid beetle, <i>Metabolus flavescens</i> , a pest of walnut, apple, pear, lilac and crab apple in Shanxi, China (Yang 1991). It is an important underground pest of nursery trees in Taijin, Gansu Province, China (Guo and Wen 1988). The adults lay their eggs in the soil, and most eggs and newly hatched larvae are found at a depth of 10-25 cm (Guo and Wen 1988). | No |
| <i>Popillia quadriguttata</i> (Fabricius, 1787) [Coleoptera: Scarabaeidae] | scarab beetle | Yes (CHNZX-Farming 2008s) | No (Cassis <i>et al.</i> 1992) | Yes (Biosecurity Australia 2003; AQIS 1998b) | Unlikely Adults attack leaves, sometimes feed on flowers or chew on fruit, and larvae damage underground parts of host plants (CHNZX-Farming 2008s). Adults chewing on fruit are unlikely to remain on fruit when disturbed during harvesting. | No |
| <i>Proagopertha lucidula</i> (Faldermann, 1835) [Coleoptera: Scarabaeidae] | lucidula chafer; apple fairy chafer | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No (Cassis <i>et al.</i> 1992) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Unlikely This beetle species rolls and eats leaves of apple trees in China (CIQSA 2001a); (AQSIQ 2005) Scarab adults and larvae have chewing mouthparts. Generally, larvae feed on roots of hosts and adults feed on flowers and leaves (CAB International 2007a). Adult scarabs are large enough to be visually detected during packing house procedures. | No |
| <i>Protaetia brevitarsis</i> Lewis, 1879 [Coleoptera: Scarabaeidae] | white-spotted flower chafer | Yes (Wan <i>et al.</i> 2006; CIQSA 2001c) | No (Cassis <i>et al.</i> 1992) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Unlikely Generally larval scarabs feed on roots of hosts and adults feed on flowers and leaves (CAB International 2007a). | No |
| <i>Rhynchites auratus</i> (Scopoli, 1763) [Coleoptera: Rhynchitidae] | apricot weevil | Yes Only reported in Xinjiang (AQSIQ 2008c) | No (Booth <i>et al.</i> 1990) | No | Likely This weevil species is a pest of apple, plum and cherry fruit in the Palearctic region (Europe to Siberia). Females oviposit deep in the fruit pulp in which the larvae develop (Booth <i>et al.</i> 1990). | Yes |
| <i>Rhynchites heros</i> Roelofs, 1874 As <i>Rhynchites foveipennis</i> (Fairmaire, 1888) in CIQSA (2001c) [Coleoptera: Rhynchitidae] | Japanese pear weevil | Yes (Wan <i>et al.</i> 2006; CIQSA 2001c) | No records found | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Likely Reported as a fruit boring and chewing pest of apple in China (Wan <i>et al.</i> 2006). Females of <i>R. heros</i> deposit one to three eggs in the hole or cavity created by the adults on fruit (Hanson 1963). | Yes |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|---|---|------------------------------------|--|---|-------------------|
| <i>Sympiezomias velatus</i> Kono, 1930 [Coleoptera: Curculionidae] | weevil | Yes (CHNZX-Farming 2008w) | No records found | No | Unlikely Adults damage young seedling, young leaves and young shoots and larvae feed on underground parts of host plants (CHNZX-Farming 2008w). | No |
| DIPTERA | | | | | | |
| <i>Bactrocera dorsalis</i> (Hendel, 1912) [Diptera: Tephritidae] | Oriental fruit fly | Yes The northern most natural border of <i>B. dorsalis</i> distribution in China is 30 ±2 degrees north latitude (CAB International 2007a; Wu 2005). | No (CAB International 2007a) | Yes (Biosecurity Australia 2005b; AFFA 2003a; AQIS 1998b) | Likely Females oviposit into the fruit of hosts, including apple. Eggs hatch inside the fruit and the larvae consume the fruit pulp (CAB International 2007a). | Yes |
| HEMIPTERA | | | | | | |
| <i>Aleurocanthus spiniferus</i> (Quaintance, 1903) [Hemiptera: Aleyrodidae] | orange spiny whitefly | Yes (Baidu Baike 2008a; Stansly and McKenzie 2007) | Yes (Martin and Gillespie 2001) | Yes (DAFF 2004a) | | No |
| <i>Aphidunguis mali</i> Takahashi, 1963 [Hemiptera: Pemphigidae] | root aphid | Yes (Zhang <i>et al.</i> 1999) | No (Hollis and Eastop 2005) | Yes (AQIS 1998a) | Unlikely This aphid species was originally described in Japan and the primary host is <i>Ulmus</i> spp. Apple trees are a secondary host and roots are damaged by this species (Zhang <i>et al.</i> 1999). | No |
| <i>Aphis pomi</i> De Geer, 1773 [Hemiptera: Aphididae] | green apple aphid | Yes (CAB International 2007a; Wan <i>et al.</i> 2006) | No (Hollis and Eastop 2005) | No | Unlikely This species can only maintain itself on growing shoots and is found on leaves (CAB International 2007a). | No |
| <i>Aphis spiraecola</i> Patch, 1914 [Hemiptera: Aphididae] | apple aphid; brown citrus aphid; green citrus aphid | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | Yes (Hollis and Eastop 2005) | No | | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|--|--------------------------------------|---|--|--|-------------------|
| <i>Arboridia apicalis</i> (Nawa 1913) Misspelt as <i>Erythro dis</i> (Linnae) in CIQSA (2001a) and AQSIQ (2005) and clarified as <i>Erythroneura apicalis</i> (Nawa, 1913) in AQSIQ (2006a) [Hemiptera: Cicadellidae] | grape leafhopper | Yes (AQSIQ 2005; CIQSA 2001c) | No (Biosecurity Australia 2005a; Fletcher and Watson 2002) | Yes (Biosecurity Australia 2005b) | Unlikely Leafhoppers usually feed on leaves. (AQSIQ 2005; CIQSA 2001c) This leafhopper would not remain on the fruit when disturbed during harvesting. | No |
| <i>Bothrogonia ferruginea</i> (Fabricius 1787) Synonym: <i>Cicadella ferruginea apicalis</i> (Walker 1851) [Hemiptera: Cicadellidae] | long brown leafhopper, black tipped leafhopper | Yes (Yang 1965) | No records found | No | Unlikely Leafhoppers usually feed on leaves (Yang 1965) and would not remain on the fruit when disturbed during harvesting. | No |
| <i>Ceroplastes ceriferus</i> (Fabricius, 1798) [Hemiptera: Coccocidae] | Indian wax scale | Yes (Ben-Dov 2005a) | Yes (Qin and Gullan 1994) | Yes (AQIS 1998a) | | No |
| <i>Ceroplastes floridensis</i> Comstock, 1881 [Hemiptera: Coccocidae] | Florida wax scale | Yes (Ben-Dov 2005a) | Yes (Qin and Gullan 1994) Not in WA (DAFWA 2009) | Yes (AQIS 1998a) | Unlikely <i>Ceroplastes floridensis</i> is a major pest of citrus (Qin and Gullan 1994). <i>Malus sylvestris</i> has been listed as a minor host (CAB International 2008; Ben-Dov 2005a). <i>Ceroplastes floridensis</i> most likely occurs on the foliage, stems and branches, same as that for the closely related species of <i>C. japonicus</i> (Luo <i>et al.</i> 1994). | No |
| <i>Ceroplastes japonicus</i> Green, 1921 [Hemiptera: Coccidae] | Japanese wax scale | Yes (CIQSA 2001c) | No (AQIS 1998a; Qin and Gullan 1994) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Unlikely Infestations of <i>C. japonicus</i> occur on the foliage, stems and branches (Luo <i>et al.</i> 1994). | No |
| <i>Ceroplastes rubens</i> Maskell, 1893 [Hemiptera: Coccidae] | red wax scale | Yes (Ben-Dov 2005a) | Yes (Qin and Gullan 1994) | No | | No |
| <i>Chrysomphalus dictyospermi</i> (Morgan, 1889) [Hemiptera: Diaspididae] | Spanish red scale | Yes (Ben-Dov <i>et al.</i> 2006a) | No (Ben-Dov <i>et al.</i> 2006a) | No | Unlikely Favoured hosts of <i>Chrysomphalus dictyospermi</i> are citrus and other trees such as olives and palms, and the preferred feeding site is on leaves (CAB International 2008). <i>Malus</i> sp. (ornamental apple) has been listed as a minor host (CAB International 2008). | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|--------------------------------------|---|--|--------------------------------------|--|-------------------|
| <i>Cicadella viridis</i> (Linnaeus, 1758) <i>As Tettigella viridis</i> (Linnaeus, 1758) in AQSIQ (2005) [Hemiptera: Cicadellidae] | green leafhopper | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No (Fletcher and Watson 2002; AQIS 1998a) | Yes (AQIS 1998a) | Unlikely Eggs are laid in stems, leaf stems, leaf veins and branches. In Northern China, there are three generations per year (AQSIQ 2005; CIQSA 2001a). This leafhopper would not remain on the fruit when disturbed during harvesting. | No |
| <i>Cryptotympana atrata</i> (Fabricius, 1775) <i>As Cryptotympana pustulata</i> (Fabricius, 1803) in China's submissions (AQSIQ 2005) [Hemiptera: Cicadidae] | blackish cicada | Yes (CHNZX-Farming 2008i) | No (AQIS 1998b) | Yes (DAFF 2004a; AQIS 1998b) | Unlikely Adults suck sap from branches and lay eggs in xylem of one year old branches and cause the death of branches beyond the egg laying site. Nymphs live in soil and feed on sap of roots (CHNZX-Farming 2008i). It is listed as a "sting suck insect pest" (CIQSA 2001a) and as an "occasionally occurring insect" (CIQSA 2001c). | No |
| <i>Diaspidiotus ostreaeformis</i> (Curtis, 1843) [Hemiptera: Diaspididae] | oystershell scale; pear oyster scale | Yes (CAB International 2007a) | Yes (CAB International 2007a) Not in WA (CAB International 2007a) | Yes (Biosecurity Australia 2006a) | Likely <i>Diaspidiotus ostreaeformis</i> mostly infests the bark on stems and branches of trees, but sometimes can be found on the fruit, where it causes red spots (CAB International 2007a). | Yes ^{WA} |
| <i>Diaspidiotus perniciosus</i> (Comstock, 1881) [Hemiptera: Diaspididae] | California scale; San Jose scale | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | Yes (Donaldson and Houston 2002; AQIS 1998a) | Yes (AQIS 1998a) | | No |
| <i>Didesmococcus koreanus</i> Borchsenius, 1955 <i>As Didesmococcus coreanus</i> in Biosecurity Australia (2005b) [Hemiptera: Coccidae] | Korean globose scale | Yes (Zhang <i>et al.</i> 2001) | No (Ben-Dov 2005a) | Yes (Biosecurity Australia 2005b) | Unlikely <i>Didesmococcus koreanus</i> infests apple, pear, peach, plum and apricot trees in China (Zhang <i>et al.</i> 2001). Coccids on deciduous fruit trees are usually found on twigs, branches and leaves (Ben-Dov and Hodgson 1997). <i>Didesmococcus koreanus</i> is listed as associated with leaves and stems of apricot, nectarine, peach and plum in China (AQSIQ 2006b; AQSIQ 2006a). | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|----------------------------------|---|--|--|--|-------------------|
| <i>Dolycoris baccarum</i> (Linnaeus, 1758) [Hemiptera: Pentatomidae] | hairy shield bug | Yes (CHNZX-Farming 2008j) | No (Cassis and Gross 2002) | Yes (AQIS 1998b) | Unlikely Adults and nymphs suck sap of leaves, young shoots and fruit (CHNZX-Farming 2008j). Eggs were found on leaves of strawberry, raspberry and lily-of-the-valley (<i>Convallaria majalis</i>), leaves and stalks of tomato and flowers of marguerite (<i>Chrysanthemum leucanthemum</i>) (Conradi-Larsen and Soemme 1973). However, they are unlikely to remain on the fruit when disturbed during harvesting and packing house processes (AQSIQ 2005). <i>Dolycoris baccarum</i> was assessed as associated with fruit in the IRA for ya pear from China (AQIS 1998b). However, it has been assessed as not likely on pathway as explained above. | No |
| <i>Drosicha corpulenta</i> (Kuwana, 1902) [Hemiptera: Margarodidae] | giant mealybug | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No (Ben-Dov 2006b; AQIS 1998a) | Yes (Biosecurity Australia 2005b; AFFA 2003a; AQIS 1998a) | Unlikely Recorded as a serious pest of willows in Beijing (1954-1956) and apples in Shanxi (Tang and Hao 1995). It was assessed as not on pathway in the IRA for Fuji apples from Japan (AQIS 1998a). It is listed as a "sting suck insect pest" in CIQSA (2001a) and as an "occasionally occurring insect" in CIQSA (2001c). | No |
| <i>Dysmicoccus wistariae</i> (Green, 1923) [Hemiptera: Pseudococcidae] | pear mealybug; taxus mealybug | Yes (Ben-Dov 2005b) | No (Ben-Dov 2005b) | Yes (AQIS 1998a) | Unlikely <i>Dysmicoccus wistariae</i> infests <i>Taxus</i> needles and cause the needle to drop prematurely (Ben-Dov 2005b). It is likely to be found on leaves of other host plants including apples. No report on this mealybug infesting fruit was found. This species was assessed as 'yes?' for association with fruit in the IRA for Fuji apples from Japan (AQIS 1998a). This assessment was reconsidered and no evidence could be found to support the association of <i>D. wistariae</i> with fruit. | No |
| <i>Empoasca fabae</i> (Harris 1841) Synonym: <i>Empoasca mali</i> (Baron 1853) [Hemiptera: Cicadellidae] | potato leafhopper | Yes (Yang 1965) | No records found | No | Unlikely Leafhoppers usually feed on leaves (Yang 1965) and would not remain on the fruit when disturbed during harvesting. | No |
| <i>Empoasca flavescens</i> (Fabricius, 1794) [Hemiptera: Cicadellidae] | small green leafhopper | Yes (CIQSA 2001c) | No (Moulds and Cowan 2004; AQIS 1998b) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Unlikely Species of leafhoppers are usually found on leaves. This leafhopper species is important in crops such as grapes and is listed as an "occasionally occurring insect" in apple orchards (CIQSA 2001c). This leafhopper would not remain on the fruit when disturbed during harvesting. | No |
| <i>Ericerus pela</i> (Chavannes, 1848) Synonym: <i>Coccus pela</i> Chavannes, 1848 [Hemiptera: Coccidae] | Chinese white wax scale | Yes (Deng 1985) | No (Ben-Dov 2005a) Not in WA (DAFWA 2009) | No | Unlikely <i>Ericerus pela</i> is an important commercial insect with great economic value for white wax production in China. The white wax excreted by this insect is an important chemical raw material which is widely applied in some chemical industries (Chen <i>et al.</i> 2008). Deng (1985) did not mention it is a apple pest. Ben-Dov (2005a) also did not mention it is a pest of apples. | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|--|----------------------------------|---|--|---|-------------------|
| <i>Eriosoma lanigerum</i> (Hausmann, 1802) [Hemiptera: Aphididae] | woolly aphid | Yes (CIQSA 2001c) | Yes (Hollis and Eastop 2005; AQIS 1998a) | Yes (AQIS 1998a) | | No |
| <i>Erthesina fullo</i> (Thunberg, 1783) [Hemiptera: Pentatomidae] | yellow spot stink bug | Yes (AQSIQ 2005; CIQSA 2001a) | No (Cassis and Gross 2002; AQIS 1998b) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Unlikely Species of Pentomidae do not usually associate with fruit. This stink bug species was assessed as not on pathway in the IRA on ya pear from China (AQIS 1998b). It is listed as a "sting suck insect pest" in AQSIQ (2001a). | No |
| <i>Eulecanium excrescens</i> (Ferris, 1920) Synonym: <i>Lecanium excrescens</i> Ferris, 1920 [Hemiptera: Coccidae] | wisteria scale | Yes (Deng 1985) | No (Ben-Dov 2005a) | No | Unlikely <i>Eulecanium excrescens</i> is a polyphagous pest of economically important orchard trees, e.g. <i>Malus</i> (apple), <i>Prunus</i> (peach/cherry) and <i>Pyrus</i> (pear) in China (Malumphy 2005; Central Science Laboratory (CSL) 2005; Deng 1985). <i>Eulecanium excrescens</i> feeds on leaves and bark, removes large quantities of sap and weakens the plant causing some leaf loss and slow dieback. Large amounts of honeydew are produced. Hosts are disfigured (Central Science Laboratory (CSL) 2005). | No |
| <i>Eulecanium kunoense</i> (Kuwana, 1907) [Hemiptera: Coccidae] | globular peach scale; peach firm scale; soft scale | Yes (CIQSA 2001c) | No (Ben-Dov 2005a; AQIS 1998a) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Unlikely Coccids are usually found on leaves and stems and twigs. This coccid species was assessed as not on pathway in the IRA on Fuji apples from Japan (AQIS 1998a), and is listed as "occasionally occurring insect" in CIQSA (2001c). | No |
| <i>Eurydema gebleri</i> (Kolenti, 1856) [Hemiptera: Pentatomidae] | shield bug | Yes (CHNZX-Farming 2008k) | No (Cassis and Gross 2002) | No | Unlikely Adults and nymphs suck the sap of leaves, stems and flowers (CHNZX-Farming 2008k). They do not affect fruit. | No |
| <i>Halyomorpha halys</i> Stål, 1855 [Hemiptera: Pentatomidae] | yellow-brown stink bug; tree stink bug | Yes (AQSIQ 2005; CIQSA 2001a) | No (Cassis and Gross 2002; AQIS 1998b) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Unlikely This species is a sap-sucking insect and feeds on shoots, leaves and fruit (Wan <i>et al.</i> 2006; Funayama 2002). Many egg batches of <i>Halyomorpha halys</i> and <i>Homalagonia obtusa</i> species were found on the apple leaves (Funayama 2002). Nymphs and adults are unlikely to remain on the fruit when disturbed during harvesting and packing house processes (AQSIQ 2005). In addition fruit damaged by adults and nymphs become distorted (University of Florida 2008) and would not be picked during harvest. <i>Halyomorpha halys</i> was assessed as associated with fruit in the IRA for Fuji apples from Japan (AQIS 1998a). However, it has been assessed as not likely on pathway as explained above. | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|---------------------------|---------------------------------|---|--|---|-------------------|
| <i>Halyomorpha picus</i> (Fabricius, 1794) [Hemiptera: Pentatomidae] | tree stink bug | Yes (Anonymous 2005) | No (Cassis and Gross 2002; AQIS 1998b) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Unlikely The species feeds on leaves, shoots and fruit (Anonymous 2005). However, nymphs and adults are unlikely to remain on the fruit when disturbed during harvesting and packing house processes (AQSIQ 2005). Fruit damaged by nymphs and adults become hardened and distorted (Anonymous 2005) and would not be picked during harvest. <i>Halyomorpha picus</i> was assessed as associated with fruit in the IRA for ya pear from China (AQIS 1998b). However, it has been assessed as not likely on pathway as explained above. | No |
| <i>Hishimonus sellatus</i> (Uhler, 1896) [Hemiptera: Cicadellidae] | rhombic marked leafhopper | Yes (Sun <i>et al.</i> 1988) | No (Moulds and Sally 2004) | Yes (Biosecurity Australia 2009b) | Unlikely <i>Hishimonus sellatus</i> was found over much of China predominantly on jujube, sesame, China rose and mulberry, but also on beans, soyabean, ground nut and apple (Sun <i>et al.</i> 1988). They attacked the shoots and females oviposited eggs into the epidermis of shoots and veins (Kim and Kim 1993). Leafhoppers usually feed on leaves and would not remain on the fruit when disturbed during harvesting. | No |
| <i>Homalagonia obtusa</i> (Walker, 1868) [Hemiptera: Pentatomidae] | four-spotted stink bug | Yes (GAAS 2008c) | No (Cassis and Gross 2002; AQIS 1998b) | Yes (AQIS 1998a) | Unlikely Like other pentatomid bugs such as <i>Halyomorpha halys</i> , this species can be a sap-sucking insect and feed on shoots, leaves and fruit (Funayama 2002). Many egg batches of <i>Halyomorpha halys</i> and <i>Homalagonia obtusa</i> species were found on the apple leaves (Funayama 2002). Nymphs and adults are unlikely to remain on the fruit when disturbed during harvesting and packing house processes (AQSIQ 2005). In addition fruit damaged by adults and nymphs become distorted (University of Florida 2008) and would not be picked during harvest or would be eliminated during the packing house process. <i>Halyomorpha obtusa</i> was assessed as associated with fruit in the IRA for Fuji apples from Japan (AQIS 1998a). However, it has been assessed as unlikely to be on pathway as explained above. | No |
| <i>Idiocerus populi</i> (Linnaeus, 1761) [Hemiptera: Cicadellidae] | leafhopper | Yes (Yang 1965) | No records found | No | Unlikely Leafhoppers usually feed on leaves (Yang 1965) and would not remain on the fruit when disturbed during harvesting. | No |
| <i>Ledra auditura</i> Walker, 1858 [Hemiptera: Cicadellidae] | auricled leafhopper | Yes (Yang 1965) | No records found | Yes (AQIS 1999a) | Unlikely Leafhoppers usually feed on leaves (Yang 1965) and would not remain on the fruit when disturbed during harvesting. | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|---------------------------------------|---|---|--|--|-------------------|
| <i>Lepidosaphes conchiformis</i> (Gmelin, 1790) [Hemiptera: Diaspididae] | pear oystershell scale | Yes (Ben-Dov <i>et al.</i> 2006a) | No (Ben-Dov <i>et al.</i> 2006a; Donaldson and Houston 2002) | Yes (AQIS 1998a) | Unlikely <i>Lepidosaphes conchiformis</i> feed on leaves and branches of woody host species including <i>Malus</i> (Watson 2005; Kumral <i>et al.</i> 2004). <i>Lepidosaphes conchiformis</i> was assessed as on pathway in the IRA for Fuji apple from Japan (AQIS 1998a). However, it is considered unlikely to be on pathway in this analysis due to the reason above. | No |
| <i>Lepidosaphes malicola</i> Borchsenius [Hemiptera: Diaspididae] | Armenian comma scale | Yes On forest trees and apricot in Xinjiang (Yang <i>et al.</i> 2005b; Tang 1984) On apple in Armenia and Iran (Mostaan <i>et al.</i> 1972) | No (Ben-Dov <i>et al.</i> 2006b) | No | Unlikely <i>Lepidosaphes malicola</i> was described on <i>Malus</i> sp. from Armenia (Ben-Dov <i>et al.</i> 2006b). It is polyphagous and has also been recorded from many woody hosts such as pear, peach, apricot, plum, cherry. It was reported as an important pest of apple in Iran in the 1970s (Mostaan <i>et al.</i> 1972). No reports of <i>L. malicola</i> on apples in China can be found. To date, there have been only two records of <i>L. malicola</i> in China, both from Xinjiang: by Tang (1984) on forest trees and by Yang <i>et al.</i> (2005b) on apricot. <i>Lepidosaphes malicola</i> is mainly found on trunk and branches, although sometimes also on the leaves and fruit of hosts (Watson 2005; Mostaan <i>et al.</i> 1972). | No |
| <i>Lepidosaphes tubulorum</i> (Ferris 1921) [Hemiptera: Diaspididae] | dark oystershell scale | Yes (Ben-Dov <i>et al.</i> 2006a) | No (Ben-Dov <i>et al.</i> 2006a; Donaldson and Houston 2002) | Yes (AQIS 1998a) | Unlikely <i>Lepidosaphes tubulorum</i> is not likely on pathway as it feeds on the stems of host plants (USDA-APHIS 2000a) | No |
| <i>Lopholeucaspis japonica</i> (Cockerell, 1897) [Hemiptera: Diaspididae] | pear white scale, Japanese long scale | Yes (Ben-Dov <i>et al.</i> 2006a; AQIS 1998a) (AQIS 1998a) | No (CABI/EPPO 2007b) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Likely Nymphs and adults of <i>L. japonica</i> are found on leaves and also on the bark of branches and sometimes on fruit (CAB International 2008; CABI/EPPO 2007b). <i>Lopholeucaspis japonica</i> was assessed as associated with fruit in the IRAs for ya pear from China and Fuji apples from Japan (AQIS 1998b; AQIS 1998a). | Yes |
| <i>Lycorma delicatula</i> (White, 1845) [Hemiptera: Fulgoridae] | plant hopper | Yes (CHNZX-Farming 2008m) | No (Fletcher and Watson 2003) | No | Unlikely Adults and nymphs suck the sap of branches and leaves (CHNZX-Farming 2008m). | No |
| <i>Lygus lucorum</i> Meyer-Dür, 1843 [Hemiptera: Miridae] | mirid bug | Yes (Wan <i>et al.</i> 2006) | No (Cassis and Gross 1995) | No | Unlikely This species is a fruit sap-sucking insect (Wan <i>et al.</i> 2006). However, nymphs and adults are unlikely to remain on the fruit when disturbed during harvesting. | No |
| <i>Naratettix zonatus</i> (Matsumura, 1915) [Hemiptera: Cicadellidae] | banded leafhopper | Yes (Yang 1965) | No records found | Yes (AQIS 1998a) | Unlikely Leafhoppers usually feed on leaves (Yang 1965) and would not remain on the fruit when disturbed during harvesting. | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|--|---|--|--------------------------------------|---|-------------------|
| <i>Neotituria kongosana</i> (Matsumura, 1915) [Hemiptera: Cicadellidae] | leafhopper | Yes (Yang 1965) | No records found | No | Unlikely Leafhoppers usually feed on leaves (Yang 1965) and would not remain on the fruit when disturbed during harvesting. | No |
| <i>Nephotettix cincticeps</i> (Uhler, 1896) [Hemiptera: Cicadellidae] | common leafhopper | Yes (Wan <i>et al.</i> 2006) | No (Fletcher and Watson 2002) | No | Unlikely This species is a fruit sap sucking insect (Wan <i>et al.</i> 2006). However, nymphs and adults are unlikely to remain on the fruit when disturbed during harvesting. | No |
| <i>Nezara antennata</i> Scott, 1874 [Hemiptera: Pentatomidae] | green stink bug | Yes In China (JNGPC 2008) On apple (AQIS 1998a) | No (Cassis and Gross 2002) | Yes (AQIS 1998a) | Unlikely This species is a sap-sucking insect and feeds on leaves and fruit. Nymphs and adults are unlikely to remain on the fruit when disturbed during harvesting. <i>Nezara antennata</i> was assessed as associated with fruit in the IRA for Fuji apples from Japan (AQIS 1998a). However, as explained above, it will not be likely on pathway. | No |
| <i>Oncotympana maculicollis</i> (Motschulsky, 1866) [Hemiptera: Cicadidae] | cicada | Yes (CHNZX-Farming 2008q) | No (Fletcher and Watson 2002) | Yes (AQIS 1998a) | Unlikely Adults suck sap from branches and lay eggs in xylem of one year old branches and cause the death of branches beyond the egg laying site. Nymphs live in soil and feed on sap of roots (CHNZX-Farming 2008q). | No |
| <i>Ovatus malisuctus</i> (Matsumura, 1918) [Hemiptera: Aphididae] | apple gall aphid; apple leaf-curling aphid | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No (Hollis and Eastop 2005; AQIS 1998a) | Yes (AQIS 1998a) | Unlikely This aphid species was assessed as not on pathway in the IRA on Fuji apples from Japan (AQIS 1998a). It is listed as a "commonly occurring insect" in CIQSA (2001c). | No |
| <i>Parlatoria oleae</i> (Colvée, 1880) [Hemiptera: Diaspididae] | olive parlatoria scale | Yes (DOA and AQSIQ 2007; AQSIQ 2004; Chen 2003) | Yes NSW & Qld (Ben-Dov 2006a) Not in WA (Poole 2008) | Yes (Biosecurity Australia 2005b) | Likely <i>Parlatoria oleae</i> is the major pest of the fragrant pear in Xinjiang, China, where it appears to be a local dominant species of Diaspididae. This pest heavily attacks the branches, leaves and fruits of its host (AQSIQ 2004). | Yes |
| <i>Parlatoria theae</i> Cockerell, 1896 [Hemiptera: Diaspididae] | tea black scale | Yes (Ben-Dov <i>et al.</i> 2006a) | No (Ben-Dov <i>et al.</i> 2006a) | Yes (AQIS 1998a) | Unlikely This species is found on stem of host plant (USDA-APHIS 2000a). | No |
| <i>Parlatoria proteus</i> (Curtis, 1843) [Hemiptera: Diaspididae] | common parlatoria scale | Yes (Ben-Dov <i>et al.</i> 2006a) | Yes (Ben-Dov <i>et al.</i> 2006a) | Yes (AQIS 1999a) | | No |
| <i>Parlatoria yanyuanensis</i> Tang, 1984 [Hemiptera: Diaspididae] | yanyuanen scale | Yes (Lu and Wu 1988) | No (Ben-Dov 2006a) | No | Likely <i>Parlatoria yanyuanensis</i> is a newly found pest of fruit trees in south-western China and it can feed on apple fruit (Lu and Wu 1988). | Yes |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|-----------------------|--|---|--------------------------------------|--|-------------------|
| <i>Penthimia nitida</i> Lethierry, 1876 [Hemiptera: Cicadellidae] | leafhopper | Yes (Yang 1965) | No record found | Yes (Biosecurity Australia 2008b) | Unlikely Leafhoppers usually feed on leaves (Yang 1965) and would not remain on the fruit when disturbed during harvesting. | No |
| <i>Phenacoccus aceris</i> (Signoret, 1875) [Hemiptera: Pseudococcidae] | apple mealybug | Yes (Ben-Dov 2005b) | No (Ben-Dov 2005b) | Yes (AQIS 1999a) | Likely <i>Phenacoccus aceris</i> feeds on twigs, leaves and fruit (Beers 2007). | Yes |
| <i>Phenacoccus pergandei</i> [Hemiptera: Pseudococcidae] | | Yes In China (Ben-Dov 2005b) On apples (AQIS 1998a) | No (Ben-Dov 2005b) | Yes (Biosecurity Australia 2004) | Unlikely <i>Phenacoccus pergandei</i> affects the leaves of citrus (USDA 2002); and will not be on pathway of apple fruit. | No |
| <i>Platyleura kaempferi</i> (Fabricius, 1794) [Hemiptera: Cicadidae] | cicada | Yes (CHNZX-Farming 2008r) | No (Moulds and Cowan 2004) | Yes (AQIS 1999a; AQIS 1998a) | Unlikely Adults suck sap from branches and lay eggs in xylem of one year old branches and cause the death of branches beyond the egg laying site. Nymphs live in soil and feed on sap of roots (CHNZX-Farming 2008r). | No |
| <i>Plautia stali</i> Scott, 1874 [Hemiptera: Pentatomidae] | Oriental stink bug | Yes In China (Baidu Baike 2008b) On apple (AQIS 1998a) | No records found | Yes (AQIS 1998a) | Unlikely <i>Plautia stali</i> is a sap-sucking insect that may be present as adults and/or nymphs on the fruit. Feeding causes visible fruit blemishing which makes it easier to observe an infestation during harvest. In addition, the insects are likely to fall off the fruit when disturbed during the harvest procedures, so are not expected to follow the pathway (USDA-APHIS 2000a). | No |
| <i>Prociphilus aurus</i> Zhang & Qiao, 1997 [Hemiptera: Pemphigidae] | woolly aphid | Yes (Zhang <i>et al.</i> 1999) | No (Hollis and Eastop 2005) | No | Unlikely This aphid species is only recorded from wild apple <i>Malus sievesii</i> in Xinjiang (Zhang <i>et al.</i> 1999) and it is not likely to be found in commercial apple orchards. Aphids are usually found on the leaves of host plants. | No |
| <i>Pseudaulacaspis pentagona</i> [Hemiptera: Diaspididae] | white peach scale | Yes (Ben-Dov <i>et al.</i> 2006a) | Yes (Ben-Dov <i>et al.</i> 2006a) | No | | No |
| <i>Pseudococcus calceolariae</i> (Maskell, 1879) As <i>Pseudococcus gahani</i> Green in Wang (1985) [Hemiptera: Pseudococcidae] | citrophilius mealybug | Yes (Wang 1985) | Yes (Ben-Dov 2005b) Not in WA (Poole 2008) | Yes (Biosecurity Australia 2006a) | Likely This mealybug species can be present on citrus and apple fruit; occurring on the aerial parts of the host plant (Cox 1987). | Yes ^{WA} |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|---------------------|---|--|--|--|-------------------|
| <i>Pseudococcus comstocki</i> (Kuwana, 1902) [Hemiptera: Pseudococcidae] | Comstock's mealybug | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No (Ben-Dov 2005b; AQIS 1998a) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Likely This mealybug species can damage fruit by spotting and producing a change in the fruit skin texture (Wan <i>et al.</i> 2006; Kim <i>et al.</i> 1988). | Yes |
| <i>Pyramidotettix mali</i> Yang, 1965 <i>As Zyginella mali</i> in Li 1988 [Hemiptera: Cicadellidae] | apple leafhopper | Yes (Li 1988; Yang 1965) | No records found | No | Unlikely This species is a sap sucking insect. Eggs overwintered in the phloem of the branches. There were 5 nymphal instars, lasting 36-50 days, which infested the undersides of the apple leaves (Li 1988). | No |
| <i>Pyramidotettix minuta</i> Yang, 1965 [Hemiptera: Cicadellidae] | leafhopper | Yes (Yang 1965) | No (Moulds and Sally 2004) | No | Unlikely Leafhoppers usually feed on leaves (Yang 1965) and would not remain on the fruit when disturbed during harvesting. | No |
| <i>Rhodococcus sariuoni</i> Borchsenius, 1955 [Hemiptera: Coccidae] | coccid scale | Yes (CIQSA 2001c) | No (Ben-Dov 2005a) | Yes (AQIS 1998a) | Unlikely Coccids are usually found on leaves and stems and twigs of hosts (Tang 1991), and it is unlikely that <i>R. sariuoni</i> would be on the fruit. | No |
| <i>Ricania speculum</i> (Walker, 1851) [Hemiptera: Ricaniidae] | black leafhopper | Yes (Ma 2006) | No (Fletcher and Watson 2003) | No | Unlikely Nymphs and adults of this leafhopper species damage young branches and shoots. Eggs are laid in branches and affect their growth. This species can cause branches to die (Ma 2006). | No |
| <i>Riptortus pedestris</i> (Fabricius, 1775) [Hemiptera: Alydidae] | bean bug | Yes (CHNZX-Farming 2008v) | No records found | Yes (AQIS 1998a) | Unlikely Adults and nymphs suck sap from leaves, young shoots and fruit (CHNZX-Farming 2008v). Species are active and mobile, and are unlikely to remain on the fruit when disturbed during harvesting (AQSIQ 2005). | No |
| <i>Sphaerolecanium prunastri</i> (Boyer de Fonscolombe, 1834) [Hemiptera: Coccidae] | blackthorn scale | Yes (Ben-Dov 2005a) | No (CAB International 2007a; Ben-Dov 2005a) | Yes (Biosecurity Australia 2005b) | Unlikely This scale species completes its whole lifecycle on the trunk, branches or twigs of host trees (CAB International 2007a). | No |
| <i>Stephanitis nashi</i> Esaki & Takeya, 1931 [Hemiptera: Tingidae] | pear lace bug | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No (AQIS 1998a; Cassis and Gross 1995) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Unlikely This bug species is a widespread pest in China and causes damage to many fruit trees, including apples and pears. Eggs are laid on the underside of leaves. Nymphs feed in groups on the underside of leaves on both sides of main veins. Adults overwinter on the ground in fallen leaves and branches, sutures, grass and gaps in soil (Shanghai Insects Online 2006). | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|--------------------|---|--|--|---|-------------------|
| <i>Urochela luteovaria</i> Distant, 1881 [Hemiptera: Urostylidae] | pear stink bug | Yes (Wan <i>et al.</i> 2006) | No (Gross 1991) | No | Unlikely This bug species is a fruit sap-sucking insect (Wan <i>et al.</i> 2006). A single female laid 30-50 eggs in masses in cracks in the bark of pear (Hoh 1933). Nymphs and adults are unlikely to remain on the fruit when disturbed during harvesting. <i>Urochela luteovaria</i> was assessed as on the fruit pathway for Fuji apples from Japan (AQIS 1998a) and ya pear from China (AQIS 1998b). However, it is considered in this analysis that the nymphs and adults are unlikely to be on the pathway of mature apple fruit as explained above. | No |
| HYMENOPTERA | | | | | | |
| <i>Hoplocampa pyricola</i> Rohwer, 1924 [Hymenoptera: Tenthredinidae] | pear fruit sawfly | Yes (Wan <i>et al.</i> 2006) | No The genus <i>Hoplocampa</i> is not reported in Australia (Naumann 1991) | Yes (AQIS 1998b) | Unlikely This sawfly species is a flower feeding insect; most damaged flowers will not be able to form fruit, or will form distorted fruit (Wan <i>et al.</i> 2006). The available scientific information indicates that on pears, the eggs of <i>H. pyricola</i> are deposited in the ovary of the flower. The larvae then feed on the ovary and the fruit. Once the larvae reach maturity, infested fruit prematurely drop from the tree and the larvae enter the soil to pupate (APHIS 2005). Therefore, larvae of this species would not be present in mature apple fruit. | No |
| <i>Vespa mandarina</i> Smith, 1852 [Hymenoptera: Vespidae] | Asian giant hornet | Yes (Wan <i>et al.</i> 2006) | No (Cardale 1985) | No | Unlikely This wasp species is a fruit chewing insect (Wan <i>et al.</i> 2006). The Asian giant hornet preys on other large insects such as bees, other hornet species, and praying mantises. Adults occasionally chew on fruit, but are unlikely to be on the pathway because they would fly away when disturbed during harvesting. | No |
| LEPIDOPTERA | | | | | | |
| <i>Acleris fimbriana</i> (Thunberg, 1791) [Lepidoptera: Tortricidae] | fruit tree tortrix | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Unlikely This moth species rolls and eats leaves of apple trees in China (AQSIQ 2005; CIQSA 2001a). This species may defoliate <i>Malus pumila</i> in China (Han and Ma 1996), and is an important apple pest in China causing severe defoliation (Liu and Meng 2003; Liu and Meng 2002a). <i>Acleris fimbriana</i> was assessed as associated with fruit on pears from China (AFFA 2003a; AQIS 1998b). However, the species is unlikely on pathway as the information above indicates. (Liu and Meng 2002b). | No |
| <i>Acrocercops astaurota</i> Meyrick, 1922 [Lepidoptera: Gracilariidae] | pear bark miner | Yes (AQSIQ 2005; CIQSA 2001a) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Unlikely This moth species damages twigs and branches of apple trees in China (CIQSA 2001a). | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|--|---|------------------------------------|--|--|-------------------|
| <i>Acronicta increta</i> Morrison, 1974 <i>As Acronycta incretata</i> in CIQSA (2001c) [Lepidoptera: Noctuidae] | apple dagger moth; raspberry bud moth | Yes (CIQSA 2001c) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Unlikely This moth species is one of the most abundant leaf-feeding pests on apple trees in Korea (Forkner <i>et al.</i> 2004; Ahn <i>et al.</i> 1989). <i>Acronicta increta</i> was assessed as “yes?” for association with fruit in the IRA for Fuji apples from Japan (as <i>A. intermedia</i>) (AQIS 1998a), implying that the assessment was questionable and no specific evidence was provided. There are no reports of <i>A. increta</i> feeding on fruit. | No |
| <i>Acronicta rumicis</i> (Linnaeus, 1758) [Lepidoptera: Noctuidae] | knotgrass moth | Yes (CIQSA 2001c; Hu and Qi 1993) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AFFA 2003a) | Unlikely Larvae of the noctuid moths usually feed on leaves, e.g. <i>Acronicta increta</i> (Forkner <i>et al.</i> 2004; Ahn <i>et al.</i> 1989). No report of <i>A. rumicis</i> feeding on fruit. Even if they can feed on fruit, they would only chew on the surface. | No |
| <i>Acronicta strigosa</i> (Denis & Schiffermüller, 1775) [Lepidoptera: Noctuidae] | cherry dagger moth | Yes (CIQSA 2001c; Cao and Wang 1986) | No (Nielsen <i>et al.</i> 1996) | Yes (AQIS 1998a) | Unlikely Newly hatched larvae and second instar larvae of this moth species feed on the upper and lower surface of apple tree leaves, skeletonising them. Third instar larvae feed on leaves, making holes in the leaf surface (Cao and Wang 1986). | No |
| <i>Actias selene ningpoana</i> Felder & Felder, 1862 [Lepidoptera: Saturniidae] | green actias moth | Yes (Yuan <i>et al.</i> 2004) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b) | Unlikely This moth species was reported on <i>Malus prunifolia</i> in China (Yuan <i>et al.</i> 2004). This species is a major pest of broadleaved trees in China (He <i>et al.</i> 1991). Larvae of this genus are large and visible to the naked eye. | No |
| <i>Adoxophyes orana</i> (Fischer von Röslerstamm, 1834) [Lepidoptera: Tortricidae] | summer fruit tortrix; smaller tea tortrix; summer fruit tortrix moth | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Likely This moth species rolls and eats leaves of apple trees in China (CIQSA 2001a), and has been recorded as an apple fruit chewing pest in China (Wan <i>et al.</i> 2006). Larvae feed and can pupate on young and mature fruit, and adults have been reported to lay eggs on growing fruit (Davis <i>et al.</i> 2005). | Yes |
| <i>Amphipyra pyramidea</i> (Linnaeus) [Lepidoptera: Noctuidae] | copper underwing moth | Yes (CHNZX-Farming 2008c) | No (Nielsen <i>et al.</i> 1996) | Yes (AQIS 1998a) | Unlikely Larvae feed on leaves and occasionally chew on skin of the fruit (CHNZX-Farming 2008c) | No |
| <i>Amsacta lactinea</i> (Cramer, 1777) [Lepidoptera: Arctiidae] | red tiger moth | Yes (CHNZX-Farming 2008d) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely Larvae feed on leaves, flowers and fruits. The eggs, which hatched in about 4 days are laid in batches of 250-500 on the leaves, however, the larvae pupated in the soil after a prepupal stage of 1.6-2.2 days (Mehra and Sah 1977). The peak damage time is the flowering time of various crops, when it significantly affects yield (CHNZX-Farming 2008d). Larvae chewing on the surface of fruit are unlikely to remain on the fruit when disturbed during harvesting. Fruit damaged by larvae are clearly visible and would not be picked during harvest or would be eliminated during the packing house process. | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|-----------------------------|---|------------------------------------|--|--|-------------------|
| <i>Anarsia lineatella</i> Zeller, 1839 [Lepidoptera: Gelechiidae] | peach twig borer | Yes (CAB International 2008) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely This borer has also been reported feeding on peaches and plums in China (Yang <i>et al.</i> 2005b). No reports of this pest on apple fruit were found. | No |
| <i>Apocheima cinerarium</i> (Erschov, 1874) [Lepidoptera: Geometridae] | geometrid moth | Yes (Feng <i>et al.</i> 2005; CIQSA 2001c) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005a) | Unlikely This moth species is a defoliating pest of forest trees in China, and pupae over-winter in the soil (Dai and Zhu 1979). In Uzbekistan, the larvae feed chiefly on leaves and bursting buds, but sometimes also attack the flowers and, on apricot and cherry, the young fruits (Nevskh 1933). | No |
| <i>Apocheima</i> sp. [Lepidoptera: Geometridae] | geometrid moth | Yes (Anonymous 1977) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely Eggs of this moth species are laid beneath the bark of trees, larvae hatch from late April to mid-May and feed on leaves. Pupation occurs in the soil, with adults emerging from late March to early May (Anonymous 1977). | No |
| <i>Aporia crataegi</i> (Linnaeus, 1758) [Lepidoptera: Pieridae] | blackveined white butterfly | Yes (CIQSA 2001c) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Unlikely <i>Aporia crataegi</i> skeletonises and consumes leaves (Jiang 2001). | No |
| <i>Archips breviplicanus</i> Walsingham, 1900 [Lepidoptera: Tortricidae] | Asiatic leafroller | Yes (Hwang 1974) | No (Nielsen <i>et al.</i> 1996) | Yes (AQIS 1998a) | Unlikely <i>Archips breviplicanus</i> is a major pest of apple leaves (Jung <i>et al.</i> 2001). It also damages apple bud (Meijerman and Ulenberg 2000). In spring, the larvae resume activity and feed in unfolding buds and also spin leaves irregularly. Attacks on flowers and young fruit are not so serious. New hatchlings feed on lower surface of leaves under linear webs along major leaf veins. Older larvae (beyond the second instar) roll a single leaf or spin a few leaves together. They also make shallow feeding scars on fruit in contact with leaves. Today, the occurrence on apple has become rare in most areas. (Meijerman and Ulenberg 2000). This leafroller species was assessed as on the fruit pathway for Fuji apples from Japan (AQIS 1998a) but no specific evidence was provided. Information provided above does suggest the larvae can attack fruit. However, they attack young fruit and older larvae can make shallow feeding scars on fruits in contact with leaves (Meijerman and Ulenberg 2000). The damaged fruit would not be harvested. It is therefore unlikely that the older larvae would be on the mature apple fruit pathway. | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|--|---|--|--|--|-------------------|
| <i>Archips xylosteana</i> (Linnaeus, 1758) [Lepidoptera: Tortricidae] | apple variegated tortrix; apple leafroller | Yes (Hwang 1974) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998a) | Unlikely No specific information was found for <i>Archips xylosteana</i> . However, the congeneric species <i>Archips breviplicatus</i> Walsingham is assessed as unlikely to be on the pathway. <i>Archips xylosteana</i> was assessed as “yes?” for association with fruit in the IRA for Fuji apples from Japan (AQIS 1998a). This assessment was reconsidered and no reports of <i>Archips xylosteana</i> feeding on fruit could be found. | No |
| <i>Argyresthia assimilis</i> Moriuti, 1977 [Lepidoptera: Yponomeutidae] | apple fruit moth | Yes (Sun and Ma 1999) | No (Nielsen <i>et al.</i> 1996) Not in WA (DAFWA 2009) | No | Likely <i>Argyresthia assimilis</i> is a pest of apple in Shaanxi and Gansu, China, and lays eggs on and bores into fruit (Sun and Ma 1999). From mid-of August to mid-September, all larvae come out of the fruit and enter into soil to pupate and overwinter. | Yes |
| <i>Bhima idiota</i> (Graeser, 1888) [Lepidoptera: Lasiocampidae] | lasiocampid moth | Yes (CHNZX-Farming 2008f) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely Larvae feed on leaves (CHNZX-Farming 2008f). | No |
| <i>Calyptra gruesa</i> (Draudt, 1950). [Lepidoptera: Noctuidae] | fruit-piercing moth | Yes In China (ZDCBIC 2005) On apples (AQIS 1998a) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2008b; AQIS 1999a; AQIS 1998a) | Unlikely Both larvae and adult noctuid moths are inactive during the day and hide amongst the foliage or leaf litter. During the night, adults usually feed on overripe or fermenting fruit (Common 1990) and will fly away when disturbed. | No |
| <i>Calyptra lata</i> (Butler, 188) Synonym: <i>Oraesia lata</i> (Butler, 1881) [Lepidoptera: Noctuidae] | fruit-piercing moth | Yes (GAAS 2008a) | No (Nielsen <i>et al.</i> 1996) | Yes (AQIS 1998a) | Unlikely Adults suck sap of fruit (GAAS 2008a) and will fly away when disturbed | No |
| <i>Calyptra thalictri</i> [Lepidoptera: Noctuidae] | fruit-piercing moth (FPM) | Yes In China (ZDCBIC 2005) On apples (AQIS 1998a) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2008b; AQIS 1999a; AQIS 1998a) | Unlikely Both larvae and adult noctuid moths are inactive during the day and hide amongst the foliage or leaf litter. During the night, adults usually feed on overripe or fermenting fruit (Common 1990) and will fly away when disturbed. | No |
| <i>Carposina sasakii</i> Matsumura, 1900 [Lepidoptera: Carposinidae] | peach fruit borer; peach fruit moth | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Likely Larvae of this moth species bore in the fruits of apples in China (Wan <i>et al.</i> 2006; Toyoshima 1931). This species damages leaves and fruit of apple trees in Japan (Toyoshima <i>et al.</i> 2005). This species is a pest of apple fruit (AQSIQ 2005; CIQSA 2001a). | Yes |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|---------------------------------|---|-------------------------------------|--|--|-------------------|
| <i>Celastrina argiolus</i> (Linnaeus, 1758) Synonym: <i>Cyaniris argiolus</i> [Lepidoptera: Lycaenidae] | holly blue butterfly | Yes (GAAS 2008b) | No (Nielsen <i>et al.</i> 1996) | Yes (AQIS 1999a) | Unlikely Larvae of <i>Cyaniris argiolus</i> eat the stems, ovaries and young fruits and also destroy the fruit (Volkov 1989; Marikovskii and Ivannikov 1966). Routine harvest and post-harvest quality control procedures undertaken in the apple orchards would remove the damaged and infested fruit prior to packing. | No |
| <i>Choreutis pariana</i> (Clerck, 1759) As <i>Eublemma pariana</i> (Clerck, 1759) in issues paper (Biosecurity Australia 2008d) [Lepidoptera: Tortricidae] | apple-and-thorn skeletonizer | Yes (Ma 2006) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely This species feeds on young and old leaves (Ma 2006). | No |
| <i>Choristoneura longicellana</i> (Walsingham, 1900) [Lepidoptera: Tortricidae] | common apple leaf roller | Yes (AQSIQ 2005; CIQSA 2001a) | No (Nielsen <i>et al.</i> 1996) | Yes (AQIS 1998a) | Unlikely This leafroller species is a leaf feeder. In the spring, larvae feed in unfolding buds, and then spin a few young leaves together. Attacks on flowers and fruits by this species are unknown. Larvae occur in summer and feed on the lower surface of leaves, under linear webs along major leaf veins (Meijerman and Ulenberg 2000). | No |
| <i>Clania minuscula</i> Butler [Lepidoptera: Psychidae] | bagworm | Yes (CHNZX-Farming 2008g) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely Larvae feed on leaves and chew on skin of young branches and fruit (CHNZX-Farming 2008g). Larvae chewing on the skin of fruit are unlikely to remain on the fruit when disturbed during harvesting. Fruit damaged by larvae are easily visible and would not be picked during harvest or would be eliminated during the packing house process. | No |
| <i>Coleophora nigricella</i> Stephens, 1834 [Lepidoptera: Coleophoridae] | | Yes (Ma 2006) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely This species is a leaf feeder (Ma 2006). | No |
| <i>Conogethes punctiferalis</i> Guenée, 1854 As <i>Dichocrocis punctiferalis</i> in CIQSA (2001a) [Lepidoptera: Crambidae] | yellow peach moth; crambid moth | Yes (Wan <i>et al.</i> 2006; CIQSA 2001c; CIQSA 2001a) | Yes (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | | No |
| <i>Cossus cossus orientalis</i> Gaede, 1929 [Lepidoptera: Cossidae] | goat moth | Yes (CHNZX-Farming 2008h) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely Larvae bore into branches and roots. Young instars mostly feed on epidermis of stem near the ground. Growing larvae disperse and bore into xylem and roots (CHNZX-Farming 2008h). | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|--|--|--|--|--|-------------------|
| <i>Cydia pomonella</i> Linnaeus, 1758. [Lepidoptera: Tortricidae] | codling moth | Yes (Yin <i>et al.</i> 1998) | Yes (Yin <i>et al.</i> 1998) Not in WA (Poole 2008) | Yes (Biosecurity Australia 2006a) | Likely Larvae of this moth species bore into fruit (CAB International 2008). This species is in Xinjiang and part of Guansu and has not invaded eastern China (AQSIQ 2008). However, it is an important pest of apple and pear in Xinjiang (Yin <i>et al.</i> 1998). | Yes ^{WA} |
| <i>Eudocima fullonia</i> (Clerck, 1764) Synonym: <i>Othreis fullonia</i> (Linnaeus, 1758) [Lepidoptera: Noetuidae] | fruit-piercing moth | Yes In China (ZDCBIC 2005) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2008b) | Unlikely Both larvae and adult noctuid moths are inactive during the day and hide amongst the foliage or leaf litter. During the night, adults usually feed on overripe or fermenting fruit (Common 1990) and will fly away when disturbed. | No |
| <i>Eudocima tyrannus</i> (Guenée, 1852) [Lepidoptera: Noctuidae] | | Yes (Ma 2006) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely Adults of this species pierce through the skin of fruit to feed, causing the flesh to become sponge-like and soft. The damaged area loses colour and becomes concave. Fruit decay may set in, causing fruit drop. Larvae roll and feed on leaves (Ma 2006). | No |
| <i>Eumeta variegata</i> (Snellen, 1879) As <i>Clania variegata</i> in CIQSA (2001c) [Lepidoptera: Psychidae] | cotton bag worm; Paulownia bagworm | Yes (CIQSA 2001c) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AFFA 2003a; AQIS 1998b) | Unlikely The larvae are usually phytophagous and can be important defoliators (CAB International 2007a). The moths of Psychidae vary in size from 10-50 mm wingspan. They are best known from their case-bearing larvae, often known as bagworms (CAB International 2007a). | No |
| <i>Euproctis similis</i> (Fuessly, 1775) As <i>Porthesia similis xanthocampa</i> (Dyar, 1905) in issues paper (Biosecurity Australia 2008d) [Lepidoptera: Lymantriidae] | browntail moth; yellowtail moth; mulberry tussock moth | Yes (CHNZX-Farming 2008u; CHNZX-Farming 2008t; CIQSA 2001c) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Unlikely Larvae are foliage feeders (leaves, stems and growth points). Leaves are skeletonised because veins are not attacked (CHNZX-Farming 2008u; CHNZX-Farming 2008t). <i>Euproctis similis</i> and <i>E. similis xanthocampa</i> are listed separately in the China website (CHNZX-Farming 2008u; CHNZX-Farming 2008t) as being associated with apple production in China. No specific subspecies is mentioned for <i>Euproctis similis</i> . <i>Euproctis similis</i> is here used in the broadest sense (<i>sensu lato</i>). | No |
| <i>Euzophera pyriella</i> Yang, 1994 [Lepidoptera: Pyralidae] | pyralid moth | Yes (Song <i>et al.</i> 1994). | No (Nielsen <i>et al.</i> 1996) | Yes (AQIS 1998b) | Likely Larvae of this moth species bore into apple and pear fruit in China (Song <i>et al.</i> 1994). | Yes |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|--|---|---|---|--|-------------------|
| <i>Gastropacha quercifolia</i> (Linnaeus, 1758) [Lepidoptera: Lasiocapidae] | lappet, lasiocampid | Yes (CAS 2008) | No (Nielsen <i>et al.</i> 1996) | Yes (AQIS 1998b) | Unlikely Phytophages on poplar (Georgiev and Beshkov 2000). In the early stages of tree growth the larvae fed on leaf and flower-buds and later in the year caused defoliation (Panait and Ciortan 1972). Older larvae overwinter on the trunks or branches, becoming active and feeding on the flower and leaf-buds (Bibolini 1960). Several instances of caterpillars of lasiocampid on plums, cherries, peach and apples were reported (Averin and Galkov 1958; Zvierezomb 1919; Vassiliev 1913). Routine harvest and post-harvest quality control procedures undertaken in the apple orchards would remove the damaged and infested fruit. | No |
| <i>Grapholita funebrana</i> (Treitschke, 1835) [Lepidoptera: Tortricidae] | plum fruit moth; red plum maggot | Yes (Kang <i>et al.</i> 1989) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely <i>Grapholita funebrana</i> is apparently a damaging species of the genus <i>Prunus</i> (Meijerman and Ulenberg 2000). There are no recent reports of this species on apples and only a few very old records refer to <i>G. funebrana</i> damaging apples (<i>Malus domestica</i>) (CAB International 2007a; Pospelov 1914; Radetsky 1913). This species is not listed in China's apple submissions (AQSIQ 2005; CIQSA 2001b). (CIQSA 2001c). Based on this evidence, it is not likely this species would be on the pathway. | No |
| <i>Grapholita inopinata</i> (Heinrich, 1928) [Lepidoptera: Tortricidae] | Manchurian fruit moth | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Likely Larvae of this moth species tunnel into fruit, feeding first under the skin and later on the seeds. Normally there is only one larva in each fruit, but up to five have been recorded (CAB International 2007a). | Yes |
| <i>Grapholita molesta</i> (Busck, 1916) [Lepidoptera: Tortricidae] | Oriental fruit moth; Oriental peach moth | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | Yes (Nielsen <i>et al.</i> 1996) Not in WA (Poole 2008) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Likely This moth species is a serious insect pest of apples in China (CIQSA 2001a). Larvae of this species injure and bore into apple fruit in China (Wan <i>et al.</i> 2006). | Yes ^{WA} |
| <i>Helicoverpa armigera</i> (Hübner, 1805) [Lepidoptera: Noctuidae] | cotton bollworm | Yes (Wan <i>et al.</i> 2006; CIQSA 2001c) | Yes (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; Biosecurity Australia 2005a; AFFA 2003a) | | No |
| <i>Hyphantria cunea</i> (Drury, 1773) [Lepidoptera: Arctiidae] | fall webworm | Yes (CAAS 1992) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely Eggs are laid on leaves and larvae feed on leaves (CAAS 1992). This species is an introduced pest for China. There are two generations per year in Liaoning: the peak of first generation larvae in June and July and the second generation during August and September. Generally, the larvae start pupation in early September to overwinter (CAAS 1992). | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|---|---|------------------------------------|--|---|-------------------|
| <i>Hypocala subsatura</i> Guenée, 1852 [Lepidoptera: Noctuidae] | | Yes (Ma 2006) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely Larvae of this species mainly feed on young shoots and rarely on young fruit (Ma 2006). | No |
| <i>Illiberis pruni</i> Dyar, 1905 [Lepidoptera: Zygaenidae] | green cochlid; pear spotted caterpillar; pear leaf worm | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Unlikely This species rolls and eats leaves of apple trees in China (CIQSA 2001a). Larvae of this species roll, feed on and skeletonise apple leaves in China (Liu <i>et al.</i> 2000). (Ohira 1991; Arakawa and Akiyama 1933). | No |
| <i>Leucoptera malifoliella</i> (Costa, 1836) As <i>Leucoptera scitella</i> (Zeller, 1839) in AQSIQ (2005) [Lepidoptera: Lyonetiidae] | pear leaf miner; apple leaf miner | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Unlikely This species rolls and eats leaves of apple trees in China (CIQSA 2001a). This species is generally a leaf-eating pest of apples, but overwinters on twigs, branches, trunks and on the soil surface (Maciesiak 1999). | No |
| <i>Lymantria dispar</i> (Linnaeus, 1758) [Lepidoptera: Lymantriidae] | Asian gypsy moth | Yes (CIQSA 2001c) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Unlikely Newly hatched larvae of this species usually feed on flushing buds then later, on leaves and flowers of hosts, including apple trees. High populations of this species often result in total tree defoliation. (CAB International 2007a). This species is listed as not on the pathway in the IRA for Fuji apples from Japan (AQIS 1998a). APAL (2008) regards <i>L. dispar</i> as being among the most undesirable pests. Although the species is not likely on the apple fruit pathway, it has been shown to spread on other pathways. Comprehensive risk assessment of <i>L. dispar</i> has been carried out by Matsuki <i>et al.</i> (2008). AQIS treats Asian gypsy moth as a high risk pest and makes information widely available including on its website and has measures in place to prevent its introduction into Australia (e.g. http://www.daff.gov.au/aqis/import/cargo/pests). | No |
| <i>Malacosoma neustria testacea</i> (Motschulsky, 1861) [Lepidoptera: Lasiocampidae] | tent caterpillar | Yes (CIQSA 2001c) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Unlikely <i>Malacosoma neustria</i> causes severe defoliation of hosts including apple, with silken nests formed amongst the bare twigs (CAB International 2007a). | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|---------------------|---|---|--|---|-------------------|
| <i>Marumba goschkewitschii</i> (Bremer & Grey, 1852) Includes three sub-species: <i>Marumba goschkewitschii carstanjeni</i> Staudinger, 1887; <i>Marumba goschkewitschii complacens</i> Walker, 1864; <i>Marumba goschkewitschii gaschkewitshi</i> (Bremer & Grey, 1852 [Lepidoptera: Sphingidae] | peach horn worm | Yes (Zhu <i>et al.</i> 1997) | No (Nielsen <i>et al.</i> 1996) | Yes (AQIS 1998b) | Unlikely Eggs of Sphingids are laid singly on the underside of leaves of the larval food plant. The early instar larvae are also found on the under surface of leaves, while the older larvae camouflage themselves on stems. When larvae are ready to pupate, they move down into the leaf litter, where they make a rough open cocoon or cell on the soil surface. Some larvae move further into the soil and pupate in an earthen chamber, below the soil surface (Australian Museum 2006). | No |
| <i>Monema flavescens</i> Walker, 1855 [Lepidoptera: Heterogeneidae] | Oriental fruit moth | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Unlikely This moth species rolls and eats leaves of apple trees in China (CIQSA 2001a). | No |
| <i>Narosa nigrisigna</i> (Wileman, 1911) [Lepidoptera: Limacodidae] | limacodid moth | Yes (CHNZX-Farming 2008p) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely Larvae feed on leaves (CHNZX-Farming 2008p). | No |
| <i>Odonestis pruni</i> (Linnaeus, 1758) [Lepidoptera: Lasiocampidae] | apple caterpillar | Yes (Ma 2006) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998a) | Unlikely This species feeds on young shoots and leaves (Ma 2006). | No |
| <i>Oraesia emarginata</i> (Fabricius, 1794) Synonym: <i>Calyptra emerginata</i> (Fabricius, 1794) [Lepidoptera: Noctuidae] | fruit-piercing moth | Yes In China (ZDCBIC 2005). On apples (AQIS 1998a). | Yes (Nielsen <i>et al.</i> 1996) Not in WA (Poole 2008) | Yes (AQIS 1998a) | Unlikely Both larvae and adult noctuid moths are inactive during the day and hide amongst the foliage or leaf litter. During the night, adults usually feed on overripe or fermenting fruit (Common 1990). | No |
| <i>Oraesia excavata</i> (Butler, 1878) [Lepidoptera: Noctuidae] | fruit-piercing moth | Yes (Liu 2002) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b) | Unlikely Larvae of <i>Oraesia excavata</i> only feed on <i>Coculus trilobus</i> (Thunb.) DC and are not associated with apples. Adults enter apple orchards after dark, and upon landing on fruit they extend their mouthparts to suck fruit juice. Adults may feed on a single fruit for 1 to 4 hours; however, they fly away when disturbed. This species also feeds on the juice of peach, pear, plum and loquat fruit in China. Adult moths are visible to the naked eye, being 23 to 26 mm long with red eyes. (Liu 2002). <i>Oraesia excavata</i> was assessed as associating with fruit in the IRA for Fuji apples from Japan (AQIS 1998a) probably due to the moths piercing the fruit. However, as the information above suggests, the adults would not be likely to stay with the fruit when disturbed by harvesting. | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|--|---|------------------------------------|------------------------------------|---|-------------------|
| <i>Orgyia antiqua</i> (Linnaeus, 1758) [Lepidoptera: Lymantriidae] | European tussock moth; scarce vaporar moth | Yes (CIQSA 2001c; Shi <i>et al.</i> 1993; CAAS 1992) | No (Nielsen <i>et al.</i> 1996) | Yes (AQIS 1998a) | Unlikely This moth species may cause serious damage to apple leaves (CAB International 2007a). Larvae pupate on leaves, or in cracks in bark or on twigs (Pairoa 1944; Di Stefano 1939). There is one generation in northeast China and two generation in Hebei, Henan and Gansu provinces (CAAS 1992). Second instar larvae overwinter in falling leaves and gaps on stems. Larvae feed on leaves and the young shoots. Mature larvae can chew on young fruit, making small holes and causing early fall of fruit (CAAS 1992). | No |
| <i>Orgyia thyellina</i> Butler [Lepidoptera: Noetuidae] | Japanese tussock moth; white-spotted tussock moth | Yes In China (ZDCBIC 2005). On apple (Sato 1977). | No (Nielsen <i>et al.</i> 1996) | Yes (AQIS 1999a; AQIS 1998a) | Unlikely <i>Orgyia thyellina</i> is a polyphagous insect and feeds on foliage of fruit trees such as apple and pear (Sato 1977). | No |
| <i>Orthosia incerta</i> Hufnagel, 1767 [Lepidoptera: Noctuidae] | clouded drab moth | Yes (Ma and Cui 1985) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely Chen and Li (1983) mentioned that the <i>Orthosia incerta</i> is a leaf-eater. Ma & Cui (1985) state that the female moth lays eggs in bark cracks and on the twigs of trees and the larva is a leaf-eater. | No |
| <i>Pandemis cerasana</i> (Hübner, 1786) [Lepidoptera: Tortricidae] | barred fruit-tree tortrix | Yes (Hwang 1974) | No (Nielsen <i>et al.</i> 1996) | Yes (AQIS 1998a) | Unlikely Larvae of <i>P. cerasana</i> gnaw on shoots and flower-buds, progressing to gnawing on young fruit. Larvae then move to leaves and shoots. Visible round holes 5–10 mm in diameter occur on young apple fruit and superficial gnawing appears on pear fruit (CAB International 2007a). Although this moth species was assessed as on the fruit pathway for Fuji apples from Japan (AQIS 1998a), it is considered in this analysis that the species is not likely to be on the pathway of mature apple fruit because of the evidence given above. | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|--|--|------------------------------------|--|---|-------------------|
| <i>Pandemis heparana</i> (Denis & Schiffermüller, 1775) [Lepidoptera: Tortricidae] | apple brown tortrix; dark fruit-tree tortrix | Yes (Wan <i>et al.</i> 2006; CIQSA 2001c) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Unlikely Newly hatched larvae over-winter inside webbed leaf or flower clusters. After apple trees flower, second-instar larvae leave their over-wintering sites to make tiny webbing shelters with leaf or flower-clusters. Older larvae remain in rolled leaves, often on shoots. Larvae reach out of their webbing and feed on nearby leaves and young fruit. On young fruit such blemishes usually heal, leaving a superficial mark. Some newly hatched larvae web leaves to adjacent fruit and feed on both plant parts. Such blemishes do not heal and remain visible as dry abrasions. Upon disturbance larvae wriggle frantically and, if possible, lower themselves out on a thread. This species is listed as an apple fruit chewing and flower pest in China (Wan <i>et al.</i> 2006). It is reported that larvae feed on leaves, and both young and mature apple fruit [but only on the surface of the fruit] (Voigt 2001; Angeli <i>et al.</i> 1997; Pralya <i>et al.</i> 1992). Although this moth species was assessed as on the fruit pathway for Fuji apples from Japan (AQIS 1998a) and ya pear from China (AQIS 1998b), it is considered in this analysis that the larvae are unlikely to be on the pathway of mature apple fruit because they mainly feed on leaves. | No |
| <i>Pangrapta obscurata</i> (Butler, 1879) [Lepidoptera: Noctuidae] | | Yes (Ma 2006) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely This species feeds on leaves of hosts (Ma 2006). | No |
| <i>Parasa consocia</i> Walker, 1865 [Lepidoptera: Limacodidae] | green urticating caterpillar; green cochlid | Yes (CIQSA 2001c) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Unlikely <i>Parasa consocia</i> Walker is a leaf feeder (Wang <i>et al.</i> 2008) | No |
| <i>Parasa hilarata</i> (Staudinger, 1887) [Lepidoptera: Limacodidae] | stinging caterpillar | Yes (Ma 2006) | No (Nielsen <i>et al.</i> 1996) | Yes (AQIS 1998b) | Unlikely Early instar larvae of this species feed on the underside of leaves in groups; during the later instars, larvae gradually disperse to feed and some can eat the whole leaf (Ma 2006). | No |
| <i>Parasa sinica</i> Moore, 1877 [Lepidoptera: Limacodidae] | Chinese cochlid | Yes (AQSIQ 2005; CIQSA 2001a) | No (Nielsen <i>et al.</i> 1996) | Yes (AQIS 1998a) | Unlikely This species rolls and eats leaves of apple in China (CIQSA 2001a). | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|-----------------------|---|------------------------------------|--|--|-------------------|
| <i>Pempelia heringii</i> Ragonot 1888 Synonym: <i>Nephopteryx rubrizonella</i> Ragonot 1893 [Lepidoptera: Pyralidae] | Pear fruit borer | Yes (Arakawa 1927) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely Although <i>Pempelia heringii</i> (as <i>Nephopteryx rubrizonella</i>) was reported on apple and pear in Manchuria (north-east of China) (Arakawa 1927) and on Chinese hawthorn in Shandong province (Sun <i>et al.</i> 1992), there have been no reports of this pest on apple in China since Arakawa's (1927) study. <i>Pempelia heringii</i> has two generations a year. The eggs, larvae and pupae of the first generation can be on young fruit but this generation completes its life cycle by the middle of June in Japan or middle of July in north-east China (Arakawa 1927; Matsumoto 1918). Therefore, the eggs, larvae and pupae are not likely to be present on fruit at harvest in September or October. When larvae feed inside the young fruit in June, they eject frass from the entry hole (Matsumoto 1918), causing visible damage. Adult moths of second generation do not lay their eggs on the fruit, but deposit a single egg (rarely two or three) on the buds or the bark near the buds (Matsumoto 1918). The hatched larvae immediately penetrate into buds and feed until late August or early September before overwintering in the bud within a white cocoon (Matsumoto 1918). This indicates that the development of the second generation is not associated with fruit. | No |
| <i>Peridroma saucia</i> (Hübner, 1808) [Lepidoptera: Noctuidae] | pearly underwing moth | Yes (Kuang 1985) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely In China, larvae of this moth species have been reported infesting maize, sorghum, wheat, potato, soybean, <i>Brassica</i> spp. and <i>Melilotus indica</i> . Adult females oviposit on the ground or on the leaves of weeds. Upon hatching, larvae feed on the leaves of hosts and fully grown larvae overwinter in the soil at a depth of 5–10 cm (Kuang 1985). | No |
| <i>Phalera flavescens</i> (Bremer & Grey, 1852) [Lepidoptera: Noctuidae] | cherry caterpillar | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Unlikely This species rolls and eats leaves of apple trees in China (CIQSA 2001a). It is recorded in the literature as an apple leaf and bud feeder (Furino and Shirai 1970; Lee 1965). | No |
| <i>Phyllonorycter crataegella</i> (Clemens, 1859) (as <i>Lithocolletis malivorella</i> in CIQSA (2001c) [Lepidoptera: Gracillariidae] | silver-striped moth | Yes (CIQSA 2001c) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely CIQSA (2001c) listed <i>L. malivorella</i> in their submission for Shandong apples. However, this name could not be verified in the literature and was confirmed by AQSIQ as a misspelling of <i>L. malimalifoliella</i> (Braun), which is a synonym of <i>Phyllonorycter crataegella</i> . Based on CAB International (2007a) <i>P. crataegella</i> is not present in China. It is therefore not likely this moth species is on the pathway for Chinese apples. Moreover, this species is found on leaves of hosts and the injury appears as small raised, spotted or bleached areas on the upper surfaces of leaves. The spots are caused when larvae of the fourth- and fifth-instar chew holes into the roof of their tentiform mines (CAB International 2007a). | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|--|---|------------------------------------|--|--|-------------------|
| <i>Phyllonorycter ringoniella</i> (Matsumura, 1931) [Lepidoptera: Gracillariidae] | apple leafminer | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Unlikely This species preferentially attacks young leaves of apple trees (Toyoshima <i>et al.</i> 2005; Chen and Li 2005; Sun <i>et al.</i> 2000; Jeon <i>et al.</i> 2000; Sun <i>et al.</i> 1999). | No |
| <i>Rhopobota unipunctana</i> (Haworth, 1811) [Lepidoptera: Tortricidae] | blackheaded fireworm | Yes (Hwang 1974) | No (Nielsen <i>et al.</i> 1996) | Yes (AQIS 1998a) | Unlikely This species has been found on apple trees in north China (Hwang 1974). Reported as an abundant foliage feeder on apple trees in Korea (Ahn <i>et al.</i> 1989). | No |
| <i>Scythropiodes issikii</i> (Takahashi, 1930) Synonym: <i>Odites issikii</i> (Takahashi, 1930) [Lepidoptera: Lecithoceridae] | tube caterpillar | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No (Nielsen <i>et al.</i> 1996) | Yes (AQIS 1998a) | Unlikely This moth species rolls and eats leaves of apple trees in China (AQSIQ 2005; CIQSA 2001a). | No |
| <i>Setora postornata</i> (Hampson, 1900) [Lepidoptera: Limacodidae] | brown cochlid | Yes (CIQSA 2001c) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely This species is recorded as a pest of three species of sycamore tree (<i>Platanus</i> spp.) in China. This species has two generations per year in Zhejiang Province, China. Older larvae over-winter in the soil, after which pupae hatch and bore into the trunk of host trees (Fang <i>et al.</i> 2001). | No |
| <i>Smerinthus planus planus</i> Walker, 1856 [Lepidoptera: Sphingidae] | hawkmoth | Yes (Zhu <i>et al.</i> 1997) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely Eggs of Sphingids are laid singly on the underside of leaves of the larval food plant. The early instar larvae are also found on the under surface of leaves, while the older larvae camouflage themselves on stems. When larvae are ready to pupate, they move down into the leaf litter where they make a rough open cocoon or cell on the soil surface. Some larvae move further into the soil and pupate in an earthen chamber, below the soil surface (Australian Museum 2006). | No |
| <i>Spilonota albicana</i> (Motschulsky, 1866) [Lepidoptera: Tortricidae] | white fruit moth; eye spotted bud moth | Yes (CIQSA 2001c) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Likely This moth species is a fruit boring insect (Wan <i>et al.</i> 2006). Adult females lay their eggs on the surface or calyx of fruit and hatched larvae bore into fruit from the calyx or stem end (CAAS 1992). | Yes |
| <i>Spilonota lechriaspis</i> Meyrick, 1932 [Lepidoptera: Tortricidae] | apple fruit licker; tipshoot tortrix | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Unlikely This moth species rolls and eats leaves of apple trees in China (CIQSA 2001c). | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|--|---|--|--|--|-------------------|
| <i>Spilonota ocellana</i> (Denis & Schiffermüller, 1775) [Lepidoptera: Tortricidae] | eye-spotted bud moth; brown apple budworm | Yes On pears in Hebei (Chang and Lin 1939) On apples (CAB International 2007a; AQIS 1998a) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely This species has been recorded in Hebei on pears. Moths oviposit on leaves and young shoots. When larvae hatch, they bore into leaf and fruit buds and remain inactive until the following spring. Larvae then attack buds and leaves (Chang and Lin 1939). Young larvae of this species cause little or no damage during the summer, and any damage to fruit on apple and pear trees is superficial. High populations of overwintering larvae feeding on fruit may cause fruit drop and scarring. Spring attacks are more significant, as infested buds are hollowed out and killed. Blossoms can also be destroyed, but damage to leaves and young shoots is relatively unimportant (CAB International 2007a). <i>Spilonota ocellana</i> was assessed as associated with fruit in the IRAs for Fuji apples from Japan (AQIS 1998a) and pears from China (AFFA 2003a; AQIS 1998b). However, as indicated from the above information, it is considered that this species is unlikely on pathway. | No |
| <i>Stathmopoda auriferella</i> (Walker, 1864) [Lepidoptera: Stathmopodidae] | Apple heliodinid | Yes (Hiramatsu <i>et al.</i> 2001). (Shanghai Insects Online 2009). <i>Malus</i> spp. are recorded as a host (Murakami <i>et al.</i> 2000). | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2009b) | Unlikely Although <i>S. auriferella</i> is called apple heliodinid, it is difficult to find published literature to associate it with apple trees. Murakami <i>et al.</i> (2000) appears to be the only published reference to include <i>Malus</i> spp. as the hosts of <i>S. auriferella</i> . <i>Stathmopoda auriferella</i> is found on leaves of host plants (Murakami <i>et al.</i> 2000). No records of <i>S. auriferella</i> on apple fruit can be found. It is concluded that <i>S. auriferella</i> is unlikely to be associated with apple fruit from China based on the data presented. <i>Stathmopoda auriferella</i> was assessed as on the pathway for Fuji apples from Japan (AQIS 1998a). However, the most recent evidence above does not support that assessment. | No |
| <i>Swammerdamia pyrella</i> (Villers, 1789) [Lepidoptera: Yponomeutidae] | ermine moth | Yes (Ma 2006) | No (Nielsen <i>et al.</i> 1996) | No | Unlikely Larvae of this species feed on young shoots, flower buds and leaves (Ma 2006). | No |
| <i>Synanthedon haitangvora</i> Yang, 1977 [Lepidoptera: Sesiidae] | Chinese crab apple clearwing moth | Yes (CHNZX-Farming 2008x) | No (Nielsen <i>et al.</i> 1996; Nielsen <i>et al.</i> 1996; Nielsen <i>et al.</i> 1996) | No | Unlikely Larvae bore into base of branches and wounded part of the plant and feed on phloem, cause irregular tunnel sometimes reaching to xylem (CHNZX-Farming 2008x). | No |
| <i>Synanthedon hector</i> (Butler, 1878) [Lepidoptera: Sesiidae] | lime-tree borer; cherry tree borer | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AFFA 2003a) | Unlikely Larval sesiids are stem borers of fruit trees and shrubs (CAB International 2008). This species is listed as a twig and branch insect pest in AQSIQ (2005) and CIQSA (2001a) and as an occasionally occurring insect in CIQSA (2001c). | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|-------------------------------|--|--|--|--|-------------------|
| <i>Telphusa chloroderces</i> Meyrick, 1929 [Lepidoptera: Gelechiidae] | black star leaf roller | Yes (CIQSA 2001c) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | Unlikely Species of this genus are known from China (Li 1990); however, references could not be found to support an association of species in this genus with apple fruit. Species from the family Gelechiidae are principally gall-forming pests of host stems. The larvae of these species also eat leaves (CAB International 2007a). | No |
| <i>Thosea sinensis</i> (Walker, 1855) [Lepidoptera: Limacodidae] | coconut cup moth; nettle grub | Yes (CIQSA 2001c) | No (Nielsen <i>et al.</i> 1996) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Unlikely This species feeds on leaves of host plants (Shanghai Insects Online 2005). | No |
| <i>Yponomeuta malinellus</i> Zeller, 1838 As <i>Hyponomeuta padellus</i> L. in CIQSA (2001c) [Lepidoptera: Yponomeutidae] | apple ermine moth | Yes (Wan <i>et al.</i> 2006; CIQSA 2001c) | No (Nielsen <i>et al.</i> 1996) | Yes (AQIS 1998a) | Unlikely This species is a pest of apple flowers (Wan <i>et al.</i> 2006). Larvae damage flowers, cones, calyx, leaves, stems, shoots and branches of host plants. Fruits are not known to carry this pest in trade or transport (CAB International 2007a). | No |
| <i>Zamacra excavate</i> Dyar, 1905 [Lepidoptera: Geometridae] | sang foot wings fold moth | Yes (CHNZX-Farming 2008y) | No (Nielsen <i>et al.</i> 1996; Nielsen <i>et al.</i> 1996; Nielsen <i>et al.</i> 1996) | No | Unlikely Larvae feed on leaves (CHNZX-Farming 2008y). | No |
| <i>Zeuzera coffeae</i> Nietner, 1861 [Lepidoptera: Cossidae] | red coffeae borer | Yes (Tang <i>et al.</i> 1980) | No (Nielsen <i>et al.</i> 1996) Not in WA (DAFWA 2009) | | Unlikely The larvae are borers which make tunnels within twigs and branches of the host plant, causing the leaves to wither and possibly the branches to die. Seedlings can be killed when the main stem is attacked (CAB International 2007a; Tang <i>et al.</i> 1980). The larvae overwinter in the stems when fully grown. | No |
| ORTHOPTERA | | | | | | |
| <i>Deracantha onos</i> (Pallas, 1772) [Orthoptera: Bradyporidae] | grasshopper | Yes (Wan <i>et al.</i> 2006) | No records found | No | Unlikely A fruit-chewing insect (Wan <i>et al.</i> 2006). It is considered not likely to be on the pathway because it feeds on the surface of fruit and would jump away when disturbed during harvesting. | No |
| <i>Gampsocleis ussuriensis</i> Adelung, 1910 [Orthoptera: Tettigoniidae] | katydid | Yes (Wan <i>et al.</i> 2006) | No records found | No | Unlikely A fruit-chewing insect (Wan <i>et al.</i> 2006). It is considered not likely to be on the pathway because it feeds on the surface of fruit and would jump away when disturbed during harvesting. | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|------------------------------------|--|---|-----------------------|---|-------------------|
| <i>Loxoblemmus doenitzii</i> Stein, 1881 [Orthoptera: Gryllidae] | Cricket | Yes (Wan <i>et al.</i> 2006) | No records found | No | Unlikely A fruit-chewing insect (Wan <i>et al.</i> 2006). This species completed one generation per year and overwintered in the egg stage at about 1.5-2.8 cm deep in the soil on south-facing areas around canals (Wu <i>et al.</i> 1993). It is considered not likely to be on the pathway because it feeds on the surface of fruit and would jump away when disturbed during harvesting. | No |
| <i>Nomadacris japonica</i> (Bolivar, 1898) As <i>Patanga japonica</i> (Bolivar, 1898) in issues paper (Biosecurity Australia 2008d) [Orthoptera: Acrididae] | Japanese spur-throated grasshopper | Yes (Wan <i>et al.</i> 2006) | No records found | No | Unlikely A fruit-chewing insect (Wan <i>et al.</i> 2006). Each female produced 2-4 egg masses consisting of 21-134 eggs, which were laid in the soil at a depth of 4.5-6 cm (Zhai 1985). It is considered not likely to be on the pathway because it feeds on the surface of fruit and would jump away when disturbed during harvesting. | No |
| <i>Teleogryllus mitratus</i> Burmeister, 1838 As <i>Gryllus testaceus</i> Walker, 1869 in issues paper (Biosecurity Australia 2008d) [Orthoptera: Gryllidae] | field cricket | Yes (Wan <i>et al.</i> 2006) | No records found | No | Unlikely A fruit-chewing insect (Wan <i>et al.</i> 2006). It is considered not likely to be on the pathway because it feeds on the surface of fruit and would jump away when disturbed during harvesting. | No |
| PATHOGENS | | | | | | |
| BACTERIA | | | | | | |
| <i>Gluconobacter oxydans</i> (Henneberg 1987) De Ley 1961 [Rhodospirillales: Acetobacteraceae] | | Yes The biochemistry and biotechnological applications of <i>Gluconobacter oxydans</i> were studied in China (Xu <i>et al.</i> 2004), but no report of this bacterium on agricultural crops in China found. It was isolated from apple fruit in Italy (Ricelli <i>et al.</i> 2007) | Yes Recorded in wine making (Drysdale and Fleet 1989). | No | | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|--|--|--|--------------------------------------|---|-------------------|
| <i>Pseudomonas syringae</i> van Hall 1902 [Pseudomonadales: Pseudomonadaceae] | leaf spot | Yes Recorded on hot pepper (Long <i>et al.</i> 2009), snow lotus (Zhao <i>et al.</i> 2009) and pears (Qiu <i>et al.</i> 2008) in China. | Yes (APPD 2009; DAWA 2006) | No | | No |
| FUNGI | | | | | | |
| <i>Alternaria alternata</i> (Fr.: Fr.) Keissl. [Anamorphic Pleosporaceae] | apple core rot; apple storage rot; leaf spot | Yes (AQSIQ 2005; CIQSA 2001c) | Yes (Letham 1995; Shivas 1989; Washington and Nancarrow 1983) | Yes (AQIS 1998b) | | No |
| <i>Alternaria mali</i> Roberts As <i>Alternaria alternata</i> f. sp. <i>mali</i> in (AQSIQ 2005; CIQSA 2001c) [Anamorphic Pleosporaceae] | apple cork spot; leaf spot; storage rot | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | Yes (APPD 2008; Shivas 1989) | Yes (AQIS 1998b; AQIS 1998a) | | No |
| <i>Alternaria malorum</i> (Ruehle) U. Braun, Crous & Dugan Synonym: <i>Cladosporium malorum</i> Ruhle [Anamorphic Pleosporaceae] | fruit rot | Yes Reported on <i>Malus</i> and <i>Prunus</i> in Shaanxi (Zhuang 2005). | No records found | Yes (Biosecurity Australia 2002) | Likely Storage pathogen. Observed on stored apple fruit (Goetz and Dugan 2006; Ruehle 1931). | Yes |
| <i>Alternaria tenuissima</i> (Fr.) Wiltshire [Anamorphic Pleosporaceae] | | Yes Reported on <i>Malus</i> in Ningxia (Zhuang 2005). | Yes (APPD 2008) | Yes (Biosecurity Australia 2008a) | | No |
| <i>Ascochyta piricola</i> Sacc. [Anamorphic Mycosphaerellaceae] | | Yes Reported on <i>Malus</i> in Ningxia (Zhuang 2005). | No (APPD 2008) Record on <i>Pyrus</i> in WA (Shivas 1989). | No | Unlikely Leaf disease (Chkistoff 1934). | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|-----------------------|--|--|-----------------------|---|-------------------|
| <i>Aspergillus glaucus</i> Link: Fr. [Anamorphic Trichocomaceae] | postharvest fruit rot | Yes Reported on other crops in China (Zhou <i>et al.</i> 2004). Apple storage rot in Japan (AQIS 1998a). | Yes NSW, Qld, Vic. (APPD 2008) Not in WA (DAWA 2006) | Yes (AQIS 1998a) | Likely Almost all <i>Aspergillus</i> spp. are saprophytes, but can also affect stored fruit and tubers, act as opportunistic pathogens, and damage and subsequently grow on living tissues (CAB International 2006; Huber 1930). | Yes ^{WA} |
| <i>Aspergillus niger</i> Tiegh. [Anamorphic Trichocomaceae] | postharvest fruit rot | Yes Reported on other crops in Shanxi, China (Fu and Zhang 1988) Apple storage rot in Japan (AQIS 1998a) | Yes (APPD 2008; Shivas 1989) | Yes (AQIS 1998a) | | No |
| <i>Aspergillus ochraceus</i> K. Wilh. [Anamorphic Trichocomaceae] | postharvest fruit rot | Yes Present in China (Yao <i>et al.</i> 1993). Apple storage rot in Japan (AQIS 1998a) | Yes Vic. (APPD 2008) Not in WA (DAWA 2006) | Yes (AQIS 1998a) | Likely Almost all <i>Aspergillus</i> spp. are saprophytes, but can also affect stored fruit and tubers, act as opportunistic pathogens, and damage and subsequently grow on living tissues (CAB International 2006; Huber 1930). | Yes ^{WA} |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|---|---|---|---|---|-------------------|
| <i>Botryosphaeria dothidea</i> (Moug.: Fr.) Ces. & De Not. Anamorph: <i>Fusicoccum aesculii</i> Corda Teleomorph: <i>Macrophoma kuwatsukai</i> (Fuckel) Huhndorf As <i>Botryosphaeria berengeriana</i> and <i>Botryosphaeria berengeriana</i> De Not. f. sp. <i>pyricola</i> Kogan. & Sakuma in CIQSA (2001c) ⁹ [Dothideales: Botryosphaeriaceae] | apple botryosphaeria canker; apple ring rot | Yes (CIQSA 2001c) | Yes (APPD 2008; APPD 2008; Cunnington <i>et al.</i> 2007; CAB International 2002) | Yes (Biosecurity Australia 2005b; AFFA 2003a) | | No |
| <i>Botryosphaeria obtusa</i> (Schwein.) Shoemaker Anamorph: <i>Sphaeropsis malorum</i> Berk. [Dothideales: Botryosphaeriaceae] | black rot; black canker | Yes Present in China on other crops (Farr <i>et al.</i> 1995). Associated with Fuji apple in Japan (AQIS 1998a) | Yes (APPD 2008; Cunnington <i>et al.</i> 2007; Letham 1995) | Yes (AQIS 1998a; Buchanan <i>et al.</i> 1984) | | No |
| <i>Botryosphaeria stevensii</i> Shoemaker Anamorph: <i>Diplodia mutila</i> (Fr.: Fr.) Mont. [Dothideales: Botryosphaeriaceae] | Botryosphaeria canker | Yes Reported on <i>Malus</i> in Ningxia (Zhuang 2005). | Yes (APPD 2008; Shivas 1989) | Yes (Biosecurity Australia 2006a) | | No |

⁹ *Botryosphaeria berengeriana* De Not. f.sp. *pyricola* Kogan. & Sakuma was reported by CIQSA (2001c) to occur on apples in China. Previously the fungus had been considered in the IRA for Ya pears from China (AQIS 1998b). The name *B. berengeriana* has been a source of taxonomic confusion. Using pathological, morphological and molecular evidence, Ogata *et al.* (2000) concluded that *B. berengeriana* in Japan comprised two distinct species, one of which was identified as *B. dothidea* (Moug.: Fr.) Ces. & De Not. Subsequently it was confirmed by Slippers *et al.* (2008; 2004) that the type specimen of *B. berengeriana* was a synonym of *B. dothidea*. Furthermore, all the forma speciales of *B. berengeriana* are synonyms of *B. dothidea*. The second species referred to by Ogata *et al.* (2000) has been identified as *Botryosphaeria parva* Pennycook & Samuels (Slippers *et al.* 2008). Recently, Barber *et al.* (2005) have shown that *B. dothidea* also forms a *Dichomera* synanamorph.

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|--|---|--|--|---|-------------------|
| <i>Botrytis cinerea</i> Pers.: Fr. Teleomorph: <i>Botryotinia fuckeliana</i> (de Bary) Whetzel [Helotiales: Sclerotiniaceae] | hui mei bing; grey mould; botrytis rot | Yes (CAB International 2007a; Jarvis 1977) | Yes (APPD 2008) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | | No |
| <i>Butlerella eustacei</i> Weresub & Illman Synonym: <i>Corticium centrifugum</i> (Lev.) Bres. [Polyporales: Atkeciaceae] | fisheye rot of apples | Yes (Farr <i>et al.</i> 2008) | No A record of <i>Corticium centrifugum</i> on <i>Delphinium</i> sp. in Victoria (Chambers 1982) is probably a misidentification. | Yes (Biosecurity Australia 2002) | Likely Causes fisheye rot of apples in storage (Rosenberger 1990a; Weresub and Illman 1980). <i>Butlerella eustacei</i> is primarily a saprophyte fungus which primarily lives on dead or dying tissue, but has also been found in orchards on the surface of apples that are not decayed and on stems of healthy apples after harvest. Apples become infected in the field and decay develops when the fungus invades the fruit through wounds or lenticels in overmature fruit (Rosenberger 1990a). A post-harvest rot that affects damaged fruit but is rare in modern storage. It appears primarily in apples that have been held late into the storage season (Rosenberger 1990a). | Yes |
| <i>Chondrostereum purpureum</i> (Pers.: Fr.) Pouzar [Poriales: Meruliaceae] | silver leaf | Yes (CIQSA 2001c) | Yes (APPD 2008; Washington and Nancarrow 1983) | Yes (Biosecurity Australia 2006a) | | No |
| <i>Colletotrichum acutatum</i> J. H. Simmons [Phyllachorales: Glomerellaceae] | black spot | Yes (CIQSA 2001c) | Yes (APPD 2008) | Yes (Biosecurity Australia 2006a) | | No |
| <i>Colletotrichum gloeosporioides</i> (Penz.) Penz. & Sacc. Anamorph: <i>Gloeosporium fructigenum</i> Berk. Teleomorph: <i>Glomerella cingulata</i> (Stoneman) Spauld. & H. Schrenk [Phyllachorales: Hypocreomycetidae] | anthracnose; bitter rot | Yes (AQSIQ 2005; CIQSA 2001a) | Yes (APPD 2008; Washington and Nancarrow 1983) | Yes (Biosecurity Australia 2005b; AQIS 1998b; AQIS 1998a) | | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|---------------------------------------|---|--|--|--|-------------------|
| <i>Cryptosporiopsis curvispora</i> (Peck) Gremmen Teleomorph: <i>Neofabraea malicorticis</i> H.S. Jacks. Synonym: <i>Pezicula malicorticis</i> (H.S. Jacks.) Nannf. [Anamorphic Dermateaceae] | anthracnose canker and bull's-eye rot | Yes (Ma 2006) | No (Cunnington 2004) | Yes (Biosecurity Australia 2006a) | Likely <i>Cryptosporiopsis curvispora</i> infects fruit and cause fruit to rot in storage (Grove 1990a). This pathogen causes Bull's eye rot of stored apple fruit (Dugan 1993). | Yes |
| <i>Cryphonectria parasitica</i> (Murrill) M.E. Barr [Diaporthales: Valsaceae] | chestnut blight | Yes Reported on chestnuts in China (Ni 1998). Apple is one of the wild hosts (CAB International 2007a). | No records found | No | Unlikely Pathogen infects trunk and stems causing cankers resulting in wilting above the canker and eventually death of oak and chestnut trees (CAB International 2007a; Ni 1998). No record on apples in China found. | No |
| <i>Cylindrosporium mali</i> (Allesch.) Wollenw. [Anamorphic Pyrenopeziza] | | Yes Reported on <i>Malus</i> in Gansu (Zhuang 2005). | No records found | No | Uncertain Although it was included as a pathogen of apple in Gansu and Ningxia (Zhuang 2005), no further reports on this pathogen were found. | Yes |
| <i>Cytospora leucostoma</i> (Pers.) Sacc. [Anamorphic Valsaceae] | dieback, peach canker | Yes Reported on <i>Malus</i> and <i>Prunus</i> in Xinjiang (Zhuang 2005). | Yes (APPD 2008) Not in WA (DAWA 2006). | Yes (Biosecurity Australia 2006a; Biosecurity Australia 2002) | Unlikely Stem and trunk disease (Leyendecker 1952). | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|---|---|---------------------------------|--|---|-------------------|
| <i>Cytospora personata</i> Fr. Sacc. Synonyms: <i>Leucocytospora personata</i> Fr. Höhn; <i>Sphaeria personata</i> Fr. Teleomorph: <i>Leucostoma auerswaldii</i> (Nitschke) Höhn [Anamorphic Valsaceae] | leucostoma canker | Yes Reported in China on other tree species (Farr and Rossman 2009; Zhang 1989). Other <i>Cytospora</i> species were recorded on apple trees (Zhuang 2005). | No records found | No | Unlikely Causes cankers on stems and trunks and dieback of twigs of forest trees (Zhang 1989). | No |
| <i>Cytospora</i> spp. [Anamorphic Valsaceae] | dieback, apple canker | Yes Reported on <i>Malus</i> and <i>Prunus</i> in Gansu, and Xinjiang (Zhuang 2005). | No records found | No | Unlikely Stem and trunk disease (Pacit 1978). | No |
| <i>Diaporthe eres</i> Nitschke Anamorph: <i>Phomopsis oblonga</i> (Desm.) Traverso [Diaporthales: Diaporthaceae] | pear canker | Yes Reported on pears in China (Ciferri 1955). Apple is one of the major hosts (Smith <i>et al.</i> 1996). | Yes (APPD 2008; Shivas 1989) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | | No |
| <i>Diaporthe pernicioso</i> Marchal & É.J. Marchal Anamorph: <i>Phomopsis mali</i> (Schulzer & Sacc.) Roberge; <i>Phomopsis prunorum</i> (Cooke) Grove [Diaporthales: Diaporthaceae] | barker canker, storage rot, promopsis rot | Yes (Ma 2006) | No record found | Yes (Biosecurity Australia 2006a) | Likely <i>Diaporthe pernicioso</i> causes fruit rot (Rosenberger 1990c). | Yes |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|---|---|--|--|---|-------------------|
| <i>Diplocarpon mali</i> Y. Harada & Sawamura Anamorph: <i>Marssonina coronaria</i> (Ellis & Davis Davis As <i>Marssonina mali</i> in CIQSA (2001a) [Helotiales: Dermateaceae] | marssonina blotch, apple leaf brown rot | Yes In Shandong (AQSIQ 2005) and Gansu (Zhuang 2005); (CIQSA 2001a) | No records found | Yes (AQIS 1998b; AQIS 1998a) | Likely Marssonina blotch caused by <i>Diplocarpon mali</i> usually occurs on leaves. It was also reported on fruit and stems (Lee <i>et al.</i> 2006; Yukita 2003; Takahashi and Sawamura 1990). | Yes |
| <i>Dissoconium mali</i> G.Y. Sun, Z Zhang & R. Zhang [Anamorphic Mycosphaerellaceae] | sooty blotch and flyspeck (SBFS) | Yes (Zhang <i>et al.</i> 2007) | No records found | No | Likely Isolated from the sooty blotch and flyspeck complex on apple fruit in Shaanxi province in China (Zhang <i>et al.</i> 2007). | Yes |
| <i>Dissoconium multiseptatae</i> G.Y. Sun & Z. Zhang [Anamorphic Mycosphaerellaceae] | sooty blotch and flyspeck (SBFS) | Yes (Zhang 2007) | No records found | No | Likely Isolated from the sooty blotch and flyspeck complex on apple fruit in China (Zhang 2007). | Yes |
| <i>Erythricium salmonicolor</i> (Berk. & Broome) Burds. Synonym: <i>Corticium salmonicolor</i> Berk. & Broome; <i>Phanerochaete salmonicolor</i> (Berk. & Broome) Jülich[Poriales: Corticiaceae] | pink disease damping off | Yes Reported in Hubei, Sichuan, Jiangsu on apple (Leng <i>et al.</i> 1982) | Yes (APPD 2008) Not in WA (DAWA 2006) | Yes (AQIS 1998a)(Biosecurity Australia 2006a) | Unlikely This pathogen causes root, stem and trunk disease in its hosts (Leng <i>et al.</i> 1982). | No |
| <i>Fusarium avenaceum</i> (Fr.: Fr) Sacc. Teleomorph: <i>Gibberella avenacea</i> R.J. Cook [Hypocreales: Nectriaceae] | water rot; fruit rot; collar rot | Yes Reported on other crops in China (Yu and Fang 1948). Associated with Fuji apple in Japan (AQIS 1998a) | Yes (APPD 2008; Shivas 1989) | Yes (AQIS 1998a) | | No |
| <i>Fusarium camptoceras</i> Wollenw. & Reinking [Anamorphic Nectriaceae] | mould | Yes Reported on <i>Malus</i> in Guansu (Zhuang 2005). | Yes (APPD 2008) Not in WA (DAWA 2006). | No | Unlikely This fungus is usually present in soil and stored seeds (Sharma and Siddiqui 1979). It was also reported in stored garlic (Roy <i>et al.</i> 1977). No records on apple fruit found. | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|----------------|--|--|--|---|-------------------|
| <i>Fusarium culmorum</i> (W.G. Sm.) Sacc. [Anamorphic Nectriaceae] | root rot | Yes Reported on other crops in China (Zhao 2001) Associated with apple in Japan (AQIS 1998a) | Yes (APPD 2008) | Yes (AQIS 1998a) | | No |
| <i>Fusarium moniliforme</i> J. Sheld. Teleomorph: <i>Gibberella fujikuroi</i> (Sawada) Wollenw. [Hypocreales: Nectriaceae] | fig endosepsis | Yes Reported on <i>Malus</i> in Guansu (Zhuang 2005). | Yes (APPD 2008) | Yes (AQIS 1999b) | | No |
| <i>Fusarium solani</i> (Mart.) Sacc. Teleomorph: <i>Haematonectria haematococca</i> (Berk. & Broome) Samuels & Rossman [Hypocreales: Nectriaceae] | root rot | Yes Reported on <i>Malus</i> in Guansu (Zhuang 2005). | Yes (APPD 2008) | Yes (AQIS 1999b) | | No |
| <i>Fusarium</i> sp. [Anamorphic Nectriaceae] | root rot | Yes (AQSIQ 2005; CIQSA 2001a) | Yes (Letham 1995; Shivas 1989; Washington and Nancarrow 1983) | Yes (Biosecurity Australia 2006a; AQIS 1998a) | | No |
| <i>Fusicladium carpophilum</i> (Thüm.) Oudem. Teleomorph: <i>Venturia carpophila</i> E.E. Fisher [Pleosporales: Venturiaceae] | mouldy core | Yes Reported on other crops in China (Tang 2004) Associated with apple in Japan (AQIS 1998a) | Yes (AQIS 1998a; Shivas 1989) | Yes (AQIS 1998a) | | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|--------------------------|--|---|---------------------------------------|--|-------------------|
| <i>Gibberella acuminata</i> C. Booth Anamorph: <i>Fusarium acuminatum</i> Ellis & Everth [Hypocreales: Nectriaceae] | stalk rot of maize | Yes Present in China (CAB International 2009). Infects apples (Biosecurity Australia 2006a). | Yes <i>Fusarium acuminatum</i> was reported in all states except NT (APPD 2009). | Yes (Biosecurity Australia 2006a). | | No |
| <i>Gibberella tricineta</i> El-Gholl Anamorph: <i>Fusarium tricinctum</i> (Corda) Sacc. [Hypocreales: Nectriaceae] | foot rot, grasses blight | Yes Reported in China (CAB International 2009). | Yes <i>Fusarium tricinctum</i> was reported in NSW, Qld, Vic. (APPD 2009). Not in WA (DAWA 2006). | No | Unlikely Causes a root discoloration (Dollahide <i>et al.</i> 1994). | No |
| <i>Gymnosporangium yamadae</i> Miyade ex G. Yamada [Uredinales: Pucciniaceae] | Japanese apple rust | Yes (AQSIQ 2005; CIQSA 2001c) | No records found | Yes (AQIS 1998a) | Likely Fruit is liable to carry this pathogen (Guo 1994). Latent infections on fruit may occur (Laundon 1998), although fruit infection is rare. This pathogen is listed as on the pathway in the IRA for Fuji apples from Japan (AQIS 1998a). | Yes |
| <i>Helicobasidium mompa</i> Tanaka [Helicobasidiales: Helicobasidiaceae] | violet root rot | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | No records found | Yes (AQIS 1998a) | Unlikely This pathogen causes root disease in its hosts (CAB International 2007a; Pegler and Gibson 1998; Segawa and Harada 1990). | No |
| <i>Inonotus hispidus</i> (Bull.: Fr.) P. Karst [Hymenochaetales: Hymenochaetaceae] | tree decay canker | Yes Reported on <i>Malus</i> in Ningxia, Gansu and Xinjiang (Zhuang 2005). | No records found | No | Unlikely <i>Inonotus hispidus</i> is a wood decay fungus (Grand and Vernia 2005). | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|---------------|---|--|--|--|-------------------|
| <i>Kalmusia coniothyrium</i> (Fuckel) Huhndorf Anamorph: <i>Microsphaeropsis fuckelii</i> (SACC.) Boereua Synonym: <i>Coniothyrium fuckelii</i> Sacc.; <i>Leptosphaeria coniothyrium</i> (Fuckel) Sacc. [Pleosporales: leptosphaeriaceae] | cane blight | Yes (Farr <i>et al.</i> 2008) | Yes Synonym <i>Coniothyrium fuckelii</i> present in Australia including WA (Farr and Rossman 2009). | No | | No |
| <i>Leptosphaeria yulan</i> Sacc. [Pleosporales: Leptosphaeriaceae] | leaf spot | Yes Reported on pear in China (Yu 1940) Associated with Fuji apple in Japan (AQIS 1998a). | No records found | Yes (AQIS 1998a) | Unlikely This pathogen causes leaf disease and is not associated with fruit (Yu 1940). | No |
| <i>Monodictys melanopa</i> (Ach.ex Dawson Turner) M.B. Ellis [Anamorphic Dothideales] | | Reported on <i>Malus</i> in Ningxia (Zhuang 2005) | No records found | No | Unlikely This pathogen attacks the bark surface of <i>Malus</i> (Farr <i>et al.</i> 2008). | No |
| <i>Monilinia fruticola</i> (G. Winter) Honey Anamorph: <i>Monilia fruticola</i> Batra [Helotiales: Sclerotiniaceae] | fruit rot | Yes Reported on peach and nectarine in an orchard in Beijing (Zhu <i>et al.</i> 2005). | Yes (APPD 2008) | Yes (Biosecurity Australia 2006b) | | No |
| <i>Monilinia fructigena</i> Honey Anamorph: <i>Monilia fructigena</i> Pers.:Fr. [Helotiales: Sclerotiniaceae] | brown rot | Yes (AQSIQ 2005; CIQSA 2001c) | No records found | Yes (Biosecurity Australia 2005b; AQIS 1998a) | Likely This pathogen causes fruit rot and fruit are liable to transmit infection (Batra and Harada 1986). <i>Monilinia fructigena</i> is a very common and destructive disease; sometimes the fungus spreads into branches from the fruit and gives rise to cankers (Byrde and Willetts 1977). This pathogen is listed as on pathway in the IRA for Fuji apples from Japan (AQIS 1998a) and the final extension of policy for pears from China (Biosecurity Australia 2005b). | Yes |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|---|--|--|--------------------------------------|--|-------------------|
| <i>Monilinia laxa</i> (Aderh. & Ruhland) Honey Anamorph: <i>Monilia laxa</i> (Ehrenb.) Sacc. & Voglino [Helotiales: Sclerotiniaceae] | fruit rot | Yes (Farr <i>et al.</i> 2008) | Yes (APPD 2008) | Yes (Biosecurity Australia 2006b) | | No |
| <i>Monilinia mali</i> (Takah.) Whetzel Synonym: <i>Monilinia laxa</i> f. sp. <i>mali</i> (Woronin) Harrison [Helotiales: Sclerotiniaceae] | monilia leaf blight; apple blossom blight | Yes (Zhuang 2005; CIQSA 2001c) | No records found (APPD 2008; Shivas 1989) | Yes (AQIS 1998a) | Unlikely <i>Monilinia mali</i> causes blossom wilt, spur-kill and canker. Young fruit can be infected by both conidia and ascospores from late-developing apothecia. After infection, young fruits quickly rot and then the fungus grows through the stem of the fruit and into the spur, which is often killed (Holb 2008). Byrde and Willetts (1977) and CAB International (2009) also suggest that the damage of this fungus is confined to apple blossoms and spurs. No reports on infection of mature apple fruit found. | No |
| <i>Mucor mucedo</i> Fresen. [Mucorales: Mucoraceae] | mucor rot | Recorded on other plant species in China (Cheng <i>et al.</i> 1988). Causes decay of apple fruit in the USA (Spotts 1990b). | No records found | No | Likely Postharvest pathogen. Causes decay of apple fruit (Spotts 1990b). <i>Mucor mucedo</i> has not been recorded on apple in China. | Yes |
| <i>Mucor racemosus</i> Fresen. [Mucorales: Mucoraceae] | mucor rot | Recorded on other plant species in China (Pei 2000). Causes decay of apple fruit in the USA (Spotts 1990b). | Yes ACT, NSW (APPD 2009). Not in WA (DAWA 2006). | No | Likely Postharvest pathogen. Causes decay of apple fruit (Spotts 1990b). <i>Mucor racemosus</i> has not been recorded on apple in China. | Yes ^{WA} |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|-----------------------------------|---|--|--------------------------------------|---|-------------------|
| <i>Mycosphaerella pomi</i> (Pass.) Lindau Anamorph: <i>Cylindrosporium pomi</i> C. Brooks [Mycosphaerellales: Mycosphaerellaceae] | Brook's fruit spot | Yes Reported on <i>Malus</i> in Ningxia (Zhuang 2005). | Uncertain Reported only from NSW as <i>Cylindrosporium pomi</i> (APPD 2008) and reported as the pathogen causing Brook's fruit spot on apple (Penrose 1984). Whether <i>Cylindrosporium pomi</i> is a synonym of <i>Mycosphaerella pomi</i> remains uncertain. | Yes (Biosecurity Australia 2006a) | Likely Infects apple leaves, shoots and fruit (Kobakhidze and Kovalenko 1976). | Yes |
| <i>Nectria cinnabarina</i> (Tode: Fr.) Fr. Anamorph: <i>Tubercularia vulgaris</i> Tode: Fr. [Hypocreales: Nectriaceae] | apple canker; nectria twig blight | Yes (Booth 1998; Yang and Tian 1988) | Yes (APPD 2008) Not in WA (DAWA 2006) | Yes (AQIS 1998a) | Unlikely This pathogen is not associated with fruit (Booth 1998; Yang and Tian 1988). | No |
| <i>Neonectria ditissima</i> (Tul. & C. Tul.) Samuels & Rossman Synonym: <i>Nectria galligena</i> Bres.; Anamorph: <i>Cylindrocarpon herteronema</i> (Berk. & Broome) Wollenw. [Hypocreales: Nectriaceae] | European canker | Yes (Ma 2006) | No (APPD 2008) Has been eradicated from Tasmania (Ransom 1997). | Yes (Biosecurity Australia 2006a) | Likely It causes a primary fruit spot. Latent fruit infection may occur (Swinburne 1971). | Yes |
| <i>Paraconiothyrium</i> sp. [Anamorphic Montagnulaceae] | sooty blotch and flyspeck (SBFS) | Yes (Zhang 2007) | No records found | No | Likely Isolated from the sooty blotch and flyspeck complex on apple fruit in China (Zhang 2007). | Yes |
| <i>Passalora</i> sp. [Anamorphic Mycosphaerellaceae] | sooty blotch and flyspeck (SBFS) | Yes (Zhang 2007) | No records found | No | Likely Isolated from the sooty blotch and flyspeck complex on apple fruit in China (Zhang 2007). | Yes |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|----------------------------------|--|--|--|---|-------------------|
| <i>Peltaster</i> sp. [Dothidiales: Dothioraceae] | sooty blotch and flyspeck (SBFS) | Yes (Zhang 2007) | No records found | No | Likely Isolated from the sooty blotch and flyspeck complex on apple fruit in China (Zhang 2007). | Yes |
| <i>Penicillium expansum</i> Link [Anamorphic Trichocomaceae] | soft rot; blue mould; wet rot | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | Yes (APPD 2008; AQIS 1998b; Shivas 1989) | Yes (AQIS 1998b) | | No |
| <i>Phoma pomorum</i> Thum. var <i>pomorum</i> As <i>Phyllosticta pirina</i> Sacc. in (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a). [Anamorphic Leptosphaeriaceae] | apple leaf grey spot | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | Yes (APPD 2008; Shivas 1989; Washington and Nancarrow 1983) | Yes (Biosecurity Australia 2005b) | | No |
| <i>Phyllactinia guttata</i> Anamorph: <i>Erysiphe suffulta</i> Rebent. [Erysiphales: Erysiphaceae] | powdery mildew | Yes (Wu and Guo 1987) | No records found | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Unlikely This pathogen mainly affects leaves (Szentivanyi and Kiss 2003; Wu and Guo 1987). It was determined as not on pathway in the policy for pears from China (Biosecurity Australia 2005b; AQIS 1998b). | No |
| <i>Phyllactinia mali</i> (Duby) U. Braun Anamorph: <i>Erysiphe mali</i> Duby [Erysiphales: Erysiphaceae] | powdery mildew | Yes (CAB International 2007a; Liu and Gao 1997) | No records found | Yes (Biosecurity Australia 2005b; AQIS 1998b) | Unlikely Apples are a host of this pathogen, which mainly affects leaves. Badly affected leaves drop early. This pathogen is not associated with fruit (Liu and Gao 1997; Wu and Guo 1987). <i>Phyllactinia guttata</i> from the same genus was determined as not on pathway in the policy for pears from China (AQIS 1998b). | No |
| <i>Phyllachora pomigena</i> (Schwein.) Sacc. Anamorph: <i>Gloeodes pomigena</i> (Schwein.) Colby [Anamorphic: Phyllachoraceae] | sooty blotch | Yes (Xiao <i>et al.</i> 2000) | Yes (APPD 2009; Farr and Rossman 2009; DAWA 2006). | Yes (Biosecurity Australia 2006a) | | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|--|---|---|--|---|-------------------|
| <i>Phyllosticta arbutifolia</i> Ellis & G. Martin As <i>Phyllosticta solitaria</i> Ellis & Everh in CIQSA (2001c). [Anamorphic Botryosphaeriaceae] | apple blotch; apple leaf round spot | Yes (CIQSA 2001c) | No records found | Yes (AQIS 1998a) | Likely This pathogen can infect leaves, twigs and fruit (Yoder 1990; Guba 1924; Gardner 1923). This pathogen is listed as on the pathway in the IRA for Fuji apples from Japan (AQIS 1998a). However, according to McClintock (1930), international movement of <i>P. arbutifolia</i> is only on seedlings or in planting material with cankers. This pathogen is able to survive at least 9 months of cold storage at 1-2 °C. | Yes |
| <i>Pleospora herbarum</i> (Pers.: Fr.) Rabenh. Anamorph: <i>Stemphylium herbarum</i> E.G. Simmons [Pleosporales: Pleosporaceae] | pleospora rot; leaf spot | Yes Reported on other crops in China (Yang <i>et al.</i> 2000) Associated with Fuji apple in Japan (AQIS 1998a) | Yes (APPD 2008; Shivas 1989) | Yes (AQIS 1998a) | | No |
| <i>Podosphaera leucotricha</i> (Ellis & Everh.) E. S. Salmon Anamorph: <i>Oidium mespili</i> Cooke [Erysiphales: Erysiphaceae] | powdery mildew of apple | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | Yes (APPD 2008; APPD 2008; Letham 1995; Washington and Nancarrow 1983) | Yes (Biosecurity Australia 2006a; AQIS 1998b; AQIS 1998a) | | No |
| <i>Pseudocercospora mali</i> (Ellis & Everch.) Deighton [Anamorphic Mycosphaerellaceae] | leaf spot | Yes Reported on <i>Malus</i> in Guangdong and <i>Pyrus</i> in Guangxi, Xinjiang and Hong Kong (Zhuang 2001). | No records found | Yes (Biosecurity Australia 2002) | Unlikely Leaf disease (Singh <i>et al.</i> 1984). | No |
| <i>Pseudocercospora</i> sp [Anamorphic Mycosphaerellaceae] | sooty blotch and flyspeck (SBFS) | Yes (Zhang 2007) | No records found | No | Likely Isolated from the sooty blotch and flyspeck complex on apple fruit in China (Zhang 2007). | Yes |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|---|--|---------------------------------|--|---|-------------------|
| <i>Rhizoctonia solani</i> J.G. Kühn. Teleomorph: <i>Thanatephorus cucumeris</i> (A.B. Frank) Donk [Ceratobasidiales: Ceratobasidiaceae] | thread blight | Yes Reported on <i>Malus</i> in Ningxia (Zhuang 2005). | Yes (APPD 2008) | Yes (AQIS 1999b) | | No |
| <i>Rhizopus stolonifer</i> (Ehrenb. ex Fr.) Vuill. [Mucorales: Mucoraceae] | rhizopus rot | Yes Reported on pears in China (Biosecurity Australia 2005b). Associated with Fuji apple in Japan (AQIS 1998a) | Yes (APPD 2008; Shivas 1989) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | | No |
| <i>Roestelia fenzeliana</i> (F.L. Tai & C.C. Cheo) F. Kern Synonym: <i>Gymnosporangium fenzelianum</i> F.L.Tai & C.C. Cheo [Anamorphic Pucciniaceae] | rust disease | Yes Reported on <i>Malus</i> in Shaanxi (Zhuang 2005). | No records found | No | Uncertain Apple is cited as the host of <i>R. fenzeliana</i> in China (Farr <i>et al.</i> 2008) referring to a book edited by Zhuang (2005). Literature searches of databases including the China National Knowledge Infrastructure (CNKI: www.global.cnki.net) found no publications of <i>R. fenzeliana</i> associated with apple fruit. Lack of reports on <i>R. fenzeliana</i> as a disease of apple suggested that this pathogen is not an economically significant pest of apple trees. | Yes |
| <i>Rosellinia necatrix</i> Prill. Anamorph: <i>Dematophora necatrix</i> R. Hartic [Xylariales: Xylariaceae] | pear tree white root rot; dematophora root rot | Yes Reported on pears in China (AQIS 1998b). Apple can be a host (CAB International 2007a) | Yes (APPD 2008; Shivas 1989) | Yes (Biosecurity Australia 2005b; AQIS 1998b) | | No |
| <i>Schizophyllum commune</i> Fr.: Fr. [Agaricales: Schizophyllaceae] | heart rot; heartwood rot; wood rot | Yes Reported in other crops in China (Dai 2005). Associated with apple in Japan (AQIS 1998a). | Yes (APPD 2008; Shivas 1989) | Yes (AQIS 1998a) | | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|----------------------------------|---|--|--------------------------------------|---|-------------------|
| <i>Schizothyrium pomi</i> (Mont. & Fr.) Arx As <i>Leptothyrium pomi</i> in CIQSA (2001c) Anamorph: <i>Zygophalia</i> sp. [Microthyriales: Schizothyriaceae] | apple fly speck | Yes (CIQSA 2001c) | Yes (APPD 2008; Letham 1995; Shivas 1989) | Yes (AQIS 1998a) | | No |
| <i>Sclerotinia sclerotiorum</i> (Lib.) de Bary [Helotiales: Sclerotiniaceae] | sclerotinia rot, white rot | Yes Reported on other plant species in China (Farr <i>et al.</i> 2008). | Yes (APPD 2008) | Yes (Biosecurity Australia 2006a) | | No |
| <i>Sclerotium rolfsii</i> Sacc. Teleomorph: <i>Athelia rolfsii</i> (Curzi) C.C. Tu & Kimbr. [Polyporales: Corticiaceae] | wilt and fruit rot | Yes (AQSIQ 2005; CIQSA 2001a) | Yes (APPD 2008; Letham 1995; Shivas 1989) | Yes (AFFA 2003a; AQIS 1998b) | | No |
| <i>Septobasidium bogoriense</i> Pat. [Septobasidiales: Septobasidiaceae] | felted fungus | Yes Reported in Shaanxi (Cao and Wang 1989) on other plant species. Associated with Fuji apple in Japan (AQIS 1998a). | No records found | Yes (AQIS 1998a) | Unlikely This pathogen is not associated with apple fruit (Cao and Wang 1989; Hsieh 1980). | No |
| <i>Stenella</i> sp. [Anamorphic Mycosphaerellaceae] | sooty blotch and flyspeck (SBFS) | Yes (Zhang 2007) | No records found | No | Likely Isolated from the sooty blotch and flyspeck complex on apple fruit in China (Zhang 2007). | Yes |
| <i>Stomiopeltis</i> spp. [Anamorphic Micropeltidaceae] | sooty blotch and flyspeck (SBFS) | Yes (Zhang 2007) | No records found | No | Likely Isolated from the sooty blotch and flyspeck complex on apple fruit in China (Zhang 2007). | Yes |
| <i>Strelitziana mali</i> G.Y. Sun & Z. Zhang [Anamorphic Chaetothyriales] | sooty blotch and flyspeck (SBFS) | Yes (Zhang 2007) | No records found | No | Likely Isolated from the sooty blotch and flyspeck complex on apple fruit in China (Zhang 2007). | Yes |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|--------------------------------|---|--|--------------------------------------|---|-------------------|
| <i>Trimmatostroma</i> sp. [Anamorphic Ascomycetes] | | Yes Reported on <i>Malus</i> in Ningxia (Zhuang 2005). | Yes Some <i>Trimmatostroma</i> species are present in Australia (APPD 2008) | No | | No |
| <i>Trichothecium roseum</i> (Pers.: Fr.) Link [Anamorphic Bionectriaceae] | apple pink rot; pink mould rot | Yes (CIQSA 2001c) | Yes (APPD 2008) | Yes (AQIS 1998b) | | No |
| <i>Truncatella hartigii</i> (Tubef) Steyaert Synonym: <i>Pestalotia hartigii</i> Tubef [Anamorphic Amphisphaeriaceae] | truncatella leaf spot | Yes Recorded on <i>Pinus</i> spp. in China (Farr and Rossman 2009). Reported to cause rotting of stored apple fruit (Pierson <i>et al.</i> 1971). | No records found | No | Likely <i>Truncatella hartigii</i> is considered to cause an apple rot of minor or very minor importance (Pierson <i>et al.</i> 1971). <i>Truncatella hartigii</i> has not been recorded on apple in China. | Yes |
| <i>Valsa ceratosperma</i> (Tode: Fr.) Maire Anamorph: <i>Cytospora sacculus</i> (Schwein.: Fr.) Gvrit. As <i>Valsa mali</i> in CIQSA (2001c) [Diaporthales: Valsaceae] | valsa canker; dieback of apple | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | Yes (APPD 2008; Letham 1995) Not in WA (DAWA 2006) | Yes (AQIS 1998b; AQIS 1998a) | Unlikely This pathogen is associated with planting materials (Sun <i>et al.</i> 2004; Hayova and Minter 1998; Xin 1996; Wang and Li 1991). | No |
| <i>Venturia inaequalis</i> (Cooke) G. Winter Anamorph: <i>Fusicladium pomi</i> (Fr.: Fr.) = <i>Fusicladium dendriticum</i> (Wallr.) Fuckel As <i>Fusicladium swnsriticum</i> in Zhuang (2005). [Pleosporales: Venturiaceae] | apple scab; black spot | Yes (Ma 2006; Wang <i>et al.</i> 1987) | Yes (APPD 2008; Letham 1995) | Yes (Biosecurity Australia 2006a) | | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|----------------------------------|---|--|-----------------------|---|-------------------|
| <i>Wallemia longxianensis</i> [Anamorphic Wallemiales] | sooty blotch and flyspeck (SBFS) | Yes Isolated from sooty blotch and flyspeck complex on apple (Zhang 2006). | No records found | No | Likely <i>Wallemia longxianensis</i> is associated with sooty blotch and flyspeck complex on apple fruit in China (Zhang 2006). | Yes |
| <i>Wallemia qiangyangensis</i> [Anamorphic Wallemiales] | sooty blotch and flyspeck (SBFS) | Yes Isolated from sooty blotch and flyspeck complex on apple (Zhang 2006). | No records found | No | Likely <i>Wallemia qiangyangensis</i> is associated with sooty blotch and flyspeck complex on apple fruit in China (Zhang 2006). | Yes |
| <i>Wallemia sebi</i> (Fr.) Arx [Anamorphic Wallemiales] | sooty blotch and flyspeck (SBFS) | Yes Isolated from sooty blotch and flyspeck complex on apple (Zhang 2006). | Yes NT (APPD 2008) Not in WA (DAWA 2006) | No | Likely <i>Wallemia sebi</i> is associated with sooty blotch and flyspeck complex on apple fruit in China (Zhang 2006). | Yes |
| <i>Xenostigmina</i> sp. [Anamorphic Mycosphaerellaceae] | sooty blotch and flyspeck (SBFS) | Yes Isolated from sooty blotch and flyspeck complex on apple (Zhang 2006). | No records found | No | Likely <i>Xenostigmina</i> sp. is associated with sooty blotch and flyspeck complex on apple fruit in China (Zhang 2006). | Yes |
| <i>Zygophiala liquanensis</i> [Anamorphic Schizothyriaceae] | sooty blotch and flyspeck (SBFS) | Yes Isolated from sooty blotch and flyspeck complex on apple (Zhang 2006). | No records found | No | Likely <i>Zygophiala liquanensis</i> is associated with sooty blotch and flyspeck complex on apple fruit in China (Zhang 2006). | Yes |
| <i>Zygophiala taiyuensis</i> [Anamorphic Schizothyriaceae] | sooty blotch and flyspeck (SBFS) | Yes Isolated from sooty blotch and flyspeck complex on apple (Zhang 2006). | No records found | No | Likely <i>Zygophiala taiyuensis</i> is associated with sooty blotch and flyspeck complex on apple fruit in China (Zhang 2006). | Yes |
| STRAMINOPIILA | | | | | | |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|--|--|--|--------------------------------------|---|-------------------|
| <i>Phytophthora cactorum</i> (Lebert & Cohn) Schröter [Pythiales: Pythiaceae] | fruit rot; root rot; collar rot; crown rot | Yes (CIQSA 2001c) | Yes (APPD 2008) | Yes (AQIS 1998a) | | No |
| <i>Phytophthora cambivora</i> (Petri) Buisman [Pythiales: Pythiaceae] | root rot; collar rot; crown rot | Yes Reported on chestnut in China (Bounous and Liu 1996) Associated with Fuji apple in Japan (AQIS 1998a). | Yes (APPD 2008) | Yes (AQIS 1998a) | | No |
| VIROIDS | | | | | | |
| <i>Apple scar skin viroid</i> [Pospiviroidae: Apscaviroid] | apple dimple; pear rusty skin disease | Yes (Biosecurity Australia 2005b; Zhou <i>et al.</i> 2004; Han <i>et al.</i> 2003) | No records found | Yes (Biosecurity Australia 2005b) | Likely This viroid can be found in the fruit pulp (Koganezawa <i>et al.</i> 2003; Hurtt and Podleckis 1995) and seeds (Han <i>et al.</i> 2003; Hadidi <i>et al.</i> 1991). | Yes |
| VIRUSES | | | | | | |
| Apple green crinkle disease [Unknown virus] | apple green crinkle | Yes (CAB International 2009) | Yes NSW, Qld, Tas. (CAB International 2009; Sampson and Walker 1982; Simmonds 1966), WA (McLean and Price 1984). | Yes (Biosecurity Australia 2006a) | | No |
| <i>Apple mosaic virus</i> [Bromoviridae: Ilarvirus] | apple mosaic virus | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | Yes (Letham 1995; Washington and Nancarrow 1983) | Yes (Biosecurity Australia 2006a) | | No |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|--|---------------------------------|---|--|--------------------------------------|---|-------------------|
| <i>Apple chlorotic leaf spot virus</i> [Flexiviridae: Trichovirus] | apple chlorotic leaf spot virus | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | Yes (Letham 1995; Washington and Nancarrow 1983) | Yes (Biosecurity Australia 2006a) | | No |
| <i>Apple stem grooving virus</i> [Flexiviridae: Capillovirus] | apple stem grooving virus | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | Yes (Letham 1995; Washington and Nancarrow 1983) Not in WA (DAWA 2006) | Yes (Biosecurity Australia 2006a) | Unlikely This virus is transmitted among woody hosts by grafting and budding (Welsh and Van der Meer 1989). | No |
| <i>Apple stem pitting virus</i> [Flexiviridae: Foveavirus] | apple stem pitting virus | Yes (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a) | Yes (Letham 1995; Washington and Nancarrow 1983) Not in WA (DAWA 2006) | Yes (Biosecurity Australia 2006a) | Unlikely Apple stem pitting virus has no known vector. Spread of this virus occurs by grafting, budding and infected clonal rootstocks (Campbell 1963). | No |
| <i>Cherry rasp leaf virus</i> Synonym: <i>Flat apple virus</i> [Sesquiviridae: Cheravirus] | cherry rasp leaf | Yes (ICTVdB 2007) | Yes (APPD 2008) | Yes (Biosecurity Australia 2002) | | No |
| <i>Tobacco necrosis virus</i> [Tombusviridae: Necrovirus] | TNV-A, TNV-D | Yes Reported on soybean (Xi <i>et al.</i> 2008) and hamimelon (Huang <i>et al.</i> 1984) in China. Isolated from apple leaves and fruits (Uyemoto and Gilmer 1972). | Yes (APPD 2009) Not in WA (DAWA 2006). | No | Likely TNVs have been detected in apple causing symptomless systemic infections (Uyemoto and Gilmer 1972). The necrovirus species involved in these infections of apple were not identified. | Yes ^{WA} |

| Scientific name | Common name/s | Associated with apples in China | Presence in Australia | Considered previously | Potential for being on pathway (mature apple fruit) | Consider further? |
|---|-----------------|---------------------------------|---|-----------------------|---|-------------------|
| <i>Tomato ringspot virus</i> Syns: <i>Peach yellow bud</i> ; <i>mosaic virus</i> ; <i>Prune brown line</i> [Couoviridae: Nepovirus] | tomato ringspot | Yes (ICTVdB 2007) | Yes Reported on one species in one location (Buchen-Osmond <i>et al.</i> 1988). Not in WA (DAWA 2006) | No | Likely Tomato ringspot virus causes a potentially lethal disease of some apple cultivars grafted onto certain rootstocks (Rosenberger <i>et al.</i> 1985). Systemic infection was reported on apple trees (Georgi 1988). | Yes ^{WA} |

Appendix A2: Potential for establishment and spread, and consequences

Only valid names are used in this table. For lists of synonyms and outdated names refer to Appendix A1 and Appendix B.

Note: Species in **bold text** are additional to those included in the pest categorisation of the draft IRA report (Biosecurity Australia 2009a)

| Scientific name | Common name | Potential for establishment and spread in the PRA area | | Potential for consequences | | Consider further? |
|------------------------------------|----------------------|--|---|------------------------------|---|-------------------|
| | | Feasible/ Not feasible | Comments | Significant/ Not significant | Comments | |
| ARTHROPODS | | | | | | |
| Acari | | | | | | |
| <i>Amphitetranychus viennensis</i> | hawthorn spider mite | Feasible | <p>Hawthorn spider mite feeds on many very common host plants which include apple cherry, apricot, peach, plum, pear, groundnut, hazel, quince, fig, cotton and raspberry (CAB International 2007a). Most of these host species are grown in Australia.</p> <p>Hawthorn spider mite is found in many countries throughout Asia and Europe (CAB International 2007a). Climatic conditions in many parts of Australia are similar to these countries.</p> | Significant | Hawthorn spider mite is an important pest in apple and other crops in Asia and Europe (CAB International 2007a). | Yes |
| <i>Cenopalpus pulcher</i> | flat scarlet mite | Feasible | <p>Flat scarlet mite feeds on a wide range of host plants including apple, quince, loquat, walnut, oriental sycamore, apricot, prune, pomegranate, pear, willow (USDA-APHIS 2000b). These host species are planted in Australia.</p> <p>Flat scarlet mite is found in various countries in Asia, Europe and Africa (USDA-APHIS 2000b) and climatic conditions in southern Australia are similar to these countries.</p> | Significant | Flat scarlet mite is an important pest in apple and other fruit crops in Asia, Europe, Africa and North America (NAPPO 2008; CAB International 2008). | Yes |

| Scientific name | Common name | Potential for establishment and spread in the PRA area | | Potential for consequences | | Consider further? |
|----------------------------|---|--|---|------------------------------|---|-------------------|
| | | Feasible/ Not feasible | Comments | Significant/ Not significant | Comments | |
| Coleoptera | | | | | | |
| <i>Rhynchites auratus</i> | Japanese pear weevil | Feasible | This weevil lays eggs and larvae develop inside fruit. Both adults and larvae are capable of overwintering in cold climates (Booth <i>et al.</i> 1990). The hosts of this species are not limited to apples. | Significant | This weevil is a serious pest of apple and other fruit in Russia, Siberia, Europe and Asia, including China (Khairushev 1970). Adults feed on all plant parts and destroy numerous buds and fruitlets (INRA 2006; Plotnikov 1914). | Yes |
| <i>Rhynchites heros</i> | Korean pear weevil | Feasible | This weevil feeds on multiple plant species (USDA 1958a). Adults and larvae are capable of overwintering (Hanson 1963; USDA 1958a). | Significant | This weevil is considered one of the most serious pests of fruit in China, with adults feeding on all plant parts (Hanson 1963). Economic impacts would occur primarily as a result of restrictions imposed on fruit from areas where Korean pear weevil becomes established. | Yes |
| <i>Tarsonemus confusus</i> | mushroom mite, confused tarsonemid mite | Feasible | <i>Tarsonemus confusus</i> has been found on many plant species, which include apple, tomatoes, African violet, azalea, Cissus, Cyclamen, Gloxinia, ivy and Pilea (Hao <i>et al.</i> 2007; Zhang 2003). It also found in soil and litter, in house dust and in birds' nests (Zhang 2003). <i>Tarsonemus confusus</i> is found in many countries throughout Asia, North America, Africa and Europe (Zhang 2003). Climatic conditions in many parts of Australia are similar to these countries. | Not significant | <i>Tarsonemus confusus</i> is primarily a fungivorous species and is also known as a minor pest of some ornamentals in greenhouses in Europe and tomatoes in North America (Zhang 2003). | No |

| Scientific name | Common name | Potential for establishment and spread in the PRA area | | Potential for consequences | | Consider further? |
|-----------------------------------|--------------------|--|--|------------------------------|--|--------------------------|
| | | Feasible/ Not feasible | Comments | Significant/ Not significant | Comments | |
| Diptera | | | | | | |
| <i>Bactrocera dorsalis</i> | Oriental fruit fly | Feasible | <p>This fruit fly has a wide host range (Allwood <i>et al.</i> 1999; Tsuruta <i>et al.</i> 1997) and disperses via both infected fruit and adult flight.</p> <p>Adults occur throughout the year and can live up to 12 months (CAB International 2007a). A total of 150–200 eggs are laid per female (Srivastava 1997).</p> | Significant | <p>Primary economic impact would result from quarantine restrictions imposed by important domestic and foreign export markets. This species is a very serious pest of a wide variety of fruit and vegetables, and damage levels can be anything up to 100% of unprotected fruit (CAB International 2007a).</p> <p>In Nauru, before its eradication, <i>B. dorsalis</i> infested up to 95% of mangoes and 90% of guavas (SPC 2002).</p> | Yes |
| Hemiptera | | | | | | |
| <i>Diaspidiotus ostreaeformis</i> | oystershell scale | Feasible | <p>Oystershell scale has a wide host range, mainly on deciduous trees. Host plants have been reported from 41 genera in 18 families. Many of these hosts are widespread in Western Australia.</p> <p>Oystershell scale is widely distributed in Palearctic and Nearctic regions and has been introduced into Australia, Argentina, Canada and New Zealand (CAB International 2007a). Modelling studies in Western Australia suggest that there are regions within Western Australia suitable for the establishment of this pest.</p> | Significant | Oystershell scale is a major scale pest of apple and pear (CAB International 2007a). | Yes ^{WA} |

| Scientific name | Common name | Potential for establishment and spread in the PRA area | | Potential for consequences | | Consider further? |
|--------------------------------|------------------|--|---|------------------------------|---|-------------------|
| | | Feasible/ Not feasible | Comments | Significant/ Not significant | Comments | |
| <i>Lopholeucaspis japonica</i> | pear white scale | Feasible | <p><i>Lopholeucaspis japonica</i> has been reported from 25 families, 43 genera and at least 58 species or subspecies of host plants (Ben-Dov <i>et al.</i> 2006a), including citrus, apples pears, teas.</p> <p><i>Lopholeucaspis japonica</i> has been reported from Asia, North and South Americas and Russia (Ben-Dov <i>et al.</i> 2006a). This indicates the species has the ability to adapt to new environments. Climatic conditions in many parts of Australia are similar to the areas where <i>L. japonica</i> currently occurs.</p> | Significant | <i>Lopholeucaspis japonica</i> is a main pest of <i>Citrus</i> species and also feeds on many other horticultural crops such as apple and pears and ornamental and amenity plants (CABI/EPPO 2007b; Ben-Dov <i>et al.</i> 2006a). | Yes |
| <i>Parlatoria oleae</i> | olive scale | Feasible | <p><i>Parlatoria oleae</i> feeds on many very common host plants which include olive, apple, peach, plum, peach, gooseberry, roses, cherry, apricot, pear, citrus and grapes (CAB International 2007b; Ben-Dov <i>et al.</i> 2006a). These host species are grown in Australia.</p> <p><i>Parlatoria oleae</i> is found in many countries throughout Asia, Africa, North America, South America and Europe (Ben-Dov <i>et al.</i> 2006a). Climatic conditions in many parts of Australia are similar to these countries.</p> | Significant | <i>Parlatoria oleae</i> is an important pest of olive and also a pest of apple, peach, plum and other crops in Asia, Africa, North America, South America and Europe (Ben-Dov <i>et al.</i> 2006a). | Yes |

| Scientific name | Common name | Potential for establishment and spread in the PRA area | | Potential for consequences | | Consider further? |
|--------------------------------|----------------|--|---|------------------------------|--|-------------------|
| | | Feasible/ Not feasible | Comments | Significant/ Not significant | Comments | |
| <i>Parlatoria yanyuanensis</i> | yanyuan scale | Feasible | <p><i>Parlatoria yanyuanensis</i> feeds on apple, paper mulberry, Chinese quince and pear (Lu and Wu 1988). Apple and pear are grown in Australia.</p> <p><i>Parlatoria yanyuanensis</i> is currently only found in China (Ben-Dov <i>et al.</i> 2006a). Climatic conditions in parts of Australia are similar to China where <i>P. yanyuanensis</i> occurs.</p> | Significant | <i>Parlatoria yanyuanensis</i> is a pest in apple and pear in China (Lu and Wu 1988). | Yes |
| <i>Phenacoccus aceris</i> | apple mealybug | Feasible | <p><i>Phenacoccus aceris</i> is a highly polyphagous species that has been recorded on apple, cherry, pear, plum, apricot, filbert, grape, currant, gooseberry, maple, oak, birch, willow, ash, linden, elm, hawthorn, quince and various ornamentals (Beers 2007; Ben-Dov 2006c). These hosts are widely available in Australia</p> <p>Apple mealybug is thought to be European in origin, but currently its distribution is cosmopolitan (Beers 2007). Climatic conditions in Australia would be suitable for its establishment and spread.</p> | Significant | <p>Apple mealybug is a pest of apple, cherry, pear, plum, apricot, fruit and ornamental trees (Beers 2007; Ben-Dov 2006c).</p> <p>Apple mealybug is also reported as the vector of little cherry virus (Beers 2007).</p> | Yes |

| Scientific name | Common name | Potential for establishment and spread in the PRA area | | Potential for consequences | | Consider further? |
|----------------------------------|----------------------|--|--|------------------------------|--|--------------------------|
| | | Feasible/ Not feasible | Comments | Significant/ Not significant | Comments | |
| <i>Pseudococcus calceolariae</i> | citrophilus mealybug | Feasible | <p>Citrophilus mealybug is a highly polyphagous species that has been recorded on 40 plant families, including many commercial and nursery plants such as apple, pear, grape, stone fruit, potato, hibiscus and rose (Ben-Dov 2005b). These hosts are widespread in Western Australia.</p> <p>Citrophilus mealybug is considered to be native to eastern Australia and now also occurs in USA, South America, New Zealand, South Africa and Europe as well as China. Conditions in Western Australia will be suitable for its establishment.</p> | Significant | Citrophilus mealybug is reported as a pest of citrus and grapevine and can occasionally be serious (CAB International 2007a). | Yes ^{WA} |
| <i>Pseudococcus comstocki</i> | Comstock's mealybug | Feasible | <p>Comstock's mealybug is known to damage several agricultural crops including banana, peach, pear, lemon, apricot, cherry, catalpa and mulberry (CAB International 2007a). It has been reported that this species infests over 300 plant species.</p> <p>Comstock's mealybug is believed to be of Asian origin, possibly indigenous to Japan. It has been recorded from a number of countries throughout the world, indicating it has the ability to adapt to new environments (CAB International 2007a).</p> | Significant | Comstock's mealybug is a pest of apples, peach and citrus in Asia and Europe, and can occasionally cause serious damage (CAB International 2007a). | Yes |

| Scientific name | Common name | Potential for establishment and spread in the PRA area | | Potential for consequences | | Consider further? |
|------------------------------|---------------------------|--|--|------------------------------|---|-------------------|
| | | Feasible/ Not feasible | Comments | Significant/ Not significant | Comments | |
| Lepidoptera | | | | | | |
| <i>Adoxophyes orana</i> | summer fruit tortrix moth | Feasible | <p><i>Adoxophyes orana</i> is a polyphagous species that feeds on more than 50 different plant species from multiple families. Economically important hosts include apple, apricot, plum, cherry and other fruit crops, although <i>A. orana</i> also feeds on many other wild plants (CAB International 2007a; Zhou and Deng 2005; Davis <i>et al.</i> 2005).</p> <p>Host plants of <i>A. orana</i> are distributed commonly and widely throughout Australia.</p> <p><i>Adoxophyes orana</i> is known to have established and spread outside its native range in areas where it has been introduced, for example, Greece and Britain (Milonas and Savopoulou-Soultani 2004; Carter 1984).</p> | Significant | <p><i>Adoxophyes orana</i> is a major pest of fruit tree crops in China and elsewhere in the world. It has been reported to cause up to 50% crop loss over large areas (Davis <i>et al.</i> 2005).</p> <p>The polyphagous nature of <i>A. orana</i> indicates the potential for consequences across a wide range of fruit growing industries, as well as for wild plants.</p> | Yes |
| <i>Argyresthia assimilis</i> | apple fruit moth | Feasible | <p><i>Argyresthia assimilis</i> feeds on apple and Chinese crab apple (Sun and Ma 1999). Apples are grown commercially and in household gardens in Australia.</p> <p><i>Argyresthia assimilis</i> is found only in China (Sun and Ma 1999). Climatic conditions in parts of Australia are similar to China where <i>Argyresthia assimilis</i> occurs.</p> | Significant | <p><i>Argyresthia assimilis</i> is an important pest in apple and Chinese crab apple in China (Sun and Ma 1999).</p> | Yes |

| Scientific name | Common name | Potential for establishment and spread in the PRA area | | Potential for consequences | | Consider further? |
|--------------------------|-------------------|--|--|------------------------------|---|--------------------------|
| | | Feasible/ Not feasible | Comments | Significant/ Not significant | Comments | |
| <i>Carposina sasakii</i> | peach fruit borer | Feasible | <p>The hosts of <i>C. sasakii</i> are mainly rosaceous fruit such as apple, pear and stone fruit, although it also feeds on wild and cultivated plants in several other plant families (CAB International 2007a). Host plants are available in Australia.</p> <p><i>Carposina sasakii</i> is found throughout many areas of China (CAB International 2007a; EPPO 2005b) that have similar climates to those available in Australia.</p> <p><i>Carposina sasakii</i> is known to have established and spread outside its native range in areas where it has been introduced. In Russia, internal quarantine measures are employed in an attempt to control the spread of <i>C. sasakii</i> (CAB International 2007a).</p> | Significant | <p>In its current distribution, <i>C. sasakii</i> is a very serious pest of fruit, causing up to 100% damage to apple and pear crops (CAB International 2007a; Gibanov and Sanin 1971; Sytenko 1960).</p> <p><i>Carposina sasakii</i> causes significant economic consequences in its current range and would potentially also do so in Australia. Consequences would include crop loss as well as quarantine restrictions on trade, both within Australia and internationally to areas where <i>C. sasakii</i> is not present.</p> | Yes |
| <i>Cydia pomonella</i> | codling moth | Feasible | <p>The main hosts of codling moth are apple and pear. Its larvae are known to be polyphagous and, apart from apple and pear, they can also feed on cherry, nectarine, prune and walnut (CAB International 2007a). Codling moth hosts are widespread in Western Australia.</p> <p>Codling moth has been reported from New South Wales, Queensland, South Australia, Tasmania and Victoria. However, several codling moth outbreaks have occurred in Western Australia and have been successfully eradicated, indicating that climatic conditions are suitable for its establishment in Western Australia.</p> | Significant | Codling moth is a well known pest of apples (CAB International 2007a). | Yes ^{WA} |

| Scientific name | Common name | Potential for establishment and spread in the PRA area | | Potential for consequences | | Consider further? |
|-----------------------------|--|--|--|------------------------------|---|--------------------------|
| | | Feasible/ Not feasible | Comments | Significant/ Not significant | Comments | |
| <i>Euzophera pyriella</i> | pyralid moth | Feasible | <p>The main hosts of this species in China are apple and pear. It has also been recorded damaging figs (Song <i>et al.</i> 1994).</p> <p>This species has not been reported in Australia or outside China. Suitable hosts are present in Australia as apple and pear are grown commercially in south west WA and in the south eastern states.</p> | Significant | This moth species has threatened the apple and pear industries in Xinjiang, China (Song <i>et al.</i> 1994). | Yes |
| <i>Grapholita inopinata</i> | Manchurian fruit moth | Feasible | <p>The recorded host plants of Manchurian fruit moth are apple, quince, pear, and host plants such as apples are available in Australia.</p> <p>Manchurian fruit moth is found in China, ranging from Guangdong in the South and Jilin in the North, and also in Far East Russia (CAB International 2007a), and this distribution covers a wide range of climate conditions. Climate conditions in many parts of Australia are similar to these areas.</p> | Significant | <i>Grapholita inopinata</i> is rather similar in terms of pest characteristics to the widely distributed <i>Cydia pomonella</i> . Both species occur in Far East Russia, where <i>C. pomonella</i> damages a larger proportion of apples than does <i>G. inopinata</i> , though the latter remains a significant pest, damaging up to 11% of apple crops. Damage from <i>G. inopinata</i> can reach 100% on apples (CAB International 2007a). | Yes |
| <i>Grapholita molesta</i> | Oriental fruit moth; Oriental peach moth | Feasible | <p>The principal economic hosts of <i>G. molesta</i> are peach, apricot, nectarine, almond, apple, quince, pear, plum and cherry (CAB International 2007a). Late ripening peach cultivars are particularly vulnerable to this pest. Some of these host species are widespread in the PRA area.</p> <p>Oriental fruit moth is already reported from New South Wales, Queensland, South Australia, Tasmania and Victoria.</p> <p>The previously eradicated incursion of Oriental fruit moth in Western Australia indicates that areas with a suitable environment for the establishment of this pest occur in Western Australia.</p> | Significant | <p>Oriental fruit moth is mainly a pest of summerfruit (CAB International 2007a).</p> <p>It would have significant potential for consequences if this species were to be introduced into Western Australia.</p> | Yes ^{WA} |

| Scientific name | Common name | Potential for establishment and spread in the PRA area | | Potential for consequences | | Consider further? |
|---------------------------|------------------|--|---|------------------------------|---|-------------------|
| | | Feasible/ Not feasible | Comments | Significant/ Not significant | Comments | |
| <i>Spilonota albicana</i> | white fruit moth | Feasible | The recorded host plants of white fruit moth are apple, pear, peach and plum, with these hosts being widely available in Australia. White fruit moth is found from the southwest to northeast regions of China (Hua and Wang 2006), which covers a wide range of climate conditions. Climate conditions in many parts of Australia are similar to these areas. | Significant | <i>Spilonota albicana</i> is a pest of apple, pear, hawthorn, peach, plum, apricot and cherry. It has become an important pest in China in untreated orchards because of the planting of large numbers of hawthorn plants (Hua and Wang 2006). In such orchards, up to 50% of fruit may be infested. | Yes |
| PATHOGENS | | | | | | |
| Fungi | | | | | | |
| <i>Alternaria malorum</i> | apple rot | Feasible | <i>Alternaria malorum</i> was reported in Canada, China, Japan, Lebanon, South Africa and Syria (Farr <i>et al.</i> 2008). Some <i>Alternaria</i> species are established in Australia (APPD 2008), suggesting that climate conditions of some parts of Australia are suitable for <i>Alternaria</i> species to establish and spread. | Not Significant | It was reported that <i>Alternaria malorum</i> is capable of producing decay of ripe apples when inoculated at 20-25 °C for 14 days (Ruehle 1931). However, at 0 °C, the fungus develops very feebly on the apple, producing small spots at the points of inoculation, which do not spread to cause decay. After 5 months incubation at 0°C, the spot lesions on inoculated apples did not advance beyond 10 mm. Despite this historical report, lack of further reports suggests that it is not an economically significant storage rot of apple. | No |

| Scientific name | Common name | Potential for establishment and spread in the PRA area | | Potential for consequences | | Consider further? |
|--|------------------------|--|---|------------------------------|---|-------------------|
| | | Feasible/ Not feasible | Comments | Significant/ Not significant | Comments | |
| <i>Aspergillus glaucus</i> <i>Aspergillus ochraceus</i> | postharvest fruit rots | Feasible | <p><i>Aspergillus</i> spp. are rapidly growing filamentous fungi or moulds that are ubiquitous to the environment and found worldwide. They commonly grow in soil and moist locations and are among the most common moulds encountered on spoiled food and decaying vegetation, in compost piles and in stored hay and grain.</p> <p>Both species are widely present in Australia except Western Australia (APPD 2008).</p> <p>Many other species of this genus are present in Western Australia (APPD 2008).</p> | Not Significant | <p>Almost all <i>Aspergillus</i> spp. are saprophytes, but can also affect stored fruit and tubers, act as opportunistic pathogens, and damage and subsequently grow on living tissues (Huber 1930).</p> <p>Under cold-storage conditions (about 0° C), none of the <i>Aspergillus</i> species caused decay within the 12 weeks of storage (Huber 1930).</p> <p>Although this historical report shows association with apples (Huber 1930), lack of further reports suggests that it is not an economically significant storage rot of apple.</p> | No |
| <i>Butleriella eustacei</i> | fish-eye rot | Feasible | <p><i>Butleriella eustacei</i> grows fastest at 18–25°C (Rosenberger 1990a). It is a saprophyte fungus which primarily lives on dead or dying tissue. Suitable hosts are present in Australia.</p> | Not significant | <p>Fisheye rot caused by <i>B. eustacei</i> is considered to be a minor post-harvest disease, but is not of economic importance in the modern world. It is rare in modern storage facilities and appears primarily in apples that have been held late into the storage season (Rosenberger 1990a). There are no known pre-harvest effects on crops or the environment.</p> | No |

| Scientific name | Common name | Potential for establishment and spread in the PRA area | | Potential for consequences | | Consider further? |
|------------------------------------|----------------|--|---|------------------------------|---|-------------------|
| | | Feasible/ Not feasible | Comments | Significant/ Not significant | Comments | |
| <i>Cryptosporiopsis curvispora</i> | bull's eye rot | Feasible | Fungal spores produced in the canker are spread by rain and wind. Infection occurs in fall. Fungal spores spread from limb cankers to maturing fruit, young limbs and twigs. Fungus fruiting bodies develop in the centre of spots on infected fruit (Pscheidt 2008). Suitable hosts, particularly apple and pear, are grown in Australia. | Significant | Bull's eye rot is the most important post-harvest disease in Washington. It can cause serious economic losses due to rot occurring in storage (Smith 2001). The disease is severe in the high-rainfall areas west of the Cascades and British Columbia (Andrews <i>et al.</i> 2008). Severe outbreaks of bull's eye-rot occurred in Washington in 1985, 1987 and 1988 (Grove <i>et al.</i> 1992). This fungus rarely kills trees as the cankers are generally confined to small branches and twigs. Losses occur due to fruit rot that occurs after fruit has been in storage for several months (Grove 1990a). Bull's eye rot is a slow growing rot and does not commonly spread from fruit to fruit (Dugan 1993). | Yes |
| <i>Cylindrosporium mali</i> | | Feasible | Many <i>Cylindrosporium</i> spp. are present in Australia (APPD 2008), suggesting that <i>C. mali</i> may establish and spread in Australia. | Not Significant | Although it was included as a pathogen of apple in Gansu and Ningxia (Zhuang 2005), no further reports on this pathogen were found, suggesting that this pathogen is not an economically important fungi. | No |
| <i>Diaporthe pernicioso</i> | phomopsis rot | Feasible | Many species of <i>Phomopsis</i> are present in Australia (APPD 2009). | Not significant | It causes secondary fruit rot. Fruit rot by <i>Phomopsis</i> spp. seldom occurs until late in storage and it is a minor disease (Rosenberger 1990c). There are many records of this genus in Australia (APPD 2009) but no reports of economic damage in the literature. | No |

| Scientific name | Common name | Potential for establishment and spread in the PRA area | | Potential for consequences | | Consider further? |
|--------------------------------|---|--|---|------------------------------|--|-------------------|
| | | Feasible/ Not feasible | Comments | Significant/ Not significant | Comments | |
| <i>Diplocarpon mali</i> | marssonina blotch, apple leaf brown rot | Feasible | <p>Natural hosts of <i>D. mali</i> are limited to <i>Malus</i> and <i>Chaenomeles</i> spp. (Farr <i>et al.</i> 2008). These host plants are grown in Australia.</p> <p>Marssonina blotch caused by <i>D. mali</i> occurs commonly in Shandong province (CIQSA 2001c) and is also reported on apples in Gansu (Zhuang 2005).</p> <p>The disease has become the most important disease in apple growing areas in Korea (Lee <i>et al.</i> 2006). It is also an important apple leaf disease in Canada, Italy, Japan and Rumania (Takahashi and Sawamura 1990). Environments with climates similar to these areas exist in various parts of Australia suggesting that <i>D. mali</i> has the potential to establish and spread in Australia.</p> | Significant | <p>Marssonina blotch is an important leaf disease of apple in India, Korea and Japan.</p> <p>In India, it caused up to 50% defoliation of apple trees from July to September, when fruits were still hanging on the defoliated branches and rendered the trees barren in the following years. In recent years, marssonina blotch has become the most important disease in apple growing areas in Korea (Lee <i>et al.</i> 2006).</p> | Yes |
| <i>Fusicladium swnsriticum</i> | | Feasible | Many <i>Fusicladium</i> spp. are present in Australia (APPD 2008), suggesting that <i>F. swnsriticum</i> may establish and spread in Australia. | Not Significant | Although it was included as a pathogen of apple trees in Ningxia (Zhuang 2005), no further reports on this pathogen were found, suggesting that this pathogen is not an economically important fungi. | No |

| Scientific name | Common name | Potential for establishment and spread in the PRA area | | Potential for consequences | | Consider further? |
|--------------------------------|---------------------------------|--|---|------------------------------|--|-------------------|
| | | Feasible/ Not feasible | Comments | Significant/ Not significant | Comments | |
| <i>Gymnosporangium yamadae</i> | Japanese apple rust, apple rust | Feasible | <p>Japanese apple rust is widely distributed in all major apple production areas of China (Guo 1994) and was also reported in Japan, North Korea and South Korea (Wang and Guo 1985). The climate conditions in many parts of Australia are similar to these countries.</p> <p>Japanese apple rust has a restricted host range, including aecial host <i>Malus</i> species and telial host <i>Juniperus</i> species (Ma 2006; Wang and Guo 1985). These host plants are grown in Australia.</p> <p>Under natural conditions, basidiospores and aeciospores are dispersed by wind (Guo 1994).</p> | Significant | <p>Apple rust is one of the major diseases of apple in China (Guo 1994) and Japan (Tanaka 1922).</p> <p><i>Gymnosporangium yamadae</i> infects leaves and stems of juniper, and leaves, stems and immature fruit of apples (Ma 2006). <i>Gymnosporangium yamadae</i> causes damage by defoliation. Infection of young fruit causes fruit drop and a reduction in apple fruit yield and quality (Guo 1994).</p> | Yes |
| <i>Monilinia fructigena</i> | brown rot | Feasible | <p><i>Monilinia fructigena</i> can infect many fruit crops include apple, pear, plum, quince, peach, apricot, nectarine and hazel (Byrde and Willetts 1977). These host plants are grown in Australia.</p> <p><i>Monilinia fructigena</i> is widely distributed throughout Europe, China, India, North Africa and South America (Mordue 1979). The climatic conditions in many parts of Australia are similar to these countries.</p> <p>Other species of this genus including <i>M. fructicola</i> and <i>M. laxa</i> are present on fruit in Australia (Byrde and Willetts 1977).</p> <p>The spores of this fungus can be spread from one orchard to another through the air (Jones 1990; Byrde and Willetts 1977).</p> | Significant | <p>Apple brown rot caused by <i>M. fructigena</i> is an important disease causing damage to apple trees and fruit in Shandong, Shaanxi, Liaoning and other major apple growing areas in China (Ma 2006; AQSIQ 2005; CIQSA 2001c; CIQSA 2001a).</p> <p><i>Monilinia fructigena</i> causes significant yield losses both before and after harvest. In Europe, losses of 7-36% were reported in individual orchards (Jones 1990).</p> | Yes |

| Scientific name | Common name | Potential for establishment and spread in the PRA area | | Potential for consequences | | Consider further? |
|----------------------------|--------------------|--|--|------------------------------|--|-------------------------|
| | | Feasible/ Not feasible | Comments | Significant/ Not significant | Comments | |
| <i>Mucor mucedo</i> | mucor rot | Feasible | Causes postharvest rot (Spotts 1990b). Suitable hosts are present in Australia. | Significant | Mucor rot of apples can be a serious problem in apples in the Pacific Northwest of the USA in fruit stored for a long period (Michailides 1991; Michailides and Spotts 1990). Serious losses due to this disease have occurred in the USA (Spotts 1990b). <i>Mucor mucedo</i> is also a post-harvest pathogen of tomato (Moline and Kuti 1984). | Yes |
| <i>Mucor racemosus</i> | mucor rot | Feasible | Causes storage rot of fruit and vegetables (Lunn 1977). Its presence in ACT, NSW and Vic. indicates potential for establishment and spread in other parts of Australia. | Significant | Mucor rot of apples can be a serious problem in apples in the Pacific Northwest of the USA (Michailides 1991; Michailides and Spotts 1990). Serious losses due to this disease have occurred in the USA (Spotts 1990b). | Yes^{WA} |
| <i>Mycosphaerella pomi</i> | Brook's fruit spot | Feasible | <i>Mycosphaerella pomi</i> is reported in USA, Canada, New Zealand and Ningxia in China. The climatic conditions in many parts of Australia are similar to these countries. <i>Mycosphaerella pomi</i> can infect fruit crops including apple, pear and quince (Farr <i>et al.</i> 2008). These host plants are grown in Australia. | Not significant | Brooks fruit spot caused by <i>Mycosphaerella pomi</i> is a minor disease in the north-eastern and mid-Atlantic apple growing regions of the USA. The pathogen is found in most apple-growing areas of New Zealand but only occasionally. It is of no economic importance in New Zealand (Atkinson 1971). <i>Mycosphaerella pomi</i> does not appear to be a pest of economic significance in the Southern Hemisphere including New Zealand and in the State of New South Wales of Australia where it is reported in the anamorph state. Based on this it is not considered a potential quarantine pest for Australia (Biosecurity Australia 2006a). | No |

| Scientific name | Common name | Potential for establishment and spread in the PRA area | | Potential for consequences | | Consider further? |
|---------------------------------|-------------------------------------|--|--|------------------------------|---|-------------------|
| | | Feasible/ Not feasible | Comments | Significant/ Not significant | Comments | |
| <i>Neonectria ditissima</i> | European canker | Feasible | <p>The disease occurs sporadically in part of Shaanxi, Gansu, Shanxi, Hebei and Henan provinces (Ma 2006).</p> <p>Common hosts of this fungus include tree species in the genera <i>Acer</i>, <i>Aesculus</i>, <i>Alnus</i>, <i>Betula</i>, <i>Carya</i>, <i>Cornus</i>, <i>Corylus</i>, <i>Fagus</i>, <i>Fraxinus</i>, <i>Julans</i>, <i>Liriodendron tulipifera</i>, <i>Malus</i>, <i>Populus</i>, <i>Prunus</i>, <i>Pyrus</i>, <i>Quercus</i>, and <i>Salix</i>. These host plants are widely available in Australia.</p> <p><i>Neonectria ditissima</i> is widely distributed throughout Europe, Asia, North Africa and South America, New Zealand. The climate conditions in many parts of Australia are similar to these countries. The disease was present in Tasmania from 1954 but it was eradicated from Tasmania (Ransom 1997).</p> | Significant | <p>The disease can be severe enough to necessitate the replacement of trees, ranging from 10% of trees (Lovelidge 1995) to the whole plantation (Grove 1990b). Losses of 10–60% of fruit crops caused by rot from European canker have been recorded in various parts of the world (Swinburne 1975). Damage to host species used for timber, through reduction in the quality and quantity of marketable logs, particularly in North America has been reported (CAB International 2007a), although there is no estimate of the magnitude of this loss.</p> <p>Sanitation (that is, removal and burning of cankered limbs or trees and spraying with fungicides) is the only feasible control measure.</p> | Yes |
| <i>Phyllosticta arbutifolia</i> | apple blotch, apple leaf round spot | Feasible | <p>The hosts of <i>P. arbutifolia</i> are restricted to apples and <i>Crataegus</i> spp. (Ma 2006; Gardner 1923). These hosts are widely available in Australia.</p> <p>Apple blotch is widely distributed in all major apple production areas in China (Ma 2006), and was also reported in Japan and many other countries (Gardner 1923). The climate conditions in many parts of Australia are similar to these countries.</p> <p>The radius of infection in wind-blown rain from a 10 m tree was estimated to be 80 m, with 100% infection occurring within 12 m of the infected trees (Ma 2006), suggesting that this pathogen has the potential to rapidly establish and spread in Australia.</p> | Significant | <p><i>Phyllosticta arbutifolia</i> causes a serious blotching of apples, which reduces fruit quality and yield (Ma 2006).</p> <p>The disease also causes damage on leaves, buds, twigs and branches of susceptible cultivars (Yoder 1990), causing defoliation of leaves and development of cankers on twigs and branches (Yoder 1990).</p> | Yes |

| Scientific name | Common name | Potential for establishment and spread in the PRA area | | Potential for consequences | | Consider further? |
|-----------------------------|-----------------------|--|--|------------------------------|--|-------------------|
| | | Feasible/ Not feasible | Comments | Significant/ Not significant | Comments | |
| <i>Roestelia fenzeliana</i> | rust disease | Feasible | Apple cited as the host of <i>R. fenzeliana</i> in Shaanxi of China (Farr <i>et al.</i> 2008) referring to a book edited by Zhuang (2005). The climate conditions in parts of Australia are similar to those of Shaanxi. | Not Significant | Apple cited as the host of <i>R. fenzeliana</i> in Shaanxi of China (Farr <i>et al.</i> 2008) referring to a book edited by Zhuang (2005). Literature search of the databases including the China National Knowledge Infrastructure (CNKI: www.global.cnki.net) found no publications of <i>R. fenzeliana</i> associated with apple fruit. Lack of reports on <i>R. fenzeliana</i> as a disease of apple suggested that this pathogen is not an economically significant pest of apple trees. | No |
| <i>Truncatella hartigii</i> | truncatella leaf spot | Feasible | Suitable hosts, including apple and conifer, are present in Australia. It has been reported to be a seedborne pathogen of apple (Chaudhary <i>et al.</i> 1987). | Significant | <i>Truncatella hartigii</i> is a significant pathogen of conifers (Vujanovic <i>et al.</i> 2000). | Yes |

| Scientific name | Common name | Potential for establishment and spread in the PRA area | | Potential for consequences | | Consider further? |
|--|---|--|--|------------------------------|--|-------------------|
| | | Feasible/ Not feasible | Comments | Significant/ Not significant | Comments | |
| <p>Fungi associated with sooty blotch and flyspeck complex (SBFS):</p> <p><i>Dissoconium mali</i></p> <p><i>Dissoconium multiseptatae</i></p> <p><i>Pseudocercospora</i> sp.</p> <p><i>Paraconiothyrium</i> sp.</p> <p><i>Passalora</i> sp.</p> <p><i>Pseudocercospora</i> sp.</p> <p><i>Stenella</i> sp.</p> <p><i>Stomiopeltis</i> spp.</p> <p><i>Strelitziana mali</i></p> <p><i>Wallemia longxianensis</i></p> <p><i>Wallemia qiangyangensis</i></p> <p><i>Wallemia sebi</i></p> <p><i>Xenostigmata</i> sp.</p> <p><i>Zygophiala taiyuensis</i></p> <p><i>Zygophiala liquanensis</i></p> | <p>sooty blotch and flyspeck diseases</p> | <p>Feasible</p> | <p>Sooty blotch and flyspeck (SBFS) caused by a group of fungi are late-season blemishes on the cuticle of apples and pears in humid regions worldwide (Batzer <i>et al.</i> 2008; Zhang 2007; Zhang 2006). Environments with climates similar to these areas exist in various parts of Australia suggesting that fungi associated with SBFS have the potential to establish and spread in Australia.</p> <p><i>Schizothyrium pomi</i> which causes flyspeck on apples and pears is widely established in Australia (Letham 1995).</p> <p>Some fungi of the SBFS have very wide range of hosts. For example, the host plants of <i>Z. jamaicensis</i> include 120 species in 44 families of seed plants including <i>Malus</i> throughout temperate and tropical regions (Zhang 2007; Zhang 2006).</p> | <p>Significant</p> | <p>Sooty blotch and flyspeck are two of the most common diseases of pome fruits in many moist, temperate growing regions of the world caused by a group of fungi.</p> <p>In the USA, the diseases are most severe on apples in the southeast, but they occur throughout the apple growing regions in the east and midwest. Although the diseases do not result in a yield loss, they cause considerable economic loss to growers of fresh market because of reduced fruit quality (Williamson and Sutton 2000; Sutton 1990). In the southeastern USA, virtually all of the apple crop would be affected each year if fungicides were not applied. Even with the use of fungicides, losses of 25% or more are reported in individual orchards in some years.</p> <p>In China, the diseases also cause significant loss to growers. In extreme years, the loss can be up to 90% in some orchards (Zhang 2007).</p> | <p>Yes</p> |

| Scientific name | Common name | Potential for establishment and spread in the PRA area | | Potential for consequences | | Consider further? |
|---------------------------------|---------------------------------------|--|--|------------------------------|--|-------------------|
| | | Feasible/ Not feasible | Comments | Significant/ Not significant | Comments | |
| Viroids | | | | | | |
| <i>Apple scar skin viroid</i> | apple dimple, pear rusty skin disease | Feasible | <p><i>Apple scar skin viroid</i> is present in main apple production areas in China. It is also present in other countries in Asia, Europe and North America. The climate conditions in many parts of Australia are similar to these countries.</p> <p>It is generally agreed that the means of transmission of <i>Apple scar skin viroid</i> is by grafting and contaminated pruning equipment (Grove <i>et al.</i> 2003; Han <i>et al.</i> 2003).</p> <p>A recent paper suggested <i>Apple scar skin viroid</i> can be transmitted from infected apple seeds to the seedlings germinated from these seeds, with a 7.7% transmission rate (Kim <i>et al.</i> 2006).</p> | Significant | <p>Apple scar skin caused by <i>Apple scar skin viroid</i> is one of the most destructive diseases in Korea (Kim <i>et al.</i> 2006).</p> <p>According to surveys conducted in the 1950s in China, in some counties of Shanxi, Hebei and Shaanxi provinces, more than 50% of apple trees were affected with this disease (Han <i>et al.</i> 2003).</p> | Yes |
| Tobacco necrosis viruses | tobacco necrosis viruses | Feasible | TNV strains are established in Australia (Teakle 1988). TNVs infect common vegetable crop plants, ornamental plants and tree species (CAB International 2009; Brunt and Teakle 1996). TNVs are transmitted by <i>Olpidium</i> spp. (Sasaya and Koganezawa 2006; Rochon <i>et al.</i> 2004) and these vectors occur in Australia (Maccarone <i>et al.</i> 2008; McDougall 2006). | Significant | TNVs cause rusty root disease of carrot, Augusta disease of tulip, stipple streak disease of common bean, necrosis diseases of cabbage, cucumber, soybean and zucchini and ABC disease of potato (Zitikaitė and Staniulis 2009; Xi <i>et al.</i> 2008; Smith <i>et al.</i> 1988; Uyemoto 1981). | Yes |

| Scientific name | Common name | Potential for establishment and spread in the PRA area | | Potential for consequences | | Consider further? |
|-------------------------------------|-----------------|--|--|------------------------------|----------|-------------------|
| | | Feasible/ Not feasible | Comments | Significant/ Not significant | Comments | |
| <i>Tomato ringspot virus</i> | tomato ringspot | Not feasible | No record of seed transmission of <i>Tomato ringspot virus</i> on apple found. <i>Tomato ringspot virus</i> can be transmitted by <i>Xiphinema</i> and <i>Longidorus</i> nematodes (Georgi 1988). These nematodes feed on live roots. No evidence of these vectors feeding on discarded apple. | | | No |

Appendix B. Additional data for quarantine pests

| ARTHROPODS | |
|------------------------|--|
| Quarantine pest | <i>Amphitetranychus viennensis</i> (Zacher, 1920) |
| Synonyms | <i>Tetranychus</i> (<i>Epitetranychus</i>) <i>viennensis</i> Zacher, 1920. <i>Tetranychus crataegi</i> Hirst, 1920 <i>Apotetranychus longipenis</i> Ugarov and Nikolskii, 1937, <i>Apotetranychus virginis</i> Ugarov, 1937 See Bolland <i>et al.</i> (1998) for complete list of synonyms. |
| Common name(s) | hawthorn spider mite |
| Main hosts | <i>Amelanchier canadensis</i> (thicket serviceberry), <i>Arachis hypogaea</i> (groundnut), <i>Chaenomeles</i> (flowering quince), <i>Corylus avellana</i> (hazel), <i>Crataegus azarolus</i> , <i>Crataegus monogyna</i> (hawthorn), <i>Cydonia oblonga</i> (quince), <i>Deutzia</i> , <i>Ficus carica</i> (fig), <i>Fragaria</i> (strawberry), <i>Gossypium</i> (cotton), <i>Malus domestica</i> (apple), <i>Malus toringo</i> , <i>Mespilus</i> , <i>Plumeria</i> (frangipani), <i>Prunus avium</i> (cherry), <i>Prunus cerasus</i> (sour cherry), <i>Prunus campanulata</i> , <i>Prunus cerasifera</i> (myrobalan plum), <i>Prunus divaricata</i> , <i>Prunus domestica</i> (plum), <i>Prunus dulcis</i> (almond), <i>Prunus mume</i> (Japanese apricot), <i>Prunus persica</i> (peach), <i>Prunus pseudocerasus</i> , <i>Prunus salicina</i> (Japanese plum), <i>Prunus spinosa</i> (blackthorn), <i>Prunus yedoensis</i> , <i>Pyrus</i> (pear), <i>Pyrus communis</i> (European pear), <i>Pyrus pyrifolia</i> (Oriental pear), <i>Quercus mongolica</i> ssp. <i>mongolica</i> , <i>Rubus idaeus</i> (raspberry), <i>Sorbus aucuparia</i> (mountain ash), <i>Tilia</i> sp. (linden) (CAB International 2007a). |
| Distribution | Presence in Australia: no records found. Presence in China: Anhui, Gansu, Henan, Jiangsu, Liaoning, Ningxia, Shandong, Taiwan, Xinjiang (CAB International 2007a; AQSIQ 2005). Presence elsewhere: Austria, Azerbaijan, Bulgaria, Georgia (Republic), Germany, Hungary, Iran, Japan, North Korea, Pakistan, Poland, Romania, Russian Federation, Spain, Sweden, Turkey, Ukraine, United Kingdom, Uzbekistan (CAB International 2007a). |
| Quarantine pest | <i>Cenopalpus pulcher</i> Canestrini and Franzago |
| Synonyms | <i>Brevipalpus pulcher</i> <i>Brevipalpus pyri</i> <i>Caligonus pulcher</i> <i>Cenopalpus oudemansi</i> <i>Cenopalpus pyri</i> <i>Tenuipalpus oudemansi</i> <i>Brevipalpus oudemansi</i> (Geijskes 1939) (USDA-APHIS 2000b) |
| Common name(s) | flat scarlet mite |
| Main hosts | <i>Cydonia oblonga</i> (quince), <i>Malus</i> sp. (apple), <i>Prunus domestica</i> (prune), <i>Pyrus communis</i> (pear), <i>Eriobotrya</i> sp. (loquat), <i>Juglans</i> sp. (walnut), <i>Plantanus orientalis</i> (Oriental sycamore), <i>Salix</i> sp. (willow) (Pritchard and Baker, 1958), <i>Prunus armeniaca</i> (apricot), <i>Punica granatum</i> (pomegranate) (USDA-APHIS 2000b) |

| | |
|------------------------|---|
| Distribution | <p>Presence in Australia: no records found.</p> <p>Presence in China: Yes (Wang 1981)</p> <p>Presence elsewhere: The USA, Egypt, Turkey, England, Denmark, The Netherlands, Portugal, Austria, Bulgaria, Libya, India, Iraq, Iran, Syria, Germany, Italy, Sicily, Cyprus, Lebanon, Algeria, Israel, Afghanistan, Georgia, USSR, Crimea, Transcaucasia and Soviet Central Asia (USDA-APHIS 2000b)</p> |
| Quarantine pest | <i>Rhynchites auratus</i> (Scopoli, 1763) |
| Synonyms | <p><i>Curculio auratus</i> Scopoli, 1763;</p> <p><i>Epirhynchites auratus</i> (Scopoli, 1763).</p> |
| Common name(s) | Korean pear weevil, apricot weevil, pear attelabid. |
| Main hosts | <p><i>Malus</i> (apple), <i>Prunus avium</i> (cherry) (CAB International 2007a; Kutinkova and Andreev 2004; Booth <i>et al.</i> 1990; Korchagin 1987; Zaitsev 1984), <i>Prunus domestica</i> (plum) (Booth <i>et al.</i> 1990), <i>Prunus padus</i> (Leather 1996), <i>Prunus spinosa</i> (blackthorn) (INRA 2006), <i>Pyrus</i> (pear) (Bashkatova <i>et al.</i> 1983).</p> |
| Distribution | <p>Presence in Australia: no records found.</p> <p>Presence in China: Xinjiang (AQSIQ 2008c; Su and Sun 1999).</p> <p>Presence elsewhere: Bulgaria (Kutinkova and Andreev 2004), Former USSR (CAB International 2007a), Italy (unconfirmed) (CAB International 2007a), Siberia (Booth <i>et al.</i> 1990; Bashkatova <i>et al.</i> 1983), United Kingdom (Leather 1996).</p> |
| Quarantine pest | <i>Rhynchites heros</i> Roelofs, 1874 |
| Synonyms | <p><i>Rhynchites foveipennis</i> (Fairmaire, 1888)</p> <p><i>Rhynchites coreanus</i>, (Legalov 2004; Podleckis 2003).</p> |
| Common name(s) | Japanese pear weevil, fruit weevil, peach weevil, peach curculio. |
| Main hosts | <p><i>Cydonia oblonga</i> (quince), <i>Eriobotrya japonica</i> (loquat) (USDA 1958a), <i>Ficus carica</i> (fig) (Nomura and Hirano 2005; Podleckis 2003; USDA 1958a), <i>Malus pumila</i> (apple) (Wan <i>et al.</i> 2006; Wan <i>et al.</i> 2006; Podleckis 2003; CIQSA 2001c; USDA 1958a), <i>Prunus persicae</i> (peach) (Podleckis 2003), <i>Prunus</i> spp. (stone fruit) (Podleckis 2003), <i>Pyrus</i> spp. (pear) (Nomura and Hirano 2005; Podleckis 2003; USDA 1958a).</p> |
| Distribution | <p>Presence in Australia: no records found.</p> <p>Presence in China: Beijing, Fujian, Hebei, Helongjiang, Hubei, Jilin, Liaoning, Shandong, Shanxi, Sichuan, Zhejiang, Yunnan (Chao and Lee 1966), Henan (Wan <i>et al.</i> 2006).</p> <p>Presence elsewhere: Japan (Lee and Morimoto 1988; Yoshizawa 1985), Korea (Hanson 1963; USDA 1958a).</p> |

| Quarantine pest | <i>Bactrocera dorsalis</i> (Hendel, 1912) |
|-----------------------|--|
| Synonyms | <p><i>Dacus dorsalis</i> Hendel, 1912</p> <p><i>Bactrocera conformis</i> Doleschall, 1858 (preocc.)</p> <p><i>Chaetodacus dorsalis</i> (Hendel, 1912)</p> <p><i>Chaetodacus ferrugineus dorsalis</i> (Hendel, 1912),</p> <p><i>Chaetodacus ferrugineus okinawanus</i> (Shiraki, 1933),</p> <p><i>Musca ferruginea</i> (Fabricius, 1794).</p> <p><i>Musca ferruginea</i> Fabricius, 1794 (preocc.),</p> <p><i>Strumeta dorsalis</i> (Hendel, 1912).</p> |
| Common name(s) | Oriental fruit fly |
| Main hosts | <p><i>Aegle marmelos</i> (bael fruit), <i>Anacardium occidentale</i> (cashew), <i>Annona reticulata</i> (bullock's heart), <i>A. squamosa</i> (sugar apple), <i>Areca catechu</i> (betelnut palm), <i>Artocarpus altilis</i> (breadfruit), <i>A. heterophyllus</i> (jackfruit), <i>Capsicum annuum</i> (bell pepper), <i>Chrysophyllum cainito</i> (caimito), <i>Citrus maxima</i> (pummelo), <i>C. reticulata</i> (mandarin orange), <i>Coffea arabica</i> (arabica coffee), <i>Cucumis melo</i> (melon), <i>C. sativus</i> (cucumber), <i>Dimocarpus longan</i> (longan), <i>Ficus racemosa</i> (cluster fig), <i>Litchi chinensis</i> (lychee), <i>Malus pumila</i> (apple), <i>Mangifera foetida</i> (bachang mango), <i>M. indica</i> (mango), <i>Manilkara zapota</i> (sapodilla), <i>Mimusops elengi</i> (Asian bulletwood), <i>Momordica charantia</i> (bitter gourd), <i>Muntingia calabura</i> (Jamaican cherry), <i>Musa</i> sp. (banana), <i>Nephelium lappaceum</i> (rambutan), <i>Persea americana</i> (avocado), <i>Prunus armeniaca</i> (apricot), <i>P. avium</i> (gean), <i>P. cerasus</i> (sour cherry), <i>P. domestica</i> (plum, prune), <i>P. mume</i> (Japanese apricot), <i>P. persica</i> (peach), <i>Psidium guajava</i> (guava), <i>Punica granatum</i> (pomegranate), <i>Pyrus communis</i> (pear), <i>Syzygium aqueum</i> (water apple), <i>S. aromaticum</i> (clove), <i>S. cumini</i> (jambolan), <i>S. jambos</i> (rose apple), <i>S. malaccense</i> (Malay apple), <i>S. samarangense</i> (wax apple), <i>Terminalia catappa</i> (Indian almond), <i>Ziziphus jujuba</i> (jujube), <i>Z. mauritiana</i> (Chinese date) (Allwood <i>et al.</i> 1999; Tsuruta <i>et al.</i> 1997).</p> |
| Distribution | <p>Presence in Australia: no records found.</p> <p>Presence in China: Northernmost border of <i>B. dorsalis</i> distribution is 30 (\pm 2) degrees north latitude in China (CAB International 2007a; Wu 2005; Drew and Hancock 1994).</p> <p>Presence elsewhere: Bangladesh, Bhutan, Cambodia, Guam, Japan, Laos, Myanmar, Nauru, Nepal, Pakistan, Sri Lanka, Taiwan, Thailand, USA (California, Florida and Hawaii), Vietnam (CAB International 2007a; Drew and Hancock 1994; Waterhouse 1993).</p> |

| | |
|------------------------|---|
| Quarantine pest | <i>Diaspidiotus ostreaeformis</i> (Curtis, 1843) |
| Synonyms | <p><i>Aspidiotus ostreaeformis</i> Curtis, 1843</p> <p><i>Aspidiotus betulae</i> Baerensprung, 1849</p> <p><i>Aspidiotus hippocastani</i> Signoret, 1869</p> <p><i>Aspidiotus ostreaeformis oblongus</i> Goethe, 1899</p> <p><i>Aspidiotus oxyacanthae</i> Signoret, 1869</p> <p><i>Quadraspidiotus williamsi</i> Takagi. 1958.</p> <p>See Ben-Dov (2006a) for complete list of synonyms.</p> |
| Common name(s) | oystershell scale |
| Main hosts | <p><i>Acer</i> spp. (maple), <i>Aesculus</i> spp. (chestnut), <i>Alnus</i> spp. (alder) (Zahradnik 1990); <i>Betula</i> spp. (birch), <i>Carpinus betulus</i> (European hornbeam), <i>Fagus sylvatica</i> (beech), <i>Fraxinus</i> spp. (ash), <i>Malus domestica</i> (apple), <i>Populus</i> spp. (poplar), <i>Prunus amygdalus</i> (almond), <i>Prunus avium</i> (cherry), <i>Prunus domestica</i> (European plum), <i>Prunus persica</i> (peach), <i>Prunus persica</i> var. <i>nucipersica</i> (nectarine), <i>Prunus salicina</i> (Japanese plum), <i>Pyrus communis</i> (pear), <i>Quercus</i> spp. (oak), <i>Salix</i> spp. (willow), <i>Sorbus</i> spp. (ash), <i>Tilia</i> spp. (linden), <i>Ulmus</i> spp. (elm) (Poole et al. 2001).</p> |
| Distribution | <p>Presence in Australia: limited distribution, present in South Australia, Tasmania, Victoria (CAB International 2007a), but not in Western Australia (Poole 2008).</p> <p>Presence in China: Anhui, Heilongjiang, Liaoning, Nei Menggu, Shaanxi, Shanxi, Xinjiang (CAB International 2007a).</p> <p>Presence elsewhere: Africa, Asia, Europe, New Zealand, North and South America (CAB International 2007a).</p> |
| Quarantine pest | <i>Lopholeucaspis japonica</i> (Cockerell, 1897) |
| Synonyms | <p><i>Leucaspis japonicus</i> Cockerell, 1897</p> <p><i>Leucaspis japonica darwiniensis</i> Green, 1916</p> <p><i>Lopholeucaspis menoni</i> Borchsenius, 1964</p> <p>For complete list see Ben-Dov et al (2006a).</p> |
| Common name(s) | pear white scale, Japanese maple scale |
| Main hosts | <p>The species has been reported from 39 genera and 58 species of host plant, including:</p> <p><i>Acer</i> sp.(maples), <i>Alnus</i> sp. (alders), <i>Citrus</i> sp.(citrus), <i>Cytisus</i> sp. (common broom), <i>Diospyros kaki</i> (persimmon), <i>Ficus</i> sp. (fig), <i>Magnolia souleana</i>, <i>Ligustrum</i> sp. (privet), <i>Malus</i> sp. (apple), <i>Poncirus trifoliata</i> (trifoliate orange), <i>Prunus</i> sp., <i>Pyracantha</i> sp. (firethorn), <i>Pyrus serotina</i> (Chinese pear), <i>Rhododendron</i> sp., <i>Rosa</i> sp., <i>Tilia miqueliana</i> (linden), <i>Ulmus</i> sp. (elm), <i>Vitis vinifera</i> (grape).</p> <p>For complete list see Ben-Dov et al (2006a).</p> |
| Distribution | <p>Presence in Australia: Reported in Northern Territory many years ago, but not established (CABI/EPPO 2007b).</p> <p>Presence in China: Anhui, Fujian, Guangdong, Guangxi, Hubei, Hunan, Jiangsu, Jiangxi, Shanxi, Sichuan, Zhejiang (CAB International 2008).</p> <p>Presence elsewhere: USA, Afghanistan, Iran, Japan and Russia (CABI/EPPO 2007b).</p> |

| | |
|------------------------|---|
| Quarantine pest | <i>Parlatoria oleae</i> (Colvée, 1880) |
| Synonyms | <i>Diaspis oleae</i> Colvée, 1880 For complete list of synonyms refer to Ben-Dov et al. (2006a). |
| Common name(s) | olive scale, olive parlatoria scale, |
| Main hosts | <i>Malus domestica</i> (apple), <i>Olea europaea</i> subsp. <i>europaea</i> (olive), <i>Pistacia vera</i> (pistachio), <i>Prunus amygdalus</i> , <i>Prunus domestica</i> (plum), <i>Prunus persica</i> (peach), <i>Prunus salicina</i> (Japanese plum), <i>Ribes uva-crispa</i> (gooseberry), <i>Rosa</i> spp. (roses), <i>Ziziphus jujuba</i> (common jujube) (CAB International 2007b). For complete list of host plants refer to Ben-Dov et al. (2006a). |
| Distribution | Presence in Australia: New South Wales and Queensland (Ben-Dov et al. 2006a), but not in Western Australia (DAFWA 2009). Presence in China: Anhui, Fujian, Guandong, Guangxi, Guizhou, Jiangsu, Jiangxi, Sichuan, Shaanxi, Xinjiang, Yunnan, Zhejiang (Ben-Dov et al. 2006a). Presence elsewhere: Afghanistan, Algeria, Argentina, Armenia, Bangladesh, Belgium, Bolivia, Brazil, Bulgaria, Canary Islands, Cayman Islands, Crete, Cyprus, Czechoslovakia, Egypt, Ethiopia, France, Germany, Greece, Republic of Georgia, Hungary, India, Iran, Iraq, Israel, Italy, Jordan, Kazakhstan, Kenya, Lebanon, Libya, Malta, Mexico, Morocco, Portugal, Pakistan, Russian Federation, Romania, Sardinia, Saudi Arabia, Sicily, Spain, Sri Lanka, Syria, Sudan, Taiwan, Turkey, Tunisia, Turkmenistan, Tajikistan, UK, Ukraine, USA, Uzbekistan, Yugoslavia (former) (Ben-Dov et al. 2006a). |
| Quarantine pest | <i>Parlatoria yanyuanensis</i> Tang, 1984 |
| Synonyms | None |
| Common name(s) | Yanyuan scale |
| Main hosts | <i>Malus pumila</i> (apple), <i>Chaenomeles cathayensis</i> (Chinese quince), <i>Broussonetia papyrifera</i> (paper mulberry), and <i>Pyrus</i> sp. (pear) (Ben-Dov et al. 2006a; Lu and Wu 1988). |
| Distribution | Presence in Australia: no records found. Presence in China: Sichuan, Yunnan (Ben-Dov et al. 2006a; Lu and Wu 1988). Presence elsewhere: no records found. |

| Quarantine pest | <i>Phenacoccus aceris</i> (Signoret, 1875) |
|-----------------------|--|
| Synonyms | <p> <i>Pseudococcus mespili</i> Signoret, 1875 <i>Pseudococcus aceris</i> Signoret, 1875 <i>Pseudococcus aesculi</i> Signoret, 1875 <i>Pseudococcus hederæ</i> Signoret, 1875 <i>Pseudococcus platani</i> Signoret, 1875 <i>Pseudococcus ulicis</i> Douglas, 1888 <i>Pseudococcus ulmi</i> Douglas, 1888 <i>Pseudococcus quercus</i> Douglas, 1890 <i>Pseudococcus socius</i> Newstead, 1892 <i>Dactylopius vagabundus</i> Reh, 1903 <i>Phenacoccus polyphagus</i> Borchsenius, 1949 <i>Phenacoccus gorgasalicus</i> Hadzibejli, 1960 <i>Phenacoccus prunicola</i> Borchsenius, 1962 (Ben-Dov 2006c) </p> |
| Common name(s) | apple mealybug, polyphagous tree mealybug. |
| Main hosts | <p> <i>Cydonia</i> sp. (quince), <i>Crataegus</i> sp. (hawthorn), <i>Malus</i> sp. (apple), <i>Prunus communis</i> (plum), <i>Pyrus communis</i> (pear), <i>Salix</i> sp. (willow), <i>Vitis vinifera</i> (grape), <i>Ulmus</i> sp. (elm), <i>Ficus carica</i> (fig), <i>Prunus persica</i> (peach), <i>Prunus spinosa</i> (blackthorn) (Ben-Dov 2006c). For complete list of host plants refer to Ben-Dov (2005b). </p> |
| Distribution | <p> Presence in Australia: no records found. Presence in China: Shanxi (Ben-Dov 2006c) Presence elsewhere: Canada, USA, Russia, Bulgaria, Corsica, Czech Republic, Denmark, Germany, Kazakstan, North Korea, South Korea (Ben-Dov 2006c). For complete list refer to Ben-Dov (2005b). </p> |

| Quarantine pest | <i>Pseudococcus calceolariae</i> (Maskell, 1879) |
|-----------------------|---|
| Synonyms | <p><i>Dactylopius calceolariae</i> Maskell, 1879, <i>Erium calceolariae</i> (Maskell, 1879) <i>Dactylopius similans</i> Lidget, 1898 <i>Pseudococcus fragilis</i> Brain, 1912 <i>Pseudococcus citrophilus</i> Clausen, 1915 <i>Pseudococcus gahani</i> Green, 1915. See Ben-Dov (2005b) for complete list of synonyms</p> |
| Common name(s) | citrophilus mealybug, currant mealybug, scarlet mealybug |
| Main hosts | <p><i>Abutilon</i> spp. (maple), <i>Aeonium balsamiferum</i> (cactus), <i>Aguilegia</i> spp. (columbine), <i>Arachis hypogaea</i> (peanut), <i>Brachychiton</i> spp. (flame tree), <i>Brassica</i> spp. (cabbage), <i>Buddleja madagascariensis</i> (smoke bush), <i>Ceanothus</i> spp. (lilac), <i>Chenopodium</i> spp. (goosefoot), <i>Choisya ternata</i> (Mexican orange blossom), <i>Citris paradisi</i> (grapefruit), <i>Citrus cedra</i> (cedrat lemon), <i>Coprosma australis</i> (raurekau), <i>Crataegus</i> spp. (hawthorn), <i>Cydonia oblonga</i> (quince), <i>Daucus carota</i> (carrot), <i>Digitalis</i> spp. (foxglove), <i>Dodonaea viscosa</i> (varnish leaf), <i>Eugenia</i> spp., <i>Exocarpos</i> spp., <i>Ficus</i> spp. (fig), <i>Fragaria</i> spp. (strawberry), <i>Geranium</i> spp. (geranium), <i>Grevillea banksii</i> (grevillea), <i>Hedera helix</i> (common ivy), <i>Helianthus</i> spp. (sunflower), <i>Heliotropium arborescens</i> (fragrant heliotrope), <i>Hibiscus</i> spp. (hibiscus), <i>Juglans regia</i> (walnut), <i>Kalanchoe beharensis</i> (kalanchoe), <i>Laburnum</i> spp. (laburnum), <i>Lavandula stoechas</i> (French lavender), <i>Ligustrum</i> spp. (privet), <i>Lolium</i> spp., <i>Malus pumila</i> (apple), <i>Malva</i> spp. (mallow), <i>Melilotus</i> spp. (melilot), <i>Nerium oleander</i> (oleander), <i>Pelargonium</i> spp. (geranium), <i>Pinus radiata</i> (pine), <i>Pisum sativum</i> (garden pea), <i>Pittosporum tobira</i> (mock orange), <i>Polyscias</i> spp. (ming aralia), <i>Prunus</i> spp. (stone fruit), <i>Pyrus communis</i> (pear), <i>Rheum rhaponticum</i> (rhubarb), <i>Rhododendron</i> spp. (rhododendron), <i>Ribes sanguineum</i> spp. (red-flowering currant), <i>Rosa</i> spp. (rose), <i>Rubus</i> spp. (berry), <i>Schinus molle</i> (California pepper tree), <i>Sechium edule</i> (chayote), <i>Solanum tuberosum</i> (potato), <i>Sophora microphylla</i> (weeping kowhai), <i>Theobroma cacao</i> (cacao), <i>Vitis vinifera</i> (grapevine), <i>Welwitschia mirabilis</i> (tree tumbo) (Ben-Dov 2005b).</p> |
| Distribution | <p>Presence in Australia: New South Wales, Queensland, South Australia, Tasmania and Victoria (Ben-Dov 2005a), but not in Western Australia (Poole 2008).</p> <p>Presence in China: Taiwan and southeastern parts of China (AQSIQ 2008c; Tang 1992). <i>Pseudococcus gahani</i>, a synonym of <i>P. calceolariae</i>, was reported in southern and northern China, including Hebei and Henan provinces (Wang 1985).</p> <p>Presence elsewhere: Africa, Asia, Europe, New Zealand, North and South America (Ben-Dov 2005a).</p> |

| Quarantine pest | <i>Pseudococcus comstocki</i> (Kuwana, 1902) |
|-----------------|--|
| Synonyms | <i>Dactylopius comstocki</i> Kuwana, 1902 |
| Common name(s) | Comstock's mealybug |
| Main hosts | <p><i>Aesculus</i> spp. (horse chestnut), <i>Aglaia odorata</i> (Chinese perfume tree), <i>Alnus japonica</i> (Japanese alder), <i>Amaryllis vittate</i>, <i>Artemisia</i>, <i>Buxus microphylla</i> (littelleaf boxwood), <i>Camellia japonica</i> (camellia), <i>Castanea</i> (chestnut), <i>Catalpa</i> (northern catalpa), <i>Celtis willdenowiana</i> (enoki), <i>Cinnamomum camphorae</i> (camphor tree), <i>Citrus</i> (citrus), <i>Crassula tetragona</i> (miniature pine tree), <i>Cydonia oblonga</i> (quince), <i>Cydonia sinensis</i> (Chinese quince), <i>Deutzia parviflora typical</i> (gaura), <i>Dieffenbachia picta</i> (dumb cane), <i>Erythrina indica</i> (rainbow eucalyptus), <i>Euonymus alatus</i> (winged euonymus), <i>Fatsia japonica</i> (Japanese aralia), <i>Ficus carica</i> (fig), <i>Fiwa japonica</i>, <i>Forsythia koreana</i> (forsythia), <i>Gardenia jasminoides</i> (gardenia), <i>Ginkgo biloba</i> (ginkgo), <i>Hydrangea</i> (hydrangea), <i>Ilex cornuta</i> (Chinese holly), <i>Ilex crenata microphylla</i> (Korean gem), <i>Krauhnia</i>, <i>Lagerstroemia indica</i> (crepe myrtle), <i>Ligustrum ibota angustifolium</i>, <i>Lonicera</i> (honeysuckle), <i>Loranthus</i> (mistletoe), <i>Malus pumila</i> (paradise apple), <i>Malus sylvestris</i> (crab apple), <i>Masakia japonica</i> (Japanese euonymus), <i>Monstera deliciosa</i> (monstera), <i>Morus alba</i> (white mulberry), <i>Musa</i> (bananas), <i>Nephelium lappaceum</i> (rambutan), <i>Opuntia dillenii</i> (prickly pear), <i>Orixa japonica</i> (Japanese orixa), <i>Pandanus</i> (screw pines), <i>Persica vulgaris</i> (peach), <i>Pinus thunbergiana</i> (Japanese black pine), <i>Populus</i> (poplar), <i>Prunus mume</i> (Japanese apricot), <i>Punica granatum</i> (pomegranate), <i>Pyrus communis</i> (European pear), <i>Pyrus serotina culta</i> (black cherry), <i>Rhamnus</i> (buckthorn), <i>Rhododendron mucronulatum</i> (Korean Rhododendron), <i>Sasamorphia</i> (bamboo), <i>Taxus</i> (yew), <i>Torreya nucifera</i> (Japanese torreya), <i>Trema orientalis</i> (nalita), <i>Viburnum awabucki</i> (acacia confuse), <i>Zinnia elegans</i> (zinnia) (Ben-Dov 2005b).</p> |
| Distribution | <p>Presence in Australia: no records found.</p> <p>Presence in China: Beijing, Fujian, Guangdong, Hong Kong, Hunan, Inner Mongolia, Xizhang, Zhejiang (CAB International 2007a).</p> <p>Presence elsewhere: Afghanistan, Argentina, Armenia, Azerbaijan, Brazil, Canada, Canary Islands, Federated States of Micronesia, Indonesia, Iran, Italy, Japan, Kampuchea, Kazakhstan, Madeira Islands, Malaysia, Mexico, Northern Mariana Islands, Russia, Saint Helena, South Korea, Sri Lanka, Tajikistan, Turkmenistan, USA, Uzbekistan, Vietnam (Ben-Dov 2005b).</p> |

| Quarantine pest | <i>Adoxophyes orana</i> (Fischer von Roeslerstamm, 1834) |
|-----------------|--|
| Synonyms | <i>Tortrix orana</i> Fischer von Roeslerstamm 1834 See Yasuda (1998) for list of more synonyms. |
| Common name(s) | summer fruit tortrix moth, smaller tea tortrix, summer fruit tortrix moth. |
| Main hosts | <p><i>Adoxophyes orana</i> is polyphagous, with hosts in more than 50 different plant species from multiple families (CAB International 2007a; Zhou and Deng 2005; Davis <i>et al.</i> 2005). Although many hosts are un-cultivated, <i>A. orana</i> often feeds on apple, pear and other rosaceous hosts (INRA 2006; Davis <i>et al.</i> 2005).</p> <p>Hosts include: <i>Acer campestre</i> (common maple), <i>Alnus</i> spp. (alder), <i>Arachis hypogaea</i>, <i>Beta</i> sp. <i>Betula</i> spp. (birch), <i>Camellia sinensis</i> (tea), <i>Carpinus betulus</i> (European hornbeam), <i>Castanea crenata</i>, <i>Castanopsis fissa</i>, <i>Citrus</i> sp., <i>Corylus</i> sp. (Carter 1984), <i>Corylus avellana</i>, <i>Crataegus</i> spp., <i>Cydonia oblonga</i> (quince), <i>Diospyros kaki</i>, <i>Eriobotrya japonica</i>, <i>Fagus sylvatica</i> (common beech), <i>Forsythia suspensa</i>, <i>Glycine max</i>, <i>Gossypium herbaceum</i> (Arabian cotton), <i>Humulus</i> spp, <i>Laburnum anagyroides</i> (laburnum), <i>Ligustrum</i> spp. (privet), <i>Litchi chinensis</i> (lychee), <i>Lithocarpus glaber</i>, <i>Lonicera periclymenum</i>, <i>Lonicera xylosteum</i> (fly honeysuckle), <i>Malus baccata</i>, <i>Malus pumila</i> (apple) <i>Medicago</i> spp., <i>Morus alba</i>, <i>Pistacia lentiscus</i> (mastic tree), <i>Populus</i> spp. (poplar), <i>Prunus armeniaca</i> (apricot), <i>Prunus avium</i> (cherry), <i>Prunus domestica</i> (plum), <i>Prunus padus</i> (bird cherry), <i>Prunus persica</i> (peach), <i>Prunus triloba</i> (flowering almond), <i>Pyrus communis</i> (European pear) (Carter 1984), <i>Quercus acutissima</i>, <i>Ribes nigrum</i> (blackcurrant), <i>Ribes rubrum</i> (red currant), <i>Ribes uva-crispa</i> (gooseberry), <i>Rosa</i> spp. (rose), <i>Rosa canina</i> (dog rose), <i>Rubus</i> sp., <i>Rubus fruticosus</i> (blackberry), <i>Rubus idaeus</i> (raspberry), <i>Salix caprea</i> (great willow), <i>Salix schwerinii</i> (basket willow) (Carter 1984), <i>Solanum dulcamara</i>, <i>Symphoricarpos albus</i> (common snowberry), <i>Syringa vulgaris</i> (lilac), <i>Tilia</i> spp., <i>Ulmus minor</i> (European field elm), <i>Vaccinium</i> spp. (blueberry). (Davis <i>et al.</i> 2005; Robinson <i>et al.</i> 2004; Carter 1984) (Cross 1997)</p> |
| Distribution | <p>Presence in Australia: no records found.</p> <p>Presence in China: all parts of China except Tibet (Wan <i>et al.</i> 2006; Ma 2006; Wu <i>et al.</i> 1999; Qiu <i>et al.</i> 1999; Cheng <i>et al.</i> 1998; He <i>et al.</i> 1996; Fu and Huang 1990; Feng <i>et al.</i> 1988; Carter 1984; Wang 1983).</p> <p>Presence elsewhere: Armenia, Austria, Azerbaijan, Belgium, Bulgaria, Denmark, England (Carter 1984), Finland, France, Georgia (Republic), Germany (CAB International 2007a), Greece (Milonas and Savopoulou-Soultani 2004), Hong Kong, Hungary, Italy, Japan (Hokkaido, Honshu, Kyushu, Shikoku) (Sakamaki and Hayakawa 2004; Yasuda 1998; Carter 1984), Korea (Republic), Netherlands, Norway, Poland, Romania, Russian Federation, Serbia and Montenegro, Spain, Sweden, Switzerland, Ukraine, United Kingdom (CAB International 2007a; Cross 1997; Carter 1984), Yugoslavia (former) (Injac 1983).</p> |

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|------------------------|---|
| Quarantine pest | <i>Argyresthia assimilis</i> Moriuti, 1977 |
| Synonyms | None |
| Common name(s) | apple fruit moth |
| Main hosts | <i>Malus</i> sp (apple and Chinese crab apple) (Sun and Ma 1999). |
| Distribution | Presence in Australia: no records found. Presence in China: Shaanxi, Gansu (Sun and Ma 1999). Presence elsewhere: no records found. |
| Quarantine pest | <i>Carpocapsa sasakii</i> Matsumura, 1900 |
| Synonyms | <i>Carpocapsa niponensis</i> Walsingham 1900 [misidentification] The peach fruit moth causing damage to rosaceous fruit in the Asian Far East has been known as <i>C. niponensis</i> in some recent literature (EPPO/CABI 1996; Savotikov and Smetnik 1995). However, it appears that <i>C. niponensis</i> has been confused with <i>Carpocapsa sasakii</i> but actually has no known economic consequences (Diakonoff 1989). <i>Carpocapsa niponensis</i> has two subspecies: <i>C. niponensis</i> confined to the Asian Far East on Rosaceae, and <i>C. niponensis ottawana</i> confined to Canada on <i>Cornus</i> and <i>Ribes</i> (Davis 1968). All references to <i>C. niponensis</i> as 'peach fruit moth' should be attributed to <i>C. sasakii</i> , which was treated as a synonym of <i>C. niponensis</i> in EPPO/CABI (1996). |
| Common name(s) | peach fruit borer, peach fruit moth |
| Main hosts | <i>Carpocapsa sasakii</i> occurs on a wide range of hosts, particularly from the Rosaceae, but also from other families. It is possible that the published host range to a certain extent confuses <i>C. sasakii</i> with authentic <i>C. niponensis</i> (CAB International 2007a). Hosts include: <i>Aronia arbutifolia</i> (red chokeberry), <i>Chaenomeles japonica</i> (Japanese quince), <i>Cydonia oblonga</i> (quince), <i>Eriobotrya japonica</i> (loquat), <i>Malus</i> (ornamental species), <i>Malus domestica</i> (apple), <i>Malus micromalus</i> , <i>Malus toringo</i> , <i>Phoenix dactylifera</i> (date-palm), <i>Prunus armeniaca</i> (apricot), <i>Prunus avium</i> (cherry), <i>Prunus domestica</i> (plum), <i>Prunus dulcis</i> (almond), <i>Prunus mume</i> (Japanese apricot), <i>Prunus persica</i> (peach), <i>Prunus salicina</i> (Japanese plum), <i>Pyrus</i> (pear), <i>Pyrus communis</i> (European pear), <i>Pyrus pyrifolia</i> (Oriental pear), <i>Ziziphus jujuba</i> (common jujube), <i>Cornus mas</i> (Cornelian cherry), <i>Crataegus</i> spp., <i>Rosa</i> (rose), <i>Sorbus aucuparia</i> (mountain ash) (CAB International 2007a). |
| Distribution | Presence in Australia: no records found. Presence in China: Anhui, Fujian, Guangdong, Hebei, Heilongjiang, Henan, Jiangsu, Jilin, Liaoning, Ningxia, Shaanxi, Shandong, Shanxi and Zhejiang (AQSIQ 2005; CIQSA 2001c; CIQSA 2001a). Presence elsewhere: USSR (former), Japan, South Korea (CAB International 2007a). |

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|------------------------|---|
| Quarantine pest | <i>Cydia pomonella</i> (Linnaeus, 1758) |
| Synonyms | <i>Phalaena pomonella</i> Linnaeus, 1758, <i>Carpocapsa pomonella</i> (Linnaeus, 1758), <i>Carpocapsa pomonana</i> (Treitschke, 1830), <i>Enarmonia pomonella</i> (Linnaeus, 1858), <i>Laspeyresia pomonella</i> (Linnaeus, 1858). |
| Common name(s) | codling moth |
| Main hosts | <i>Castanea dentata</i> (chestnut) (Hely <i>et al.</i> 1982), <i>Citrus sinensis</i> (orange), <i>Crataegus laevigata</i> (hawthorn), <i>Cydonia oblonga</i> (quince), <i>Diospyros kaki</i> (persimmon), <i>Juglans regia</i> (walnut), <i>Malus domestica</i> (apple), <i>Malus sylvestris</i> (crab apple), <i>Prunus armeniaca</i> (apricot), <i>Prunus avium</i> (cherry) (Moffitt <i>et al.</i> 1992), <i>Prunus damson</i> (plum), <i>Prunus domestica</i> (plum) (Yokoyama and Miller 1988), <i>Prunus persica</i> (peach), <i>Prunus persica</i> var. <i>nucipersica</i> (nectarine), <i>Punica granatum</i> (pomegranate) and <i>Pyrus communis</i> (pear) (CAB International 2007a). |
| Distribution | Presence in Australia: New South Wales, Queensland, South Australia, Tasmania and Victoria (CAB International 2007a), but not in Western Australia (Poole 2008). Presence in China: Xinjiang and some areas in neighbouring Gansu Province (AQSIQ 2008c). Presence elsewhere: Afghanistan, Albania, Algeria, Argentina, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bolivia, Brazil, Bulgaria, Canada, Chile, Colombia, Cyprus, Czech Republic, Denmark, Egypt, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, India, Iran, Iraq, Ireland, Israel, Italy, Jordan, Kazakhstan, Kyrgyzstan, Latvia, Lebanon, Libya, Lithuania, Malta, Mauritius, Mexico, Moldova, Morocco, Netherlands, New Zealand, Norway, Pakistan, Peru, Poland, Portugal, Romania, Russian Federation, Slovakia, South Africa, Spain, Sweden, Switzerland, Syria, Tajikistan, Tunisia, Turkey, Turkmenistan, Ukraine, United Kingdom, Uruguay, USA, Uzbekistan, and Yugoslavia (former) (CAB International 2007a). |
| Quarantine pest | <i>Euzophera pyriella</i> Yang, 1994 |
| Synonyms | None |
| Common name(s) | pyralid moth |
| Main hosts | <i>Malus</i> spp. (apple), <i>Pyrus</i> spp. (pear), <i>Ficus</i> spp. (fig), <i>Zizyphus mauritiana</i> (Chinese date), <i>Prunus armeniaca</i> (apricot), <i>Prunus persica</i> (peach) and <i>Populus adenopoda</i> (poplar) (AQSIQ 2008c; Lu and Deng 2003). |
| Distribution | This species was newly described as a pest of pear in China in 1994 (AQSIQ 2008c; Lu and Deng 2003). |

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| Quarantine pest | <i>Grapholita inopinata</i> (Heinrich, 1928) |
| Synonyms | <i>Cydia inopinata</i> (Heinrich, 1928) <i>Laspeyresia prunifoliae</i> (Kozhanchikov, 1953) <i>Grapholita cerasana</i> Kozhanchikov, 1953 (CABI/EPPO 2005) |
| Common name(s) | Manchurian fruit moth |
| Main hosts | <i>Cydonia oblonga</i> (quince) <i>Malus domestica</i> (apple), <i>Malus pallasiana</i> , <i>Prunus persica</i> (peach), <i>Prunus</i> sp., <i>Pyrus</i> (pear) and <i>P. communis</i> (European pear) (CAB International 2008; CABI/EPPO 2005). |
| Distribution | Presence in Australia: no records found Presence in China: Heilongjiang, Hebei, Henan, Jilin, Liaoning, Shaanxi and Shandong provinces (Ma 2006). Presence elsewhere: Japan, Korea, Russia (Ma 2006; CABI/EPPO 2005). |
| Quarantine pest | <i>Grapholita molesta</i> (Busck, 1916) |
| Synonyms | <i>Laspeyresia molesta</i> Busck, 1916; <i>Cydia molesta</i> (Busck, 1916); <i>Carpocapsa molesta</i> (Busck, 1916). |
| Common name(s) | Oriental fruit moth |
| Main hosts | <i>Cotoneaster</i> , <i>Crataegus laevigata</i> (hawthorn), <i>Cydonia oblonga</i> (quince), <i>Eriobotrya japonica</i> (loquat), <i>Malus</i> (ornamental species apple), <i>M. domestica</i> (apple), <i>Prunus</i> (stone fruit), <i>P. amygdalus</i> (almond), <i>P. armeniaca</i> (apricot), <i>P. avium</i> (cherry), <i>P. domestica</i> (plum), <i>P. dulcis</i> (almond), <i>P. persica</i> (peach), <i>P. persica</i> var. <i>nucipersica</i> (nectarine), <i>Pyrus</i> (pear), <i>P. communis</i> (European pear) and <i>Vitis vinifera</i> (grapevine) (CAB International 2007a). |
| Distribution | Presence in Australia: New South Wales, Queensland, South Australia, Tasmania and Victoria (CAB International 2007a), but not Western Australia (Poole 2008). Presence in China: Yes (AQSIQ 2005). Presence elsewhere: Argentina, Armenia, Austria, Azerbaijan, Brazil, Bulgaria, Canada, Chile, Croatia, Czech Republic, France, Georgia, Germany, Greece, Hungary, Italy, Japan, Kazakhstan, South Korea, Malta, Mauritius, Moldova, Morocco, New Zealand, Portugal, Romania, Russian Federation, Slovakia, South Africa, Spain, Switzerland, Turkey, Ukraine, Uruguay, USA, Uzbekistan, Yugoslavia (former) (CAB International 2007a). |

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| Quarantine pest | <i>Spilonota albicana</i> (Motschulsky, 1866) |
| Synonyms | <i>Grapholita albicana</i> Motschulsky, 1866 |
| Common name(s) | white fruit moth, large apple fruit moth |
| Main hosts | <i>Cerasus pseudocerasus</i> , <i>C. tomentose</i> , <i>Corylus heterophylla</i> , <i>Cotoneaster melanocarpus</i> , <i>Crataegus pinnatifida</i> (hawthorn), <i>C. dahurica</i> , <i>C. maximowiczii</i> , <i>Larix leptolepis</i> , <i>L. gmelini</i> , <i>Malus pumila</i> (apple), <i>M. sieboldii</i> , <i>M. mandshurica</i> , <i>M. pallasiana</i> , <i>Photinia glabra</i> , <i>Pyrus</i> sp. (pear), <i>Prunus armeniaca</i> (= <i>Armeniaca vulgaris</i>) (apricot), <i>P. persica</i> (= <i>Amgdalus persica</i>) (peach), <i>P. salicina</i> (plum), <i>P. serrulate</i> var. <i>sponanea</i> , <i>Sorbus amurensis</i> (Hua and Wang 2006; Zhang and Li 2005). |
| Distribution | Presence in Australia: no records found. Presence in China: Fujian, Gansu, Guizhou, Hebei, Heilongjiang, Henan, Hubei, Hunan, Shaanxi, Sichuan, Tianjin and Zhejiang (Zhang and Li 2005). Presence elsewhere: Japan, South Korea, Russian Federation (Hua and Wang 2006; Zhang and Li 2005). |
| PATHOGENS | |
| Quarantine pest | <i>Cryptosporiopsis curvispora</i> (Peck) Gremmen |
| Synonyms | <i>Neofabraea malicorticis</i> H. Jacks. <i>Cryptosporiopsis malicorticis</i> (Cordley) Nannf. <i>Gloeosporium malicorticis</i> Cordley <i>Macrophoma curvispora</i> Peck <i>Pezicula malicorticis</i> (H. Jacks.) Nannf. |
| Common name(s) | bull's eye rot, anthracnose |
| Main hosts | <i>Amelanchier pallida</i> , <i>Chaenomeles</i> sp., <i>Crataegus</i> spp., <i>Cydonia oblonga</i> , <i>Malus</i> spp., <i>Prunus</i> spp., <i>Pyrus</i> spp., <i>Rosa</i> spp. and <i>Sorbus</i> spp. (de Jong et al. 2001; Kienholz 1939). |
| Distribution | Presence in Australia: no records found. Some specimens formerly labelled <i>Pezicula malicorticis</i> have been found to be <i>Neofabraea alba</i> , an undescribed <i>Neofabraea</i> species found by (2001), or a <i>Pyricularia aquatica</i> -like fungus (Cunnington 2004). Some specimens formerly labelled <i>Cryptosporiopsis malicorticis</i> have been found to be <i>Cryptosporiopsis perennans</i> (Cunnington 2004). Presence in China: Yes, as <i>Neofabraea malicorticis</i> and <i>Pezicula malicorticis</i> (Ma 2006). <i>Pezicula malicorticis</i> is listed as a quarantine pest of concern to China. Presence elsewhere: Canada, Denmark, Estonia, Finland, France, Germany, Ireland, Japan, Lithuania, Netherlands, New Zealand, Norway, Poland, Portugal, Russia, Sweden, United Kingdom, USA, Zimbabwe (Farr and Rossman 2009; de Jong et al. 2001). |

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| Quarantine pest | <i>Diplocarpon mali</i> Y. Harada & Sawamura |
| Synonyms | <i>Marssonia coronaria</i> (Ellis & Davis) Davis |
| Common name(s) | marssonina blotch, apple leaf brown rot |
| Main hosts | <i>Malus</i> spp. (apple) and <i>Chaenomeles</i> spp. (flowering quince) (Farr <i>et al.</i> 2008) |
| Distribution | Presence in Australia: no records found. Presence in China: Shandong (CIQSA 2001c) and Gansu (Zhuang 2005) provinces. Presence elsewhere: Japan, South Korea (Farr <i>et al.</i> 2008) . |
| Quarantine pest | <i>Gymnosporangium yamadae</i> Miyabe |
| Synonyms | None |
| Common name(s) | Japanese apple rust |
| Main hosts | Telial hosts : <i>Juniperus</i> spp.. Aecial hosts : <i>Malus</i> spp (Farr <i>et al.</i> 2008; CAB International 2007a). |
| Distribution | Presence in Australia: no records found. Presence in China: all major apple production areas in China (Ma 2006). Presence elsewhere: Japan (Hokkaido, Honshu), North Korea, South Korea (Farr <i>et al.</i> 2008). |

| Quarantine pest | <i>Monilinia fructigena</i> (Aderh. & Ruhland) Honey |
|-----------------|--|
| Synonyms | <p><i>Monilia fructigena</i> (Schumach)</p> <p><i>Sclerotinia fructigena</i> (J. Schröt.) (Norton)</p> <p><i>Stromatinia fructigena</i> (J. Schröt.) (Boud)</p> <p>See Farr <i>et al</i> (2008) for more synonyms of this fungus.</p> |
| Common name(s) | apple brown rot |
| Main hosts | <p><i>Amelanchier canadensis</i> (thicket serviceberry), <i>Berberis</i> spp., <i>Capsicum</i> spp., <i>Cornus mas</i> (Cornelian cherry), <i>Corylus avellana</i> (hazel), <i>Cotoneaster</i> spp., <i>Crataegus laevigata</i>, <i>Cydonia oblonga</i> (quince), <i>Diospyros kaki</i> (persimmon), <i>Eriobotrya japonica</i> (loquat), <i>Ficus carica</i> (fig), <i>Fragaria</i> spp., <i>F. ananassa</i> (strawberry), <i>Lycopersicon esculentum</i> (tomato), <i>Malus domestica</i> (apple), <i>Mespilus germanica</i> (medlar), <i>Prunus</i> spp., <i>P. armeniaca</i> (apricot), <i>P. avium</i> (cherry), <i>P. cerasus</i> (sour cherry), <i>P. domestica</i> (plum), <i>P. persica</i> (peach), <i>P. dulcis</i> (almond), <i>P. spinosa</i> (blackthorn), <i>Psidium guajava</i> (guava), <i>Pyrus</i> spp. (pear), <i>P. communis</i> (European pear), <i>Rhododendron</i> spp., <i>Rosa</i> (roses), <i>Rubus</i> (blackberry, raspberry), <i>R. occidentalis</i> (black raspberry), <i>Sorbus</i> spp., <i>Vaccinium</i> spp., <i>Vitis vinifera</i> (grapevine) (CAB International 2007a; Ma 2006).</p> |
| Distribution | <p>Presence in Australia: no records found.</p> <p>Presence in China: Anhui, Henan, Hubei, Hunan, Jiangsu, Liaoning, Shaanxi, Shandong, Shanxi, Sichuan, Yunnan and Zhejiang provinces (Ma 2006; AQSIQ 2005; CIQSA 2001c; CIQSA 2001a).</p> <p>Presence elsewhere: Afghanistan, Austria, Belarus, Belgium, Brazil, Bulgaria, Chile, Croatia, Cyprus, Czech Republic, Denmark, Egypt, Finland, France, Georgia, Germany, Greece, Hungary, India, Iran, Ireland, Israel, Italy, Japan, Latvia, Lebanon, Lithuania, Luxembourg, Moldova, Montenegro, Morocco, Nepal, North Korea, Norway, Netherlands, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom, Uruguay, Uzbekistan, Yugoslavia (former) (CAB International 2007a).</p> |

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| Quarantine pest | <i>Mucor mucedo</i> Fresen. |
| Synonyms | None |
| Common name(s) | mucor rot |
| Main hosts | Multiple genera in multiple families including: <i>Fragaria</i> spp., (strawberries), <i>Malus pumila</i> (apple), <i>Pyrus communis</i> (pear), <i>Rubus</i> spp. (blackberry, raspberry), <i>Lycopersicon esculentum</i> (tomato) (Farr and Rossman 2009; Spotts 1990b; Moline and Kuti 1984; Dennis and Mountford 1975). |
| Distribution | Presence in Australia: No records found. Presence in China: Yes (Cheng <i>et al.</i> 1988). Presence elsewhere: Chile, Cuba, Dominican Republic, Germany, India, Libya and USA (Farr and Rossman 2009). |
| Quarantine pest | <i>Mucor racemosus</i> Fresen. |
| Synonyms | <i>Mucor dimorphosporus</i> Lendn. <i>Mucor oudemansii</i> Váňová <i>Mucor paronychius</i> Suth.-Campb. & Plunkett |
| Common name(s) | mucor rot |
| Main hosts | Stored fruit and vegetables (Lunn 1977). |
| Distribution | Presence in Australia: ACT, NSW, Vic (APPD 2009). Presence in China: Yes (Pei 2000). Presence elsewhere: World-wide (Lunn 1977). |

| Quarantine pest | <i>Neonectria ditissima</i> (Tul. & C. Tul.) Samuels & Rossman |
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| Synonyms | The name of <i>Nectria galligena</i> was changed to <i>Neonectria galligena</i> in 1999 (Rossman <i>et al.</i> 1999). In 2006, it was determined that <i>Neonectria galligena</i> is the same as <i>Neonectria ditissima</i> (Castlebury <i>et al.</i> 2006). It was agreed that <i>Neonectria ditissima</i> is the current scientific name for European canker. <i>Cylindrocarpon heteronema</i> (Berk. & Broome) Wollenw (Anamorph) See Farr <i>et al</i> (2008) for more synonyms of this fungus. |
| Common name(s) | European canker |
| Main hosts | <i>Acer circinatum</i> (vine maple); <i>Acer macrophyllum</i> (bigleaf maple), <i>Acer pensylvanicum</i> , <i>Acer rubrum</i> (red maple), <i>Acer saccharum</i> (hard maple), <i>Acer spicatum</i> (mountain maple), <i>Aesculus</i> sp. (horse-chestnut), <i>Alnus incana</i> (grey alder), <i>Betula papyrifera</i> (paper birch), <i>Betula pendula</i> (European white birch), <i>Betula lenta</i> (sweet birch), <i>Betula nigra</i> (river birch), <i>Betula populifolia</i> (grey birch), <i>Carpinus betulus</i> (common hornbeam), <i>Carya cordiformis</i> (Bitternut hickory), <i>Carya glabra</i> (pignut hickory), <i>Carya illinoensis</i> (pecan), <i>Carya ovata</i> (shagbark hickory), <i>Carya tomentosa</i> (mockernut hickory), <i>Cornus nuttallii</i> (Pacific dogwood), <i>Corylus avellana</i> (hazel), <i>Fagus grandifolia</i> (American beech), <i>Fagus sylvatica</i> (European beech), <i>Frangula alnus</i> (Alder buckthorn), <i>Fraxinus excelsior</i> (common ash), <i>Fraxinus nigra</i> (black ash), <i>Juglans cinerea</i> (butternut tree), <i>Juglans nigra</i> (black walnut tree), <i>Liriodendron tulipifera</i> (yellow poplar), <i>Malus domestica</i> (apple), <i>Nyssa sylvatica</i> (blackgum), <i>Populus grandidentata</i> (bigtooth aspen), <i>Populus tremuloides</i> (trembling aspen), <i>Prunus serotina</i> (black cherry tree), <i>Pyrus communis</i> (pear), <i>Pyrus pyrifolia</i> var. <i>culta</i> (Oriental pear), <i>Quercus alba</i> (white oak), <i>Quercus bicolor</i> (swamp white oak), <i>Quercus coccinea</i> (scarlet oak), <i>Quercus garryana</i> (Oregon white oak), <i>Quercus laurifolia</i> (laurel oak), <i>Quercus rubra</i> (Northern red oak), <i>Quercus velutina</i> (black oak), <i>Rosa</i> spp. (rose), <i>Rhus typhina</i> (staghorn sumac), <i>Salix alba</i> (white willow), <i>Salix amygdaloides</i> (peachleaf willow), <i>Sorbus aucuparia</i> (rowan tree), <i>Tilia americana</i> (American basswood), <i>Ulmus americana</i> (American elm), <i>Ulmus glabra</i> (mountain elm) (CAB International 2007a). |
| Distribution | Presence in Australia: The disease has been eradicated from Tasmania (Ransom 1997). Presence in China: The disease occurs sporadically in part of Shaanxi, Guansu, Shanxi, Hebei and Henan provinces (Ma 2006). Presence elsewhere: Afghanistan, Argentina, Austria, Belgium, Bulgaria, Canada (British Columbia, New Brunswick, Nova Scotia, Ontario, Prince Edward Island, Quebec), Chile, Taiwan, Czechoslovakia, Denmark, Estonia, Faeroe Islands, France, Germany, Greece, Hungary, Iceland, India (Himachal Pradesh), Indonesia (Java), Iran, Iraq, Ireland, Italy, Japan, South Korea, Lithuania, Lebanon, Macedonia, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal (Azores, Madeira), Romania, Russia, Saudi Arabia, Slovakia, South Africa, Spain (Canary Islands), Sweden, Switzerland, Syria, Taiwan, Ukraine, United Kingdom, USA (California, Connecticut, Florida, Illinois, Indiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, New Hampshire, New York, North Carolina, North Dakota, Oregon, Pennsylvania, Rhode Island, South Dakota, Vermont, Virginia, Washington, West Virginia), Uruguay (CAB International 2007a). |

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| Quarantine pest | <i>Phyllosticta arbutifolia</i> Ellis & G. Martin |
| Synonyms | <i>Phyllostictina solitaria</i> (Ellis & Everh.) Shear (Farr <i>et al.</i> 2008; Index Fungorum 2006) |
| Common name(s) | apple blotch |
| Main hosts | <i>Aronia</i> spp., <i>Crataegus</i> spp., <i>Malus</i> spp., <i>Pyrus</i> spp. (Farr <i>et al.</i> 2008; Ma 2006; Zherikhin and Gratshev 1995). |
| Distribution | <p>Presence in Australia: no records found.</p> <p>Presence in China: all major apple production regions (Ma 2006; CIQSA 2001c)</p> <p>Presence elsewhere: Brazil, Canada, Denmark, Greece, India, South Africa, USA (Alabama, Florida, Illinois, Indiana, Iowa, Kansas, Louisiana, Maryland, Mississippi, New Jersey, North Carolina, Ohio, Oklahoma, Texas, Washington, West Virginia, Wisconsin), Zimbabwe (Farr <i>et al.</i> 2008).</p> |
| Quarantine pest | <i>Truncatella hartigii</i> (Tubeuf) Steyaert |
| Synonyms | <i>Pestalotia hartigii</i> Tubeuf |
| Common name(s) | leaf spot |
| Main hosts | <i>Abies</i> spp., <i>Cannomois virgata</i> , <i>Fagus sylvatica</i> , <i>Fraxinus excelsior</i> , <i>Lactuca sativa</i> , <i>Larix occidentalis</i> , <i>Malus</i> spp., <i>Olea laurifolia</i> , <i>Picea</i> spp., <i>Pinus</i> spp., <i>Pseudotsuga</i> spp., <i>Pyrus</i> spp., and <i>Rhodocoma capensis</i> (Farr and Rossman 2009; Lee <i>et al.</i> 2006; Vujanovic <i>et al.</i> 2000; Spaulding 1956; Cooke 1906). |
| Distribution | <p>Presence in Australia: no records found.</p> <p>Presence in China: Yes (Farr and Rossman 2009)</p> <p>Presence elsewhere: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, India, Japan, Korea, Norway, Pakistan, Poland, South Africa, Sweden, Turkey, United Kingdom and USA (Farr and Rossman 2009).</p> |

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| Quarantine pest | Fungi associated with sooty blotch and flyspeck complex (SBFS): <i>Dissoconium mali</i> <i>Dossoconium multiseptatae</i> <i>Pseudocercospora</i> sp. <i>Paraconiothyrium</i> sp. <i>Passalora</i> sp. <i>Pseudocercospora</i> sp. <i>Stenella</i> sp. <i>Stomiopeltis</i> spp. <i>Strelitziana mali</i> <i>Wallemia longxianensis</i> <i>Wallemia qiangyangensis</i> <i>Wallemia sebi</i> <i>Xenostigmina</i> sp. <i>Zygophiala taiyuensis</i> <i>Zygophiala liquanensis</i> |
| Common name(s) | sooty blotch and flyspeck diseases |
| Main hosts | <p>Fungi associated with sooty blotch and flyspeck complex grow on a wide range of plants, including trees, shrubs, and vines, that are near or bordering orchards (Zhang 2007; Zhang 2006). For example, the host plants of <i>Z. jamaicensis</i> include 120 species in 44 families of seed plants including <i>Malus</i> spp. throughout temperate and tropical regions: <i>Acanthopanax spinosus</i>, <i>Acer</i> spp., <i>Actinidia chinensis</i>, <i>Actinodaphne lancifolia</i>, <i>Aesculus turbinata</i>, <i>Akebia quinata</i>, <i>Albizia julibrissin</i>, <i>Allium cepa</i>, <i>Alnus</i> spp., <i>Ampelopsis brevipedunculata</i>, <i>Annona squamosa</i>, <i>Antiaris africana</i>, <i>Asimina triloba</i>, <i>Aucuba japonica</i>, <i>Buxus microphylla</i>, <i>Calycophyllum candidissimum</i>, <i>Camellia japonica</i>, <i>Carpinus</i> spp., <i>Castanea crenata</i>, <i>Celastrus orbiculata</i>, <i>Cercidiphyllum japonicum</i>, <i>Chaenomeles</i> spp., <i>Chamaenerion angustifolium</i>, <i>Cinnamomum camphora</i>, <i>Citrus</i> spp., <i>Clematis terniflora</i>, <i>Coccoluc orbiculatus</i>, <i>Cornus</i> spp., <i>Daphniphyllum</i> spp., <i>Dendropanax trifidus</i>, <i>Desmodium canum</i>, <i>Deutzia crenata</i>, <i>Dianthus</i> spp., <i>Diospyros kaki</i>, <i>Eucalyptus</i> spp., <i>Euonymus</i> spp., <i>Euscaphis japonica</i>, <i>Ficus carica</i>, <i>Firmiana simplex</i>, <i>Forsythia</i> spp., <i>Ginkgo biloba</i>, <i>Hydrangea paniculata</i>, <i>Hymenocardia acida</i>, <i>Idesia polycarpa</i>, <i>Ilex</i> spp., <i>Illicium religiosum</i>, <i>Kalopanax pictus</i>, <i>Kerria japonica</i>, <i>Lespedeza bicolor</i>, <i>Ligustrum lucidum</i>, <i>Lindera</i> spp., <i>Lonicera</i> spp., <i>Machilus thunbergia</i>, <i>Magnolia</i> spp., <i>Malus</i> spp., <i>Millettia japonica</i>, <i>Morus</i> spp., <i>Musa</i> spp., <i>Myrica rubra</i>, <i>Neolitsea aciculata</i>, <i>Philadelphus satsumi</i>, <i>Phyllostachys</i> spp., <i>Platanus acerifolia</i>, <i>Pleioblastus simony</i>, <i>Prunus</i> spp., <i>Psidium guajava</i>, <i>Pueraria lobata</i>, <i>Pyrus</i> spp., <i>Quercus</i> spp., <i>Rhus javanica</i>, <i>Rosa</i> spp., <i>Sambucus racemosa</i>, <i>Sapium</i> spp., <i>Smilax china</i>, <i>Sorbus alnifolia</i>, <i>Spiraea cantoniensis</i>, <i>Stachyurus praecox</i>, <i>Stewartia pseudocamellia</i>, <i>Theobroma cacao</i>, <i>Tilia japonica</i>, <i>Vaccinium</i> spp., <i>Vitis</i> spp., <i>Weigela hortensis</i>, <i>Wisteria brachybotrys</i> (Farr et al. 2008)</p> |

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| Distribution | <p>Presence in Australia: there is one record of <i>Z. jamaicensis</i> in Western Australia (APPD 2008). However, this record was made before the article clarifying the taxonomy relationship between <i>Z. jamaicensis</i> and <i>S. pomi</i> was published in 2008 (Batzer <i>et al.</i> 2008).</p> <p>Presence in China: a number of fungi were isolated from SBFS complex on apples sampled from apple orchards in Shaanxi, Shandong, Liaoning, Henan and Yunnan provinces (Zhang 2007; Zhang 2006; Sun <i>et al.</i> 1991).</p> <p>Presence elsewhere: Cuba, Jamaica, Japan, Papua New Guinea, Russia, South Korea, Tanzania, USA (Farr <i>et al.</i> 2008).</p> |
| Quarantine pest | Apple scar skin viroid (ASSVd) |
| Common name(s) | Apple scar skin disease, apple dimple, pear rusty skin, pear fruit crinkle, Japanese pear fruit dimple. |
| Main hosts | <i>Malus domestica</i> (apple), <i>Pyrus</i> sp. (pear), <i>Pyrus amygdaliformis</i> , <i>Pyrus bretschneideri</i> (ya pear), <i>Pyrus communis</i> (European pear), <i>Pyrus pyrifolia</i> and <i>Pyrus ussuriensis</i> (Asian pears) (CAB International 2008). |
| Distribution | <p>Presence in Australia: no records found.</p> <p>Presence in China: Hebei, Liaoning, Shaanxi, Shanxi (Han <i>et al.</i> 2003).</p> <p>Presence elsewhere: Canada, Denmark, France, Greece, India, Iran, Italy, Japan, Poland, Republic of Korea, Turkey, United Kingdom, USA (CAB International 2008).</p> |
| Quarantine pest | Tobacco necrosis viruses |
| Synonyms | <p>The names below are used for distinct necrovirus species that have been called 'tobacco necrosis virus':</p> <p><i>Chenopodium necrosis virus</i></p> <p><i>Olive mild mosaic virus</i></p> <p><i>Tobacco necrosis virus A</i></p> <p><i>Tobacco necrosis virus D</i></p> <p><i>Tobacco necrosis virus</i> Nebraska isolate</p> |
| Common name(s) | tobacco necrosis virus |
| Main hosts | <i>Brassica oleracea</i> (cabbage), <i>Chenopodium quinoa</i> (quinoa), <i>Cucumis sativus</i> (cucumber), <i>Cucurbita pepo</i> (zucchini), <i>Daucus carota</i> (carrot), <i>Fragaria × ananassa</i> (strawberry), <i>Glycine max</i> (soybean), <i>Malus pumila</i> (apple), <i>Nicotiana tabacum</i> (tobacco), <i>Lactuca sativa</i> (lettuce), <i>Olea europaea</i> (olive), <i>Phaseolus vulgaris</i> (common bean), <i>Solanum tuberosum</i> (potato), <i>Tulipa</i> sp. (tulip) (other hosts are infected but remain symptomless) (Zitkaić and Staniulis 2009; CAB International 2009; Brunt and Teakle 1996; Kassanis 1970). |
| Distribution | <p>Presence in Australia: Queensland and Victoria (Teakle 1988; Finlay and Teakle 1969).</p> <p>Presence in China: Probably widespread but species and strain distributions are unknown; recorded in Xinjiang and Jiangsu (Xi <i>et al.</i> 2008; Huang <i>et al.</i> 1984).</p> <p>Presence elsewhere: Probably worldwide but species and strain distributions are largely unknown; recorded in Belgium, Brazil, Canada, Czechoslovakia (former), Denmark, Finland, France, Germany, Hungary, India, Italy, Japan, Latvia, Netherlands, New Zealand, Norway, Romania, Russia, South Africa, Spain, Sweden, Switzerland, Turkey, United Kingdom (CAB International 2009).</p> |

Appendix C. Australia's biosecurity policy framework

Australia's biosecurity policies

The objective of Australia's biosecurity policies and risk management measures is the prevention or control of the entry, establishment and spread of pests and diseases that could cause significant harm to people, animals, plants and other aspects of the environment.

Australia has diverse native flora and fauna and a large agricultural sector, and is relatively free from the more significant pests and diseases present in other countries. Therefore, successive Australian Governments have maintained a conservative, but not a zero-risk, approach to the management of quarantine risks. This approach is consistent with the World Trade Organisation's (WTO's) *Agreement on the Application of Sanitary and Phytosanitary Measures* (SPS Agreement).

The SPS Agreement defines the concept of an 'appropriate level of protection' (ALOP) as the level of protection deemed appropriate by a WTO Member establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory. Among a number of obligations, a WTO Member should take into account the objective of minimising negative trade effects in setting its ALOP.

Like many other countries, Australia expresses its ALOP in qualitative terms. Our ALOP, which reflects community expectations through Australian Government policy, is currently expressed as providing a high level of sanitary and phytosanitary protection, aimed at reducing risk to a very low level, but not to zero.

Consistent with the SPS Agreement, in conducting risk analyses Australia takes into account as relevant economic factors:

- the potential damage in terms of loss of production or sales in the event of the entry, establishment and spread of a pest or disease in the territory of Australia
- the costs of control or eradication of a pest or disease
- and the relative cost-effectiveness of alternative approaches to limiting risks.

Roles and responsibilities within Australia's quarantine system

Australia protects its human¹⁰, animal and plant life or health through a comprehensive quarantine system that covers the quarantine continuum, from pre-border to border and post-border activities.

Pre-border, Australia participates in international standard-setting bodies, undertakes risk analyses, develops offshore quarantine arrangements where appropriate, and engages with our neighbours to counter the spread of exotic pests and diseases.

At the border, Australia screens vessels (including aircraft), people and goods entering the country to detect potential threats to Australian human, animal and plant health.

The Australian Government also undertakes targeted measures at the immediate post-border level within Australia. This includes national co-ordination of emergency responses to pest and disease incursions. The movement of goods of quarantine concern within Australia's

¹⁰ The Australian Government Department of Health and Ageing is responsible for human health aspects of quarantine.

border is the responsibility of relevant state and territory authorities, which undertake inter- and intra-state quarantine operations that reflect regional differences in pest and disease status, as a part of their wider plant and animal health responsibilities.

Roles and responsibilities within the Department

The Australian Government Department of Agriculture, Fisheries and Forestry is responsible for the Australian Government's animal and plant biosecurity policy development and the establishment of risk management measures. The Secretary of the Department is appointed as the Director of Animal and Plant Quarantine under the *Quarantine Act 1908* (the Act).

- The Biosecurity Services Group (BSG) within the Department takes the lead in biosecurity and quarantine policy development and the establishment and implementation of risk management measures across the biosecurity continuum, and through Biosecurity Australia, conducts risk analyses, including IRAs, and develops recommendations for biosecurity policy as well as providing quarantine advice to the Director of Animal and Plant Quarantine
- through the Australian Quarantine and Inspection Service, develops operational procedures, makes a range of quarantine decisions under the Act (including import permit decisions under delegation from the Director of Animal and Plant Quarantine) and delivers quarantine services and
- coordinates pest and disease preparedness, emergency responses and liaison on inter- and intra-state quarantine arrangements for the Australian Government, in conjunction with Australia's state and territory governments.

Roles and responsibilities of other government agencies

State and territory governments play a vital role in the quarantine continuum. The BSG works in partnership with state and territory governments to address regional differences in pest and disease status and risk within Australia, and develops appropriate sanitary and phytosanitary measures to account for those differences. Australia's partnership approach to quarantine is supported by a formal Memorandum of Understanding that provides for consultation between the Australian Government and the state and territory governments.

Depending on the nature of the good being imported or proposed for importation, Biosecurity Australia may consult other Australian Government authorities or agencies in developing its recommendations and providing advice.

As well as a Director of Animal and Plant Quarantine, the Act provides for a Director of Human Quarantine. The Australian Government Department of Health and Ageing is responsible for human health aspects of quarantine and Australia's Chief Medical Officer within that Department holds the position of Director of Human Quarantine. Biosecurity Australia may, where appropriate, consult with that Department on relevant matters that may have implications for human health.

The Act also requires the Director of Animal and Plant Quarantine, before making certain decisions, to request advice from the Environment Minister and to take the advice into account when making those decisions. The Australian Government Department of the Environment, Water, Heritage and the Arts (DEWHA) is responsible under the *Environment Protection and Biodiversity Conservation Act 1999* for assessing the environmental impact

associated with proposals to import live species. Anyone proposing to import such material should contact DEWHA directly for further information.

When undertaking risk analyses, Biosecurity Australia consults with DEWHA about environmental issues and may use or refer to DEWHA's assessment.

Australian quarantine legislation

The Australian quarantine system is supported by Commonwealth, state and territory quarantine laws. Under the Australian Constitution, the Commonwealth Government does not have exclusive power to make laws in relation to quarantine, and as a result, Commonwealth and state quarantine laws can co-exist.

Commonwealth quarantine laws are contained in the *Quarantine Act 1908* and subordinate legislation including the Quarantine Regulations 2000, the *Quarantine Proclamation 1998*, the *Quarantine (Cocos Islands) Proclamation 2004* and the *Quarantine (Christmas Island) Proclamation 2004*.

The quarantine proclamations identify goods which cannot be imported, into Australia, the Cocos Islands and or Christmas Island unless the Director of Animal and Plant Quarantine or delegate grants an import permit or unless they comply with other conditions specified in the proclamations. Section 70 of the *Quarantine Proclamation 1998*, section 34 of the *Quarantine (Cocos Islands) Proclamation 2004* and section 34 of the *Quarantine (Christmas Island) Proclamation 2004* specify the things a Director of Animal and Plant Quarantine must take into account when deciding whether to grant a permit.

In particular, a Director of Animal and Plant Quarantine (or delegate):

- must consider the level of quarantine risk if the permit were granted, and
- must consider whether, if the permit were granted, the imposition of conditions would be necessary to limit the level of quarantine risk to one that is acceptably low, and
- for a permit to import a seed of a plant that was produced by genetic manipulation – must take into account any risk assessment prepared, and any decision made, in relation to the seed under the Gene Technology Act and
- may take into account anything else that he or she knows is relevant.

The level of quarantine risk is defined in section 5D of the *Quarantine Act 1908*. The definition is as follows:

reference in this Act to a *level of quarantine risk* is a reference to:

- (a) the probability of:
 - (i) a disease or pest being introduced, established or spread in Australia, the Cocos Islands or Christmas Island; and
 - (ii) the disease or pest causing harm to human beings, animals, plants, other aspects of the environment, or economic activities; and
- (b) the probable extent of the harm.

The Quarantine Regulations 2000 were amended in 2007 to regulate key steps of the import risk analysis process. The Regulations:

- define both a standard and an expanded IRA
- identify certain steps which must be included in each type of IRA
- specify time limits for certain steps and overall timeframes for the completion of IRAs (up to 24 months for a standard IRA and up to 30 months for an expanded IRA)

- specify publication requirements
- make provision for termination of an IRA and
- allow for a partially completed risk analysis to be completed as an IRA under the Regulations.

The Regulations are available at www.comlaw.gov.au.

International agreements and standards

The process set out in the *Import Risk Analysis Handbook 2007 (update 2009)* is consistent with Australia's international obligations under the SPS Agreement. It also takes into account relevant international standards on risk assessment developed under the International Plant Protection Convention (IPPC) and by the World Organisation for Animal Health (OIE).

Australia bases its national risk management measures on international standards, where they exist and when they achieve Australia's ALOP. Otherwise, Australia exercises its right under the SPS Agreement to apply science-based sanitary and phytosanitary measures that are not more trade restrictive than required to achieve Australia's ALOP.

Notification obligations

Under the transparency provisions of the SPS Agreement, WTO Members are required, among other things, to notify other members of proposed sanitary or phytosanitary regulations, or changes to existing regulations, that are not substantially the same as the content of an international standard and that may have a significant effect on trade of other WTO Members.

Risk analysis

Within Australia's quarantine framework, the Australian Government uses risk analyses to assist it in considering the level of quarantine risk that may be associated with the importation or proposed importation of animals, plants or other goods.

In conducting a risk analysis, Biosecurity Australia:

- identifies the pests and diseases of quarantine concern that may be carried by the good
- assesses the likelihood that an identified pest would enter, establish or spread, and
- assesses the probable extent of the harm that would result.

If the assessed level of quarantine risk exceeds Australia's ALOP, Biosecurity Australia will consider whether there are any risk management measures that will reduce quarantine risk to achieve the ALOP. If there are no risk management measures that reduce the risk to that level, trade will not be allowed.

Risk analyses may be carried out by Biosecurity Australia's specialists, but may also involve relevant experts from state and territory agencies, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), universities and industry to access the technical expertise needed for a particular analysis.

Risk analyses are conducted across a spectrum of scientific complexity and available scientific information. An IRA is a type of risk analysis with key steps regulated under the

Quarantine Regulations 2000. Biosecurity Australia's assessment of risk may also take the form of a non-regulated analysis of existing policy or technical advice to AQIS. Further information on the types of risk analysis is provided in the *Import Risk Analysis Handbook 2007 (update 2009)*.

Appendix D. Status of fire blight in China

A number of stakeholders expressed their views about fire blight (caused by the bacterium *E. amylovora*) and its status in China.

Fire blight had previously been recorded in China with the most recent report being 1959, however internationally recognised researchers indicate these reports to be from unconfirmed records (van der Zwet and Keil 1979) and fire blight is not considered to be present (van der Zwet 1996).

Fire blight has never been present in China, and is listed on China's official list of quarantine pests (AQSIQ 2007a). It is a serious potential quarantine pest of concern for China's enormous pome fruit industry and surveys conducted in recent years by China in the major pome fruit production areas (AQSIQ 2008c) and ongoing general surveillance throughout pome fruit production areas have not detected fire blight. China's quarantine authority, AQSIQ, maintains quarantine requirements for the import of pome fruit or planting material from countries where fire blight is known to be present.

Biosecurity Australia accepts international recognition of China's ongoing pest free status for fire blight. However, in order to verify the status of quarantine pests of concern to Australia in China and fire blight, Biosecurity Australia/AQIS experts have visited many pear and apple production areas in China in 1997, 1998, 1999, 2000, 2005, 2007, 2008 and 2009 at different times of the year and found no evidence of fire blight.

Prior to the commencement of importation of pears from China in 1999, pear production orchards in Hebei and Shandong provinces were visited by a plant pathologist from Biosecurity Australia, and an Australian expert on fire blight in 1997 and 1998. Initial policy required that China continue to demonstrate freedom from fire blight by surveying for this disease in production areas. Monitoring requirements and pre-clearance audits since the commencement of trade in 1999 provided confidence that fire blight was not present in the export areas. Subsequently in 2005, pear production orchards in Xinjiang and Shaanxi provinces were inspected by a plant pathologist from Biosecurity Australia. These main production areas were specifically targeted for detection of fire blight symptoms. Fire blight was removed from the pest list for pears from China and currently Australia does not require any specific measures for fire blight for the import of pears. China is required to notify Australia immediately if any exotic disease of quarantine concern to Australia, including fire blight, is detected (Biosecurity Australia 2005b). AQIS inspectors have also visited and randomly inspected orchards in Hebei, Shandong, Xinjiang and Shaanxi since trade in pears commenced from these areas in 1999, 2000, 2005 and 2009, respectively, during the annual pre-clearance programs for export of pears without detection of any pathogens of quarantine concern to Australia, including *E. amylovora*.

Early in 2008, AQSIQ provided Biosecurity Australia with a report of a three-year orchard survey (2005-2007) conducted twice a season, and the laboratory testing of samples using various molecular methods for fire blight in apple and pear production areas of Shaanxi, Hebei and Shandong. The surveys and testing concluded that no fire blight had been found (AQSIQ 2008c). China exports apples to countries free of fire blight such as South Africa, Argentina and Chile.

It is customary for Biosecurity Australia technical experts/officials to visit orchards in production areas to assess production and packing house processes and verify the pest and disease status, as part of any risk assessment. Apple orchards and a packing house in Shandong were visited in July 2006 during preliminary work on the apple request. As part of

this IRA, Biosecurity Australia planned a visit during the main harvesting season. In March 2008, AQSIQ invited Biosecurity Australia to visit during September 2008. Two officials including a plant pathologist familiar with fire blight visited registered export apple orchards and packing houses in the main export production areas of Shaanxi, Shandong and Hebei provinces, 18-27 September 2008.

During the visit no substantiated symptoms of fire blight were detected. However, in the orchards visited in Shandong and Hebei provinces some terminal shoots which appeared scorched, occasionally with bending of the shoot tip (shepherd's crook appearance) were detected (Figure A). At first sight these symptoms appeared to be similar to those that can be caused by fire blight. A provincial plant protection specialist suggested that the damage and scorching symptoms were probably caused by cicadas, laying eggs in the shoot. Close examination of shoots showing these symptoms sampled from orchards in both provinces, revealed callusing of tissue around a tiny point of entry between the dead and healthy part of the shoot (Figure B). Breaking the shoots at this point showed a number of white/cream elongated eggs that the adult cicadas had oviposited into the shoots (Figure C). The eggs develop in the internal tissues of shoots and the larvae fall to the ground to pupate in the ground for many years before emerging as adults. No adult cicadas were found at the time to identify the cicadas as either *Cryptotympana atrata*, *Oncotympana maculicollis* or *Platypleura kaempferi*, the three cicada species included in the pest categorisation in this draft IRA report (Appendix A1). AQSIQ (2009) advised that these observed symptoms are caused by the egg-laying of *Cryptotympana atrata*. A number of small branches with these symptoms were checked and cicada eggs were found each time. The biology and habits of these and similar cicadas confirm that the adult cicadas oviposit into somewhat tender shoots eventually causing death of the terminal part. The orchard owners and provincial specialists noted that these symptoms were common in apple orchards in most years.

On all shoots observed with these symptoms there was no evidence of bacterial ooze, which is a characteristic sign of fire blight, nor any discoloration of the vascular tissue distal to the margins of lesions. Such symptoms are common in tissues affected by *E. amylovora*.

It is highly probable that symptoms noted by the Australian pome fruit industry delegation in September 2007 in an orchard in Hebei were those affected by cicada damage. Biosecurity Australia officials visited the same orchard in September 2008, and confirmed that cicadas were responsible for causing the necrotic shoot damage in that orchard. AQSIQ confirmed that molecular testing of the shoots in the orchard did not detect *E. amylovora*.

Further follow up visits to Shanxi, Gansu and Liaoning provinces and the Beijing region, also nominated by AQSIQ for export to Australia, were conducted in April 2009 during blossoming and early fruit set stage, which is the best time to see fire blight symptoms if they were present. Biosecurity Australia experts visited orchards and packing houses in these four provinces 23-30 April 2009 to verify their pest status and general commercial practices. No quarantine pests of concern to Australia were observed. A range of orchards were visited, including some additional unscheduled orchard visits all of which demonstrated consistent approaches in orchard and pest management.

Fire-blight-like symptoms of dead terminal shoots were observed in one orchard in Shanxi province and were confirmed as cicada damage by the presence of cicada eggs in the shoots.

Several stakeholders commented on the risk of fire blight with the importation of pome fruit and budwood and planting material into China. AQSIQ (2009) has advised that China has strict quarantine requirements for the import of apple from countries where fireblight is present, including sourcing apple fruit from production areas free from fireblight as established by surveys. Biosecurity Australia acknowledges that the risk of spreading fire

blight through the pathway of infected root stock and budwood is well known. The import of various nursery stock and planting material into China is regulated through either the Ministry of Agriculture, AQSIQ or the Ministry of Forestry and their respective provincial and local bureaux. For the import of pome fruit material the Ministry of Agriculture will issue an import permit to the importer which will include the quarantine pests of concern to AQSIQ and the phytosanitary requirements depending on the country of origin. Any material sourced from a country where a disease such as fire blight is present would need to be certified as free of fire blight by the quarantine authority of the exporting country. AQSIQ have confirmed the importation of root stock material and budwood of fruit trees including apple for a program of genetic improvement by a few private companies and fruit bureaux, to be grown in premises isolated from other pome fruit orchards. On arrival in China the material is inspected at the port by the quarantine authorities (CIQ) before release to an approved premises where it can be checked by the local or provincial department of agriculture.

***Erwinia* spp. on pears in North Asia**

Other *Erwinia* spp. have been reported from Japan and the Republic of Korea. Goto (1992) described the disease affecting certain Asian pear (*Pyrus pyrifolia*) cultivars occurring in Hokkaido in Japan as Bacteria Shoot Blight of Pear (BSBP). Japan eradicated *E. amylovora* pv. *piri* causing BSBP. A bacterium isolated in the Republic of Korea caused shoot blight resembling symptoms of fire blight in shoots of Asian pear was described by Rhim *et al.* (1999), and was designated as a new species, *Erwinia pyrifoliae* (Kim *et al.* 1999). The symptoms by both pathogens on pear were very similar to those of fire blight caused by *E. amylovora*, but their host range is more restricted than the host range for typical *E. amylovora* (Maxson-Stein *et al.* 2003). However, inoculation of apple by both pathogens produced localised necrotic reaction unlike the typical fire blight infection. A comparison of plasmid profiles, protein patterns and genomic deoxyribonucleic acid (DNA) by pulsed field gel electrophoresis of the *Erwinia* strains of Japanese pear with *E. pyrifoliae* were different from *E. amylovora* (Kim *et al.* 2001b; Kim *et al.* 2001a).

Mizuno *et al.* (2000) have compared the bacteriological properties and DNA-DNA homology values of *Erwinia* strains causing BSBP isolated in 1994-1996 with *E. amylovora* obtained from outside Japan and other representatives of the *Amylovora* group. Some *Erwinia* strains of BSBP showed greater than 70 % homology with *E. amylovora*, justifying the inclusion of *Erwinia* strains causing BSBP in that species. The BSBP pathogen in Hokkaido was designated as biovar 4, distinct from *E. amylovora* biovar 1, 2 and 3 isolated from other countries. Matsuura *et al.* (2007) showed that *E. amylovora* biovar 4 was more closely related to *E. pyrifoliae* than to other biovars of *E. amylovora* based on phylogenetic analysis relationships of *E. pyrifoliae* strains from Korea. Geider *et al.* (2008) have confirmed through DNA sequencing, hybridisation kinetics, microbiological assays and host range studies that *Erwinia* strains that caused BSBP in Japan, are taxonomically related to *E. pyrifoliae* that affects pear in Korea, with the exception of slight divergences in nucleotide sequences.

A disease tentatively named, 'Bacterial Black Shoot Disease of European Pear' (BBSE), caused by an *Erwinia* sp., was detected in Yamagata Prefecture in Japan in 2007 (Mizuno *et al.* 2009). This pathogen caused blackening of shoots but typical symptoms of fire blight were not present. Based on several molecular tests, the causal organism was identified as a novel species in the genus *Erwinia*. It was different from *E. amylovora*, *E. pyrifoliae* and the pathogen of 'Bacterial Shoot Blight of Pear' (Matsuura *et al.* 2009).

None of these *Erwinia* species has been reported from China on pears.

Figure A: Symptoms of scorched leaves observed on shoots in September 2008.



Figure B: Callusing and evidence of cicada damage and ovipositing of eggs in shoot.



Figure C: Cicada eggs inside the shoot.



Glossary

| Term | Definition |
|---|--|
| Additional declaration | A statement that is required by an importing country to be entered on a phytosanitary certificate and which provides specific additional information pertinent to the phytosanitary condition of a consignment in relation to regulated pests (FAO 2009). |
| Appropriate level of protection | The level of protection deemed appropriate by the Member establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory (WTO 1995). |
| Area | An officially defined country, part of a country or all or parts of several countries (FAO 2009). |
| Biosecurity Australia | The unit, within the Biosecurity Services Group, responsible for recommendations for the development of Australia's biosecurity policy. |
| Biosecurity Services Group (BSG) | the group responsible for the delivery of biosecurity policy and quarantine services within the Department of Agriculture, Fisheries and Forestry |
| Consignment | A quantity of plants, plant products and/or other articles being moved from one country to another and covered, when required, by a single phytosanitary certificate (a consignment may be composed of one or more commodities or lots) (FAO 2009). |
| Control (of a pest) | Suppression, containment or eradication of a pest population (FAO 2009). |
| Endangered area | An area where ecological factors favour the establishment of a pest whose presence in the area will result in economically important loss (FAO 2009). |
| Entry (of a pest) | Movement of a pest into an area where it is not yet present, or present but not widely distributed and being officially controlled (FAO 2009). |
| Establishment | Perpetuation, for the foreseeable future, of a pest within an area after entry (FAO 2009). |
| Establishment potential | Likelihood of the establishment of a pest. |
| Fresh | Living; not dried, deep-frozen or otherwise conserved (FAO 2009). |
| Fruits and vegetables | A commodity class for fresh parts of plants intended for consumption or processing and not for planting (FAO 2009). |
| Host | A species of plant capable, under natural conditions, of sustaining a specific pest. |
| Import Permit | Official document authorising importation of a commodity in accordance with specified phytosanitary import requirements (FAO 2009). |
| Infestation (of a commodity) | Presence in a commodity of a living pest of the plant or plant product concerned. Infestation includes infection (FAO 2009). |
| Inspection | Official visual examination of plants, plant products or other regulated articles to determine if pests are present and/or to determine compliance with phytosanitary regulations (FAO 2009). |
| Intended use | Declared purpose for which plants, plant products, or other regulated articles are imported, produced, or used (FAO 2009). |
| Interception (of a pest) | The detection of a pest during inspection or testing of an imported consignment (FAO 2009). |
| Introduction | The entry of a pest resulting in its establishment (FAO 2009). |
| Lot | A number of units of a single commodity, identifiable by its homogeneity of composition, origin etc., forming part of a consignment (FAO 2009). |
| National Plant Protection Organisation | Official service established by a government to discharge the functions specified by the IPPC (FAO 2009). DAFF is Australia's National Plant Protection Organisation. |
| Official control | The active enforcement of mandatory phytosanitary regulations and the application of mandatory phytosanitary procedures with the objective of eradication or containment of quarantine pests or for the management of regulated non-quarantine pests (FAO 2009). |
| Pathway | Any means that allows the entry or spread of a pest (FAO 2009). |
| Pest | Any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products (FAO 2009). |
| Pest categorisation | The process for determining whether a pest has or has not the characteristics of a quarantine pest or those of a regulated non-quarantine pest (FAO 2009). |
| Pest free area | An area in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained (FAO 2009). |

| Term | Definition |
|--|--|
| Pest risk analysis | The process of evaluating biological or other scientific and economic evidence to determine whether an organism is a pest, whether it should be regulated and the strength of any phytosanitary measures to be taken against it (FAO 2009). |
| Pest risk assessment (for quarantine pests) | Evaluation of the probability of the introduction and spread of a pest and the magnitude of the associated potential economic consequences (FAO 2009). |
| Pest risk management (for quarantine pests) | Evaluation and selection of options to reduce the risk of introduction and spread of a pest (FAO 2009). |
| Phytosanitary certificate | Certificate patterned after the model certificates of the IPPC (FAO 2009). |
| Phytosanitary measure | Any legislation, regulation or official procedure having the purpose to prevent the introduction and/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests (FAO 2009). |
| Phytosanitary regulation | Official rule to prevent the introduction and/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests, including establishment of procedures for phytosanitary certification (FAO 2009). |
| Polyphagous | Feeding on a relatively large number of host plants from different plant families. |
| Protected area | A regulated area that an NPPO has determined to be the minimum area necessary for the effective protection of an endangered area (FAO 2009). |
| Quarantine pest | A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled (FAO 2009). |
| Regulated article | Any plant, plant product, storage place, packaging, conveyance, container, soil and any other organism, object or material capable of harbouring or spreading pests, deemed to require phytosanitary measures, particularly where international transportation is involved (FAO 2009). |
| Restricted risk | 'Restricted' risk estimates apply to situations where risk management measures are used |
| Spread | Expansion of the geographical distribution of a pest within an area (FAO 2009). |
| SPS Agreement | WTO Agreement on the Application of Sanitary and Phytosanitary Measures (WTO 1995). |
| Stakeholders | Government agencies, individuals, community or industry groups or organisations, whether in Australia or overseas, including the proponent/applicant for a specific proposal |
| Systems approach(es) | The integration of different risk management measures, at least two of which act independently, and which cumulatively achieve the appropriate level of phytosanitary protection (FAO 2009). |
| Unrestricted risk | 'Unrestricted' risk estimates apply in the absence of risk management measures. |

Reference list

- ABS (2007) 7121.0.55.002 - Agricultural Survey, Apples and Pears, Australia, 2006-07. Released 18 December 2007. Australian Bureau of Statistics, Australia.
- ABS (2008) International Trade: Customised Report. Sources: Australian Bureau of Statistics, International Merchandise Trade. Australian Bureau of Statistics, Australia.
- AFFA (2003a) Import of Asian ('Shandong') pear (*P. pyrifolia* (Burm.) Nakai and *P. ussuriensis* var. *viridis* T. Lee) fruit from Shandong Province in the People's Republic of China: A review under existing import conditions for Ya pear (*Pyrus bretschneideri* Redh.) fruit from Hebei and Shandong Provinces. Agriculture, Fisheries and Forestry, Australia, Canberra. 54 pp.
- AFFA (2003b) Review of the Australian requirement for petal testing and flower cluster examination at blossoming for pome fruit from Japan, the Republic of Korea and the People's Republic of China. Agriculture, Fisheries and Forestry, Australia, Canberra. 76 pp.
- Ahn SB, Im DJ, Kim IS and Cho WS (1989) Foliage-feeding lepidopterous pests on apple trees in Suwon. *Research Reports of the Rural Development Administration, Crop Protection, Korea Republic* **31**, 27-33.
- Aldwinckle HS (1990) Japanese apple rust. In 'Compendium of Apple and Pear Diseases'. (Eds AL Jones and HS Aldwinckle) (American Phytopathological Society Press, St. Paul, Minnesota, USA): 14-15.
- Alfieri SA (1968) Limb blight disease caused by *Corticium salmonicolor* B. & Br. Plant Pathology Circular No. 71. Florida Department of Agriculture Division of Plant Industry.
- Allwood AJ, Chinajariyawong A, Kritsaneepaiboon S, Drew RAI, Hamacek EL, Hancock DL, Hengsawad C, Jipanin JC, Jirasurat M, Krong CK, Leong CTS and Vijayasegaran S (1999) Host plant records for fruit flies (Diptera: Tephritidae) in Southeast Asia. *Raffles Bulletin of Zoology Supplement* **7**, 1-192.
- Andrews N, duToit LJ, Ocamp CM, Parke J, Pscheidt JW, Putnam M, Smiley R and Skinkis P (2008) Apple (*Malus*) - Anthracnose (Bull's-eye Rot). In: *An online guide to plant disease control*. Oregon State University Extension. <http://plant-disease.ippc.orst.edu/disease.cfm?RecordID=36>, Accessed: July 2009.
- Angeli G, Ioriatti C, Boscheri S, Rizzi C and Delaiti M (1997) Pheromone traps for monitoring the efficacy of leafrollers moth mating disruption. *Difesa delle Piante* **20**, 79-84.
- Anonymous (1977) A preliminary study on the apple geometrid *Apocheima* sp. *Acta Entomologica Sinica* **20**, 4405-4408.
- Anonymous (2005) *Halyomorpha picus*. <http://tieba.baidu.com/f?kz=36125192>, Accessed: 14 October 2008.

- Anonymous (2008) *Holotricha parallela* Motschulsky.
<http://www.last.gov.cn:8080/main.php?page=19>, Accessed: 14 October 2008.
- APAL (2008) Response to the Biosecurity Australia Issues paper for the import risk analysis for fresh apple fruit from the People's Republic of China. September 2008. Apple & Pear Australia Limited (APAL). Available at http://www.daff.gov.au/ba/ira/current-plant/apples_china/submissions. 5 pp.
- APHIS (2005) Importation of Fragrant Pears From China. Federal Register 70 (246): 76133-76140.
<http://a257.g.akamaitech.net/7/257/2422/01jan20051800/edocket.access.gpo.gov/2005/pdf/05-24423.pdf>, Accessed: 12 May 2006.
- APPD (2008) Australian Plant Pest Database. <http://www.planthealthaustralia.com.au/APPD>, Accessed: 2008.
- APPD (2009) Australian Plant Pest Database.
<http://www.planthealthaustralia.com.au/APPD/queryForm.asp>, Accessed: July 2009.
- APVMA (2005) Endosulfan user's notice: effective October 2005. Australian Pesticides and Veterinary Medicines Authority, Canberra.
- AQIS (1998a) Final import risk analysis of the importation of fruit of the Fuji apple (*Malus pumila* Miller var. *domestica* Schneider) from Aomori Prefecture in Japan. Australian Quarantine and Inspection Service, Canberra, Australia. 58 pp.
- AQIS (1998b) Final import risk analysis of the importation of fruit of ya pear (*Pyrus bretschneideri* Redh.) from the People's Republic of China (Hebei and Shandong Provinces). Australian Quarantine and Inspection Service, Canberra, Australia. 42 pp.
- AQIS (1999a) Final import risk analysis on the importation of fresh fruit of Korean pear (*Pyrus ussuriensis* var. *viridis* T. Lee) from the Republic of Korea. Australian Quarantine and Inspection Service, Canberra, Australia. 49 pp.
- AQIS (1999b) Pathogen risks associated with bulk maize imports to Australia from USA. AQIS, Canberra . 10 pp.
- AQSIQ (2004) Technical materials and information for fresh Chinese pears export to Australia. Provided on 21 May 2004. The General Administration for Quality Supervision and Inspection and Quarantine of the People's Republic of China (AQSIQ), Beijing, China. [Government to government document].
- AQSIQ (2005) Export technical reference information for Chinese apple (Chinese and English translation). The General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (AQSIQ), Beijing, China. [Government to government document].
- AQSIQ (2006a) Exchanging opinions and supplementary material for the pest risk analysis of Chinese apples export to Australia. AQSIQ's responses to Biosecurity Australia's questions on Chinese apple risk analysis. The General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (AQSIQ), Beijing, China. [Government to government document]. 6 pp.

- AQSIQ (2006b) Pests and diseases associated with summerfruit (Apricot, Plum, Peach and Nectarines) in China. The General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (AQSIQ), Beijing, China. [Government to government document].
- AQSIQ (2007a) List of plant quarantine pests of the People's Republic of China, announced on 28 May 2007. The General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (AQSIQ), Beijing, China.
- AQSIQ (2007b) Pest risk management measures for Chinese apples export to Australia. Hard copy provided by AQSIQ during the technical workshop between AQSIQ and DAFF held on 22-23 May 2007 in Beijing (In Chinese). The General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (AQSIQ), Beijing, China.[Government to government document].
- AQSIQ (2008a) Advice on issues paper for the import risk analysis for apples from China [Response to the Issues Paper for the import risk analysis for fresh apple fruit from the People's Republic of China]. July 2008. The General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (AQSIQ). Available at http://www.daff.gov.au/ba/ira/current-plant/apples_china/submissions. 5 pp.
- AQSIQ (2008b) Letter on providing technical information on pathogens for Chinese apples to be exported to Australia. The General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (AQSIQ), Beijing, China. [Government to government document].
- AQSIQ (2008c) Technical information provided by the General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (AQSIQ) on 17 March 2008. The General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, Beijing, China. [Government to government document].
- AQSIQ (2009) Responses to the relevant questions on apples from China to Australia. The General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (AQSIQ), Beijing, China. [Government to government document].
- Arabuli T and Tskitishvili M (2008) Quantitative dynamic of *Cenopalpus pulcher* (Acari: Tenuipalpidae) on the quince (*Cydonia oblonga*). *Proceedings of the Institute for Zoology, Tbilisi XXIII*, 74-76.
- Arakawa Y (1927) Studies on Moths infesting Apples in Manchuria. *Manchuria and Mongolia February*, 1-46.
- Arakawa Y and Akiyama T (1933) On the Life-history of *Illiberis pruni* Dyar in Manchuria. *Journal of Plant Protection* **20**, 530-537.
- Asjes CJ and Blom-Barnhoorn GJ (2002) Control of spread of Augusta disease caused by tobacco necrosis virus in tulip by composting residual waste of small bulbs, tunics, roots and soil debris. *Acta Horticulturae (ISHS)* 570: 283-286. http://www.actahort.org/books/570/570_36.htm, Accessed: July 2009.

- Atkinson ID (1971) Bacterial Diseases of Pip fruit. In: Diseases of Tree fruits in New Zealand. *New Zealand Department of Scientific and Industrial Research Information Series* **81**, 102-106.
- Australian Museum (2006) Australian Museum Online: Hawk Moths.
http://www.amonline.net.au/factsheets/hawk_moths.htm, Accessed: 2006.
- Averin VG and Galkov VP (1958) Short notes. *CAB Abstracts Archive 1910-1958* 30-31.
- Baidu Baike (2008a) *Aleurocanthus spiniferus* (Quaintanca).
<http://baike.baidu.com/view/619896.htm>, Accessed: 17 October 2008a.
- Baidu Baike (2008b) *Plautia stali*. <http://baike.baidu.com/view/1586906.htm>, Accessed: 17 October 2008b.
- Bajwa WI and Kogan M (2003) Field biology of *Cenopalpus pulcher* (C. & F.) (Tenuipalpidae), an invasive mite new to Oregon apple and pear orchards. Poster Abstracts. Fourth National IPM Symposium/Workshop 2003
. <http://cipm.ncsu.edu/symposium/posterabstracts/S2-P.pdf>, Accessed: 27 October 2008.
- Bajwa WI, Krantz GW and Kogan M (2001) Discovery of *Cenopalpus pulcher* (C.& F.) (Acari: Tenuipalpidae) in the New World . *Proceedings of the Entomological Society of Washington* **103**, 754-756.
- Barber PA, Burgess TJ, Hardy GESJ, Slippers B, Keane PJ and Wingfield MJ (2005) *Botryosphaeria* species from Eucalyptus in Australia are pleoanamorphic, producing *Dichomera* synanamorphs in culture. *Mycological Research* **109**, 1347-1363.
- Barel CJA (1973) 'Studies on the dispersal of *Adoxophyes orana* F.v.R. in relation to the population sterilisation technique'. (Mededeling. Landbouwhogeschool, Wageningen). 1-107 pp.
- Barrass IC, Jerie P and Ward.S.A (1994) Aerial dispersal of first- and second- instar longtailed mealybug, *Pseudococcus longispinus* (Targioni Tozzetti) (Pseudococcidae: Hemiptera). *Australian Journal of Experimental Agriculture* **34**, 1205-1208.
- Bashkatova TV, Prokofev MA, Ogneva LI and Shamanskaya LD (1983) Tested in orchards in Siberia. *Zashchita Rastenii* **8**, 30.
- Batra LR (1979) First authenticated North American record of *Monilinia fructigena*, with notes on related species. *Mycotaxon* **8**, 476-484.
- Batra LR (1991) World species of *Monilinia* (Fungi): their ecology, biosystematics and control. *Mycologia Memory* **16**, 1-246.
- Batra LR and Harada Y (1986) A field record of apothecia of *Monilinia fructigena* in Japan and its significance. *Mycologia* **78**, 913-917.
- Batzer JC, Arias MMD, Harrington TG, Gleason ML, Groenewald JZ and Crous PW (2008) Four species of *Zygophiala* (Schizothyriaceae, Capnodiales) are associated with the sooty blotch and flyspeck complex on apple. *Mycologia* **100**, 246-258.

- Batzer JC, Gleason ML, Weldon B, Dixon PM and Nutter FWJr (2002) Evaluation of postharvest removal of sooty blotch and flyspeck on apples using sodium hypochlorite, hydrogen peroxide with peroxyacetic acid, and soap. *Plant Disease* **86**, 1325-1332.
- Batzer JC, Harrington TG, Gleason ML and Tiffany LH (2005) Expansion of the sooty blotch and flyspeck complex on apple based on analysis of ribosomal DNA gene sequences and morphology. *Mycologia* **97**, 1268-1286.
- Bawden FC (1956) 'Plant Viruses and Virus Diseases.'. (3rd Edition) (Chronica Botanica Company, Waltham.).
- Beardsley JW and Gonzalez RH (1975) The biology and ecology of armoured scales. *Annual Review of Entomology* **20**, 47-73 .
- Beers EH (2007) Apple mealybug, *Phenacoccus aceris* Signoret, Tree Fruit research and Extension: Orchard pest Management Online.
<http://jenny.tfrec.wsu.edu/opm/displaySpecies.php?pn=135>, Accessed: 01 September 2008.
- Bellamy C (2001) Coleoptera: Buprestoidea. Australian Faunal Directory.
<http://www.deh.gov.au/biodiversity/abrs/online-resources/fauna/afd/index.html>, Accessed: 07 April 2006.
- Ben-Dov Y (2005a) ScaleNet, Coccidae.
<http://www.sel.barc.usda.gov/scalecgi/chklist.exe?Family=Coccidae&genus=>, Accessed: 06 April 2006.
- Ben-Dov Y (2005b) ScaleNet, Pseudococcidae.
<http://www.sel.barc.usda.gov/scalecgi/chklist.exe?Family=Pseudococcidae&genus=>, Accessed: 23 June 2006.
- Ben-Dov Y (2006a) ScaleNet, Diaspididae: Aspidiotinae, Comstockiellinae & Odonaspidinae. <http://nlbif.eti.uva.nl/bis/diaspididae.php?>, Accessed: 08 August 2006.
- Ben-Dov Y (2006b) ScaleNet, Margarodidae.
<http://www.sel.barc.usda.gov/scalecgi/chklist.exe?Family=Margarodidae&genus=>, Accessed: 23 June 2006.
- Ben-Dov Y (2006c) ScaleNet, Pseudococcidae; *Phenacoccus aceris*.
<http://www.sel.barc.usda.gov/scalecgi/chklist.exe?Family=Pseudococcidae&genus=Phe>
[nacoccus](http://www.sel.barc.usda.gov/scalecgi/chklist.exe?Family=Pseudococcidae&genus=Phe), Accessed: 2008.
- Ben-Dov Y and Hodgson CJ (1997) 'Soft scale insects: their biology, natural enemies and control. Vol. 7B, World Crop Pests'. (Elsevier, Amsterdam; New York).
- Ben-Dov Y, Miller DR and Gimpel ME (2006a) ScaleNet: Diaspididae.
<http://www.sel.barc.usda.gov/scalenet/valid.htm>, Accessed: 23 October 2008.
- Ben-Dov Y, Miller DR and Gimpel ME (2006b) Scalenet: Diaspididae: *Lepidosaphes malicola* Borchsenius.
<http://www.sel.barc.usda.gov/catalogs/diaspidi/Lepidosaphesmalicola.htm>

- Bertrand P and Saulie-Carter J (1979) Postharvest decay control of apples and pears after immersion dumping. Special Report 545. Agricultural Experiment Station, Oregon State University, Corvallis, OR.
- Bertrand P and Saulie-Carter J (1980) Mucor rot of pears and apples. Special Report 568, Agricultural Experiment Station, Oregon State University, Corvallis, OR.
- Bi Y, Ge YH, Wang CL and Li XW (2007) Melon production in China. *Proceedings of III International Symposium on Cucurbits. Acta Horticulturae* **731**, 493-500.
- Bi Y, Tian SQ, Lui HX, Zhao J, Cao JK, Li YC and Zhang WY (2003) Effect of temperature on chilling injury, decay and quality of Hami melon during storage. *Postharvest Biology and Technology* **29**, 229-232.
- Bibolini C (1960) Sulla biologia della *Gastropacha quercifolia* L. (Lepidoptera-Lasiocampidae).; On the bionomics of *G. quercifolia*. *Frust ent* **3**, 1-93.
- Biosecurity Australia (2002) Review of post-entry quarantine protocols for the importation into Australia of apple (*Malus*) and pear (*Pyrus*) budwood. Biosecurity Australia, Canberra, Australia. 68 pp.
- Biosecurity Australia (2003) Technical issues paper import risk analysis for the importation of fresh longan and lychee fruit from the People's Republic of China. Biosecurity Australia, Canberra, Australia.
- Biosecurity Australia (2004) Persimmon fruit (*Diospyros kaki* L.) from Japan, Korea and Israel: final import policy. Biosecurity Australia, Canberra, Australia.
- Biosecurity Australia (2005a) Draft extension of policy for the importation of pears from the People's Republic of China. Biosecurity Australia, Canberra, Australia. 58 pp.
- Biosecurity Australia (2005b) Final extension of policy for the importation of pears from the People's Republic of China. Biosecurity Australia, Canberra, Australia. 97 pp.
- Biosecurity Australia (2005c) Final report for the extension of existing policy for Sweet Oranges from Italy. Biosecurity Australia, Canberra, Australia. 228 pp.
- Biosecurity Australia (2006a) Final import risk analysis report for apples from New Zealand. Biosecurity Australia, Canberra, Australia. 598 pp.
- Biosecurity Australia (2006b) Final import risk analysis report for stone fruit from New Zealand into Western Australia. Biosecurity Australia, Canberra, Australia.
- Biosecurity Australia (2006c) Policy for the importation of fresh mangoes (*Mangifera indica* L.) from Taiwan. Biosecurity Australia, Canberra, Australia. 210 pp.
- Biosecurity Australia (2008a) Draft import risk analysis report for fresh capsicum paprika fruit from the Republic of Korea . Biosecurity Australia, Canberra, Australia. 98 pp.
- Biosecurity Australia (2008b) Draft import risk analysis report for fresh Unshu mandarin fruit from Japan. Biosecurity Australia, Canberra, Australia.

- Biosecurity Australia (2008c) Final import risk analysis report for fresh mango fruit from India. Biosecurity Australia, Canberra, Australia. 210 pp.
- Biosecurity Australia (2008d) Issues paper for the import risk analysis for fresh apple fruit from the People's Republic of China. Biosecurity Australia, Canberra, Australia.
- Biosecurity Australia (2009a) Draft import risk analysis report for fresh apple fruit from the People's Republic of China. Biosecurity Australia, Canberra, Australia.
- Biosecurity Australia (2009b) Final import risk analysis report for fresh unshu mandarin fruit from Shizouka Prefecture, Japan. Biosecurity Australia, Canberra, Australia.
- Bolland HR, Gutierrez J and Flechtman CHW (1998) 'World catalogue of the spider mite family (Acari: Tetranychidae)'. (Brill, Leiden). 392 pp.
- BOM (2009) Average annual & monthly maximum, minimum, & mean temperature. Bureau of Meteorology. http://www.bom.gov.au/jsp/ncc/climate_averages/temperature/, Accessed: 05 June 2009.
- Bondoux P and Built J (1959) Sur la pourriture des au *Cylindrocarpon mali* (All.) Wr. *Comptes Rendus de l'Academie d' Agriculture de France* **45**, 275-277.
- Booth C (1998) '*Nectria cinnabarina*. CMI Descriptions of Pathogenic Fungi and Bacteria No. 531'. (CAB International, Wallingford, UK). 2 pp.
- Booth RG, Cox ML and Madge RB (1990) 'IIE Guides to Insects of Importance to Man: No. 3: Coleoptera '. (vol. 3) (CAB International, London, UK).
- Bos L (1999) 'Plant viruses, unique and intriguing pathogens.'. (Backhuys Publishers, Leiden).
- Bounous G and Liu L (1996) Chestnut production in China. *Rivista di Frutticoltura e di Ortofloricoltura* **58**, 41-48.
- Branson A, Wu BG and Bean CE (2004) China, People's Republic of. Fresh Deciduous Fruit. Annual. 2004. <http://www.fas.usda.gov/gainfiles/200409/146107541.doc> GAIN Report. Ralph Gifford, US Embassy, Beijing, China. 31 pp.
- Brown EM and Sutton TB (1995) An empirical model for predicting the first symptoms of sooty blotch and flyspeck of apples. *Plant Diseases* **79**, 1165-1168.
- Brunt AA and Teakle DS (1996) Tobacco necrosis necrovirus. In 'Viruses of Plants: Descriptions and Lists from the VIDE Database '. (Eds A Brunt, K Crabtree, M Dallwitz, A Gibbs and L Watson) (CAB International, Wallingford): 1256-1259.
- Buchen-Osmond C, Crabtree K, Gibbs A and McLean G (1988) 'Viruses of Plants in Australia: Descriptions and Lists from the VIDE Database'. (The Australian National University Research School of Biological Sciences, Canberra, Australia).
- Burger HC and Ulenberg SA (1990) Quarantine problems and procedures. In 'Armoured Scale Insects, their Biology, Natural Enemies and Control'. (vol. 4B) (Ed. D Rosen) (Elsevier, Amsterdam, Netherlands): 313-327.

- Butler EJ (1949) Apple canker, *Nectria galligena* Bres. In 'Plant Pathology'. (Eds EJ Butler and SG Jones) (Macmillan, London, UK): 724-728.
- Byrde RJW and Willetts HJ (1977) 'The brown rot fungi of fruit: their biology and control'. (A. Wheaton & Co., Exeter, UK). 169 pp.
- CAAS (1992) 'Disease and Pest Fauna of Fruit Trees in China'. (2nd Edition) (Fruit Tree Research Institute & Citrus Research Institute, Chinese Academy of Agricultural Science, China Agriculture Publishing House, Beijing, China). 1093 pp.
- CAB International (2008) Crop Protection Compendium (2008 edition). Wallingford, UK.
<http://www.cabicompendium.org/cpc/home.asp>.
- CABI/EPPO (2005) Data Sheets on Quarantine Pests - *Cydia inopinata*. EPPO Quarantine Pests .
http://www.eppo.org/QUARANTINE/insects/Cydia_inopinata/CYDIIN_ds.pdf#search=%22cydia%20inopinata%22., Accessed: 14 September 2006.
- CABI/EPPO (2007a) Data Sheets on Quarantine Pests - *Carposina niponensis* .
http://www.eppo.org/QUARANTINE/insects/Carposina_sasakii/CARSSA_ds.pdf, Accessed: 2008.
- CABI/EPPO (2007b) Data Sheets on Quarantine Pests - *Lopholeucaspis japonica* .
http://www.eppo.org/QUARANTINE/insects/Lopholeucaspis_japonica/LOPLJA_ds.pdf, Accessed: 2007.
- Cai NH, Qin YC and Hu DX (1992) Evaluations of the damage of two spider mite species to apple tree. *Acta Phytophylacica Sinica* **19**, 165-170.
- Campbell AI (1963) The effect of some latent virus infections on the growth and cropping of apples. *Journal of Horticultural Science* **38**, 15-19.
- Campbell RN (1996) Fungal transmission of plant viruses. *Annual Review of Phytopathology* **34**, 87-108.
- Cao KC and Wang CX (1986) A preliminary report on bionomics of *Acronycta strigosa*. *Plant Protection* **12**, 29-32.
- Cao ZM and Wang X (1989) A survey of stem diseases of *Zanthoxylum*. *Forest Pest and Disease* **1**, 47.
- Cardale JC (1985) Hymenoptera: Sphecoidea. Australian Faunal Directory. Australian Biological Resources Study, Canberra. Updated by A A Calder 2000.
<http://www.deh.gov.au/biodiversity/abrs/online-resources/fauna/afd/index.html>, Accessed: 14 June 2006.
- Carter DJ (1984) 'Pest Lepidoptera of Europe with special reference to the British Isles'. (Dr W Junk, Dordrecht, The Netherlands). 431 pp.
- Carver M, Gross GF and Woodward TE (1991) Hemiptera. In 'Insects of Australia CSIRO (Division of Entomology)'. (Ed. ID Naumann) (Melbourne University Press, Carlton, Victoria): 429-509.

- CAS (2008) *Gastropacha quercifolia*. <http://www.cas.ac.cn/html/Dir/2005/09/23/4207.htm>, Accessed: 20 October 2008.
- Cassis G and Gross G (1995) Hemiptera: Heteroptera (Coleorrhyncha to Cimicomorpha). Australian Faunal Directory. Australian Biological Resources Study, Canberra. <http://www.deh.gov.au/biodiversity/abrs/online-resources/fauna/afd/index.html>, Accessed: 06 April 2006.
- Cassis G and Gross G (2002) Hemiptera: Pentatomomorpha. Australian Faunal Directory. Australian Biological Resources Study, Canberra. <http://www.deh.gov.au/biodiversity/abrs/online-resources/fauna/afd/index.html>, Accessed: 06 April 2006.
- Cassis G, Houston WWK, Weir TA and Moore BP (1992) Coleoptera: Scarabaeoidea. Australian Faunal Directory. Australian Biological Resources Study, Canberra Updated by A. A. Calder 2002. <http://www.deh.gov.au/biodiversity/abrs/online-resources/fauna/afd/index.html>, Accessed: 06 April 2006.
- Castlebury LA, Rossman AY and Hyten AS (2006) Phylogenetic relationships of *neonectria*/*Cylindrocarpon* on *Fagus* in North America. *Canadian Journal of Botany* **84**, 1417-1433.
- Central Science Laboratory (CSL) (2005) CSL Pest risk analysis for *Eulecanium excrescens*. <http://www.fera.defra.gov.au/plants/plantHealth/pestsDiseases/documents/eulecanium.pdf>, Accessed: May 2009.
- Chai RX, Yue SX and Hu GL (1990) Study of threshold for development and effective thermal summation of *Eotetranychus* sp. *Journal of Sichuan Agricultural University* **8**, 1822.
- Chambers SC (1982) Lists of diseases recorded on ornamentals, native plants and weeds in Victoria before 30 June 1980. Department of Agriculture, Melbourne, Victoria.
- Chang TP and Lin CAS (1939) Life histories of the important insect pests of the pear trees in Ting Hsien. *Peking Natural History Bulletin* **13**, 201-226.
- Chao YC and Lee YJ (1966) Revision of some common species of *Rhynchites* Schneider (Coleoptera, Attelabidae) in China. *Acta Entomologica Sinica* **15**, 249-250.
- Charmillot PJ and Brunner JF (1989) Summer fruit tortrix *Adoxophyes orana* life cycle warning system and control. *Entomologia Hellenica* **7**, 17-26.
- Chaudhary KCB, Puttoo BL and Ashraf SS (1987) Seed-borne nature of *Pestalotia hartigii* on apple seeds. *International Journal of Tropical Plant Diseases* **5**, 111-112.
- Chen HM and Li GH (1983) A preliminary observation on *Orthosia incerta*. *Forest Science and Technology (Linze Keji Tongxun)* **11**, 23-24.
- Chen JM and Li Y (2005) The attack characteristics of *Lithocelletis ringeniella* to apple trees and its control. *China Fruits* **3**, 53.
- Chen SJ (2003) Bionomics of *Parlatoria oleae* and its control. *Entomological Knowledge* **40**,

266-267.

- Chen XM, Wang Z, Chen Y, Zhao JJ, Ye SD and Wang SY (2008) Age specific life table of Chinese white wax scale (*Ericerus pela*) natural population and analysis of death key factors. *Scientia Silvae Sinicae* **44**, 87-94.
- Cheng J, Li W, Meng X, Tian Y and Mang K (1998) Detecting the resistance of transgenic in vitro apple plantlets to pests. *China Fruits* **4**, 21.
- Cheng ZM, Fu JM, Ma YK and Hou F (1988) Studies on mycoflora infecting crucifer vegetable seeds. *Journal of Shenyang Agricultural University* **19**, 35-37.
- Chkistoff A (1934) Some plant diseases new to Bulgaria (2nd contribution). *Bull-Soc-Bot-de-Bulgarie* **6**, 37-48.
- CHNZX-Farming (2008a) *Adoretus puberulus* Motsch.
<http://www.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/>, Accessed: 20 October 2008.
- CHNZX-Farming (2008b) *Adoretus tenuimaculatus* Waterhouse.
<http://www.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/>, Accessed: 20 October 2008.
- CHNZX-Farming (2008c) *Amphipyra pyramidea* (Linnaeus).
<http://www.suihua.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/50.htm>, Accessed: 20 October 2008.
- CHNZX-Farming (2008d) *Amsacta lactinea* (Cramer).
<http://www.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/37.htm>, Accessed: 20 October 2008.
- CHNZX-Farming (2008e) *Asias halodendri* (Pallas).
<http://www.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/38.htm>, Accessed: 20 October 2008.
- CHNZX-Farming (2008f) *Bhima idiota* Graeser.
<http://www.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/05.htm>, Accessed: 20 October 2008.
- CHNZX-Farming (2008g) *Clania miniscule* Butler.
<http://www.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/14.htm>, Accessed: 20 October 2008.
- CHNZX-Farming (2008h) *Cossus cossus orientalis* Gaede.
<http://www.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/25.htm>, Accessed: 20 October 2008.
- CHNZX-Farming (2008i) *Cryptotympana atrata* (Fabricius).
<http://www.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/36.htm>, Accessed: 20 October 2008.
- CHNZX-Farming (2008j) *Dolycoris baccarum* (Linnaeus).

- <http://www.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/07.htm>,
Accessed: 20 October 2008.
- CHNZX-Farming (2008k) *Eurydema gebleri* Kolenati.
<http://www.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/59.htm>,
Accessed: 20 October 2008.
- CHNZX-Farming (2008l) *Holotricha diomphalia* Batesa.
<http://www.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/15.htm>,
Accessed: 20 October 2008.
- CHNZX-Farming (2008m) *Lycorma delicatula* (White).
<http://www.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/08.htm>,
Accessed: 20 October 2008.
- CHNZX-Farming (2008n) *Megopsis sinica* White.
<http://www.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/11.htm>,
Accessed: 20 October 2008.
- CHNZX-Farming (2008o) *Mesosa myops* (Dalman).
<http://www.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/54.htm>,
Accessed: 20 October 2008 .
- CHNZX-Farming (2008p) *Narosa nigrisigna* Wileman.
<http://www.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/34.htm>,
Accessed: 20 October 2008.
- CHNZX-Farming (2008q) *Oncotympana maculiocllis* Motschulsky.
<http://www.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/22.htm>,
Accessed: 20 October 2008.
- CHNZX-Farming (2008r) *Platypleura kaempferi* Fabricius.
<http://www.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/41.htm>,
Accessed: 20 October 2008.
- CHNZX-Farming (2008s) *Popillia quadriguttata* Fabr.
<http://www.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/55.htm>,
Accessed: 20 October 2008.
- CHNZX-Farming (2008t) *Porthesia similes* (Fueszly).
<http://www.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/20.htm>,
Accessed: 20 October 2008.
- CHNZX-Farming (2008u) *Prothesia* [sic] *similes xanthocampa* Dyar.
<http://www.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/43.htm>,
Accessed: 20 October 2008.
- CHNZX-Farming (2008v) *Riptortus pedestris* Fabricius.
<http://www.chnzx.com/book/Farming/index3/guoshu/pinguo/chonghai/09.htm>,
Accessed: 20 October 2008.
- CHNZX-Farming (2008w) *Sympiezomias velatus* (Chevrloot).

- <http://www.chnx.com/book/Farming/index3/guoshu/pinguo/chonghai/16.htm> ,
Accessed: 20 October 2008.
- CHNZX-Farming (2008x) *Synanthedon haitangvora* Yang.
<http://www.chnx.com/book/Farming/index3/guoshu/pinguo/chonghai/30.htm>,
Accessed: 20 October 2008.
- CHNZX-Farming (2008y) *Zamacra excavata* Dyar.
<http://www.chnx.com/book/Farming/index3/guoshu/pinguo/chonghai/52.htm>,
Accessed: 20 October 2008.
- Chou I (1985) 'Monographia Diaspididarum Sinensium. Volume 2.' (Shaanxi Science and technology Press, Shaanxi, China).
- Ciferri R (1955) Preliminary list of noteworthy diseases of cultivated plants in continental eastern China. *Plant Disease Reporter* **39**, 785-792.
- CIQSA (2001a) The document concerning exports of apples of Shaanxi China to Australia. The State Administration for Entry-Exit Inspection and Quarantine of the People's Republic of China (AQSIQ), Beijing, China. [Government to government document].
- CIQSA (2001b) Market Access Submission: Report on Exportation of China peach to Australia (Shandong Province). The State Administration for Entry-Exit Inspection and Quarantine of the People's Republic of China (AQSIQ), Beijing, China. [Government to government document].
- CIQSA (2001c) Report on exportation of apple from the People's Republic of China (Shandong Province) to Australia. The State Administration for Entry-Exit Inspection and Quarantine of the People's Republic of China (AQSIQ), Beijing, China. [Government to government document].
- Cohen O, Ozgur BO, Moskowits Y, Rozov A, Gootwine E, Mawassi M and Bar-Joseph M (2005) Goate horns: platforms for viroid transmission to fruit trees. *Phytoparasitica* **33**, 141-148.
- Colby AS (1920) Sooty blotch of pomaceous fruits. *Transactions of the Illinois Academy of Science* **13**, 139-175.
- Common IFB (1990) 'Moths of Australia'. (Melbourne University Press, Carlton, Victoria, Australia). 535 pp.
- Conradi-Larsen E and Soemme L (1973) Notes on the biology of *Dolycoris baccarum* L. (Het., Pentatomidae). *Norsk Entomologisk Tidsskrift* **20**, 245-247.
- Cooke MC (1906) 'Fungoid pests of cultivated plants. '. (Spottiswoode & Co., London.).
- Coutts RH, Rigden JE, Slabas AR, Lomonossoff GP and Wise PJ (1991) The complete nucleotide sequence of tobacco necrosis virus strain D. *Journal of General Virology* **72**, 1521-1529.
- Cox JM (1987) Pseudococcidae (Insecta: Hemiptera). *Fauna of New Zealand* **11**, 1-228.

- Cranham JE and Helle W (1985) Chapter 3.4 Pesticide Resistance in Tetranychidae. In 'Spider Mites: Their Biology, Natural Enemies and Control'. (vol. 1B) (Eds W Helle and MW Sabelis) (Elsevier Science Publishers, Amsterdam): 405-421.
- Cranshaw WS and Sclar DC (2008) Spider mites. Insect series: home and garden, No. 5.507. <http://www.ext.colostate.edu/pubs/insect/05507.pdf> . Colorado State University, Cooperative Extension program.
- Cross JV (1997) Susceptibility of the summer fruit tortrix moth, *Adoxophyes orana* (Lepidoptera: Tortricidae), to chlorpyrifos and strategies for insecticidal control in orchards. *Annals of Applied Biology* **131**, 197-212.
- CUES (2007) Introduction to mealybugs. Centre for Urban Ecology and Sustainability. University of Minnesota. <http://www.entomology.umn.edu/cues/inter/inmine/Mbugs.html>, Accessed: 05 December 2008.
- Cunnington JH (2004) Three *Neofabraea* species on pome fruit in Australia. *Australasian Plant Pathology* **33**, 453-454.
- Cunnington JH, Priest MJ, Powney RA and Cother NJ (2007) Diversity of *Botryosphaeria* species on horticultural plants in Victoria and New South Wales. *Australasian Plant Pathology* **36**, 157-159.
- DAFF (2004a) Longan and lychee fruit from the People's Republic of China and Thailand: Final Import Risk Analysis Report. Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, Australia. 344 pp.
- DAFF (2004b) Mangosteen fruit from Thailand: Final Import Risk Analysis Report. Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, Australia. 158 pp.
- DAFWA (2009) Submission to the draft import risk analysis for fresh apple fruit from China. Available at http://www.daff.gov.au/ba/ira/current-plant/apples_china/submissions_to_the_draft_ira. Government of Western Australia Department of Agriculture and Food, Perth, Western Australia, Australia. 26 pp.
- Dai YC (2005) First report of sapwood rot of peach caused by *Schizophyllum commune*. *Plant Disease* **89**, 778.
- Dai ZY and Zhu MY (1979) The bionomics and control of the geometrid *Apocheima cinerarius* Erschoff in Inner Mongolian Autonomous Region. *Acta Entomologica Sinica* **22**, 420-427.
- Davis DR (1968) A revision of the American moths of the family Carposinidae. *Bulletin of the Smithsonian Institution US National Museum* **289**, 1-103.
- Davis EE, French S and Venette RC (2005) Mini risk assessment - summer fruit tortrix moth, *Adoxophyes orana* (Fischer von Roslerstamm, 1834) [Lepidoptera: Tortricidae]. University of Minnesota and USDA Forest Service, St Paul, Minnesota. 48 pp.
- DAWA (2006) Draft plant pathology lists of pathogen species. Department of Agriculture,

- Government of Western Australia, Perth. 48 pp.
- de Jong SN, Levesque CA, Verkley GJM, Abeln ECA, Rahe JE and Braun PG (2001) Phylogenetic relationships among *Neofabraea* species causing tree cankers and bull's-eye rot of apple based on DNA sequencing of ITS nuclear rDNA, mitochondrial rDNA, and the β -tubulin gene. *Mycological Research* **105**, 658-669.
- Deng DL (1985) *Anthribus niveovariegatus* (Reolofs) a natural enemy of *Eulecanium excrescens* Ferris. *Plant Protection (Zhiwu Baohu)* **11**, 14-15.
- Deng Z, Zhang NX and Jia XF (1990) Colonization of *Metaseiulus occidentalis* (Acari: Phytoseiidae) and its control effect on *Eotetranychus pruni* (Acari: Tetranychidae) in Lanzhou apple orchards. *Chinese Journal of Biological Control* **6**, 54-58.
- Dennis C and Mountford J (1975) The fungal flora of soft fruits in relation to storage and spoilage. *Annals of Applied Biology* **79**, 141-147.
- Desvignes JC, Grasseau N, Boye R and Cornaggia D (1999) Biological properties of apple scar skin viroids: isolates, host range, different sensitivity of apple cultivars, elimination, and natural transmission. *Plant Disease* **83**, 768-772.
- Di Serio F, Malfitano M, Alioto D, Ragozzino A, Desvignes JC and Flores R (2001) *Apple dimple fruit viroid*: Fulfilment of Koch's postulates and symptom characteristics. *Plant Disease* **85**, 179-182.
- Di Stefano G (1939) A contribution to the knowledge of *Orgyia antiqua*. (Original title: Contributo alla conoscenza dell' *Orgyia antiqua*, L. (Lepid. Lymantriidae)). *Redia* **25**, 303-318.
- Diakonoff A (1989) Revision of the Palaearctic Carposinidae with description of a new genus and new species (Lepidoptera: Pyraloidea). *Zoologische Verhandelingen* **251**, 1-155.
- Dixon GR (2009) Plasmodiophora brassicae in its environment. *Journal of Plant Growth Regulation* DOI 10.1007/s00344-009-9098-3.
- DOA and AQSIQ (2007) Protocol of phytosanitary requirements for the export of apple fruit from China to South Africa between the Department of Agriculture [DOA] of the Republic of South Africa and the General Administration of Quality Supervision, Inspection and Quarantine [AQSIQ] of the People's Republic of China . http://www.nda.agric.za/daDev/topMenu/PlantHealth/docs/Protocol_%20import_apple_China-SA.pdf, Accessed: May 2009.
- Dogmus-Lehtijärvi HT, Lehtijärvi A, Karaca G and Aday AG (2007) *Sphaeropsis sapinea* Dyko & Sutton associated with shoot blight on *Pinus brutia* Ten. in southwestern Turkey. *Acta Silvatica et Lignaria Hungarica Special Edition*, :95-99 .
- Donaldson J and Houston WWK (2002) Hemiptera: Coccoidea. Australian Faunal Directory. Australian Biological Resources Study, Canberra. <http://www.deh.gov.au/biodiversity/abrs/online-resources/fauna/afd/index.html>, Accessed: 06 April 2006.
- Dosse G (1953) *T. oudemansi* a species of mite new to Germany. *Z-angew-Ent.* **34**, 587-597.

- Drake CR (1970) Report No. 10. *Fungicide Nematicide Tests* . **26**, 8-9 pp.
- Drake CR (1972) Report No. 18. *Fungicide Nematicide Tests* . **28**, 14 pp.
- Drake CR (1974) Report No. 11. *Fungicide Nematicide Tests* . **30**, 10 pp.
- Drew RAI and Hancock DL (1994) The *Bactrocera dorsalis* complex of fruit flies (Diptera: Tephritidae: Dacinae) in Asia. *Bulletin of Entomological Research* **2**, 1-68.
- Drew RAI, Hooper GHS, Bateman MA (1982) 'Economic Fruit Flies of the South Pacific Region. 2nd Edition .' (Queensland Department of Primary Industries, Brisbane).
- Drysdale GS and Fleet GH (1989) The effect of acetic acid bacteria upon the growth and metabolism of yeasts during the fermentation of grape juice. *Journal of Applied Bacteriology* **67**, 471-481.
- Dugan FM (1993) Anthracnose, perennial canker and bull's eye rot of apple and pear. *Tree Fruit Postharvest Journal* **4**, 56.
- Dugan FM, Grove GG and Rogers JD (1993) Comparative studies of *Cryptosporiopsis curvispora* and *C. perennans*. I. Morphology and pathogenic behaviour. *Mycologia* **85**, 551-564.
- Dullahide SR, Stirling GR, Nikulin A and Stirling AM (1994) The role of nematodes, fungi, bacteria, and abiotic factors in the etiology of apple replant problems in the Granite Belt of Queensland. *Australian Journal of Experimental Agriculture* **34**, 1177-1182.
- Edney KL (1956) The rotting of apples by *Gloeosporium perennans* Zeller & Childs. *Annals of Applied Biology* **44**, 113-128.
- Elmosa HM (1971) Studies on the biology of *Cenopalpus pulcher* (C. & F.) (Acarina, Tenuipalpidae) in Baghdad. *Zeitschrift-fur-Angewandte-Entomologie* **67**, 394-396.
- EPPO (2005a) Data sheets on quarantine pests *Bactrocera dorsalis*: EPPO Quarantine Pests. http://www.eppo.org/QUARANTINE/insects/Bactrocera_dorsalis/DACUDO_ds.pdf, Accessed: October 2005.
- EPPO (2005b) PQR database (version 4.4) *European and Mediterranean Plant Protection Organization, Paris, France*.
- EPPO/CABI (1996) *Carposina niponensis*. In 'Quarantine pests for Europe'. (2) (CAB International, Wallingford, UK): 139-142.
- Fang ZG, Wang YP, Zhou K and Zhou ZL (2001) Biological characteristics of *Setora postornata* and its chemical control. *Journal of Zhejiang Forestry College* **18**, 173-176.
- FAO (1996) 'International Standards for Phytosanitary Measures (ISPM) No. 4. Requirements for the establishment of pest free areas'. (Secretariat of the International Plant Protection Convention, Food and Agriculture Organization of the United Nations, Rome). 8 pp.
- FAO (1999) 'International Standards for Phytosanitary Measures (ISPM) No. 10. Requirements for the establishment of pest free places of production and pest free

- production sites'. (Secretariat of the International Plant Protection Convention, Food and Agriculture Organization of the United Nations, Rome). 10 pp.
- FAO (2003) 'International Standards for Phytosanitary Measures (ISPM) No. 18 Guidelines for the use of irradiation as a phytosanitary measure'. (Secretariat of the International Plant Protection Convention, Food and Agricultural Organization of the United Nations, Rome). 16 pp.
- FAO (2004) 'International Standards for Phytosanitary Measures (ISPM) No. 11. Pest risk analysis for quarantine pests including analysis of environmental risks and living modified organisms'. (Secretariat of the International Plant Protection Convention, Food and Agricultural Organization of the United Nations, Rome). 26 pp.
- FAO (2005) 'International Standards for Phytosanitary Measures (ISPM) No. 22. Requirements for the establishment of areas of low pest prevalence'. (Secretariat of the International Plant Protection Convention, Food and Agriculture Organization of the United Nations, Rome). 10 pp.
- FAO (2006) 'International Standards for Phytosanitary Measures (ISPM) No. 26: Requirement for the establishment of pest free areas for fruit flies (Tephritidae)'. (Secretariat of the International Plant Protection Convention, Food and Agriculture Organization of the United Nations, Rome). 15 pp.
- FAO (2007) 'International Standards for Phytosanitary Measures (ISPM) No. 2. Framework for pest risk analysis'. (Secretariat of the International Plant Protection Convention, Food and Agricultural Organization of the United Nations, Rome). 15 pp.
- FAO (2009) 'International Standards for Phytosanitary Measures (ISPM) No. 5. Glossary of phytosanitary terms'. (Secretariat of the International Plant Protection Convention, Food and Agricultural Organization of the United Nations, Rome). 27 pp.
- FAOSTAT (2006) FAO Statistical Databases. <http://faostat.fao.org/faostat>, Accessed: 2006.
- Farr DF, Bills GF, Chamuris GP and Rossman AY (1995) 'Fungi on plants and plant products in the United States'. (APS Press, American Phytopathological Society, St. Paul Minn., USA). 931 pp.
- Farr DF and Rossman AY (2009) Fungal Databases, Systematic Mycology and Microbiology Laboratory, ARS, USDA., Accessed: July 2009.
- Farr DF, Rossman AY, Palm ME, McCray EB, Farr DF, Rossman AY, Palm ME and McCray EB (2008) Fungal Databases. Systematic Botany & Mycology Laboratory, ARS, USDA. <http://nt.ars-grin.gov/fungaldatabases>, Accessed: August 2008.
- FCC (1997) Average Weather Data for Cities in China. Provided by Families with Children from China (FCC) in their website. <http://fwcc.org/climate.htm>, Accessed: August 2008.
- Feng HZ, Wang L and Hu WJ (2005) Occurrence and aerial control of *Apocheima cinerarius* in the natural euphrates poplar forests in Shaya County. *Forest Pests and Diseases* **24**, 22-24.

- Feng JG, Zhang Y, Tao X and Chen XL (1988) Use of radioisotope P32 to evaluate the parasitization of *Adoxophyes orana* (Lep.: Tortricidae) by mass released *Trichogramma dendrolimi* (Hym.: Trichogrammatidae) in an apple orchard. *Chinese Journal of Biological Control* **4**, 10-12.
- Feng MX (1997) On the integrated pest management for deciduous fruit crops. *China Fruits* **1**, 47-49.
- Feng MX, Jiang RD, Wang JQ, Li Q, Wang PS and Li RG (2004) Study on the choice of chemicals for use in green apple production. *China Fruits* **4**, 8-10.
- Finlay JR and Teakle DS (1969) The effect of pH on the particle stability of phosphotungstate-stained tobacco necrosis virus. *Journal of General Virology* **5**, 93-96.
- Fletcher MJ and Watson S (2002) Hemiptera: Membricoidea. Australian Faunal Directory. Australian Biological Resources Study, Canberra.
<http://www.deh.gov.au/biodiversity/abrs/online-resources/fauna/afd/index.html>, Accessed: 06 April 2006.
- Fletcher MJ and Watson S (2003) Hemiptera: Fulgoroidea. Updated 2006 by Fletcher and Watson. Australian Faunal Directory. Australian Biological Resources Study, Canberra.
<http://www.deh.gov.au/biodiversity/abrs/online-resources/fauna/afd/index.html>, Accessed: 06 April 2006.
- Foldi I (1990) Moulting and scale-cover formation. In 'Armoured Scale Insects, their Biology, Natural Enemies and Control'. (vol. 4A) (Ed. D Rosen) (Elsevier, Amsterdam, Netherlands): 257-265.
- Forkner RE, Marquis RJ and Lill JT (2004) Feeny revisited: condensed tannins as anti-herbivore defences in leaf-chewing herbivore communities of *Quercus*. *Ecological Entomology* **29**, 174-187.
- Fu W and Huang CB (1990) Studies on release rates and ratios of two isomers of sex pheromone of summer fruit tortrix moth *Adoxophyes orana* in South China. *Contributions from Shanghai Institute of Entomology* **9**, 150.
- Fu YH and Zhang YS (1988) Pathogenic fungi of maize stalk rot in northern-central Shanxi and their virulence. *Shanxi Agricultural Science* **8**, 4-6.
- Fukushi T (1925) Studies on the apple rust caused by *Gymnosporangium yamadae* Miyabe. *Journal of the College of Agriculture* **15**, 269-307.
- Funayama K (2002) Oviposition and development of *Halyomorpha halys* (Stal) and *Homalagonia obtusa* (Walker) (Heteroptera: Pentatomidae) on apple trees. *Japanese Journal of Applied Entomology and Zoology* **46**, 6.
- Funayama K and Takahashi Y (1995) Development of chlorpyrifos resistance in leafroller moth, *Adoxophyes orana fasciata* Walsingham (Lepidoptera, Tortricidae) in southern Akita Prefecture. *Japanese Journal of Applied Entomology and Zoology* **39**, 81-83.
- Furino T and Shirai K (1970) On the feeding especially of the black-marked prominent (*Phalera flavescentis* Bremer et Grey) and the black-back prominent (*Clostera*

- anastomosis tristis* Staudinger). *Kyoto University Bulletin, Kyoto University Forests* **41**, 26-40.
- GAAS (2008a) *Calyptra lata* (Butler). Gansu Academy of Agricultural Science.
<http://gsagr.ac.cn/zypt/kongchong/showsoft.asp?id=1671>, Accessed: 20 October 2008a.
- GAAS (2008b) *Celastrina argiolous* (Linnaeus). Gansu Academy of Agricultural Science.
<http://www.gsagr.ac.cn/zypt/kongchong/showsoft.asp?id=973>, Accessed: 21 October 2008b.
- GAAS (2008c) *Homalogonia obtusa* (Walker). Gansu Academy of Agricultural Science.
<http://www.gsagr.ac.cn/zypt/kongchong/showsoft.asp?id=83>, Accessed: 22 October 2008c.
- Gardner MW (1923) Origin and control of apple blotch cankers. *Journal of Agricultural Research* **25**, 403-418.
- Gariepy TD, Rahe JE, Lévesque CA, Spotts RA, Sugar DL and Henriquez JL (2005) *Neofabraea* species associated with bull's-eye rot and cankers of apple and pear in the Pacific Northwest. *Canadian Journal of Plant Pathology* **27**, 118-124.
- Geider K, Auling G, Jakovljevic V and Völksch B (2009) A polyphasic approach assigns the pathogenic *Erwinia* strains from disease pear trees in Japan to *Erwinia pyrifoliae*. *Letters in Applied Microbiology*, **48**, 324-330.
- Georgi LL (1988) Transmission of tomato ringspot virus by *Xiphinema americanum* and *X. rivesi* from New York apple orchards. *Journal of Nematology* **20**, 304-308.
- Georgiev G and Beshkov S (2000) New and little-known lepidopteran (Lepidoptera) phytophages on the poplars (*Populus* spp.) in Bulgaria. *Anzieger-fur-Schadlingskunde* **73**, 1-4.
- Gibanov PK and Sanin YV (1971) Lepidoptera - pests of fruits in the Maritime Province. *Zashchita Rastenii* **16**, 41-43.
- Gibbs A and Harrison B (1976) 'Plant Virology: The Principles.'. (Edward Arnold, London).
- Glawe DA (2009) *Pacific Northwest Fungi Database*. Department of Plant Pathology, Washington State University, Puyallup, WA.
<http://pnwfungi.wsu.edu/programs/aboutDatabase.asp>.
- Goetz J and Dugan FM (2006) *Alternaria malorum*: A mini-review with new records for hosts and pathogenicity. *Pacific Northwest Fungi* **1**, 1-8.
- Goto M (1992) Fundamentals of bacterial plant pathology. In 'Fire Blight - the disease and its causative agent, *Erwinia amylovora*'. (Ed. JL Vanneste) (Academic Press, San Diego, California, USA).
- Grand LF and Vernia CS (2005) Biogeography and hosts of poroid wood decay fungi in North Carolina: species of *Coltricia*, *Coltriciella* and *Inonotus*. *Mycotaxon* **91**, 35-38.
- Gross GF (1991) Superfamily Pentatomoidea. In 'The insects of Australia: A textbook for

- students and research workers'. (Second Edition) (vol. II) (Ed. CSIRO) (Melbourne University Press, Australia): 504-509.
- Grove GG (1990a) Anthracnose and perennial canker. In 'Compendium of Apple and Pear Diseases'. (Eds AL Jones and HS Aldwinckle) (American Phytopathological Society, St. Paul, Minnesota, USA): 36-38.
- Grove GG (1990b) Nectria canker. In 'Compendium of Apple and Pear Diseases'. (Eds AL Jones and HS Aldwinckle) (American Phytopathological Society, St. Paul, Minnesota, USA): 35-36.
- Grove GG, Dugan FM and Boal RJ (1992) Perennial canker of apple: seasonal host susceptibility, spore production, and perennation of *Cryptosporiopsis perennans* in infected fruit in eastern Washington. *Plant Disease* **76**, 1109-1114.
- Grove GG, Eastwell KC, Jones AL and Sutton TB (2003) Diseases of apple. In 'Apples: Botany, Production and Uses'. (Eds DC Ferree and IJ Warrington) (CAB International): 672.
- Guba EF (1924) Phyllosticta leaf spot, fruit spot and canker of the apples: its ecology and control. *Phytopathology* **14**, 234-237.
- Guo PI and Wen YZ (1988) Study on the occurrence and control of *Metabolus flavescens* Brenske. *Insect Knowledge* **25**, 271-272.
- Guo YN (1994) The integrated management of the rust of apple (*Gymnosporangium yamadae* Miyobe). *Bulletin of Agricultural Science Society for Horticultural Science* **4**, 228.
- Gutierrez J (1994) Acari - leaf feeding mites. In 'Insect pests of cotton'. (Ed. TJ Matthews GA) (CAB International, Wallingford, UK): 407-424.
- Hadidi A, Hansen AJ, Parish CL and Yang X (1991) Scar skin and dapple apple viroids are seed-borne and persistent in infected apple trees. *Research in Virology* **142**, 289-296.
- HAL (2004) The Australian Horticulture Statistics Handbook 2004. Horticulture Australia Limited. Available on-line at: http://www.horticulture.com.au/docs/industry/Statistics_Handbook.pdf, Accessed: July 2009.
- Halliday RB (2000) Arachnida: Acarina. Australian Faunal Directory. Australian Biological Resources Study, Canberra. <http://www.deh.gov.au/biodiversity/abrs/online-resources/fauna/afd/index.html>, Accessed: 10 April 2006.
- Hammond RW and Owens RA (2006) Viroids: new and continuing risks for horticultural and agricultural crops. APSNet, the American Phytopathological Society. <http://www.apsnet.org/online/feature/viroids/>.
- Han G and Ma R (1996) Scanning electron microscopy of antennal sensilla of *Acleris fimbriana*. *Forest Research* **9**, 300-304.
- Han L, Wang G, Yang X, Zhu SF and Hadidi A (2003) Viroids in China. In 'Viroids'. (Eds A Hadidi, R Flores, JW Randles and JS Semancik) (CSIRO Publishing, Australia): 283-

285.

- Hanson HC (1963) 'Diseases and pests of economic plants of central and south China, Hong Kong and Taiwan (Formosa)'. (American Institute of Crop Ecology, Washington D. C.).
- Hao BF, Yu LC and Xu CX (2007) *Tarsonemus confusus*, a new pest for bagged apples. *Journal of Fruit Science* **24**, 180-184.
- Harada Y, Sawamura K and Konno K (1974) *Diplocarpon mali* sp. nov., the perfect state of apple blotch fungus *Marssonina coronaria*. *Annals of the Phytopathological Society of Japan* **40**, 412-418.
- Harrison BD (1960) The biology of soil-borne plant viruses. *Advances in Virus Research* **7**, 131-162.
- Harrison BD (1977) Ecology and control of viruses with soil-inhabiting vectors. *Annual Review of Phytopathology* **15**, 331-360.
- Hayova VP and Minter DW (1998) '*Valsa ceratosperma*. CMI Descriptions of Fungi and Bacteria No. 1366'. (CAB International, Wallingford, UK). 2 pp.
- He B, Peng SG, He GY, Wei YL and Tan XQ (1991) Bionomics of *Actias selene ningpoana* Felder and its control. *Insect Knowledge* **28**, 353-354.
- He Y, Qiu Z, Qiu H, Zhou J, Huang J and Zhou M (1996) Observation of the sex behavior responses by *Adoxophyes orana* moths in different parts of China. *Entomological Journal of East China* **5**, 57-61.
- Hely PC, Pasfield G and Gellatley GJ (1982) 'Insect pests of fruit and vegetables in NSW'. (Inkata Press, Melbourne). 312 pp.
- Henriquez JL, Sugar D and Spotts RA (2008) Effects of environmental factors and cultural practices on bull's eye rot of pear. *Plant Disease* **92**, 421-424.
- Hetherington SD (2005) 'Integrated Pest and Disease Management for Australian Summerfruit'. (The State of New South Wales, NSW Department of Primary Industries, Orange, NSW, Australia).
- Hibben CR, Bozarth RF and Reese J (1979) Identification of Tobacco Necrosis Virus in Deteriorating Clones of Aspen. *Forest Science* **25**, 557-567.
- Hiramatsu A, Samamaki Y and Kusigemati K. (2001) A list of pest-insects feeding on the Kenaf in Kagoshima city with seasonal abundance of some major pest-insects. *Bulletin of the Faculty of Agriculture, Kagoshima University* **51**, 1-7.
- Hnatiuk RJ (1990) 'Census of Australian vascular plants. Australian Government Bureau of Flora and Fauna.' (Australian Government Publishing Service, Canberra).
- Hoh K (1933) A study of *Urochela luteovaria* Distant. *Journal of Science of the National University of Shantung* **1**, 452-466.

- Holb IJ (2008) Brown rot blossom blight of pome and stone fruits: symptom, disease cycle, host resistance, and biological control. *International Journal of Horticultural Science* **14**, 15-21.
- Hollis D and Eastop VF (2005) Hemiptera: Aphidoidea. Australian Faunal Directory. Australian Biological Resources Study, Canberra.
<http://www.deh.gov.au/biodiversity/abrs/online-resources/fauna/afd/index.html>, Accessed: 04 June 2006.
- HortResearch (1999) BugKEY; Insects and mites of pipfruit and stonefruit.
<http://www.hortnet.co.nz/key/pipfruit.htm>.
- Hou BH and Zhang RJ (2005) Potential distribution of the fruit fly *Bactrocera dorsalis* (Diptera: Tephritidae) in China as predicted by CLIMEX. *Acta Ecologica Sinica* **25**, 1569-1574.
- Howell WE, Skrzeczkowski LJ, Wessels T, Mink GI and Nunez A (1995) Non-transmission of apple scar skin viroid and peach latent mosaic viroid through seed. *Acta Horticulturae* **472**, 635-639.
- Hsieh HJ (1980) Survey of diseases of woody plants in Taiwan. *Quarterly Journal of Chinese Forestry* **13**, 129-130.
- Hu M and Qi M (1993) The morphology and behaviour of the *Acronicta rumicis* L. *Entomological Knowledge* **30**, 95-96.
- Hua L and Hua BZ (1995) A preliminary study on the host biotypes of the peach fruit borer. *Acta Phytopylacica Sinica* **22**, 165-170.
- Hua L and Wang S (2006) Apple pest and disease control system. College of Plant Protection, Northwest A&F University. <http://www.appleonline.com.cn/apple2000/>.
- Huan JL, Cheng XM and Zhou CB (1987) Infestation pattern of *Carposina niponensis* in plantations of *Ziziphus jujuba* and its control. *Plant Protection* **13**, 18-20.
- Huang CX, Qin BY, Xi ZX and Mang KI (1984) On the tobacco necrosis virus isolated from hami-melon in Xinjiang and its chemico-physical properties. *Acta Phytopathologica Sinica* **14**, 153-158.
- Huber GA (1930) The *Aspergilli* and their relation to decay in apples. *Journal of Agriculture Research* **41**, 801-807.
- Hurt SS and Podleckis EV (1995) Apple scar skin viroid is not seed transmitted or transmitted at a low rate in oriental pear. *Acta Horticulture* **309**, 311-318.
- Hwang KH (1974) Identification of ten species of leafrollers (Lepidoptera, Tortricidae) on apple trees in North China. *Acta Entomologica Sinica* **17**, 29-42.
- Hwang KH and Woo WC (1958) Studies on the biology and chemical control of the apple fruit borer, *Carposina niponensis* Walsingham (Lepidoptera, Carposinidae). *Acta Oeconomica Entomologica Sinica* **1**, 31-66.

- ICON (2009) Conditions C13996, C13997, C14921 , C14922, C16532, C16534. Import Conditions Database. Australian Government Department of Agriculture, Forestry and Fisheries. Available on-line at <http://www.daffa.gov.au/aqis>, Accessed: July 2009.
- ICTVdB (2007) The Universal Virus Database, version 4.
<http://www.ncbi.nlm.nih.gov/ICTVdb/ICTVdB/>.
- Index Fungorum (2006) Index Fungorum.
<http://www.speciesfungorum.org/Names/Names.asp>, Accessed: August 2006 .
- Injac M (1983) The occurrence of leaf-rollers (*Pandemis heparana* Den & Schiff., *Adoxophyes orana* F. v. R.: Lep. Tortricidae) on apple. *Zastita Bilja* **34**, 365-379.
- INRA (2006) Bonjour et bienvenue sur, HYPPZ - Datasheets.
<http://www.inra.fr/Internet/Produits/HYPPZ/pa.htm>, Accessed: 16 June 2006.
- International Atomic Energy Agency (2003) Trapping Guidelines for Area-Wide Fruit Fly Programmes. <http://www.iaea.org/nafa/d4/public/trapping-web.pdf>.
- Ishiguri Y and Shirai Y (2004) Flight activity of the peach fruit moth, *Carposina sasakii* (Lepidoptera: Carposinidae), measured by a flight mill. *Applied Entomology and Zoology* **39**, 127-131.
- Jacobs K and Botha A (2008) *Mucor renisporus* sp. nov., a new coprophilous species from Southern Africa. *Fungal Diversity* **29**, 27-35.
- Jarvis WR (1977) *Botryotinia and Botrytis* species: taxonomy, physiology, and pathogenicity Monograph, Research Branch Canada Department of Agriculture, No. 15. Department of Agriculture , Ottawa, Ont., Canada. 195 pp.
- Jeewon R, Liew ECY and Hyde KD (2003) Molecular systematics of the Amphisphaeriaceae based on cladistic analyses of partial LSU rDNA gene sequences. *Mycological Research* **107**, 1392-1402.
- Jeon HY, Kim DS, Cho MR, Yiem MS and Chang YD (2000) Recent status of major fruit tree pest occurrences in Korea. *Journal of the Korean Society for Horticultural Science* **41**, 607-612.
- Jeppson LR, Keifer HH and Baker EW (1975) 'Mites Injurious to Economic Plants'. (University of California Press, Berkeley, USA). 614 pp.
- Ji J, Zhang YX, Chen X and Lin JZ (2005) Laboratory population life table of *Amphitetranychus viennensis* (Zacher) (Acari: Tetranychidae) at different temperatures. *Systematic and Applied Acarology* **10**, 7-10.
- Jiang RD, Lu SJ, Wang PS, Wang JQ and Li Q (1997) Control of apple leaf spot diseases by spraying. *China Fruits* **2**, 51.
- Jiang S (2001) Biology of *Aporia crataegi* and its control. *Entomological Knowledge* **38**, 198-199.
- Jiang YZ, Zhang SF, Zhao FY, Wu SQ and Piao SC (1986) Control of *Carposina sasakii*

- Matsumura with cypermethrin. *Plant Protection* **12**, 21-22.
- JNGPC (2008) *Nezara antennata* Scott.
<http://www.jngpc.cn/Page.aspx/guid=1610&iid=4355>, Accessed: 17 October 2008.
- Jo HM and Kim Y (2001) Relationship between cold hardiness and diapause in the smaller fruit tortrix, *Adoxophyes orana* (Fischer von Roslerstamm). *Journal of Asia Pacific Entomology* **4**, 1-9.
- Johnson EM and Sutton TB (1994) First report of *Geastrumia polystigmatis* on apple and common blackberry in North America. *Plant Disease* **78**, 1219.
- Johnson EM, Sutton TB and Hodges CS (1997) Etiology of apple sooty blotch disease in North Carolina. *Phytopathology* **87**, 88-95.
- Jones AL (1990) Brown rot diseases. In 'Compendium of Apple and Pear Diseases'. (Eds AL Jones and HS Aldwinckle) (American Phytopathological Society, St Paul, Minnesota, USA): 32-33.
- Jung CR, Han KS, Jung JK, Choi KH, Lee SW and Boo KS (2001) Composition and activity of the asiatic leafroller, *Archippus breviplicanus* (Lepidoptera: Tortricidae) sex pheromone at apple orchards in Korea. *Korean Journal of Applied Entomology* **40**, 219-226.
- Kajino Y and Nakao H (1977) Ecology of peach fruit moth, *Carposina niponensis* Walsingham. I. Period of adult emergence of the first brood. *Bulletin of Hokkaido Prefectural Agricultural Experiment Stations* **37**, 77-84.
- Kang ZX (1995) Studies on the occurrence and appropriate time for chemical control of *Carposina niponensis* in Changchun region. *Journal of Jilin Agricultural University* **17**, 22-26.
- Kang ZX, Zhang FY, Sun Q, Lu X and Guo MZ (1989) Application of sex attractant of *Grapholitha molesta* for forecasting and control of *Grapholitha funebrana*. *Insect Knowledge* **26**, 142-145.
- Kassanis B (1970) Tobacco necrosis virus. In Descriptions of Plant Viruses 414. Rothamsted Research, Harpenden. Available online at <http://www.dpvweb.net>, Accessed: July 2009.
- Kassanis B and MacFarlane I (1964) Transmission of Tobacco necrosis virus by zoospores of *Olpidium brassicae*. *Journal of General Microbiology* **36**, 79-93.
- Kegler H, Proll E, Schmidt HB and Opel H (1969) Nachweis des Tabaknekrosevirus (tobacco necrosis virus) in Obstgehölzen. *Phytopathologische Zeitschrift (Journal of Phytopathology)* **65**, 21-42.
- Khairushev EK (1970) The cherry-fruit weevil (*Rhynchites auratus*). *Zashchita Rastenii* **15**, 41.
- Khan MA, Muhammad A, Abdul K and Amjad A (2003) Population of fruit fly species trapped by methyl eugenol and cue lure versus infestation in apple orchards of Murree

- Hills. *Pakistan Entomologist* **25**, 191-194.
- Kharin I (1916) Extract from the Report of the Syzran Branch (Govt. of Simbirsk) of the Russian Imperial Horticultural Society. *Fruit Growing* **27**, 462-464.
- Kienholz JR (1939) Comparative study of the apple anthracnose and perennial canker fungi. *Journal of Agricultural Research* **59**, 635-665.
- Kim HR, Lee SH, Lee DH, Kim JS and Park JW (2006) Transmission of *Apple scar skin viroid* by grafting, using contaminated pruning equipment, and planting infected seeds. *The Plant Pathology Journal* **22**, 63-67.
- Kim JB, Kim KY, Kim JK and Kim SB (1988) Studies on the development of fruit bags for improving fruit quality. 1. Physical characteristics of different types of bag and their relation to pear fruit quality. *Research Reports of the Rural Development Administration, Horticulture* **30**, 55-63.
- Kim KC and Kim MS (1993) Host range and bionomics of the rhombic marked leafhopper, *Hishimonus sellatus* Uhler (Homoptera: Cicadellidae) as a vector of the jujube witches broom mycoplasma. *Korean Journal of Applied Entomology* **32**, 338-347.
- Kim WS, Hildebrand M, Jock S and Geider K (2001a) Molecular comparison of pathogenic bacteria from pear trees in Japan and fire blight pathogen *Erwinia amylovora*. *Microbiology* **147**, 2951-2959.
- Kim WS, Jock S, Paulin J.P., Rhim SL and Geider K (2001b) Molecular detection and differentiation of *Erwinia pyrifoliae* and host range analysis of the Asian pear pathogen. *Plant Disease* **85**, 1183-1188.
- Kim WS, Rhim SL, Völksch B, Gardan L, Paulin JP, Jock S and Geider K (1999) Characterization of new *Erwinia* species affecting Asian pear trees. *Acta Horticulturae* **489**, 201-205.
- Kirk PM (1997) *Mucor piriformis*. IMI Descriptions of Fungi and Bacteria No. 1309. CAB International.
- Kobakhidze DM and Kovalenko MS (1976) Biological characteristics of the development of phyllostictosis of apple. *Byulleten' Vsesoyuznogo Nauchno Issledovatel' skogo Instituta Zashchity Rastenii* **36**, 35-38.
- Koganezawa, H., Yang, X., Zhu, S. F., Hashimoto, J., and Hadidi, A. (2003) Apple scar skin viroid in apple. (Eds A Hadidi, R Flores, JW Randles, and JS Semancik). Viroids. 137-141. Australia, CSIRO Publishing.
- Kojima T (1931) Further investigation on the immature stages of some Japanese *Cerambycid*-beetles, with notes of their habits. *Journal of the College of Agriculture, Imperial University of Tokyo* **11**, 263-308.
- Korchagin VN (1987) Curculionids and attelabids. *Zashchita Rastenii* **2**, 58-59.
- Kuang CZ (1985) Studies on the biology and control of *Peridroma saucia* Hubner. *Insect Knowledge* **22**, 61-64.

- Kumral NA, Gencer NS, Coskuncu KS (2004) Life History of *Lepidosaphes conchiformis* (Gmelin) in Fig Orchards in Bursa, Turkey. In 'Proceedings of the X International Symposium on Scale Insect Studies 19-23 April 2004.'
- Kuoh JL and Chang HG (1959) A study on *Anomala corpulenta* Motschulsky (Coleoptera: Rutelidae). *Acta Entomologica Sinica* **9**, 491-514.
- Kutinkova H and Andreev R (2004) Integrated pest management in sweet cherry (*Prunus avium* L.) orchards in Bulgaria. *Journal of Fruit and Ornamental Plant Research* **12**, 41-47.
- Kuwana SI (1902) *Dactylopius comstocki*. *Proceedings of California Academy of Science* **3**, 52.
- Kyriakopoulou PE and Hadidi A (1998) Natural infection of wild and cultivated pears with apple scar skin viroid in Greece. *Acta Horticulturae* **472**, 617-625.
- Kyriakopoulou, P. E., Osaki, H., Zhou, S. F., and Hadidi, A. (2003) Apple scar skin viroid in pear. (Eds A Hadidi, R Flores, JW Randlles, and JS Semancik). Virioids. 142-145. Australia, CSIRO Publishing.
- Lack KJ (1989) The spread of apple brown rot (*M. fructigena*) by insects. *Annals of Applied Biology* **115**, 221-227.
- Landcare Research (2009) New Zealand Fungi.
<http://nzfungi.landcareresearch.co.nz/html/data.asp?ID=&NAMEPKey=2479>,
Accessed: July 2009.
- Laundon G (1998) '*Gymnosporangium yamadae*. CMI Descriptions of pathogenic fungi and bacteria No. 550'. (CAB International, Wallingford, UK). 2 pp.
- Lazarevic B (1955) The bionomics and control of *Rhynchites auratus*. *Plant Protection* **30**, 11-36.
- Leather S (1996) Biological flora of the British Isles *Prunus padus* L. *Journal of Ecology* **84**, 125-132.
- Lee CY and Morimoto K (1988) Larvae of the weevil family Attelabidae of Japan Part 2. Subfamily Rhynchitinae (Insects: Coleoptera). *Journal of the Faculty of Agriculture, Kyushu University* **32**, 239-254.
- Lee DH, Lee SW, Choi KH, Kim DA and Uhm JY (2006) Survey on the occurrence of apple diseases in Korea from 1992 to 2000. *The Plant Pathology Journal* **22**, 375-380.
- Lee LC (1965) A preliminary study on *Phalera flavescentis* Bremer et Grey (Lepidoptera, Notodontidae). *Acta Phytophylacica Sinica* **4**, 69-76.
- Lee PC, Woo WC and Hwang KH (1963) A preliminary study on the effect of photoperiod and temperature on 'the induction of diapause in the peach fruit borer (*Carposina niponensis* Walsingham). *Acta Entomologica Sinica* **12**, 423-431.
- Lee S, Crous PW and Wingfield MJ (2006) *Pestalotioid* fungi from Restionaceae in the Cape

- floral kingdom. *Studies in Mycology* **55**, 175-187.
- Lee SW, Lee MH, Choi KM, Hyun JS and Yiem MS (1994) The effects of pesticide applications on the major apple insect pests and their natural enemies. *RDA Journal of Agricultural Science, Crop Protection* **36**, 383-394.
- Legalov A (2004) Personal communication - *Rhynchites*. Ed. Email received by Biosecurity Australia on 11 October 2004.
- Lemoine J and Cathala MH (2006) Les maladies de dégénérescence des arbres fruitiers à pépins (pommiers, poiriers) Maladies à virus, viroïdes, phytoplasmes. Institut National de la Recherche Agronomique (INRA). <http://www-intranet.angers.inra.fr/dossiers/virus/fichvir4.html>, Accessed: 07 July 2009.
- Leng H, Liu D, Cai R and Jiang C (1982) On the pink disease of apple. *Acta Phytopathological Sinica* **12**, 39-44.
- Leng H, Liu D, Cai R and Liu X (2009) On the pink disease of apple. <http://cababstractsplus.org/abstracts/Abstract.aspx?AcNo=19821383765>., Accessed: July 2009.
- Letham DB (1995) Host-Pathogen index of plant diseases in New South Wales. New South Wales Agriculture, Rydalmere. 84 pp.
- Leyendecker PJJr (1952) Cytospora canker of apple in New Mexico. *Plant Disease Reporter* **36**, 276-277.
- Li DL, Zhang CT and Xu GL (1998) A study on the population dynamics and damage of red spider mite (*Tetranychus viennensis*). *Forest-Research* **11**, 335-338.
- Li H (1990) New records of gelechiid moths from China. *Journal of Northwest Forestry College* **5**, 812.
- Li HF, Lu DG and Liu T (2005) Methods for control of apple beetles at blossom stage. *China Fruits* **2**, 53-54.
- Li Q and Cai RX (1996) Occurrence and damage of the apple rust mite *Aculus schlechtendali*. *Plant Protection* **22**, 16-17.
- Li SC, Lian JS, Yang P and Zhang YQ (1986) A preliminary study on entomopathogenic nematode, Taishan No. 1 (*Heterorhabditis* sp.). *Acta Phytophylactica Sinica* **13**, 267-272.
- Li SC, Liu H and Wu HT (2004) The occurrence of Comstock mealybug under bagging apple culture and its control. *China Fruits* **1**, 44-51.
- Li T (1988) A preliminary study on the bionomics of *Pyramidotettix mali* Yang. *Insect Knowledge* **25**, 29-31.
- Li XY, Zhao XQ, Gong SX, Chen FS, Tan T and Cheng AD (2008) The population dynamics and its role in controlling *Eriosoma lanigerum* of *Harmonia axyridis* (Pallas). *Southwest China Journal of Agricultural Sciences* **21**, 1165-1168.

- Li Y, Liu Z, Zhang L, Chai F and Zong J (1993) Application of *Steinernema feltiae* agriotes against the peach fruit borer. *Acta Phytophylactica Sinica* **20**, 337-342.
- Liang BY, Du YX, Gong XL and Hu HW (2007) *Aulacophora femoralis chinensis* (Weise). *China Plant Protection* **12**, 104-105.
- Lindquist R (2000) Mealybugs. Ohio Floriculture, Ohio State University.
<http://floriculture.osu.edu/archive/aug00/mealyup.html>, Accessed: 05 December 2008.
- Lingafelter SW and Hoebeke ER (2002) 'Revision of the genus *Anoplophora* (Coleoptera: Cerambycidae)'. (Entomological Society of Washington, Washington, USA). 236 pp.
- Liu CZ (1993) A study on the predation of *Chilocorus rubidus* Hope on the Korean lecanium (*Didesmococcus koreanus*). *Plant Protection* **19**, 13-14.
- Liu SM, Li QM and Han JH (2000) Life history of *Illiberis pruni* Dyar and its parasitoid natural enemies in Longdong district in Gansu province. *Entomological Knowledge* **37**, 168-169.
- Liu TZ and Gao XW (1997) Discovery and identification of a new powdery mildews pathogen on apple trees in ChiFeng area. *China Fruits* **2**, 35-36.
- Liu XQ (2002) The occurrence of fruit piercing moth in Wuhan area and its control. *South China Fruits* **31**, 15-15.
- Liu XS, Wu XR, Zhao CM, Wei GS and Deng TF (1991) Study on control of *Rhynchites foveipennis* (Col: Curculionidae) with *Steinernema feltiae* (Nematoda: Steinernematidae). *Chinese Journal of Biological Control* **7**, 166-168.
- Liu Y and Meng X (2003) Trapping effect of synthetic sex pheromone of *Acleris fimbriana* (Lepidoptera: Tortricidae) in Chinese Northern Orchard. *Zeitschrift fur Naturforschung: Section C, Biosciences* **58**, 421-425.
- Liu YX and Meng XZ (2002a) Behavioral response of male *Acleris fimbriana* Thunberg et Becklin (Lepidoptera: Tortricidae) to synthetic sex pheromones. *Acta Entomologica Sinica* **45**, 436-440.
- Liu YX and Meng XZ (2002b) Identification of sex-pheromone components for *Acleris fimbriana* (Lepidoptera: Tortricidae). *Canadian Entomologist* **134**, 511-518.
- Liu ZM (2004) The control of powdery scale in the apple orchards in the western part of Henan province. *China Fruits* **5**, 43-44.
- Lommel SA, Martelli GP, Rubino L and Russo M (2005) Family Tombusviridae. In 'Virus Taxonomy Classification and Nomenclature, Eighth Report of the International Committee on Taxonomy of Viruses.'. (Eds CM Fauquet, MA Mayo, J Maniloff, U Desselberger and LA Ball) (Elsevier Academic Press, San Diego.): 907-936.
- Long L, Liu HM, Xia ZM, Yu XL, Xiong Y and Li L (2009) Occurrence regularity of bacterial leaf spot on hot pepper and its field trials of fungicide. *Guizhou Agricultural Sciences* **2**, 73-74.

- Lovelidge B (1995) Solving the apple canker mystery. *Grower* **123**, 23-25.
- Lozhaunikas EE and Yakovishena YK (1978) The Telman observation point. *Zashchita Rastenii* **11**, 39.
- Lu CH and Wu DH (1988) A preliminary study on bionomics of *Parlatoria yanyuanensis* and its control. *China fruits* **3**, 17-19.
- Lu CZ (2004) Control of the occurrence of *Euzophera pyriella* and integrated control. *China Fruits* **3**, 38-39.
- Lu CZ and Deng YG (2003) A study on occurrence and harm and precaution of the pest of apple. *Journal of Tarim University of Agricultural Reclamation* **15**, 23-26.
- Lu QG, Zhang NX, Jiang YZ and Zhang SF (1993) Laboratory and field tests on the efficacy of a Chinese produced *Bacillus thuringiensis* wettable powder against peach fruit borer, *Carposina niponensis* (Lep.: Carposinidae). *Chinese Journal of Biological Control* **9**, 156-159.
- Lunn JA (1977) *Mucor racemosus*. CMI Descriptions of Pathogenic Fungi and Bacteria No. 529. CAB International.
- Luo CF, Wu HX, Fang WR, He DB, He HF and Ding JL (1994) Control of *Ceroplastes japonicus* by spreading insecticide on twigs and branches of jujube trees. *Plant Protection* **20**, 32-33.
- Lykouressis D, Kapsaskis A, Perdakis D, Vatos A and Fantinou A (2004) Rates of population increase, abundance and life stage distribution of *Rhynchites cribipennis* (Coleoptera: Attelabidae) on trees and in the soil in an olive grove. *Ecology and Behavior* **97**, 316-320.
- Ma CS (2006) Pests, diseases and weeds of apples published by Key Laboratory of Agriculture Department, China . http://www.ecolsafety.org.cn/db/Fruit/login_pg.asp, Accessed: 19 June 2006.
- Ma RL and Cui BQ (1985) A preliminary observation on *Orthosia incerta* (Hufnagel). *Insect knowledge (Kunchong Zhishi)* **22**, 158-160.
- Maccarone LD, Sivasithamparam K, Barbetti M and Jones RAC (2008) Phylogenetic analysis of *Olpidium virulentus*, *Lettuce big-vein associated virus* and *Mirafiori lettuce big-vein virus* isolates from Western Australia. Australasian Plant Pathology Society, WA Student Symposium Abstracts. DAFWA. Available on-line at <http://www.cpsm.murdoch.edu.au/downloads/news/symposiumflyer4.pdf>, Accessed: July 2009.
- Maciesiak A (1999) Pear leaf blister moth (*Leucoptera scitella* Zell.) appearance and control (Original title: Toczyk grusowiaczek (*Leucoptera scitella* Zell.) - wystepowanie i zwalczanie). *Progress in Plant Protection* **39**, 444-447.
- Mahr S (2001) Pest advisory: The flat scarlet mite.
<http://www.hort.wisc.edu/mastergardener/Features/insects/flat%20scarlet%20mite/flatscarletmite.htm> , Accessed: 21 August 2008.

- Malumphy CP (2005) *Eulecanium excrescens* (Ferris) (Hemiptera: Coccidae), an Asian pest of woody ornamentals and fruit trees, new to Britain. *British Journal of Entomology and Natural History* **18**, 45-49.
- Marikovskii P and Ivannikov A (1966) Natural enemies of dodder in Kazakhstan. *Zaschita Rastenii* **11**, 27-28.
- Martin JH and Gillespie PS (2001) Hemiptera: Aleyrodoidea. Australian Faunal Directory. Australian Biological Resources Study, Canberra.
<http://www.deh.gov.au/biodiversity/abrs/online-resources/fauna/afd/index.html>, Accessed: 23 October 2008.
- Martin RR and Tzanetakis IE (2006) Characterization and recent advances in the detection of strawberry viruses. *Plant Disease* **90**, 384-396.
- Matsuki M, Kay M, Serin J, Floyd R and Scott JK (2008) Potential risks of accidental introduction of Asian gypsy moth (*Lymantria dispar*) to Australia and New Zealand: effects of climatic conditions and suitability of native plants.
http://www.daff.gov.au/_data/assets/pdf_file/0006/146886/agmreport.pdf, Accessed: 24 October 2008.
- Matsumoto S (1918) Studies on the Pear Borer. Nashi no Shinkuimushi. ni kwansuru kenkyn. *Rinji-Hokoku [Extra Report]*, Okayama Agricultural Experiment Station **19**, 1-22.
- Matsuo Y (1969) Studies on the ecology and control of the flower visiting insects of citrus tree. II. On the overwintering sites of smaller green flower chafer, *Oxycetonia jucunda* Faldermann. *Kyushu Association of Plant Protection Proceedings* **15**, 149-151.
- Matsuura T, Mizuno A, Shimizu Y, Uematsu H, Tsukamoto T, Saito N, Sato S, Kikuchi S, Uzuki T, Azegami K (2009) Classification of causal bacteria of bacterial black shoot disease of European pear (Abstract 307). In 'Proceedings of the Phytopathological Society of Japan Conference.' Yamagata, Japan.
- Matsuura T, Shinohara H, Inoue Y, Azegami K, Tsushima S, Tsukamoto T and Mizuno A (2007) *Erwinia* isolates from bacterial shoot blight of pear in Japan are closely related to *Erwinia pyrifoliae* based on phylogenetic analyses of *gyrB* and *rpoD* genes. *Journal of General Plant Pathology* **73**, 53-58.
- Maxson-Stein K, McGhee GC, Smith JJ, Jones AL and Sundin GW (2003) Genetic analysis of a pathogenic *Erwinia* sp. isolated from pear in Japan. *Phytopathology* **93**, 1393-1399.
- McCartney WO (1967) An unusual occurrence of eye rot of apple in California due to *Nectria galligena*. *Plant Disease Reporter* **51**, 278-281.
- McClintock JA (1930) The longevity of *Phyllosticta solitaria* on apple seedlings held in cold storage. *Phytopathology* **20**, 841-843.
- McDougall S (2006) Lettuce IPM. Primefact 154. NSW Department of Primary Industries.
- McKay R (1947) Observations on the development of apple canker. *Gardeners' Chronicle* **121**, 53-54.

- McLean GD and Price LK (1984) Virus, viroids, mycoplasma and rikettsial diseases of plants in Western Australia. Department of Agriculture, Western Australia. *Technical Bulletin* **68**, 122.
- Mehra BP and Sah BN (1977) Bionomics of *Amsacta lactinea* Cramer a pest of bhailia. *Indian Journal of Entomology* **39**, 29-34.
- Meijerman L and Ulenberg SA (2000) Arthropods of Economic Importance. <http://ip30.eti.uva.nl/bis/tortricidae.php>, Accessed: 2006.
- Mellott JL and Krantz GW (2007) Some common plant-feeding mites and plant-inhabiting mite predators in the Northwestern United States. <http://weeds.ippc.orst.edu/pnw/insects?30MITE01.dat>, Accessed: 21 July 2009.
- Meulewaeter F, Seurinck J and van Emmelo J (1990) Genome structure of tobacco necrosis virus strain A. *Virology* **177**, 699-709.
- Michailides TJ (1991) Characterization and comparative studies of *Mucor* isolates from stone fruits from California and Chile. *Plant Disease* **75**, 373-380.
- Michailides TJ and Ogawa JM (1987) Effects of soil temperature and moisture on the survival of *Mucor piriformis*. *Phytopathology* **77**, 251-256.
- Michailides TJ and Spotts RA (1990) Postharvest diseases of pome and stone fruits caused by *Mucor piriformis* in the Pacific Northwest and California. *Plant Disease* **74**, 537-543.
- Migeon A and Dorkeld F (2006) Spider Mites Web: a comprehensive database for the Tetranychidae. <http://www1.montpellier.inra.fr/CBGP/spmweb/notespecies.php?id=893>, Accessed: 21 July 2009.
- Milonas PG and Savopoulou-Soultani M (2000) Development, survivorship and reproduction of *Adoxophyes orana* (Lepidoptera: Tortricidae) at constant temperatures. *Annals of the Entomological Society of America* **93**, 96-102.
- Milonas PG and Savopoulou-Soultani M (2004) Diapause termination in overwintering larvae of a Greek strain of *Adoxophyes orana* (Lepidoptera: Tortricidae). *Environmental Entomology* **33**, 513-519.
- Minks AK, Noordink JPW and van den Anker CA (1971) Recapture by sex traps of *Adoxophyes orana*, released from one point in an apple orchard. *Mededelingen Fakulteit Landbouwwetenschappen Gent* **36**, 274-282.
- Mizuno A, Matsuura T, Shimizu Y, Uematsu H, Tsukamoto T, Saito N, Sato S, Kikuchi S, Uzuki T, Azegami K (2009) Occurrence of bacterial black shoot disease of European pear in Yamagata Prefecture (Abstract 306). In 'Proceedings of the Phytopathological Society of Japan Conference.' Yamagata, Japan.
- Mizuno A, Sato S, Kawai A and Nishiyama K (2000) Taxonomic position of the causal pathogen of bacterial shoot blight of pear. *Journal of General Phytopathology* **66**, 48-58.

- MOA (2006) Announcement No. 617, Ministry of Agriculture, People's Republic of China. Attachment: The National Agricultural Plant Quarantine Pest List. March 2, 2006 . http://www.agri.gov.cn/ztlz/zwjy/t20060308_566115.htm, Accessed: 11 July 2006.
- Moffitt HR, Drake SR, Toba HH and Hartshell PL (1992) Comparative efficacy of methyl bromide against codling moth (Lepidoptera: Tortricidae) larvae in 'Bing' and 'Rainier' cherries and confirmation of efficacy of a quarantine treatment for 'Rainier' cherries. *Journal of Economic Entomology* **85**, 1855-1858.
- Moline HE and Kuti JO (1984) Comparative studies of two *Mucor* species causing postharvest decay of tomato and their control. *Plant Disease* **68** , 524-526.
- Mordue JEM (1979) '*Sclerotinia fructigena*. CMI Descriptions of pathogenic fungi and bacteria No. 617'. (CAB International, CAB International, Wallingford, UK). 2 pp.
- Morimoto R (1976) A study of the biological control of Comstock mealybugs, *Pseudococcus comstocki* Kuwana. *Review of Plant Protection Research* **9**, 72-89.
- Mostaan M, Seyedoleslami H, Farivar-Mahin G, Farahbakhch G and Daftari K (1972) Complementary study of the biology and methods of control of *Lepidosaphes malicola* Borkh. in Iran. *Entomologie et Phytopathologie Appliquees* **33**, 4-20.
- Moulds MS and Cowan S (2004) Superfamily: Cicadoidea. Australian Faunal Directory. Australian Biological Resources Study, Canberra. <http://www.environment.gov.au/biodiversity/abrs/online-resources/fauna/afd/taxa/CICA DOIDEA>, Accessed: 06 April 2006.
- Moulds MS and Sally C (2004) Superfamily Cicadoidea. Australian Museum, Sydney, NSW, Australia. <http://www.environment.gov.au/biodiversity/abrs/online-resources/fauna/adf/taxa/CICADOIDEA>, Accessed: May 2004.
- Munson RG (1939) Observations on apple canker. I. The discharge and germination of spores of *Nectria galligena* Bres. *Annals of Applied Biology* **26**, 440-457.
- Murakami M, Tsuda K and Kusigemati K (2000) Biological studies of the pests feeding on *Gynura bicolor* (Willd.) DC. (Asteraceae) III. List of feeding species, seasonal abundance and damage-occurrence in Kagoshima Prefecture in 1998 and 1999. *South Pacific Study* **20**.
- Muramarsu S (1924) Life history of *Agrilus mali*, Mats. (Buprestidae). *Korea Agricultural Experimental Station Report* **2**, 1-21.
- Murrell VC and Lo PL (1998) Control of Oriental fruit moth (*Grapholita molesta*) on Golden Queen peaches. In 'Proceedings of the 51st New Zealand Plant Protection Conference 1998.' pp. 189-194.
- Musaev SA and Bushkov NM (1977) Fumigation of pomegranate fruits against eggs of the Comstock mealybug. *Zashchita Rastenii* **1**, 56.
- Myers CT, Hull LA and Krawczyk G (2006) Seasonal and cultivar-associated variation in oviposition preference of Oriental fruit moth (Lepidoptera: Tortricidae) adults and feeding behavior of neonate larvae in apples. *Journal of Economic Entomology* **99**, 349-

358.

NAPPO (2008) *Cenopalpus pulcher* (Canestrini and Fanzago). <http://pestalert/org/viewArchPestAlert.cfm?rid=54>, Accessed: 10 October 2008.

Nasu Y, Arita Y, Kimura M and Ogata A (2004) Some lepidopterous pests of *Eucalyptus* trees from Japan. *Japanese Journal of Applied Entomology and Zoology* **48**, 123-133.

Naumann I (1991) Hymenoptera (Wasps, bees, ants, sawflies). In 'The Insects of Australia: A textbook for students and research workers (Volume II)'. (Second Edition) (Ed. CSIRO) (Melbourne University Press, Melbourne, Australia): 916-1000.

NCBI (2009) Necrovirus. National Center for Biotechnology Information. <http://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id=12052> , Accessed: July 2009.

Nemeth M (1986) Tobacco necrosis virus. In 'Virus, mycoplasma and rickettsia diseases of fruit trees'. (Ed. M Nemeth) (Martinus Nijhoff Publishes, Dordrecht): 572-575.

Neven LG (1998) Cold hardiness adaptations of codling moth, *Cydia pomonella*. *USDA Terktran Agricultural Research Service* 1 .

Nevskh VP (1933) 'The mulberry geometrid (*Apocheima cinerarius* Erseh.) and its control'. (SAOGIZ, Moscow). 80 pp.

Nevskii VP (1928) *Rhynchites auratus* Scop. *ferganensis*, subsp. n., ennemi de l'abricot au Ferghana. *Defense des Plantes* **5**, 443-473.

Ni DW (1998) Main pests and diseases of *Castanea mollissima* in Zhejiang and its control techniques. *Journal of Zhejiang Forest Science and Technology* **18**, 68-71.

Nielsen ES, Edwards ED and Rangsi TV (1996) 'Checklist of the Lepidoptera of Australia'. (CSIRO Publishing, Melbourne). 529 pp.

Nienhaus F and Castello JD (1989) Viruses in forest trees. *Annual Review of Phytopathology* **27**, 165-186.

Nikitenko VG and Ponomarev VG (1981) A quarantine lifted. *Zashchita Rastenii* **12**, 44.

Nishino T, Ohgushi R and Ono K (1970) Observations on the daily fluctuation in flower visiting activity of smaller green flower chafer, *Oxycetonia jucunda* Faldermann on citrus flowers. *Japanese Journal of Applied Entomology and Zoology* **14**, 39-43.

Nomura S and Hirano Y (2005) A faunistic study on the order Coleoptera from the Akasaka Imperial Gardens and the Tokiwamatsu Imperial Villa, Tokyo, Japan. *Memoirs-of-the-National-Science-Museum-Tokyo* **39**, 183-223.

NRA (1999) The NRA review of Fenithrothion - draft for public comment, Volume II, August. The National Registration Authority for Agricultural and Veterinary Chemicals, Australia, Canberra. 29 pp.

Oberprieler R (2006) *Rhynchites* spp. Email to Biosecurity Australia.

- OEPP/EPPO (2006) *Gymnosporangium* spp. (non-European). *OEPP/EPPO Bulletin* **36**, 441-446.
- Ogata T, Sano T and Harada Y (2000) *Botryosphaeria* spp. isolated from apple and several deciduous fruit trees are divided into three groups based on the production of warts on twigs, size of conidia, and nucleotide sequences of nuclear ribosomal DNA ITS regions. *Mycoscience* **41**, 331-337.
- Ogawa JM and English H (1991) Diseases of temperate zone tree fruit and nut crops, University of California, Oakland, CA.
- Ohira Y (1991) Observation on oviposition and fecundity of two *Illiberis* moths (Lepidoptera: Zygaenidae). *Bulletin of the Fruit Tree Research Station* **20**, 93-105.
- Osman MAM and Mahmoud MF (2008) Seasonal abundance patterns of insects and mites on pear trees during the blooming and fruiting seasons at Ismailia Governorate, Egypt. *Tunisian Journal of Plant Protection* **3**, 47-57.
- Ozbek H, Guclu S and Hayat R (1996) Investigations on the phytophagous and predator insect species on stone fruits in the north-east agricultural region of Turkey. *Turkish Journal of Agriculture and Forestry* **20**, 267-282.
- Pacit J (1978) Types of mycoparasitic die-back diseases in apple trees. *Acta Phytopathologica Academiae Scientiarum Hungaricae* **13**, 151-159.
- Pairoa EH (1944) Observations on the biology of the tussock moth, *Orgyia antiqua*, in Chile. *Review Chilean History Natural* **46-47**, 133-140.
- Panait N and Ciortan G (1972) Semnalarea daunatorului *Gastropacha quercifolia* L. pe piersic in Romania.; Occurrence of the pest *Gastropacha quercifolia* L. on peach in Rumania. *Analele Institutului de Cercetari pentru Protectia Plantelor* 265-272.
- Pedgley DE (1982) 'Windborne pests and diseases meteorology of airborne organisms'. (Ellis Horwood, West Sussex).
- Pegler DN and Gibson IAS (1998) '*Armillaria mellea*. CMI Descriptions of Pathogenic Fungi and Bacteria No. 321'. (CAB International, Wallingford, UK).
- Pei KQ (2000) Three new records of *Mucor* from China. *Mycostema* **19**, 563-565.
- Penrose LJ (1984) Occurrence of "Brooks spot" apples in New South Wales. *Australasian Plant Pathology* **13**, 223-225.
- Pham KTK, Lemmers MEC, van Doorn J and Derks AFLM (2007a) Tobacco necrosis virus A from Hyacinth cv. White Pearl coat protein (CP) gene, partial cds. National Center for Biotechnology Information. GenBank database. Accession Code EF201610 <http://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id=12052> , Accessed: 07 July 2009.
- Pham KTK, Lemmers MEC, van Doorn J and Derks AFLM (2007b) Tobacco necrosis virus A from Lily cv. Baria Blanca coat protein (CP) gene, partial cds. National Center for Biotechnology Information. GenBank database. Accession Code EF201611.

- <http://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id=12052>, Accessed: 07 July 2009.
- Pierson CF, Ceponis MJ and McColloch LP (1971) *Market diseases of apples, pears and quinces*. Agriculture Handbook No. 376, Agricultural Research Service, USDA .
http://postharvest.tfrec.wsu.edu/market_diseases.html, Accessed: July 2009.
- Plotnikov V (1914) The pests of orchards in the province of Semiryetchensk. *Agriculture of Turkestan* **8**, 740-642.
- Podleckis EV (2003) Chinese fragrant pears memo Information memo for the record, 2 June. United States Department of Agriculture, USA.
- Polk DF, Hogmire HW, and Felland CM (2003) Oriental fruit moth, *Grapholita molesta* (Busck). <http://www.ento.vt.edu/Fruitfiles/OFM.html>. Virginia Technical Department of Entomology, Blacksburg, Virginia, USA .
- Poole MC (2008) An annotated catalogue of insect and allied species of economic significance or of potential export quarantine concern for Western Australian Primary and Related Industries. Perennial Draft Report (August 2008 update). Department of Agriculture and Food Western Australia, Perth, Australia.
- Poole MC, Kumar S, McKirdy SJ, Grimm M, Mackie A, Astbury C and Stuart MJ (2001) Categorisation of Pests of stone fruit from Eastern Australia; Final State Import Risk Analysis of cherry fruit (*Prunus avium*) from South Australia into Western Australia. The Western Australian Department of Agriculture, Perth, Australia. 153 pp.
- Pospielov TH (1914) A short review of the state of agriculture in the district of Katta-Kurgan in 1913. *Agriculture of Turkestan* **6**, 560-569.
- Pralya II, Sen' kova EA and Shapar' MV (1992) Methods of counting orchard leafrollers (Lepidoptera, Tortricidae). *Zoologicheskii Zhurnal* **71**, 131-138.
- Pritchard AE and Baker EW (1955) A revision of the spider mite family Tetranychidae. *Pacific Coast Entomological Society Memoirs* **2**, 1-472.
- Pscheidt JW (2008) Apple (*Malus*) anthracnose (bull's-eye rot). In *An online guide to plant disease control*. Oregon State University Extension. <http://plant-disease.ippc.orst.edu/disease.cfm?RecordID=36>, Accessed: 25 May 2009.
- Pschorn-Walcher H (1964) On the parasites of some injurious Lepidoptera from northern Japan. *Technical Bulletin Commonwealth Institute of Biological Control* **4**, 24-37.
- Qiang WX, Bing JC and Su W (2002) Occurrence regularity and control of geometrid moths attacking *Robinia pseudoacacia* in Tianshui. *Zhongguo Senlin Bingchong* **21**, 23-25.
- Qin DR, Guo TB, Jiang FR, Zhou Y, Zhao HZ and Wang KF (1994) A study on the relationship between ovary development and complementary nutrition of *Apriona germarii* (Hope). *Journal of Nanjing Forestry University* **18**, 46-50 .
- Qin TK and Gullan PJ (1994) Taxonomy of the wax scales (Hemiptera: Coccidae: Ceroplastinae) in Australia. *Invertebrate Systematics* **8**, 923-959.

- Qiu W, Xu FS, Xie GL, Xu LH, Huai Y, Li B, Yu SH and Qian J (2008) Identification of *Pseudomonas syringae* pv. *syringae* causing pear blossom and bud blast in China. *Scientia Agricultura Sinica* **41**, 2657-2662.
- Qiu Y, Shi A and Zho D (1999) Occurrences and distribution patterns of *Aphis citricola* and *Adoxophyes orana* on apple trees. *Entomological Journal of East China* **8**, 86-91.
- Radetsky AF (1913) *Carpocapsa pomonella* L., in the territory of Turkestan and the struggle against it. *Turkestan Entomological Station Reports. Tashkent* **52**.
- Rahmani H, Kamali K and Fathipour Y (2008) A new record for Iranian false spider mites with key to the known species of Tenuipalpidae (Acari: Prostigmata) in Iran. *Turkish Journal of Entomology* **32**, 163-175.
- Ransom LM (1997) The eradication of *Nectria galligena* from apple trees in Tasmania, 1954 to 1991. *Australian Plant Pathology* **26**, 121-125.
- Rhim SL, Völksch B, Gardan L, Paulin JP, Langlotz C, Kim WS and Geider K (1999) *Erwinia pyrifoliae*, an *Erwinia* species different from *Erwinia amylovora*, causes a necrotic disease of Asian pear trees. *Plant Pathology* **48**, 514-520.
- Ricelli A, Baruzzi F, Solfrizzo M, Morea M and Fanizzi FP (2007) Biotransformation of patulin by *Gluconobacter oxydans*. *Applied Environmental Microbiology* **73**, 785-792.
- Robinson GS, Ackery PR, Kitching IJ, Beccaloni GW and Hernández LM (2004) HOSTS: a database of the host plants of the world's Lepidoptera. <http://www.nhm.ac.uk/entomology/hostplants/>, Accessed: 2006.
- Rochon DA, Kakani K, Robbins M and Reade R (2004) Molecular aspects of plant virus transmission by Olpidium and Plasmodiophorid vectors. *Annual Review of Phytopathology* **42**, 211-241.
- Rosenberger DA (1990a) Fisheye rot. In 'Compendium of Apple and Pear Diseases'. (Eds AL Jones and HS Aldwinckle) (American Phytopathological Society Press, St. Paul, Minnesota, USA): 59.
- Rosenberger DA (1990b) Miscellaneous postharvest decay fungi. In 'Compendium of Apple and Pear Diseases'. (Eds AL Jones and HS Aldwinckle) (American Phytopathological Society, St. Paul, Minnesota, USA): 60-61.
- Rosenberger DA (1990c) Phomopsis canker, rough bark and fruit decay. In 'Compendium of Apple and Pear Diseases'. (Eds AL Jones and HS Aldwinckle) (American Phytopathological Society, St. Paul, Minnesota, USA): 38-39.
- Rosenberger DA, Cummins JN and Gonsalves D (1985) Development of apple union necrosis and decline in apple trees inoculated with tomato ringspot virus. *Phytopathology* **75**, 3-12.
- Rossmann AY, Samuels GJ, Rogerson CT and Lowen R (1999) Genera of Bionectriaceae, hypocreaceae and nectriaceae (Hypocreales, Ascomycetes). *Studies in Mycology* **42**, 1-248.

- Rothschild GHL and Vickers RA (1991) Biology, ecology and control of the oriental fruit moth. In 'World Crop Pests. Tortricid pests: their biology, natural enemies and control'. (vol. 5) (Eds LPS van der Geest and HH Evenhuis) (Elsevier, Amsterdam): 389-412 pp.
- Roy AN, Sharma RB and Gupta KC (1977) Occurrence of three new rot diseases of stored garlic (*Allium sativum* L.). *Current Science* **46**, 716-717.
- Ruehle GD (1931) New apple-rot fungi from Washington. *Phytopathology* **21**, 1141-1152.
- Saeki K, Takahashi Y, Oh-Oka H, Umeoka T, Oda Y and Fukuyama K (2001) Primary structure and phylogenetic analysis of the coat protein of a Toyama isolate of tobacco necrosis virus. *Bioscience, Biotechnology and Biochemistry* **65**, 719-724.
- SAI (2009) Facts and Figures. Strawberries Australia Inc. Available on-line at <http://www.strawberriesaustralia.com.au/6860050/strawberries-australia-facts-figures.htm>, Accessed: 15 July 2009.
- Sakamaki Y and Hayakawa T (2004) Specific differences in larval and pupal characters of Japanese species of *Adoxophyes* (Lepidoptera, Tortricidae). *Applied Entomology and Zoology* **39**, 443-453.
- Sampson PJ and Walker J (1982) In 'An annotated list of plant diseases in Tasmania'. (Department of Agriculture, Tasmania).
- Sarbhoy AK (1966) *Mucor racemosus* CMI Descriptions of Pathogenic Fungi and Bacteria No. 107. .CAB International.
- Sasaya T and Koganezawa H (2006) Molecular analysis and virus transmission tests place *Olpidium virulentus*, a vector of Mirafiori lettuce big-vein virus and tobacco stunt virus, as a distinct species rather than a strain of *Olpidium brassicae*. *Journal of General Plant Pathology* **72**, 20-25.
- Sato T (1977) Life history and diapause of the white-spotted tussock moth, *Orgyia thyellina* Butler (Lepidoptera: Lymantriidae). *Japan Journal of Applied Entomology and Zoology* **21**, 6-14.
- Savio PA (1929) Longicornes du feas Yang-ise. Genre *Linda*. *Notes d'Entomologie Chinoise* **1**, 1-9.
- Savopoulou-Soultani M, Hatzivassiliadis A, Vlug HJ, Minks AK and Tzanakakis ME (1985) First records of the summerfruit tortricid, *Adoxophyes orana* F. v. R. in Greece. *Entomologia Hellenica* **3**, 65-66.
- Savotikov YF and Smetnik AI (1995) 'Manual of the pests, plant diseases and weeds of quarantine significance for the territory of the Russian Federation'. (Arnika, Nizhnii Novgorod, Russia). 143-145 pp.
- Schipper MAA (1975) On *Mucor mucedo*, *Mucor flavus* and related species. *Studies in Mycology* **10**, 1-33.
- Schipper MAA (1976) On *Mucor circinelloides*, *Mucor racemosus* and related species. *Studies in Mycology* **12**, 1-40.

- Schreiner JF (1914) Species of *Rhynchites* and *Anthonomus pomorum* injuring orchards. *Memoirs of the Bureau of Entomology of the Scientific Committee of the Central Board of Land Administration and Agriculture* **2**, 65.
- Segawa K and Harada Y (1990) Violet root rot. In 'Compendium of Apple and Pear Diseases'. (Eds AL Jones and HS Aldwinckle) (American Phytopathological Society, St Paul, Minnesota, USA): 52-53.
- Sekiguchi A (1960) Studies on the control of peach fruit moth by the entomogenous fungus *Isaria fumosorosea*. *Bulletin of the Tohoku National Agricultural Experimental Station* **16**, 89-93.
- Sepasgosarian H (1970) The red false spider mite of apple *Cenopalpus* (Can. & Fanz.) (Acari.-Tenuipalpidae). *Bulletin of the Agricultural College* **115**, 37.
- Shang ZH, Zhang XH, Liu YS and Xia HL (2000) A survey of the damage to fruit trees caused by longhorn beetles and the methods for the control of the pests. *Ningxia Journal of Agricultural and Forestry Science and Technology* **2**, 10-12.
- Shanghai Insects Online (2005) *Thosea sinensis* (Walker). <http://www.insects.cn/spjj.asp?pestno=1096>, Accessed: 15 October 2008.
- Shanghai Insects Online (2006) Pear lace bug *Stephanitis nashi* Esaki et Takeya. <http://www.insects.cn/spjj.asp?pestno=889>, Accessed: 11 May 2006.
- Shanghai Insects Online (2009) Checklist of insects [*Stathmopoda auriferella* included in the table]. <http://www.insects.cn/shkc.asp?page=22>, Accessed: December 2009.
- Sharma IP and Siddiqui MR (1979) *Drechslera holmii* and *Fusarium camptoceras* two records on paddy seeds. *Indian Physiology* **31**, 508-509.
- Sharma JN, Sharma A and Sharma P (2004) Outbreak of *Marssonina* blotch in warmer climates causing premature leaf fall problem of apple and its management. *Acta Horticulturae* **662**, 405-409.
- Sharp WL and Yoder KS (1985) Correlation between humidity periods and sooty blotch and flyspeck incidence in Virginia apple orchards. *Phytopathology* **75**, 628.
- Shen YW and Chang SM (1964) Studies on the pear-twig Cerambycid *Linda fraterna* Chev. *Acta Phytomycol Sinica* **3**, 131-134.
- Shi WC, Li JR and Liu X (1993) A study of the diversity of insect communities using gray relational grade analysis in some apple orchards in Maoxian County. *Journal of Southwest Agricultural University* **15**, 137-143.
- Shirai Y and Kosugi Y (2000) Flight activity of the smaller tea tortrix, *Adoxophyes honmai* (Lepidoptera: Tortricidae). *Applied Entomology and Zoology* **35**, 459-466.
- Shivas RG (1989) Fungal and bacterial diseases of plants in Western Australia. *Journal of the Royal Society of Western Australia* **72**, 1-62.
- Sholberg PL and Haag PD (1996) Incidence of postharvest pathogens of stored apples in

- British Columbia. *Canadian Journal of Plant Pathology* **18**, 81-85.
- Shutova NN (1970) The peach moth *Carposina sasakii*. In 'Manual on quarantine and other dangerous pests, diseases and weeds'. (Kolos, Moscow, Russia): 67-68.
- Simmonds JH (1966) Host index of plant diseases in Queensland. *Queensland Department of Primary Industries, Brisbane* **1966**, 1-11.
- Singh J, Narain U and Koul AK (1984) *Pseudocercospora mali* on *Malus baccata*. *National-Academy-of-Sciences,-India-Science-Letters* **7**, 175.
- Singh RP, Ready KFM and Nie X (2003) Biology. In 'Viroids'. (Eds A Hadidi, R Flores, JW Randles and JS Semanick) (CSIRO Publishing, Collingwood): 30-48.
- Skorupska A and Boczek J (1985) Effect of the host plants change on the reproduction of hawthorn spider mite (*Tetranychus viennensis* Zacher). *Prace Naukowe Instytutu Ochrony Roślin* **27**, 5-22.
- Slippers B, Smit WA, Crous PW, Coutinho TA, Wingfield BD and Wingfield MJ (2004) Combined multiple gene geneologies and phenotypic characters differentiate several species previously identified as *Botryosphaeria dothidea*. *Mycologia* **96**, 83-101.
- Slippers B, Smit WA, Crous PW, Coutinho TA, Wingfield BD and Wingfield MJ (2008) Taxonomy, phylogeny and identification of *Botryosphaeriaceae* associated with pome and stone fruit trees in South Africa and the rest of the world. *Plant Pathology* **56**, 128-139.
- Smigell CG and Hartman JR (1997a) Evaluation of multi-layer fruit bags for sooty blotch and flyspeck control, Caldwell County, Kentucky, 1996. *Biological and Cultural Tests* **12**, 44.
- Smigell CG and Hartman JR (1997b) Evaluation of multi-layer fruit bags for sooty blotch and flyspeck control, Woodford County, Kentucky, 1996. *Biological and Cultural Tests* **12**, 45.
- Smigell CG and Hartman JR (1998) Evaluation of multi-layer fruit bags for sooty blotch and flyspeck control, 1997. *Biological and Cultural Tests* **13**, 44.
- Smith D, Beattie GAC and Broadley RH (1997) 'Citrus pests and their natural enemies: integrated pest management in Australia'. (Department of Primary Industries and Horticultural Research and Development Corporation, Brisbane). 263 pp.
- Smith IM, Dunez J, Lelliot RA, Phillips DH and Archer SA (1988) 'European Handbook of Plant Diseases.'. (Blackwell Scientific Publications, Oxford.).
- Smith PR, Campbell RN and Fry PR (1969) Root discharge and soil survival of viruses. *Phytopathology* **59**, 1678-1687.
- Smith WA, Viljoen CD, Wingfield BD, Wingfield MJ and Calitz FJ (1996) A new canker disease of apple, pears, and plum rootstocks caused by *Diaporthe ambigua* in South Africa. *Plant Disease* **80**, 1331-1335.

- Smith WL Jr, Moline HE and Johnson KS (1979) Studies with *Mucor* species causing postharvest decay of fresh produce. *Phytopathology* **69**, 865-869.
- Song MJ, Zhou NL, Zai YD and Zhang X (1994) A preliminary study on *Euzophera pyriella* Yang. *Plant Protection* **20**, 13-15.
- Spaulding P (1956) *Diseases of North American forest trees planted abroad*. Agriculture Handbook No. 100. USDA.
- SPC (2002) Pacific Fruit Fly Web Asian Papaya Fruit Fly (*Bactrocera papayae* Drew and Hancock), Secretariat of the Pacific Community.
http://www.spc.int/pacifly/Species_profiles/B_papayae.htm, Accessed: October 2005.
- Spence NJ (2001) Virus-vector interactions in plant virus disease transmission and epidemiology. In 'Biotic interactions in plant-pathogen associations'. (Eds MJ Jeger and NJ Spence) (CABI Publishing, Wallingford.): 15-26.
- Spotts RA (1990a) Bull's eye rot. In 'Compendium of Apple and Pear Diseases'. (Eds AL Jones and HS Aldwinckle) (American Phytopathological Society, St. Paul, Minnesota, USA): 56-57.
- Spotts RA (1990b) Mucor rot. In 'Compendium of Apple and Pear Diseases'. (Eds AL Jones and HS Aldwinckle) (American Phytopathological Society, St. Paul, Minnesota, USA): 57-58.
- Spotts RA and Cervantes LA (1986) Populations, pathogenicity, and benomyl resistance of *Botrytis* spp., *Penicillium* spp., and *Mucor piriformis* in packinghouses. *Plant Disease* **70**, 106-108.
- Srivastava RP (1997) 'Mango Insect Pest Management.' (International Book Distributing Co., New Delhi. pp. 61-74).
- Stamenkovic S and Stamenkovic T (1985) The life cycle of the summer fruit tortrix *Adoxophyes orana* F. v. R. (Lepidoptera, Tortricidae) in western Serbia. *Zastita Bilja* **36**, 65-80.
- Stansly PA and McKenzie CL (2007) Fourth international Bemisia workshop, International Whitefly Genomics Workshop, December 3-8, 2006, Duck Key, Florida, USA. *Journal of Insect Science* **8**.
- Su HK and Sun YX (1999) Bionomics and control of *Rhynchites auratus* Scop. *Senlin Bingchong Tongxun* **18**, 18-19.
- Sun FL, Lin SF and Zhang LX (1991) New hardy apple variety "Luxiangziao". *China Fruits* **4**, 6-7.
- Sun LQ, Zhang HQ and Li YY (1987) Studies on dispersal of sterile *Carposina nipponensis* using mark-release-recapture technique. *Acta Agriculturae Nucleatae Sinica* **1**, 29-37.
- Sun RH, Li AH, Gu HC and Zhang Y (1999) Study on the damage of *Lithocolletis ringoneilla* to apple trees and its control index. *China Fruits* **4**, 38-39.

- Sun RH, Li AH, Sun JX, Gu HC and Yin CS (2000) On the biology and chemical control of Asiatic apple leafminer. *Acta Phytophylactica Sinica* **27**, 157-162.
- Sun XM, Zhang FW and Tian XD (1988) Study on the biology and control of *Hishimonus sellatus* Uhler a vector of jujube witches broom. *Acta Phytophylactica Sinica* **15**, 173-177.
- Sun YZ and Ma GF (1999) The biological characteristics of *Argyresthia assimilis*. *China Fruits* **3**, 11-13.
- Sun YZ, Sun GL, Zhang GQ and Sun GD (2004) 'Biological Control of Fruit Tree Pests and Diseases'. (Jindun Press, Beijing, China). 100 pp.
- Sun, Z P, Wang, W, and Meng, F Y(1992) Survey of pests and diseases of Chinese hawthorn. *Bulletin-of-Agricultural-Science-and-Technology*. **4**: 25-26.
- Sutton TB (1990) Sooty blotch and flyspeck. In 'Compendium of Apple and Pear Diseases'. (Eds AL Jones and HS Aldwinckle) (American Phytopathological Society, St Paul, Minnesota, USA): 20-22.
- Sutton TB, Bond JJ and Ocamb-Basu CM (1988) Reservoir hosts of *Schizothyrium pomi*, cause of flyspeck of apple, in North Carolina. *Plant Disease* **72**, 801.
- Swinburne TR (1964) Rotting of apples of the variety Bramley's seedling by *Nectria galligena* (Bres.). *Nature* **204**, 493-494.
- Swinburne TR (1971) The infestation of apples, cv. Bramley's seedling, by *Nectria galligena* Bres. *Annals of Applied Biology* **68**, 253-262.
- Swinburne TR (1975) European canker of apple (*Nectria galligena*). *Review of Plant Pathology* **54**, 787-799.
- Sytenko LS (1960) On the specific composition of fruit moths in Maritime Province. *Entomologicheskoe obozrenie* **39**, 551-555.
- Szentivanyi O and Kiss L (2003) Overwintering of *Ampelomyces* mycoparasites on apple trees and other plants infected with powdery mildews. *Plant Pathology* **52**, 737-746.
- Takahashi S and Sawamura K (1990) Marssonina blotch. In 'Compendium of Apple and Pear Diseases'. (Eds AL Jones and HS Aldwinckle) (American Phytopathological Society, St. Paul, Minnesota, USA): 33.
- Tanaka T (1922) New Japanese fungi. Notes and translations XII. *Mycologia* **14**, 282-287.
- Tang DZ (2004) Investigation of the diseases of American Almond. *China Fruits* **4**, 49-51.
- Tang FD (1991) 'The Coccidae of China'. (United Publisher of Shanxi Higher Education, China, Taiyun, Shanxi, China). 377 pp.
- Tang FD (1992) 'The Pseudococcidae of China'. (Agricultural Science & Technology Published House of China, Beijing, China). 686 pp.

- Tang FT (1984) Observation on the scale insects injurious to forestry of North China. *Shanxi Agricultural University Press Research Publication* **2**, 122-133.
- Tang FT and Hao J (1995) 'The Margarodidae and others of China'. (Chinese Agricultural Science Technology Press, Beijing, the People's Republic of China). 738 pp.
- Tang ZT, Qin DR and Wang YJ (1980) A study of the red coffee borer (Lepidoptera: Cossidae). *Scientia Silvae Sinicae* **16**, 208-213.
- Teakle DS (1988) Tobacco necrosis necrovirus. In 'Viruses of Plants in Australia'. (Eds C Buchen-Osmond, K Crabtree, A Gibbs and G McLean) (Australian National University Printing Service, Canberra.): 490-491.
- Teng SC (1996) 'Fungi of China'. (vol. xiv) (Mycotaxon Ltd., Ithaca, USA). 586 pp.
- Tomlinson JA, Faithful EM, Webb MJW, Fraser RSS and Seeley ND (1983) *Chenopodium* necrosis: a distinctive strain of tobacco necrosis virus isolated from river water. *Annals of Applied Biology* **102**, 135-147.
- Tosheva-Tsverkova T (1965) Bioecological studies on the cherry-fruit weevil (*Rhynchites auratus* Scop.). *Gradinar lozar Nauka* **2**, 589-596.
- Toyoshima A (1931) Injurious Insects of Apple. I. On the Life-history of *Carposina sasakii* Mats. *Results of Agricultural Experiments, Aomori Agricultural Experiment Station* **26**, 1-28.
- Toyoshima S, Yaginuma K and Takanashi M (2005) Trends in the prevention of insect pest infestation in an unsprayed apple orchard using the mating disruption technique. *Bulletin of the National Institute of Fruit Tree Science* **4**, 71-81.
- Troitzky NN (1913) On an egg-eating parasite of *Rhynchites auratus*, Scop. *Journal of Agriculture of Turkestan* **5**.
- Tsuruta K, White IM, Bandara HMJ, Rajapakse H, Sundaraperuma SAH, Kahawatta SBMUC and Rajapakse GBJP (1997) A preliminary note on the host-plants of fruit flies of the tribe Dacini (Diptera, Tephritidae) in Sri Lanka. *Esakia* **37**, 149-160.
- University of Florida (2008) Brown marmorated stink bug *Halyomorpha halys*. http://creatures.ifas.ufl.edu/veg/bean/brown_marmorated_stink_bug.htm, Accessed: 14 October 2008.
- USDA (1958a) Fruit weevil (*Rhynchites heros* Roelofs). In 'USDA Cooperative Economic Insect Report No. 45: Insects Not Known to Occur in the United States'. (The United States Department of Agriculture, USA).
- USDA (1958b) Peach fruit moth (*Carposina niponensis*). In 'USDA Cooperative Economic Insect Report No. 34: Insects Not Known to Occur in the United States'. (The United States Department of Agriculture, USA).
- USDA (2002) Expansion of the Importation of Fresh Unshu Orange Fruit (*Citrus reticulata* Blanco var. *unshu* Swingle) from the Republic of Korea into Citrus Producing States of the Continental United States: A Pathway-Initiated Pest Risk Assessment. Plant

- Epidemiology and Risk Analysis Laboratory Center for Plant Health Science and Technology, Plant Protection and Quarantine Animal and Plant Health Inspection Service, United States Department of Agriculture, USA.
- USDA-APHIS (2000a) Importation of Grapes (*Vitis* spp.) from Korea into the United States: A Qualitative Pathway-Initiated Pest Risk Assessment (Revised 2002).
[https://web01.aphis.usda.gov/oxygen_fod/fb_md_ppq.nsf/0/6a4c6eb951006d8685256e2a005ecd0/\\$FILE/0058.pdf](https://web01.aphis.usda.gov/oxygen_fod/fb_md_ppq.nsf/0/6a4c6eb951006d8685256e2a005ecd0/$FILE/0058.pdf), Accessed: September 2009.
- USDA-APHIS (2000b) NPAG Data: *Cenopalpus pulcher* flat scarlet mite.
<http://www.pestalert.org/storage/CpulcherNPAGdatasheet.pdf>, Accessed: 27 October 2008.
- USDA-APHIS (2003) Personal communication from D. Hannapel of APHIS Attache, Canberra, Australia, on the US pest interceptions on New Zealand apples. Sent via e-mail on 24 October 2003.
- Uyemoto JK (1981) Tobacco necrosis and satellite viruses. In '*Handbook of Plant Virus Infections and Comparative Diagnosis*'. (Ed. E Kurstak) (Elsevier/North-Holland Biomedical Press, Amsterdam.): 123-146.
- Uyemoto JK and Gilmer RM (1972) Properties of tobacco necrosis virus strains isolated from apple. *Phytopathology* **62**, 478-481.
- van der Zwet T (1996) Present worldwide distribution of fire blight. *Acta Horticulturae* **411**, 7-8.
- van der Zwet T and Keil HL (1979) 'Fire blight, a bacterial disease of rosaceous plants. Agriculture Handbook No. 9510'. (USDA).
- Vassiliev E (1913) The Entomological Section of the Report of the Experimental Entomological Station of the Ail-Russian Society of Sugar-Refiners for 1912. *The Entomological Section of the Report of the Experimental Entomological Station of the Ail-Russian Society of Sugar-Refiners for 1912* 12-33.
- Verma KS and Sharma RC (1999) 'Diseases of Horticultural Crops'. (Indus Publishing Co., New Delhi).
- Voigt E (2001) Insect problems in a scab resistant / tolerant apple orchard in Hungary. *Bulletin OILB / SROP* **24**, 293-298.
- Volkov OG (1989) Prospects for biological regulation of Cuscuta. *Zaschita-Rastenii-Moskva* **11**, 18-19.
- Vujanovic V, St-Arnaud M and Neumann PJ (2000) Susceptibility of cones and seeds to fungal infection in a pine (*Pinus* spp.) collection. *Forest Pathology* **30**, 305-320.
- Waite GK and Hwang JS (2002) Chapter 11 - Pests of litchi and longan. In 'Tropical fruit pests and pollinators: biology, economic importance, natural enemies and control'. (Eds JE Pena, JL Sharp and M Wysoki) (CABI Publishing, Wallingford, UK): 331-360.
- Wan SX, Gao JS, Chou HC, Li WD, Hang HL and Zhang GH (2006) The pest species and

- damage on apple flower and fruit in western Henan province. The Yellow River Agriculture.
<http://www.smxagri.gov.cn/xcdeta/detail.asp?id=38657&mykindname=????>, Accessed: 11 May 2006.
- Wang CL and Wang FX (2009) Advances in interception and control of the codling moth. *Plant Protection* **2**.
- Wang F, Ju RT, Li YZ, Chi XZ and Du YZ (2008) Feeding behavior and feeding amount of *Parasa consocia*. *Chinese Bulletin of Entomology* **2**.
- Wang HF (1981) 'Economic insect fauna of China, Acari : Tetranychoida'. (Science Press, Beijing, China). 150 pp.
- Wang JY and Feng MX (2004) 'Control Techniques of Apple Pests and Diseases - New Edition'. (Jindun Press, Beijing, China). 317 pp.
- Wang JY and Li MN (1991) Study on the infection and occurrence conditions of apple tree canker (*Valsa mali*). *China Fruits* 14-17.
- Wang SY (1983) Occurrence and control of *Adoxophyes orana* Fischer von Roslerstamm in the cotton fields of northern Jiangxi Province. *Entomological Knowledge* **20**, 111-113.
- Wang YC and Guo L (1985) Taxonomic studies on *Gymnosporangium* in China. *Acta Mycologica Sinica* **4**, 24-34.
- Wang ZQ (1985) 'Identification Manual for Common Scale Insects'. (3rd Edition) (Science Press, Beijing, China). 252 pp.
- Washington State University (2005) Mucor Rot. Tree Fruit Postharvest Pathology Postharvest Diseases of Apples and Pears. Tree Fruit Research Centre, Washington State University. <http://decay.tfrec.wsu.edu/displayPage.php?id=pathlab&pn=40> , Accessed: 20 April 2009.
- Washington WS and Holmes R (2006) Mucor rot of pome fruit. Agriculture Notes, AG0166. Department of Primary Industries, Victoria.
- Washington WS and Nancarrow RJ (1983) 'List of diseases recorded on fruit and vegetable crops in Victoria before June 30, 1980. Technical Report No. 66'. (Department of Agriculture, Victoria, Australia). 54 pp.
- Waterhouse DF (1993) 'The Major Arthropod Pests and Weeds of Agriculture in Southeast Asia'. (Australian Centre for International Agricultural Research (ACIAR), Canberra, Australia). 141 pp.
- Watson GW (2005) Arthropods of Economic Importance: Diaspididae.
<http://nlbif.eti.uva.nl/bis/diaspididae.php?>, Accessed: September 2008.
- Wei XD (1990) Control of pear borer, *Chreonoma fortunei* (Col.: Cerambycidae) with *Scleroderma guani* (Hym.: Bethyridae). *Chinese Journal of Biological Control* **6**, 116-117.

- Welsh MF and Van der Meer FA (1989) 'Virus and Viruslike Diseases of Pome Fruit and Simulating Noninfectious Disorders'. (Cooperative Extension, Washington State University, Washington, USA). 127 pp.
- Weresub LK and Illman WI (1980) *Corticium centrifugum* reisolated from fisheye rot of stored apples. *Canadian Journal of Botany* **56**, 137-146.
- White IM and Elson-Harris MM (1992) 'Fruit flies of economic significance: their identification and bionomics'. (CAB International, London).
- Willetts HJ and Harada Y (1984) A review of apothecial production by *Monilinia* fungi in Japan. *Mycologia* **76**, 314-325.
- Williamson SM and Sutton TB (2000) Sooty blotch and flyspeck of apple: etiology, biology, and control. *Plant Disease* **84**, 714-724.
- Wormald H (1954) The Brown Rot Diseases of Fruit Trees. Technical Bulletin of the Ministry of Agriculture No. 3. HMSO, London, UK.
- WTO (1995) Agreement on the application of sanitary and phytosanitary measures. World Trade Organization, Switzerland. 13 pp.
- Wu BG, Liu E, Trachtenberg E and Beckman C (2007) The People's Republic of China. Fresh Deciduous Fruit. Annual 2007.
<http://www.fas.usda.gov/gainfiles/200711/146292990.pdf> GAIN Report, CH7085. U.S. Embassy, Beijing, China. 24 pp.
- Wu GJ, Chen ZJ, Zhang SL, Zhang MR and Wu YJ (1993) Study on species law of life and integrated control of crickets in pepper fields. *Acta Phytophylacica Sinica* **20**, 223-228.
- Wu SY, Fu WJ, Qiu HG and Liu GH (1999) Hybridization experiments with two strains of *Adoxophyes orana* and study on their esterase isozymes. *Entomological Journal of East China* **8**, 81-84.
- Wu XB and Guo XL (1987) Primary study on control of powdery mildews by ladybugs. *Journal of Northeast Forestry University* **15**, 13-17.
- Wu YF (2005) Geographical distribution model of Oriental fruit fly. *Journal of Fujian Agriculture and Forestry University (Natural Science Edition) (In Chinese with English abstract)* **34**, 168-171.
- Xi D, Li J, Han C, Li D, Yu J and Zhou X (2008) Complete nucleotide sequence of a new strain of *Tobacco necrosis virus A* infecting soybean in china and infectivity for its full-length cDNA clone. *Virus Genes* **36**, 259-266.
- Xiao ZF, Wang SX, Li SP and Zhang HZ (2000) Experiment of control of apple blemish diseases. *South China Fruits* **29**, 40-41.
- Xin YC (1996) Study on valsa canker of apple. *China Fruits* **3**, 15-16.
- Xu A, Yao J, Yu L, Lv S, Wang J, Yan B and Yu Z (2004) Mutation of *Gluconobacter oxydans* and *Bacillus megaterium* in a two-step process. *Journal of Applied Microbiology*

- 96**, 1317-1323.
- Xu QG and Hua BZ (2004) RAPD analysis on the speciation in host races of *Carposina sasakii* Matsumura (Lepidoptera: Carposinidae). *Acta Entomologica Sinica* **47**, 379-383.
- Yaginuma K and Takagi K (1987) Use of entomogenous fungi for the control of the peach fruit moth, *Carposina niponensis* Extension Bulletin No. 257 (25), ASPAC Food and Fertilizer Technology Center for the Asian and Pacific Region, Taiwan, Kyushu, Japan.
- Yago M and Ishikawa H (1936) Ecological notes and methods of controlling the pear fruit borer, *Carposina sasakii* Mats. *Bulletin Shizuoka Ken. Agricultural Experimental Station* **39**, 27.
- Yamaguchi, Kiritani K, Matsuhira K and Fukuda K (2001) The influence of unusual hot weather on the occurrence of several arthropod crop pests. *Japanese Journal of Applied Entomology and Zoology* **45**, 1-7.
- Yang CK (1965) Two new leafhoppers of the genus *Pyramidotettix* (Homoptera: Jassidae) injuring apple trees. *Acta Entomologica Sinica* **14**, 196-202.
- Yang DL, Song WH and Din CW (2000) Efficacy of five fungicides on garlic leaf blight (*Pleospora herbarum*) control. *Acta Phytopathologica Sinica* **3**, 282.
- Yang FT (1991) Bionomics of *Metabolus flavescens* Brenske and its control. *Insect Knowledge* **28**, 285-287.
- Yang J (1994) Description of a new pear pest from Kurla (Lepidoptera: Pyralidae). *Journal of Huazhong Agricultural University* **13**, 560-562.
- Yang P, Carey JR and Dowell RV (1994) Temperature influences on the development and demography of *Bactrocera dorsalis* (Diptera: Tephritidae) in China. *Environmental Entomology* **23**, 971-974.
- Yang QL, Zhang MC, Wang GM and Zhang HP (2005a) Effectiveness of using 8% cypermethrin for control of *Apriona germarii*. *China Fruits* **1**, 54.
- Yang S, Tulake T and Li J (2005b) Occurrence and infestation of pest insects on apricot in Xinjiang, China. *Xinjiang Agricultural Sciences* **42**, 363-365.
- Yang YL and Tian ZJ (1988) Studies on causes and control of dieback of spruces in the Xiaojin region, Sichuan. *Forest Pest and Disease* **4**, 1-2.
- Yang YN (1994) Integrated management in newly planted orchards. *Bulletin of Agricultural Science and Technology* **4**, 27.
- Yao IL, Cao MD and Xia XM (1993) Analysis of some mold strains by pyrolysis gas chromatography. *Journal of Instrumental Analysis* **12**, 42-44.
- Yasuda T (1998) The Japanese species of the genus *Adoxophyes* Meyrick (Lepidoptera, Tortricidae). *Transactions of the Lepidopterological Society of Japan* **49**, 159-173.

- Yin RG, Zhou BR, Zhang LS and Chen QL (1998) Study on controlling of apple fruit moth by sex attractant. *China Fruits* **3**, 9-11.
- Yoder KS (1990) Blotch. In 'Compendium of Apple and Pear Diseases'. (Eds AL Jones and HS Aldwinckle) (American Phytopathological Society, St Paul, Minnesota, USA): 26-27.
- Yokoyama VY and Miller GT (1988) Laboratory evaluations of codling moth (Lepidoptera: Tortricidae) oviposition on three species of stone fruit grown in California. *Journal of Economic Entomology* **81**, 568-572.
- Yoshizawa E (1985) Biology and control of peach curculio, *Rhynchites heros* Roelofs. I. Seasonal prevalence of occurrence (in Japan) and death of hibernated adults. *Proceedings of the Kanto Tosan Plant Protection Society* **32**, 197-198.
- Yu TF (1940) A list of important crop diseases occurring in Kiangsu Province (1934-1937). *Lingnan Science Journal* **19**, 67-78.
- Yu TF and Fang CT (1948) Fusarium diseases of broad bean. II. Further studies on broad bean wilt caused by *Fusarium avenaceum* var. *fabae*. *Phytopathology* **38**, 331-342.
- Yuan HB, Liu Y, Shen DS, Mao YW and Shi SS (2004) Observations on morphological and biological characters on *Actias selene ningpoana*. *Journal of Jilin Agricultural University* **26**, 431-433.
- Yukita K (2003) Development of the twig lesions caused by apple blotch *Diplocarpon mali* and significance of conidia as possible source of primary infection. *Japanese Journal of Phytopathology* **69**, 263.
- Zaher MA, Soliman ZR and El-Safi GS (1974) Biological studies on *Cenopalpus pulcher* (Canestrini and Fanzago) (Acarina: Tenuipalpidae). *Bulletin de la Societe Entomologique d' Egypte* **58**, 367-373.
- Zahradnik J (1990) 'Other forests. In Armoured scale insects, their biology, natural enemies and control. World Crop Pests'. (vol. 4B) (Elsevier, Amsterdam, the Netherlands).
- Zaitsev EF (1984) Protection of stone fruits. *Zashchita Rastenii* **4**, 54-55.
- ZDCBIC (2005) Noctuidae; *Calyptra* genus.
http://zd1.brim.ac.cn/specieslist.asp?x_genus=Calyptra&z_genus=LIK, Accessed: 20 October 2008.
- Zeitner R (2006) China's apple and pear industry. Economic Consultants Group, Western Growers Association, USA. 19 pp.
- Zeller SM (1929) Contribution to our knowledge of Oregon fungi III. *Mycologia* **21**, 97-111.
- Zhai YJ (1985) Preliminary observations on *Patanga japonica* (I. Bol.). *Insect Knowledge* **22**, 202-204.
- Zhang AH and Li HH (2005) Catalogue of Eucosmini from China (Lepidoptera: Tortricidae). *Shilap Revista de Lepidopterologia* **33**, 265-298.

- Zhang GX, Qiao GX, Zhong TS and Zhang WY (1999) 'Fauna Sinica Insecta Volume 14 - Homoptera Mindaridae and Pemphigidae'. (Science Press, Beijing, China). 380 pp.
- Zhang, J. Y., Kong, D. S., and Liu, H. J.(2001) The occurrence of Korean globose scale in the River's Western Corridor region of Gansu province and its control. *China Fruits* **2** 8-10.
- Zhang L, French R and Langenberg WG (1993) Molecular cloning and sequencing of the coat protein gene of a Nebraskan isolate of tobacco necrosis virus: the deduced coat protein sequence has only moderate homology with those of strain A and strain D. *Archives of Virology* **132**, 291-305.
- Zhang M (1989) Birch diseases from the Western Tianshan Mountain. *Forest Pest and Disease* **4**, 25-27.
- Zhang M (2006) Diversity of fungi of sooty blotch and flyspeck of apple in China. 'Thesis for Masters degree.,' Northwest Agriculture and Forestry University.
- Zhang R, Zhang Z, Zhai X, Zhang M, Sun G and Gleason ML (2007) A new species of *Dissoconium* from China colonizing apples. *Mycotaxon* **101**, 165-172.
- Zhang Z (2007) Pathogen diversity of fungi of sooty blotch and flyspeck. 'Thesis for Masters degree.,' Northwest Agriculture and Forestry University.
- Zhang ZQ (2003) 'Mites of greenhouses, identification, biology and control.' (CABI Publishing, UK).
- Zhao SF, Luo YN, Zhao HY, Du J and Fang XY (2009) First report of bacterial leaf spot on snow lotus caused by *Pseudomonas syringae* in China. *Plant Disease* **93**, 204.
- Zhao Y and Niu J (2008) Apricot is a new host of *Apple scar skin viroid*. *Australasian Plant Disease Notes* **3**, 98-100.
- Zhao YJ (2001) Study on the causal organisms of wheat fusarium blight and its pathogenicity in eastern Qinghai. *Plant Protection* **27**, 17-19.
- Zherikhin VV and Gratshev VG (1995) A comparative study of the hind wing venation of the superfamily Curculionoidea, with phylogenetic implications. In 'Biology, Phylogeny and Classification of Coleoptera: Papers Celebrating the 80th Birthday of Roy A. Crowson'. (Eds J Pakaluk and SA Slipinski) (Muzeum i Instytut Zoologii PAN, Warszawa): 633-777.
- Zhou HJ, Li JH, Zhao LF, Han J and Yang XJ (2004) Study on main microbes on quality formation of yunnan puer tea during pile-fermentation process. *Journal of Tea Science* **24**, 212-218.
- Zhou ZS and Deng GR (2005) Preliminary study on the host plants of leaf rollers on longan and litchi. *Kunchong Zhishi* **42**, 639-642.
- Zhu HF, Chu HF and Wang LY (1997) 'Fauna Sinica Insecta Volume 11 - Lepidoptera Sphingidae'. (Science Press, Beijing, China). 410 pp.
- Zhu XQ, Chen XY, Luo Y and Guo LY (2005) 1st report of *Monilinia fructicola* on peach

- and nectarine in China. *British Society for Plant Pathology, New Disease Reports* **10**, 575.
- Zhuang WY (2001) 'Higher Fungi of Tropical China.'. (Mycotaxon, Ltd., Ithaca, NY). 485 pp.
- Zhuang WY (2005) 'Fungi of northwestern China.'. (Mycotaxon Ltd., Ithaca, NY). 430 pp.
- Zitikaitė I and Staniulis J (2009) Isolation and characterization of tobacco necrosis virus detected on some vegetable species. *Biologija* **55**, 35-39.
- Zvierzomb ZE (1919) [Review of the Pests of Agriculture in the Don Province]. *Brief Report on the Work of the Don Bureau for the Control of Pests of Agricultural Plants for 1917, and Review of the Pests of Agriculture in the Don Province 1918* **36**.