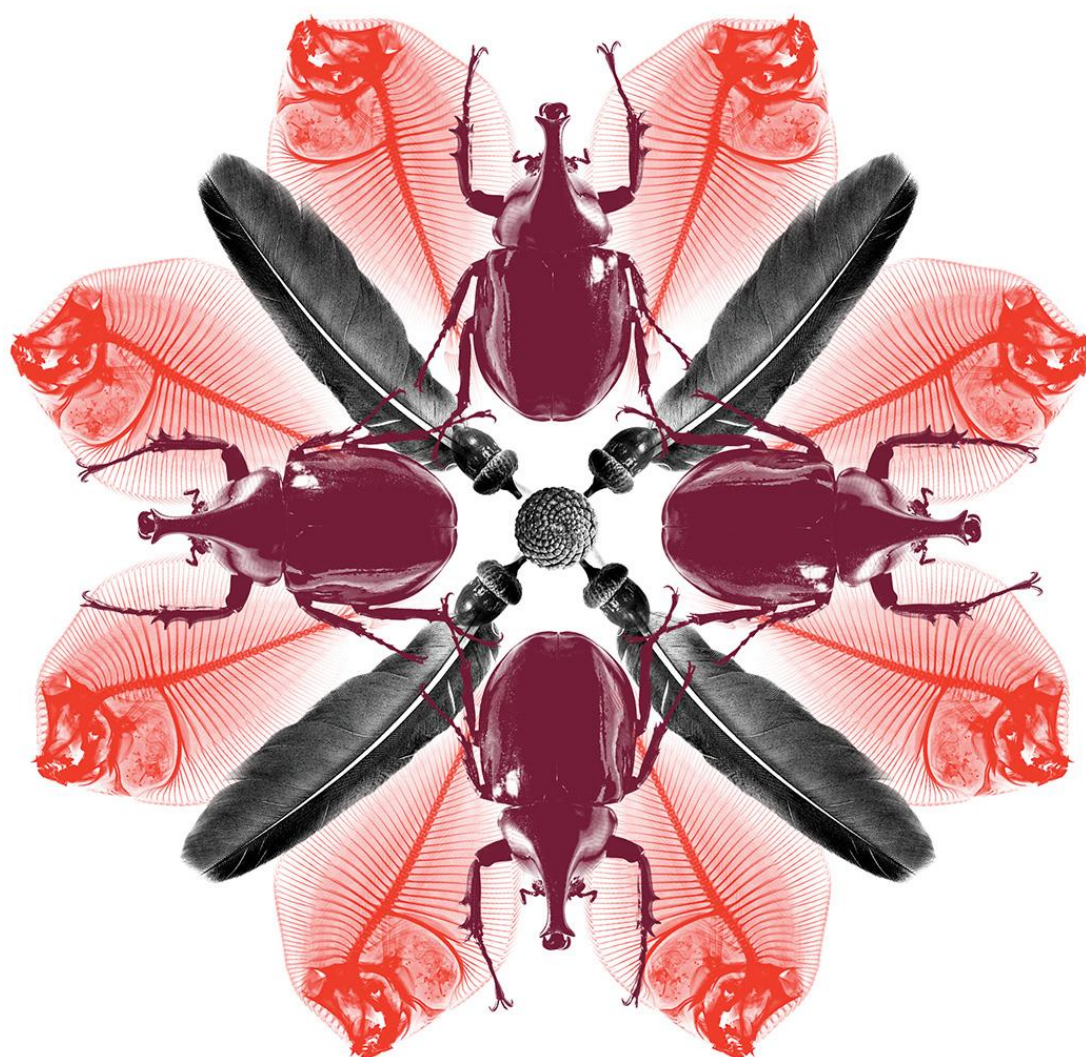




Australian Government
Department of Agriculture
and Water Resources

Final group pest risk analysis for mealybugs and the viruses they transmit on fresh fruit, vegetable, cut-flower and foliage imports

January 2019



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Acronyms and abbreviations

ACT	Australian Capital Territory
ALOP	Appropriate level of protection
APHIS	Animal and Plant Health Inspection Service
APVMA	The Australian Pesticides and Veterinary Medicines Authority
BIRA	Biosecurity import risk analysis
CPC	Crop Protection Compendium
FAO	Food and Agriculture Organization of the United Nations
GVP	Gross value of production
ICTV	The International Committee on Taxonomy of Viruses
IPM	Integrated Pest Management
IPPC	International Plant Protection Convention
ISPM	International Standard for Phytosanitary Measures
MRLs	Maximum residue limits
NSW	New South Wales
NPPO	National Plant Protection Organisation
NT	Northern Territory
PRA	Pest risk analysis
Qld	Queensland
SA	South Australia
SDQMA	Subcommittee on Domestic Quarantine and Market Access
SPS	Sanitary and Phytosanitary
Tas.	Tasmania
The department	The Department of Agriculture and Water Resources
URE	Unrestricted risk estimate
US	United States
USDA	United States Department of Agriculture
Vic.	Victoria
WA	Western Australia
WTO	World Trade Organization

Summary

The Department of Agriculture and Water Resources is improving the effectiveness and consistency of the Pest Risk Analysis (PRA) process. A key step in this improvement is the development of the Group PRA, which considers the biosecurity risk posed by a group of pests across numerous import pathways. It applies the significant body of available scientific knowledge, including pest interception data and previous PRAs, to provide an overarching analysis of the risks posed by the group.

The International Plant Protection Convention (IPPC) defines PRA as ‘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 2017b). International Standard for Phytosanitary Measures (ISPM) 2: Framework for pest risk analysis (FAO 2016a), states that ‘Specific organisms may ... be analysed individually, or in groups where individual species share common biological characteristics.’ This is the basis for the Group PRA, in which organisms are grouped if they share common biological characteristics, and as a result also have similar likelihoods of entry, establishment and spread and comparable consequences—thus posing a similar level of biosecurity risk.

Undertaking and utilising PRAs on groups of pests that share common biological characteristics provides significant opportunities to improve effectiveness and consistency of commodity-based PRAs with which those pests are also associated and to maintain a high level of biosecurity protection against new and emerging risks. The group approach to PRA was initiated by the department to take advantage of these opportunities. It is a ‘building block’ that can be used to review existing trade pathways, and can also be applied to prospective pathways for which a specific PRA is required.

If a Group PRA is used to review existing or new trade pathways there may be no need to undertake further detailed PRAs on these pests—if the trade-dependent factors relating to the likelihood of entry on specific pathways have been verified, the Group PRA can be applied.

This is the second Group PRA to be finalised—the first Group PRA was for thrips and orthospoviruses. This second Group PRA considers the biosecurity risk posed by all members of the Pseudococcidae, Putoidae and Rhizoecidae families, commonly referred to as mealybugs, which in total comprise about 2,300 described species. In addition the Group PRA considers all viruses transmitted by mealybugs that are (or are likely to be) associated with fresh fruit, vegetables, cut flowers or foliage imported into Australia as commercial consignments.

Mealybugs and the viruses they transmit can have consequences across a range of crops by reducing yield, quality and marketability.

This Group PRA identifies and analyses the key quarantine pests of biosecurity importance to Australia. It is built on a foundation of 19 years of PRAs undertaken by the department, all of which were subjected to robust scientific analyses and extensive stakeholder consultation. These pest risk assessments showed marked consistency in the level of biosecurity risk posed by mealybugs relative to the appropriate level of protection (ALOP) for Australia. They also indicated that certain mealybug species are associated with a broad range of plant commodities from many countries.

This report's conclusions have been validated with available scientific evidence including 30 years of interception data collected at Australia's borders, similar interception records available from other countries, and an extensive literature review. The report includes significant pests that have been recognised internationally, by Australian industry, and those identified by states and territories as regional pests for Australia.

Selection criteria were used to identify mealybug species with potential biosecurity importance for Australia. One hundred and sixty-nine species were confirmed as quarantine pests for Australia. The Group PRA also identified nine viruses transmitted by mealybugs that are quarantine pests for Australia.

Mealybug quarantine pests were estimated to have an 'indicative' unrestricted risk estimate of 'Low' which does not achieve the appropriate level of protection (ALOP) for Australia. This risk estimate is regarded as 'indicative' because the likelihood of entry (importation and distribution) can be influenced by a range of pathway-specific factors (such as the commodity, seasonal considerations, or the incidence of mealybugs in specific export production areas), and must be verified on a case-by-case basis. In some cases the likelihood of entry may need to be adjusted to take account of these factors. In order to achieve an appropriate level of protection for Australia, measures will be required for quarantine mealybugs when the unrestricted risk estimate of 'Low' has been confirmed for a specific plant import pathway.

In contrast, the viruses of biosecurity concern transmitted by mealybugs were estimated to have an 'indicative' unrestricted risk estimate of 'Very Low' for the plant import pathway, which achieves the ALOP for Australia. This is because mealybugs can only transmit viruses for a short period of time (semi-persistent transmission) and these viruses also have a limited host range compared to their mealybug vectors. These biological factors significantly limit the likelihood that mealybugs present on imported fresh fruit, vegetable, cut-flowers and foliage will be able to transmit exotic viruses to a host plant in Australia. Therefore no additional measures are required for these viruses transmitted by mealybugs on the plant import pathway.

Imported commodities will be regulated if they are infested with mealybug quarantine pests to reduce the risk of establishment of these organisms in Australia. Regulation will be in accordance with this PRA and any other relevant commodity-based PRAs.

Phytosanitary measures will also be required if the indicative unrestricted risk estimate is verified for a specific plant import pathway and the ALOP for Australia is not achieved.

The Group PRA identifies measures for mealybug quarantine pests, and alternative risk management options that may be considered on a case-by-case basis when developing new import conditions for specific commodities, or when reviewing existing import conditions for commodities that are currently traded. These measures are consistent with long-standing established import requirements for mealybug quarantine pests.

Measures are applied to ensure that goods in consignments are free from mealybug quarantine pests. Verification measures, such as inspection, are required to provide assurance that Australia's import conditions have been met and the appropriate level of protection achieved. Additional operational procedures may be required on a case-by-case basis for specific plant import pathways, such as a system of traceability, registration of packing house and treatment

providers and auditing of procedures, packaging and labelling requirements and specific conditions for storage and movement.

Imported goods that are frequently found to be infested with mealybug quarantine pests may be subject to mandatory treatment, which may be required pre-export rather than as a remedial action on arrival.

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1 Introduction

1.1 Initiation and scope

Initiation

This pest risk analysis (PRA) was initiated by the department.

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 2017b). The 'PRA area', the area in relation to which the PRA is conducted (FAO 2017b) is defined as Australia for this report. A pest is any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products (FAO 2017b). More specifically, 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 (FAO 2017b).

Scope

This PRA considers all members of the insect families Pseudococcidae, Putoidae and Rhizoecidae (commonly referred to as mealybugs) in the insect order Hemiptera. It also considers viruses known to be transmitted by mealybugs that may be associated with fresh fruit, vegetables and cut-flowers and foliage imported into Australia as commercial consignments from any country. This will be referred to as the plant import pathway in this report.

Out of scope

This report does not address the risk posed by mealybugs and the viruses they transmit on propagative plant material imports.

1.2 The Group PRA approach

The department is improving the effectiveness and consistency of Pest Risk Analysis (PRA) process. A key step in this improvement is the development of the Group PRA, which considers the biosecurity risk posed by a group of pests across numerous import pathways. It applies the significant body of available scientific knowledge, including pest interception data and previous PRAs, to provide an overarching analysis of the risks posed by the group.

Underpinning principles

Share common biological characteristics

The International Standard for Phytosanitary Measures Number 2: Framework for pest risk analysis (FAO 2007) states that 'Specific organisms may ... be analysed individually, or in groups where individual species share common biological characteristics.' This is the basis for the Group PRA in which organisms are grouped if they share common biological characteristics, and as a result also have similar likelihoods of entry, establishment and spread and comparable consequences—thus posing a similar level of biosecurity risk.

Mealybugs share common biological characteristics including their small size, plant feeding and sap sucking habits with many being polyphagous, ability to live in concealed habitats, frequent association with and transport on commodities in domestic and international commerce, and in some cases ability to reproduce parthenogenetically as well as sexually, or transmit viruses.

The Group PRA is built on the foundation of previous PRAs undertaken by the department—all of which were subjected to robust scientific analysis and extensive stakeholder consultation. For many common groups of pests, these pest risk assessments show marked consistency in the level of biosecurity risk posed by the pests relative to the appropriate level of protection (ALOP) for Australia. They also indicate that certain species are associated with a broad range of plant commodities from many countries.

Supported by and validated with available scientific information

The conclusions of the Group PRA are validated with available scientific evidence including interception data collected at Australia's borders, similar interception records available from other countries, and extensive literature review. The Group PRA includes significant pests that have been recognised internationally and by Australian industry, and those identified by states and territories as regional pests for Australia.

Consistent with international standards and requirements

The Group PRA is consistent with relevant international standards and requirements—including ISPM 2: Framework for Pest Risk Analysis, ISPM 11: Pest Risk Analysis for Quarantine Pests, (FAO 2017c) and the SPS Agreement (WTO 1995).

Defined scope

Each Group PRA has clearly defined scope in relation to the pests being grouped and the entry pathways under consideration.

Benefits of Group PRA

Undertaking and utilising PRAs on groups of pests that share common biological characteristics provides significant opportunities to improve effectiveness and consistency of commodity-based PRAs with which those pests are associated, and to maintain a high level of biosecurity protection against new and emerging risks. The group approach to PRA was initiated by the department to take advantage of these opportunities and assist with activities aimed at reforming and modernising Australia's biosecurity system. It is a building block that can be used to review existing trade pathways or be applied to prospective pathways for which a specific PRA is required.

If a Group PRA approach is used to review existing or new trade pathways there may be no need to undertake further detailed PRAs on these pests—once the trade-dependent factors relating to the likelihood of entry on specific pathways have been verified, the Group PRA can be applied.

Group PRAs identify the key pest species within the group that are of biosecurity importance to Australia. Broader uptake of the group approach to cover other major pest groups would create a master list of Australia's key quarantine pests.

By clearly identifying key, new and emerging risks, Group PRAs provide opportunities to better inform strategic surveillance and preparedness strategies, including industry biosecurity planning. The approach can also facilitate enhanced alignment and accord between domestic and international biosecurity policies, and ensure greater clarity and visibility of priority and regional pests.

1.3 This Group PRA

This is the second Group PRA to be released for public consultation—the first Group PRA was for thrips and orthotospoviruses. This Group PRA considers the biosecurity risk posed by all members of the insect families Pseudococcidae, Putoidae and Rhizoecidae (commonly referred to as mealybugs) in the order Hemiptera. It also considers viruses known to be transmitted by mealybugs that may be associated with fresh fruit, vegetables, cut-flowers and foliage imported into Australia as commercial consignments from any country.

Mealybugs and the viruses they transmit can cause considerable economic consequences across a range of crops by reducing yield, quality and marketability.

This Group PRA identifies the key quarantine pests of biosecurity importance to Australia in these two groups of organisms.

Comparable risk

Previous detailed pest risk analyses undertaken by the department on individual mealybug species associated with the plant import pathway show a marked consistency in the estimated level of biosecurity risk relative to the appropriate level of protection (ALOP) for Australia.

Nevertheless, the department recognizes there may be exceptional circumstances where risk differs significantly. If technically justified, a specific risk assessment would be undertaken where such exceptions exist. However, the evidence to date suggests this Group PRA is likely to apply with few exceptions.

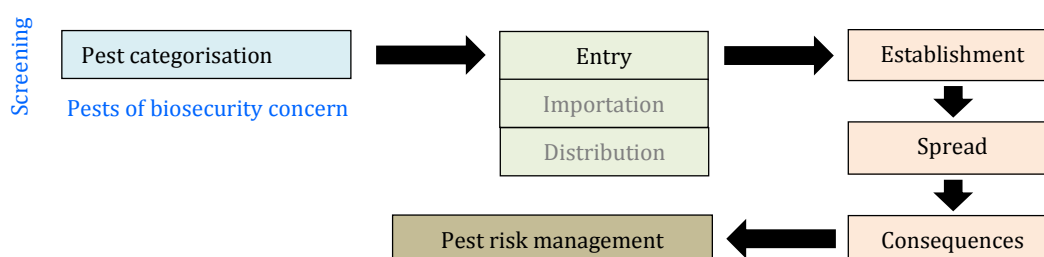
Identification of key pests

The purpose of this Group PRA was to focus on and identify the mealybugs that are of biosecurity significance to Australia. Pest categorisation was included for both mealybugs and viruses transmitted by mealybugs. Several selection criteria were used to identify which mealybug and virus species to categorise in detail (see Tables 2.1 and 4.1 respectively).

Group risk assessment

Species that were categorised as quarantine pests for Australia were assessed further. Likelihoods of entry (importation and distribution), establishment and spread, and the magnitude of economic consequences were then estimated for this group of key pests (Figure 1.1).

Figure 1.1 Core steps for the Group PRA



The likelihood of entry can be affected by a range of pathway-specific factors. For this reason, an 'indicative' likelihood was assigned for entry based on extensive historic and contemporary analysis of the plant import pathway. If this Group PRA is subsequently applied to a specific pathway, these factors must be verified on a case-by-case basis, as appropriate. Until this occurs, the likelihood of pest entry in this Group PRA is indicative only.

In contrast, the risk factors considered in the likelihoods of establishment and spread, and the impact (consequences) for a pest are not pathway specific, and are therefore comparable across all plant import pathways within the scope of this report. This is because at these stages of the risk analysis the pest is assumed to have already found a host within Australia (the end-point of entry).

An 'indicative' unrestricted risk was estimated by combining the likelihood of entry (indicative), establishment and spread with the estimate of consequence.

Phytosanitary measures are identified in the report for use in specific trade pathways when the unrestricted risk is verified and does not achieve the ALOP for Australia.

Application

Risk estimates derived from this Group PRA should be regarded as 'indicative'. This is because the likelihood of entry (importation and distribution) can be influenced by a range of pathway-specific factors such as the commodity, seasonal considerations, or the incidence of mealybugs in specific export production areas (see Appendix A for more detail). The likelihood of entry therefore needs to be verified on a case-by-case basis when developing new import conditions for specific commodities, or reviewing existing import conditions for commodities that are currently traded.

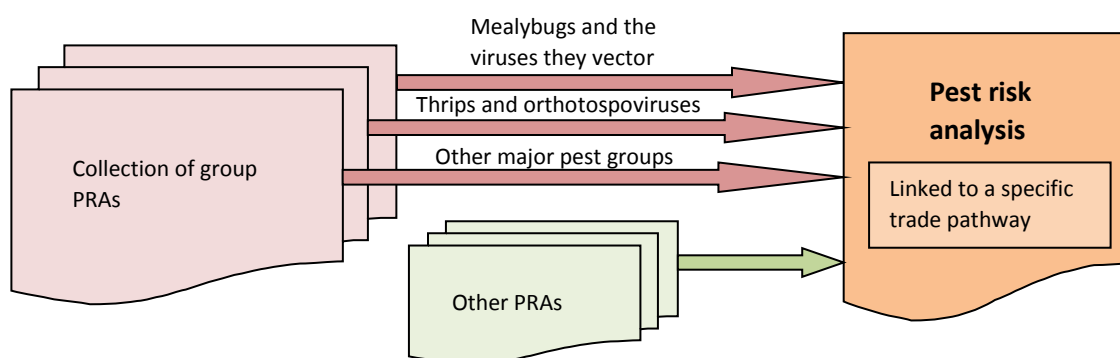
A key premise of the Group PRA is that organisms are grouped if they share common biological characteristics, and as a result pose a similar level of biosecurity risk. The common biological characteristics of mealybugs of biosecurity concern to Australia are such that if they successfully distribute to a susceptible host, they then have an inherently high capability to establish and spread and comparable consequences.

When the indicative likelihood of entry is confirmed for a specific plant import pathway, the default unrestricted risk estimate of 'Low' will apply. Measures will then be required for mealybug quarantine pests in order to achieve an appropriate level of protection for Australia (see Appendix A for more details).

1.4 Future of Group PRA

In addition to mealybugs and viruses they transmit (this report) and thrips and orthospoviruses (previous Group PRA), the department intends to apply the Group PRA approach to other key pest groups.

Broader uptake of the Group PRA approach provides opportunities to assemble future pest risk analyses by incorporating pre-existing Group PRAs of the major pests that are relevant to review of existing trade pathways or new market access requests, along with any additional PRAs that may be required (Figure 1.2).

Figure 1.2 Assembly of pest risk analyses by incorporating relevant group and other PRAs

1.5 Australia's biosecurity policy framework

Australia's biosecurity policies aim to protect Australia against the risks that may arise from exotic pests 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 risk analysis process is an important part of Australia's biosecurity policies. It enables the Australian Government to formally consider the level of biosecurity risk that may be associated with proposals to import goods into Australia. If the biosecurity risks do not achieve the ALOP for Australia, risk management measures are proposed to reduce the risks to an acceptable level. If the risks cannot be reduced to an acceptable level, the goods will not be imported into Australia until suitable measures are identified.

Successive Australian Governments have maintained a stringent, but not a zero risk, approach to the management of biosecurity risks. This approach is expressed in terms of the ALOP for Australia, which is defined in the *Biosecurity Act 2015* as providing a high level of protection aimed at reducing risk to a very low level, but not to zero.

Australia's risk analyses are undertaken by the Department of Agriculture and Water Resources using technical and scientific experts in relevant fields, and involve consultation with stakeholders at various stages during the process.

Risk analyses may take the form of a biosecurity import risk analysis (BIRA) or a non-regulated risk analysis (such as scientific review of existing policy and import conditions, pest-specific assessments, weed risk assessments, biological control agent assessments or scientific advice).

Further information about Australia's biosecurity framework is provided in provided in the *Biosecurity Import Risk Analysis Guidelines 2016* located on the [Department of Agriculture and Water Resources](#) website.

2 Pest categorisation of mealybugs

2.1 Introduction

The pest categorisation process identifies pests with the potential to be on the plant import pathway that are quarantine pests for Australia, and as a result require pest risk assessment. It confirms the identity of a pest, its absence or presence and regulatory status within the PRA area, its potential for establishment and spread, and its potential for economic and environmental consequences in the PRA area (FAO 2017c).

Mealybugs as a group contain about 2,300 species (García Morales et al. 2018). It is not practical or necessary to categorise them all. Instead, a set of criteria (Table 2.1) were used to identify pest mealybug species for inclusion in pest categorisation, with inclusion dependent on meeting one or more criteria.

Table 2.1 Criteria for inclusion of mealybug species in pest categorisation

Criterion	Description
1	Species is known to have a history of being intercepted at Australian and/or international ports of entry on the plant import pathway
2	Species is known to transmit a plant virus
3	Species is identified by Australian industries as a high priority pest in relevant industry biosecurity plans, provided by Plant Health Australia
4	Species is identified as a pest of importance in the Crop Protection Compendium, and a pest data sheet is available in CABI (CABI 2015), and/or is listed as a major pest in the regional mealybug monographs (Williams 2004; Williams & Granara de Willink 1992; Williams & Watson 1988a), and/or as an invasive species (Miller, Miller & Watson 2002)
5	Species has previously been considered by Australia at species level (excluding unidentified species) in pest categorisation in final risk analyses, regardless of whether it was absent or present in Australia and whether or not they were found to be associated with the specific commodity pathway at the time
6	Species is under official control as a regional pest within Australia

Based on these selection criteria, identified mealybug species were included for the pest categorisation process. This produced a list of 192 species likely to be of biosecurity concern on the plant import pathway (Appendix B). In the future, subsequent inclusion in pest categorisation of additional species that meet one or more of the selection criteria will be considered on a case-by-case basis.

In order to support the pest categorisation as detailed in Appendix B, relevant information on taxonomic classification (Section 2.2) and biology (Section 2.3) are presented.

In this pest categorisation of mealybugs, the potential for establishment and spread and potential for economic and environmental consequences in the PRA area were not considered for individual species in the categorisation table (Appendix B), but rather are addressed for all the pest mealybugs as a group in sections 2.4 and 2.5, respectively. This approach is consistent with the categorisation guideline set out in the ISPM 11 (FAO 2017c).

2.2 Taxonomy

Traditionally, all mealybugs were placed in a single family, the Pseudococcidae. However, phylogenetic analyses on the female and male characters, as well as molecular and other data,

have validated the previously proposed family Putoidae, and also resulted in a separation of the family Rhizoecidae from Pseudococcidae (Downie & Gullan 2004; Hardy, Gullan & Hodgson 2008; Hodgson 2012; Hodgson & Foldi 2006). Phylogenetically, these three families may not form a monophyletic group (Gullan & Cook 2007); however, they are considered in this pest risk analysis as a single group as they share common biological characteristics and thus pose a similar level of biosecurity risk.

Relevant information for the three families of mealybugs is summarised in Table 2.2, based on Miller et al. (2014b) and Garcia et al. (2018).

Table 2.2 Summarised information for the three mealybug families

Family name	Common name	No. of genera	No. of species	Host families	Plant parts attacked
Pseudococcidae	Mealybugs	259	1997	265	Mainly aerial parts
Putoidae	Giant mealybugs	2	48	69	Mainly aerial parts
Rhizoecidae	Ground mealybugs	20	244	101	Roots

A total of 2,289 species have been described (Table 2.2). The most species-rich family Pseudococcidae contains 1,997 species in 259 genera, followed by Rhizoecidae with 244 species in 20 genera, and finally Putoidae with 48 species, with all 47 extant species in a single genus *Puto* and one fossil species in another genus.

The common name ‘mealybugs’ generally refers to these three families, although separately the Putoidae are also called ‘giant mealybugs’ and the Rhizoecidae are referred to as ‘ground mealybugs’ (Table 2.2).

2.3 Biology

The description of the life history refers to the three mealybug families – Pseudococcidae, Putoidae and Rhizoecidae – unless otherwise specified.

Life history

Mealybugs are small, soft-bodied sap-sucking insects (Williams & Granara de Willink 1992). They are usually covered with a layer of fine mealy wax, which often extends laterally to form a series of short filaments. This covering is frequently white, although the colour may vary for different species (Williams & Granara de Willink 1992).

Most mealybug species are biparental so that reproduction requires both males and females. Female and male mealybugs have different life cycles.

Female mealybugs have five life stages: egg, female crawler, second and third instar nymphs, and adult (Franco, Zada & Mendel 2009). Adult females are 3 to 8 mm long, slow-moving and oval-shaped. Adult female mealybugs may live for several months and lay their eggs (oviparity) in a waxy covering (the ovisac), or produce their young directly by retaining their eggs in the body until hatching (ovoviviparity) (Franco, Zada & Mendel 2009).

Males have six life stages: egg, male crawler second instar nymph, non-feeding pre-pupa and pupa inside a waxy cocoon, and adult. The adult male is a tiny winged insect, which possesses a pair of long wax terminal filaments, believed to assist in stabilising flight (Franco, Zada & Mendel 2009; Mani & Shivaraju 2016b; University of Minnesota 2007). Adult males are minute, without

functional mouthparts, and possess either a single pair of wings, or are wingless and morphologically degenerate (Williams 2004).

Mating appears to rely mainly on chemical cues: adult females utilise sex pheromones to attract males (Franco, Zada & Mendel 2009). Adult males require 30 to 40 hours to reach sexual maturity. Mature males generally live for 2 to 3 days, and fly only 2 to 4 hours per day to search for a mate.

There are two different types of genetic systems in mealybugs. The first system is a sexual reproductive strategy known as paternal genome elimination, and is related to a particular type of haplodiploidy. In this system, both males and females develop from fertilised eggs. For males, however, although the zygote develops into a male containing one haploid genome from each parent, only the maternal genome is transmitted to the offspring via sperm because the set of chromosomes of paternal origin becomes heterochromatic and genetically inactive (Normark 2003; Nur 1990). The second system is an asexual strategy known as thelytokous parthenogenesis; in this system there are no males produced and hence no mating occurs (Franco, Zada & Mendel 2009; Normark 2003). The advantages of parthenogenesis may include maintenance of a superior genotype and/or increased reproductive output, because all offspring are female (Gullan and Koztarab 1997).

Mealybugs can overwinter as one or two of the life stages depending on the species, namely, as eggs, first- or second-instar nymphs, or adult females. It appears that the second-instar nymph is the most common overwintering stage (Miller 2005). Franco et al. (2009) provide some examples of species that are able to overwinter during different life stages, namely, *Pseudococcus maritimus* as eggs and first-instars located under the bark, *Pseudococcus viburni* as first instars in bark crevices, and rarely as second or third instars, *Planococcus vovae* as first and second instars, and *Phenacoccus azaleae* Kuwana as second-instar nymphs within wax cocoons. More detailed information on the overwintering of mealybugs is provided by Mani and Shivaraju (2016d).

Mealybugs generally produce one or two generations per year, however there are exceptions where mealybugs can produce up to 8 to 11 generations per year (Miller et al. 2014b). Studies show that temperature has significant effect on the life cycle of mealybugs, such as of *Paracoccus marginatus* (Amarasekare et al. 2008) and *Phenacoccus solenopsis* (Sreedevi et al. 2013). For example, *Paracoccus marginatus* was able to develop and complete its life cycle at 18, 20, 25, and 30 °C in laboratory conditions, but the longevity for each life stage decreased with the increase of temperature (Amarasekare et al. 2008). The time from egg to adult was longest at 18 °C for both males (85 d) and females (74 d) and shortest at 30 °C (male 25 d and female 23 d, respectively). The estimated minimum temperature thresholds for the adult males and females were 14.5 °C and 13.9 °C, respectively. The estimated maximum temperature thresholds for the adult males and females were 31.9 °C and 32.1 °C, respectively.

Mani and Shivaraju (2016b) summarise the biological information for 41 mealybug species in 22 genera, including for the important pests *Antonina graminis*, *Dysmicoccus* spp., *Geococcus citrinus*, *Phenacoccus manihoti*, *Planococcus citri*, *Pseudococcus comstocki* and *Rastrococcus invadens*.

Honeydew produced by mealybugs

'Honeydew' produced by mealybugs is closely related to their impact on plants, both from the perspective of development of sooty mould, and of mealybug interaction with ants.

The honeydew production process is explained in detail by Franco et al. (2009). In summary, mealybugs suck sap from the plant phloem and/or mesophyll cell contents through their stylets, and consume a diet containing mainly carbohydrates with limited amounts of free amino acids and other nitrogen compounds. Organic compounds in phloem sap need to be concentrated before they can be absorbed, and this occurs in the filter chamber, a specialized component of the digestive system, which enables the direct passage of water from the anterior midgut to the Malpighian tubules, thereby concentrating food in the midgut. The residue of ingested phloem sap, after digestion and assimilation in the insect gut, is released from the anus as a sugar-rich material, known as 'honeydew'. Up to 90 per cent of ingested sugars may be excreted as honeydew.

Gullan and Kosztarab (1997) reviewed the literature on how phloem-feeding scale insects, including mealybugs, have evolved effective methods of preventing contamination of themselves by their own sticky, sugar-rich honeydew. These immobile insects could quickly become contaminated and trapped in their own waste if it were not discharged some distance away from their bodies or removed regularly by ants. Such contamination would be likely to be especially detrimental to first-instar nymphs (Foldi 1984).

It has been recognised that mealybugs have different ways of keeping honeydew droplets from contaminating their body surface (Williams 2004). For most mealybugs, the excreted honeydew falls away in droplets or is discharged a short distance from the body. Often the anal ring of the mealybugs possesses rows of cells secreting a short tube of wax, ensuring that the honeydew droplets are kept away from the body surface. If honeydew droplets fall on the body, small wax filaments, normally secreted by the trilocular pores, prevent the droplets adhering to the cuticle.

Mealybugs and sooty mould

The sugary honeydew produced by mealybugs provides a substrate for the growth of saprophytic sooty mould fungi. Sooty moulds form a black, powdery coating adhering to the leaves or fruit of plants, fouling plant surfaces and impairing photosynthesis. The fungi themselves do little harm to the plant, but can reach densities that cause yellowing of foliage or stunt plant growth. Thus, sooty moulds are also largely a cosmetic problem, making plants and plant produce unsaleable as a result. Some common genera of fungi causing sooty moulds include *Cladosporium*, *Aureobasidium*, *Antennariella*, *Limacinula*, *Scorias* and *Capnodium*.

Mealybugs and ants

It is also appropriate to note the relationship between ants and mealybugs, because the presence of ants can increase the impact and damage of mealybugs on plants. The relationship between mealybugs and ants has been reviewed by Gullan and Kosztarab (1997), Williams (2004), Franco et al. (2009) and Mani and Shivaraju (2016a). The mealybug-ant association can vary from strong dependence to weak, casual and seasonal relationships (Mani & Shivaraju 2016d).

Benefits that mealybugs can obtain from being attended by ants include elimination of contamination by the honeydew they produce, and protection from adverse weather, unfavourable environment and natural enemies (Mani & Shivaraju 2016d). In turn, ants benefit

from accessing honeydew produced by the mealybugs as food; some ants can even switch between tending and preying on mealybugs (Franco, Zada & Mendel 2009).

Honeydew excretions from mealybugs are a major source of food for many species of ants. In many cases, mealybugs are only serious pests in the presence of ants because the ants protect them from predators and other natural enemies including parasitoids (Williams 2004).

Both obligate and facultative attendance by ants alleviates the honeydew contamination of scale insects (Gullan & Kosztarab 1997; Way 1954), including mealybugs. A few taxa, mostly tropical or subtropical scale insects, have such an intimate relationship with their attendant ants that they survive only in ant nests or shelters (Flanders 1957; Gullan & Kosztarab 1997). These taxa display obvious behavioural and morphological adaptations to living with ants.

All the southeast asian myrmecophilous mealybugs display unusual morphology, as discussed by Williams (1978), and have been collected only with ant species of the genera *Acropyga*, *Dolichoderus* or *Polyrhachis*, which tend to the mealybugs either in subterranean nests or on aerial plant parts (Reyne 1954; Williams 1978).

Feeding nymphs of *Hippeococcus* spp. display the apparently adaptive behaviour of climbing on to the thorax of an ant when danger threatens (Reyne 1954). The ants elicit this response from the mealybugs by tapping them with their antennae, upon which the mealybugs ascend the ant and probably hold on using enlarged claw digitules while the ants evacuate them to safety.

Another mealybug species, *Xenococcus annandalei* of the family Rhizoecidae, has a female pupal instar, the only known female pupa among coccoids. This species also has an unusual adult male that partly resembles a fly larva and partly a mite (Williams 1986b). All instars of *X. annandalei* live in the nests of the ant *Acropyga acutiventris*; Williams (1986b) speculated that the peculiar features of the mealybugs evolved over a long association with the ants.

2.4 Potential for establishment and spread

Mealybugs have the potential to establish and spread in Australia because they possess biological characteristics that enable them to adapt to new regions, the climatic conditions in Australia are suitable, and host plants are widely available.

Share common biological characteristics

Mealybugs share common biological characteristics which would enable them to establish and spread in Australia. These characteristics include their small size, plant feeding and sap sucking habits with many being polyphagous, ability to live in concealed habitats, and frequent association with and transport on commodities in domestic and international commerce, and in some cases ability to reproduce parthenogenetically as well as sexually (García Morales et al. 2018; Miller et al. 2014a; Miller, Miller & Watson 2002; Williams 1985a). Many pest mealybugs are recognised as invasive species as a result of these characteristics (Miller, Miller & Watson 2002).

Climatic conditions

Mealybugs have been reported from every part of the world (Miller et al. 2014a) and many pest mealybugs occur worldwide. Species of Pseudococcidae and Rhizoecidae are reported from all the six zoogeographical regions of Europe, Asia, North America, South Americas, Africa and

Australasia; in contrast those of Putoidae are found in all regions other than Africa and Australasia (Miller et al. 2014a). Suitable climatic conditions for establishment and spread are available in Australia, which possesses a range of tropical, subtropical, temperate, and cool temperate regions (Bureau of Meteorology 2013).

Hosts plants

The ten most common host plant families for each mealybug family are presented in Table 2.3, which was compiled based on information from Garcia et al. (2018).

Table 2.3 The ten most common host plant families for each mealybug family

Pseudococcidae		Putoidae		Rhizoecidae	
Host family	No. of host species	Host family	No. of host species	Host family	No. of host species
Poaceae	613	Poaceae	27	Poaceae	80
Asteraceae	408	Asteraceae	16	Asteraceae	56
Fabaceae	407	Pinaceae	15	Arecaceae	23
Cactaceae	204	Fabaceae	11	Araceae	19
Orchidaceae	181	Euphorbiaceae	9	Cactaceae	19
Malvaceae	141	Ericaceae	9	Fabaceae	18
Rosaceae	132	Rutaceae	8	Rubiaceae	17
Lamiaceae	126	Amaranthaceae	7	Rosaceae	17
Euphorbiaceae	104	Fagaceae	6	Asparagaceae	16
Amaranthaceae	100	Cupressaceae	5	Solanaceae	13

Mealybugs occur on a diverse range of host plants. Pseudococcidae are found on 265 families of host plants (Table 2.2); common host families include 613 host species within the Poaceae, 408 host species within the Asteraceae and 407 host species within the Fabaceae (Table 2.3). Grasses and composites are thus important hosts for Pseudococcidae, as reflected in their tendency to occur on herbaceous plants rather than trees and woody shrubs. Consequently, few Pseudococcidae are reported on the plant families of Salicaceae, Pinaceae, Palmaceae and Betulaceae (Miller et al. 2014a).

The pattern of host preference of Rhizoecidae is very similar to that of Pseudococcidae. Species of Rhizoecidae have been reported on 101 plant families (Table 2.2) (García Morales et al. 2018) and the common host families include 80 host species within the Poaceae, 56 host species within the Asteraceae and 23 host species within the Arecaceae (Table 2.3).

Putoidae are reported on 69 plant families (Table 2.2) (García Morales et al. 2018). This is a very high number of plant families attacked considering there have been only 47 extant species reported. In contrast to the other two families, Putoidae are most common on conifers, grasses and a series of woody shrubs (Table 2.3) (Miller et al. 2014a).

Pseudococcidae and Putoidae are mainly found on the aerial parts of the plant, while species of Rhizoecidae feed on roots (Table 2.2). Many host plants of mealybugs are cultivated as agricultural and horticultural crops. Australia grows a wide range of fruit and vegetable crops, and also grows plants for cut-flowers and foliage; such crops include apple, banana, citrus, cucurbits, grapes, mango, orchids and roses. These hosts are widely available in Australia, and

could facilitate the establishment and spread of mealybugs. In addition, exotic mealybugs may be able to colonise Australia's native vegetation once introduced.

Examples of mealybugs that have established and spread within Australia

There is a long history of exotic mealybugs becoming established globally. Many exotic mealybugs have also been accidentally introduced and become established in Australia, including *Dysmicoccus brevipes*, *Maconellicoccus hirsutus*, *Phenacoccus solenopsis*, *Planococcus citri* and *Pseudococcus viburni* (Brookes 1957, 1964; Williams 1985a).

Summary

All exotic pest mealybugs included in the pest categorisation were considered to have the potential to establish and spread in the PRA area on the basis that they possess and share common biological characteristics, their actual or potential host plants are widely available, and there are suitable climatic conditions in Australia. This assessment is supported by the fact that many introduced mealybug species have already established and spread in Australia.

Furthermore, in all previous mealybug pest categorisations undertaken by the department, all mealybug quarantine pests have been assessed as having the potential to establish and spread in Australia.

2.5 Potential for economic consequences

Mealybugs feed by inserting their stylets through the plant tissues to feed on sap from either the phloem or mesophyll. Stylet penetration is accomplished by secretion of solidified saliva that forms a sheath around the stylets. Mealybugs consume a diet containing mainly carbohydrates but also limited amounts of free amino acids and other nitrogen compounds (Franco, Zada & Mendel 2009). Typical mealybug damage includes leaf and fruit discoloration; leaf, flower and fruit dropping, reduction of fruit growth rate, distortion of leaves, new shoots and fruit, aborted plant shoots, development of cork tissue on fruit peel, contamination of fruit with mealybugs and honeydew, and reduction of plant vigour (Franco, Zada & Mendel 2009). Perennial plants may be killed by high densities of mealybug populations or repeated annual infestations (Franco, Zada & Mendel 2009). Many mealybugs are polyphagous, feeding on plants that include important agricultural and horticultural crops such as banana, capsicum, citrus, grapevines, mango (Williams & Granara de Willink 1992).

Many cosmopolitan mealybug pests are species in the genera *Pseudococcus*, *Planococcus*, *Dysmicoccus* and *Phenacoccus* (Franco, Zada & Mendel 2009; Miller, Miller & Watson 2002). Miller et al. (2002) compiled a list of 158 pest species of mealybugs and included information on their principal host plants and their probable areas of origin. The information in Miller et al. (2002) was summarised by Franco et al. (2009) who notes that while approximately 22 per cent of the pests are polyphagous, some 20 per cent feed only on Poaceae such as sugar cane, 16 per cent on citrus and tropical fruits and six per cent on coffee. Mealybugs were found to originate from all over the world: 29 per cent from Europe and North Asia, 17 per cent North America, 16 per cent Central and South America, 15 per cent South Asia, 12 per cent from Africa and 11 per cent Australasia (Franco, Zada & Mendel 2009; Miller, Miller & Watson 2002).

There are instances of mealybug damage on host plants that are much more serious in introduced regions than in native areas. The fruit tree mealybug *Rastrococcus invadens*, the

cassava mealybug *Phenacoccus manihoti* and the papaya mealybug *Paracoccus marginatus* are three such examples.

Rastrococcus invadens is not a recognised pest in its native India but became a notorious pest on fruit trees in West Africa when introduced accidentally in the early 1980s (Agouké, Agricola & Bokonon-Ganta 1988). The pest seriously damages mango and also attacks citrus, banana, breadfruit and guava. Fortunately, biological control involving the introduction of a parasitic wasp, *Gyranusoidea tebygi*, from India appears to be effective at reducing and managing the pest populations. For mango alone, it was estimated that this biological control program would save an accrued benefit of US\$531 million, based on current value, over a 20 year period in Benin (Bokonon-Ganta, de Groote & Neuenschwander 2002).

Phenacoccus manihoti is native to South America, was accidentally introduced to Africa in the early 1970s, and became a major pest of cassava, spreading rapidly through the major African cassava belt. By 1986, it had reached about 25 countries, covering 70 per cent of the African cassava belt, where it caused severe damage to cassava, sometimes defoliating the plant completely (CABI 2015). Defoliation reduces the availability of healthy leaves, which are consumed as leafy vegetables in most of West and Central Africa. Yield losses of cassava tubers averaged 65 per cent during the 1983 outbreak (Norgaard 1988). A small parasitoid wasp, *Epidinocarsis lopezi*, was discovered to be a parasitoid of the cassava mealybug in the pest's native region of South America and introduced to Africa. Mass rearing and distribution techniques were developed in Nigeria in the early 1980s. By 1987 *E. lopezi* was established in 90 per cent of the cassava-growing region of Africa, and losses of cassava from mealybug were brought under control (Norgaard 1988).

Paracoccus marginatus is an emerging pest and probably presents a significant threat to countries within 30 degrees of the equator (CABI 2015). The species is native to Central America and now found in 48 countries in Africa, Asia, North America, and Oceania as well as Central and South America (García Morales et al. 2018). It is highly polyphagous, being reported on 134 genera of 49 families of plants (García Morales et al. 2018). In Asia it was first reported in Indonesia and India in 2008 (Muniappan et al. 2009; Muniappan et al. 2008) and subsequently spread to other countries in the region. It has caused significant damage to cassava in Central America and has the capacity to seriously affect other tropical fruit and ornamentals such as *Papaya*, *Hibiscus* and *Annona* species (CABI 2015). On papaya, the pest infests the veins of older leaves and all parts of young leaves and fruits. Papaya trees can die within a few months of becoming infested (Muniappan et al. 2008).

In addition, mealybug damage can be compounded by other associated lepidopteran pests (Franco, Zada & Mendel 2009). It is reported that fruit moths have been attracted to the honeydew produced by mealybugs. The moths lay eggs in the vicinity of the mealybug colonies, near plant parts contaminated with sooty mould. The hatched larvae can bore into fruit skin or branch cortex or the wood. For example, in the Mediterranean region, the honeydew moth, *Cryptoblabes gnidiella* (Lepidoptera: Phycitidae) occurs on citrus fruit infested by *Planococcus citri* and *Pseudococcus cryptus*, and on avocado fruit infested by *Pseudococcus longispinus* (Franco, Zada & Mendel 2009). The carob moth, *Ectomyelois ceratoniae*, has been associated with *Planococcus citri* on citrus fruit and persimmon, and also associated with *Planococcus ficus* on pomegranate fruit (Franco, Zada & Mendel 2009). The damage inflicted on citrus in Israel by

the honeydew moth and the carob moth may be severe, although the infestation by *Planococcus citri* alone would be tolerated by the plant (Franco, Zada & Mendel 2009).

In addition to the direct damage caused by mealybug feeding activity, sooty mould growing on the secreted honeydew can affect the photosynthesis of the plant (Charles 1982) and reduce marketability of the crops. Some mealybug species are also responsible for transmission of viral diseases in crops such as banana, black pepper, cocoa, pineapple, sugarcane and grapevine (Franco, Zada & Mendel 2009). Mealybug species that are potential vectors for viruses are indicated in the pest categorisation table (Appendix B).

Summary

All exotic pest mealybugs included in the pest categorisation process (Appendix B) were considered to have the potential to cause economic (including environmental) consequences in Australia because they damage plants by sucking sap, secreting honeydew that encourages growth of sooty mould, and/or transmit viral diseases. Exotic mealybug may cause much more serious damage in introduced regions than in their native areas, as shown in the three examples.

This assessment is consistent by the outcome of previous pest categorisations undertaken by the department, in which all but one species was assessed to have the potential to cause economic consequences in Australia when found to be on plant import pathway and to have the potential for establishment and spread.

2.6 Process of pest categorisation of mealybugs

In overview, the pest categorisation process identifies pests with the potential to be on the plant import pathway that are quarantine pests for Australia and as a result require a pest risk assessment. The process for pest categorisation is described in Appendix A. Species are included for pest categorisation based on the selection criteria identified in Table 2.1. Factors considered for each included species in the pest categorisation process are:

- identity of the pest
- presence or absence of the pest in the PRA area
- regulatory status of the pest in the PRA area
- potential for pest establishment and spread in the PRA area
- potential for the pest to cause economic consequences (including environmental consequences) in the PRA area (FAO 2017c).

The pest categorisation of mealybugs is presented in Appendix B and the outcome is summarised in Chapter 2.7.

2.7 Conclusion of pest categorisation of mealybugs

Based on selection criteria (Table 2.1) for inclusion of mealybug species in the pest categorisation process, a total of 192 species from Pseudococcidae (184), Putoidae (1) and Rhizoecidae (7) were categorised (Appendix B).

As an outcome of pest categorisation process, a total of 175 species were considered further in the pest risk assessment (Table 2.4). Of these species 169 were determined to be quarantine pests for Australia, and six additional species are identified as virus vectors noting that the

mealybugs are not themselves quarantine pests. Eighteen species were identified as both quarantine pests and virus vectors. Nine species are pests of regional concern for Western Australia (Table 2.4).

Table 2.4 Outcome of pest categorisation of mealybugs

Mealybug	Common name if available	Considered further as quarantine pest	Considered further as a virus vector
PSEUDOCOCCIDAE			
<i>Anisococcus crawii</i> (Coquillett)	White sage mealybug	Yes	No
<i>Antonina maritima</i> Ramakrishna Ayyar	–	Yes	No
<i>Antonina nakaharai</i> Williams & Miller	Nakahara grass mealybug	Yes	No
<i>Antonina pretiosa</i> Ferris	Noxious Bamboo mealybug	Yes	No
<i>Antonina purpurea</i> Signoret	Red legless mealybug	Yes	No
<i>Antonina vietnamensis</i> Williams	–	Yes	No
<i>Antonina zonata</i> Green	–	Yes	No
<i>Atrococcus paludinus</i> (Green)	Marsh mealybug	Yes	No
<i>Coccidohystrix insolita</i> (Green)	Eggplant mealybug	Yes	No
<i>Coccura suwakoensis</i> (Kuwana & Toyoda)	–	Yes	No
<i>Crisicoccus azaleae</i> (Tinsley)	Azalea mealybug	Yes	No
<i>Crisicoccus echinodes</i> Williams	–	Yes	No
<i>Crisicoccus hirsutus</i> (Newstead)	–	Yes	No
<i>Crisicoccus matsumotoi</i> (Siraiwa)	–	Yes	No
<i>Crisicoccus pilosus</i> Ezzat & McConnell	–	Yes	No
<i>Crisicoccus pini</i> (Kuwana)	Kuwana pine mealybug	Yes	No
<i>Crisicoccus theobromae</i> Williams & Watson	–	Yes	No
<i>Dysmicoccus boninsis</i> (Kuwana)	Gray sugarcane mealybug	Yes (WA)	Yes
<i>Dysmicoccus brevipes</i> (Cockerell)	Pineapple mealybug	No	Yes
<i>Dysmicoccus cocotis</i> (Maskell)	Pacific coconut mealybug	Yes	No
<i>Dysmicoccus finitimus</i> Williams	Asian coconut mealybug	Yes	No
<i>Dysmicoccus grassii</i> (Leonardi)	–	Yes	No
<i>Dysmicoccus hambletoni</i> Williams & Granara de Willink	–	Yes	No
<i>Dysmicoccus lamsii</i> Williams	–	Yes	No
<i>Dysmicoccus lepelleyi</i> (Betrem)	–	Yes	No
<i>Dysmicoccus mackenziei</i> Beardsley	McKenzie mealybug	Yes	No
<i>Dysmicoccus neobrevipes</i> Beardsley	Annona mealybug	Yes	Yes

Mealybug	Common name if available	Considered further as quarantine pest	Considered further as a virus vector
<i>Dysmicoccus nesophilus</i> Williams & Watson	–	Yes	No
<i>Dysmicoccus orchidum</i> Williams	–	Yes	No
<i>Dysmicoccus probrevipes</i> (Morrison)	–	Yes	No
<i>Dysmicoccus</i> sp. nr. <i>texensis</i> (Tinsley)	–	Yes	Yes
<i>Dysmicoccus texensis</i> (Tinsley)	–	Yes	No
<i>Dysmicoccus viatorius</i> Williams	–	Yes	No
<i>Dysmicoccus wistariae</i> (Green)	Taxus mealybug	Yes	No
<i>Exallomochlus camur</i> Williams	–	Yes	No
<i>Exallomochlus hispidus</i> (Morrison)	Cocoa mealybug	Yes	No
<i>Exallomochlus liti</i> Williams	–	Yes	No
<i>Exallomochlus philippinensis</i> Williams	–	Yes	No
<i>Ferrisia gilli</i> Gullan	Gill's mealybug	Yes	Yes
<i>Ferrisia malvastra</i> (McDaniel)	–	Yes (WA)	No
<i>Ferrisia virgata</i> (Cockerell)	Striped mealybug	No	Yes
<i>Formicococcus celtis</i> (Strickland)	–	Yes	Yes
<i>Formicococcus latens</i> Williams	–	Yes	No
<i>Formicococcus matileae</i> Williams	–	Yes	No
<i>Formicococcus njalensis</i> (Laing)	Cocoa mealybug	Yes	Yes
<i>Formicococcus polysperes</i> Williams	–	Yes	No
<i>Formicococcus robustus</i> (Ezzat & McConnell)	–	Yes	No
<i>Heliococcus bohemicus</i> Šulc	Bohemian mealybug	Yes	Yes
<i>Heliococcus osborni</i> (Sanders)	Osborn mealybug	Yes	No
<i>Hordeolicoccus heterotrichus</i> Williams	–	Yes	No
<i>Hordeolicoccus invocatus</i> Williams	–	Yes	No
<i>Hordeolicoccus nephelii</i> (Takahashi)	Big-eyed mealybug	Yes	No
<i>Humococcus resinophilus</i> (Green)	–	Yes	No
<i>Hypogeococcus boharti</i> Miller	–	Yes	No
<i>Hypogeococcus gilli</i> Miller	–	Yes	No
<i>Hypogeococcus othnius</i> Miller & McKenzie	Strange mealybug	Yes	No
<i>Hypogeococcus pungens</i> Granara de Willink	–	Yes	No
<i>Hypogeococcus spinosus</i> Ferris	Spinose mealybug	Yes	No
<i>Kiritshenkella sacchari</i> (Green)	–	Yes	No

Mealybug	Common name if available	Considered further as quarantine pest	Considered further as a virus vector
<i>Lankacoccus ornatus</i> (Green)	–	Yes	No
<i>Lantanacoccus sauroides</i> Williams & Granara de Willink	–	Yes	No
<i>Leptococcus metroxyli</i> Reyne	–	Yes	No
<i>Maconellicoccus multipori</i> (Takahashi)	–	Yes	No
<i>Maconellicoccus ramchensis</i> Williams	–	Yes	No
<i>Maculicoccus malaitensis</i> (Cockerell)	–	Yes	No
<i>Neotrionymus monstatus</i> Borchsenius	–	Yes	No
<i>Nipaecoccus filamentosus</i> (Cockerell)	–	Yes	No
<i>Nipaecoccus gilli</i> Williams & Granara de Willink	–	Yes	No
<i>Nipaecoccus nipae</i> (Maskell)	Coconut mealybug	Yes	No
<i>Oracella acuta</i> (Lobdell)	Loblolly pine mealybug	Yes	No
<i>Palmicultor palmarum</i> (Ehrhorn)	Palm mealybug	Yes	No
<i>Paracoccus burnerae</i> (Brain)	Oleander mealybug	Yes	Yes
<i>Paracoccus circuliprivis</i> Ezzat & McConnell	–	Yes	No
<i>Paracoccus ferrisi</i> Ezzat & McConnell	–	Yes	No
<i>Paracoccus glaucus</i> (Maskell)	–	Yes	No
<i>Paracoccus hamoni</i> Williams & Granara de Willink	–	Yes	No
<i>Paracoccus herreni</i> Williams & Granara de Willink	–	Yes	No
<i>Paracoccus interceptus</i> Lit	Intercepted mealybug	Yes	No
<i>Paracoccus invectus</i> Williams	–	Yes	No
<i>Paracoccus lycopersici</i> Ezzat & McConnell	–	Yes	No
<i>Paracoccus marginatus</i> Williams & Granara de Willink	Papaya mealybug	Yes	No
<i>Paracoccus mexicanus</i> Ezzat & McConnell	–	Yes	No
<i>Paraputo aracearum</i> Williams	–	Yes	No
<i>Paraputo banzigeri</i> Williams	–	Yes	No
<i>Paraputo carnosae</i> (Takahashi)	–	Yes	No
<i>Paraputo corbetti</i> (Takahashi)	–	Yes	No
<i>Paraputo guatemalensis</i> (Ferris)	Largeduct mealybug	Yes	No
<i>Paraputo ingrandi</i> (Balachowsky)	–	Yes	No
<i>Paraputo kukumi</i> Williams	–	Yes	No

Mealybug	Common name if available	Considered further as quarantine pest	Considered further as a virus vector
<i>Paraputo larai</i> (Williams)	–	Yes	No
<i>Paraputo leverii</i> (Green)	–	Yes	No
<i>Paraputo odontomachi</i> (Takahashi)	–	Yes	No
<i>Paraputo olivaceus</i> (Cockerell)	–	Yes	No
<i>Paraputo pandanicola</i> Williams	–	Yes	No
<i>Paraputo theaeicola</i> (Green in Green & Mann)	–	Yes	No
<i>Pelionella cycliger</i> (Leonardi)	–	Yes	No
<i>Phenacoccus aceris</i> (Signoret)	Apple mealybug	Yes	No
<i>Phenacoccus avenae</i> Borchsenius	Oat mealybug	Yes	No
<i>Phenacoccus azaleae</i> (Kuwana)	–	Yes	No
<i>Phenacoccus franseriae</i> Ferris	–	Yes	No
<i>Phenacoccus gossypii</i> Townsend & Cockerell	Mexican mealybug	Yes	No
<i>Phenacoccus hargreavesi</i> (Laing)	–	Yes	Yes
<i>Phenacoccus madeirensis</i> (Green)	Madeira mealybug	Yes	No
<i>Phenacoccus manihoti</i> Matile-Ferrero	Cassava mealybug	Yes	No
<i>Phenacoccus pergandei</i> Cockerell	–	Yes	No
<i>Phenacoccus saccharifolii</i> (Green)	–	Yes	No
<i>Phenacoccus solenopsis</i> Tinsley	–	Yes (WA)	No
<i>Planococcus angkorensis</i> (Takahashi)	–	Yes	No
<i>Planococcus citri</i> (Risso)	Citrus mealybug	No	Yes
<i>Planococcus dendrobii</i> Ezzat & McConnell	–	Yes	No
<i>Planococcus dioscoreae</i> Williams	–	Yes	No
<i>Planococcus ficus</i> (Signoret)	Vine mealybug	Yes	Yes
<i>Planococcus halli</i> Ezzat & McConnell	–	Yes	No
<i>Planococcus hosnyi</i> (Ezzat & McConnell)	–	Yes	No
<i>Planococcus hospitus</i> De Lotto	–	Yes	No
<i>Planococcus japonicus</i> Cox	Japanese mealybug	Yes	No
<i>Planococcus kenyae</i> (Le Pelley)	Coffee mealybug	Yes	Yes
<i>Planococcus kraunhiae</i> (Kuwana)	Japanese mealybug	Yes	No
<i>Planococcus lilacinus</i> (Cockerell)	Coffee mealybug	Yes	No
<i>Planococcus litchi</i> Cox	–	Yes	No
<i>Planococcus mali</i> Ezzat & McConnell	–	Yes (WA)	No

Mealybug	Common name if available	Considered further as quarantine pest	Considered further as a virus vector
<i>Planococcus minor</i> (Maskell)	Pacific mealybug	Yes (WA)	Yes
<i>Planococcus orchidi</i> Cox	–	Yes	No
<i>Planococcus philippinensis</i> Ezzat & McConnell	–	Yes	No
<i>Pseudococcus agavis</i> MacGregor	–	Yes	No
<i>Pseudococcus apomicrocirculus</i> Gimpel & Miller	Mexican orchid mealybug	Yes	No
<i>Pseudococcus apoplanus</i> Williams	–	Yes	No
<i>Pseudococcus aurantiacus</i> Williams	–	Yes	No
<i>Pseudococcus baliteus</i> Lit	Aerial root mealybug	Yes	No
<i>Pseudococcus calceolariae</i> (Lidgett)	Citrophilus mealybug	Yes (WA)	No
<i>Pseudococcus comstocki</i> (Kuwana)	Comstock mealybug	Yes	Yes
<i>Pseudococcus concavocerarii</i> James	–	Yes	Yes
<i>Pseudococcus cryptus</i> (Hempel)	Cryptic mealybug	Yes (WA)	No
<i>Pseudococcus donrileyi</i> Gimpel & Miller	Riley citrus mealybug	Yes	No
<i>Pseudococcus elisae</i> Borchsenius	Banana mealybug	Yes	Yes
<i>Pseudococcus gilbertensis</i> (Beardsley)	–	Yes	No
<i>Pseudococcus importatus</i> McKenzie	Imported mealybug	Yes	No
<i>Pseudococcus jackbeardsleyi</i> Gimpel & Miller	Jack Beardsley mealybug	Yes	No
<i>Pseudococcus landoi</i> (Balachowsky)	Lando mealybug	Yes	No
<i>Pseudococcus longispinus</i> (Targioni Tozzetti)	Longtailed mealybug	No	Yes
<i>Pseudococcus maritimus</i> (Ehrhorn)	Grape mealybug	Yes	Yes
<i>Pseudococcus microcirculus</i> McKenzie	Orchid mealybug	Yes	No
<i>Pseudococcus nakaharai</i> Gimpel & Miller	Nakahara mealybug	Yes	No
<i>Pseudococcus neomaritimus</i> Beardsley	New sea mealybug	Yes	No
<i>Pseudococcus neomicrocirculus</i> Gimpel & Miller	Venezuela orchid mealybug	Yes	No
<i>Pseudococcus odermatti</i> Miller & Williams	–	Yes	No
<i>Pseudococcus orchidicola</i> Takahashi	–	Yes	No
<i>Pseudococcus philippinus</i> Williams	–	Yes	No
<i>Pseudococcus sociabilis</i> Hambleton	Hambleton mealybug	Yes	No
<i>Pseudococcus solenedyos</i> Gimpel & Miller	Oral-rim mealybug	Yes	No
<i>Pseudococcus solomonensis</i> Williams	–	Yes	Yes

Mealybug	Common name if available	Considered further as quarantine pest	Considered further as a virus vector
<i>Pseudococcus viburni</i> (Signoret)	Obscure mealybug	No	Yes
<i>Rastrococcus iceryoides</i> (Green)	–	Yes	No
<i>Rastrococcus invadens</i> Williams	Mango mealybug	Yes	No
<i>Rastrococcus jabadii</i> Williams	–	Yes	No
<i>Rastrococcus mangiferae</i> (Green)	–	Yes	No
<i>Rastrococcus spinosus</i> (Robinson)	Philippine mango mealybug	Yes	No
<i>Rastrococcus tropiciasiaticus</i> Williams	–	Yes	No
<i>Saccharicoccus sacchari</i> (Cockerell)	Pink sugarcane mealybug	No	Yes
<i>Stricklandina williamsi</i> (Matile-Ferrero & Le Ruyet)	–	Yes	No
<i>Synacanthococcus bispinosus</i> Morrison	–	Yes	No
<i>Trabutina serpentina</i> (Green)	–	Yes	No
<i>Trionymus bambusae</i> (Green)	–	Yes	No
<i>Trionymus internodii</i> (Hall)	–	Yes	No
<i>Trionymus townesi</i> Beardsley	–	Yes	No
<i>Tympanococcus gardeniae</i> Williams	–	Yes	No
<i>Vryburgia trionymoides</i> (De Lotto)	–	Yes	No
<i>Vryburgia viator</i> (De Lotto)	–	Yes	No
PUTOIDAE			
<i>Puto barberi</i> (Cockerell)	–	Yes	No
RHIZOECIDAE			
<i>Geococcus coffeae</i> Green	Coffee root mealybug	Yes (WA)	No
<i>Geococcus johorensis</i> Williams	–	Yes	No
<i>Rhizoecus americanus</i> (Hambleton)	–	Yes	No
<i>Rhizoecus falcifer</i> (Kunckel d'Herculais)	Ground mealybug	Yes (WA)	No
<i>Ripersiella hibisci</i> (Kawai & Takagi)	–	Yes	No
<i>Ripersiella kondonis</i> (Kuwana)	Citrus ground mealybug	Yes	No

3 Pest risk assessment of mealybugs

3.1 Introduction

Mealybug pests have been assessed individually in previous PRAs undertaken by the department. To date (2017), a total of 37 species, including three unidentified species, in 12 genera have been fully assessed in 30 PRAs (Appendix C).

In all instances, when the likelihood of importation was assessed as high, the unrestricted risk estimate (URE) was found to be low, which does not achieve the ALOP for Australia. In four of the 30 risk assessments when the likelihood of importation was assessed as Low or Moderate, the URE was found to be Very low, which achieves the ALOP for Australia. These differences in URE can be explained by factors such as commercial pre-border production practices and other influences such as the specific commodity, which influenced the likelihood of importation by reducing the likelihood of mealybugs being present on a given pathway in a given country.

In previous risk assessments, the estimated likelihoods for distribution, establishment and spread were relatively consistent and did not significantly influence the URE (Appendix C). Consequences of entry, establishment and spread were also consistently assessed as low, although there were minor differences for the impact scores assigned to specific direct and indirect impacts.

Significantly, these previous risk assessments have undergone extensive review and consultation with stakeholders.

The pest risk assessment for mealybugs as a group, presented in this report, builds on these previous risk assessments for individual species. Entry, establishment, spread and consequences are estimated according to the method described in Appendix A. The likelihood ratings and the estimate of consequence are applied to individual species within the group.

Based on the selection criteria listed in Table 2.1, a total of 192 species were included in the pest categorisation process (Appendix B). One hundred and seventy-five species were identified as requiring further pest risk assessment: 169 species were quarantine pests, and six additional species were potential virus vectors but not quarantine pests (Table 2.2). However, the results of this risk assessment should also apply to other quarantine mealybugs not yet identified in this report.

3.2 Likelihood (indicative) of entry

Entry is defined as the movement of a pest into an area where it is not yet present, or present but not widely distributed and being officially controlled (FAO 2017b). The likelihood of entry is considered in two parts, the likelihood of importation and the likelihood of distribution, which consider pre-border and post-border issues, respectively.

The likelihood of entry in this Group PRA is indicatively assessed, because it is not linked to a specific plant import pathway, and the rating may be adjusted when linked to a specific plant import pathway. The likelihood of importation and likelihood of distribution are influenced by a range of factors. Most of these factors can be considered fully at the group level, but some cannot (see Appendix A). These factors were considered in the Group PRA in generic terms, based on

extensive historic and contemporary analysis of the plant import pathway. Entry is also conditional on the mealybugs being present in the exporting region.

Where the Group PRA is applied to a specific pathway, these factors must be verified on a case-by-case basis, as appropriate. Until this occurs, the likelihood of entry in the Group PRA is indicative only, and potentially subject to revision.

Likelihood (indicative) of importation

The likelihood (indicative) that a quarantine pest mealybug will be imported into Australia on the plant import pathway is assessed as **High**.

The supporting evidence for this assessment is provided.

Association with export crops

Around 2,300 species of mealybugs have been reported from all over the world (Table 2.2). They feed on a wide variety of plants in hundreds of families (Tables 2.2 and 2.3), including angiosperm, gymnosperm and fern families (Franco, Zada & Mendel 2009). Many species are also important pests of agricultural and horticultural crops (Miller et al. 2006; Williams 2004; Williams & Granara de Willink 1992).

Williams (2004) lists 40 species in 26 genera of mealybugs that are known to cause damage to plants either in southern Asia or elsewhere. These species include *Dysmicoccus neobrevipes* on pineapple and other crops, *Exallomochlus hispidus* on stems and fruit of a wide range of crops including longan and mangosteen, *Formicococcus robustus* on mango and other crops, *Paracoccus burnerae* on citrus, *Planococcus lilacinus* on lychee and cocoa, *Pseudococcus cryptus* on citrus and coconut, and *Rastrococcus iceryoides* on mango, citrus and grapevine. These mealybugs are polyphagous, meaning each species can attack many host plants.

Williams and Granara de Willink (1992) discussed many mealybug species as being important pests of major plants or plant groups such as bananas, bromeliads, cassava, citrus, cocoa, coffee, mango and orchids in Central and South America. Miller et al. (2002) identified 158 invasive mealybug species and discussed their threat to US agriculture. The main hosts of these pests include fruit trees (e.g. citrus, blueberry, apples, lychees, mango and grapes), vegetables (e.g. eggplants, potato and lettuce) and cut-flowers and foliage (e.g. azalea, lily and orchids).

On host plants, mealybugs can feed on all parts of the plant; more specifically Pseudococcidae and Putoidae feed on aerial plant parts, and Rhizoecidae feed on below ground parts (Table 2.2). Thus they collectively attack root, stem and bark, leaf, flower and fruit of host plants (Hoffmann & Botha 2011). A single host plant can be attacked by many species of mealybugs.

Mealybug eggs, nymphs and adult females are all relatively small, ranging from about 0.3 mm for eggs to a maximum of 8 mm for adults. They can often be located in crevices and protected spaces, such as under the calyx of fruit. This makes them difficult to detect during harvest and routine commercial packing house inspections.

These characteristics make mealybugs likely to be associated with export crops of fresh fruit, vegetables and cut-flowers and foliage. These commodities typically arrive in Australia as non-refrigerated air freight, most being subject to cold storage both before and after air

transportation. Refrigerated sea transport is also used for a number of commodities, such as avocado, citrus fruit, kiwifruit and table grapes.

There are limited studies of cold tolerance of mealybug species in the literature, but different species of mealybugs appear to have variable resistance to cold temperatures. Hoy and Whiting (1997) studied the impact of low temperature storage on the mortality of *Pseudococcus viburni* (as *P. affinis*, a wide-spread species, on royal gala apples). They found that at 0 °C it took 28 days to kill first, second and third instars and adult females. At 4 °C, it took 70 days to kill 99.8 per cent of first instars, 99.3 per cent of second and third instars and 95.0 per cent of adult females. At 7 °C, it took 126 days (more than three months) to kill 92.4 per cent of first instars, 53.2 per cent of second and third instars and only 40.7 per cent of adult females.

The cold tolerance of mealybugs may also be inferred from their overwintering behaviours. Many mealybugs overwinter as second instars (Miller 2005), and some as adults, first instars, and/or eggs (such as citrus mealybug *Planococcus citri* (Kerns, Wright & Loghry 2015)). Abbas et al. (2010) observed that when a mature adult female of *Phenacoccus solenopsis* was near to death during winter period, it produced its crawler sac, which was sheltered under its moribund body through the un-favourable cold conditions, allowing the development of the crawlers to be prolonged during the low temperatures. When favourable conditions returned, the crawlers emerged from beneath the body of the dead female in search of suitable feeding sites.

Based on this information, it is considered that mealybugs would have the ability to tolerate cold storage of plant commodities. In addition, live mealybugs have been intercepted in international trade transported in refrigerated conditions (Appendix B and Appendix D), which confirms that they have the ability to survive cold transportation.

Mealybug interceptions (Australian data)

There have been over 3,100 mealybug interception events recorded on the plant import pathway by Australia in the last 30 years (1986–2015) (Table 3.1). On average, there were 103 interceptions of mealybugs per year for the last 30 years.

Almost all the intercepted mealybugs were recorded as belonging to the family Pseudococcidae (99.9 per cent); as noted this is the largest recognised family, and all mealybugs were placed in this family until the two other families were recognised in recent years. There are only four interception events for the family Rhizoecidae during the same period, and no recorded interceptions for members of the family Putoidae.

Table 3.1 Australian mealybug interceptions on the plant import pathway by family (1986–2015)

Family	Interceptions (a)	Percentage (%)	Yearly average
Pseudococcidae	3,097	99.9	103.3
Putoidae	0	0	0
Rhizoecidae	4	0.1	0.1
Total	3,101 (b)	100	103.5

a Each interception is based on presence of at least a single mealybug individual on a consignment. The number of mealybugs present per event is not generally recorded, and multiple mealybug individuals can contaminate the same commodity. **b** of this total, 20 interceptions were confirmed as dead specimens.

The majority (65.3 per cent) of intercepted mealybugs were identified only to family level (Table 3.2). Only 24.7 per cent were identified to genera and 10 per cent to species level. The high proportion of unidentified mealybugs is due to several reasons, including lack of adequate taxonomic expertise in Australia, the time-consuming process of preparing slide-mounted specimens for identification, intercepted specimens being damaged and/or immature, and importers opting for treatment of their goods without requesting specimen identification.

Table 3.2 Proportion of identified Australian mealybug interceptions (1986–2015)

Mealybugs identified	Number of taxa	Interception events	Percentage (%)
Families	2	2,027	65.3
Genera	22	765	24.7
Species	40	309	10.0
Total	N/A	3,101	100

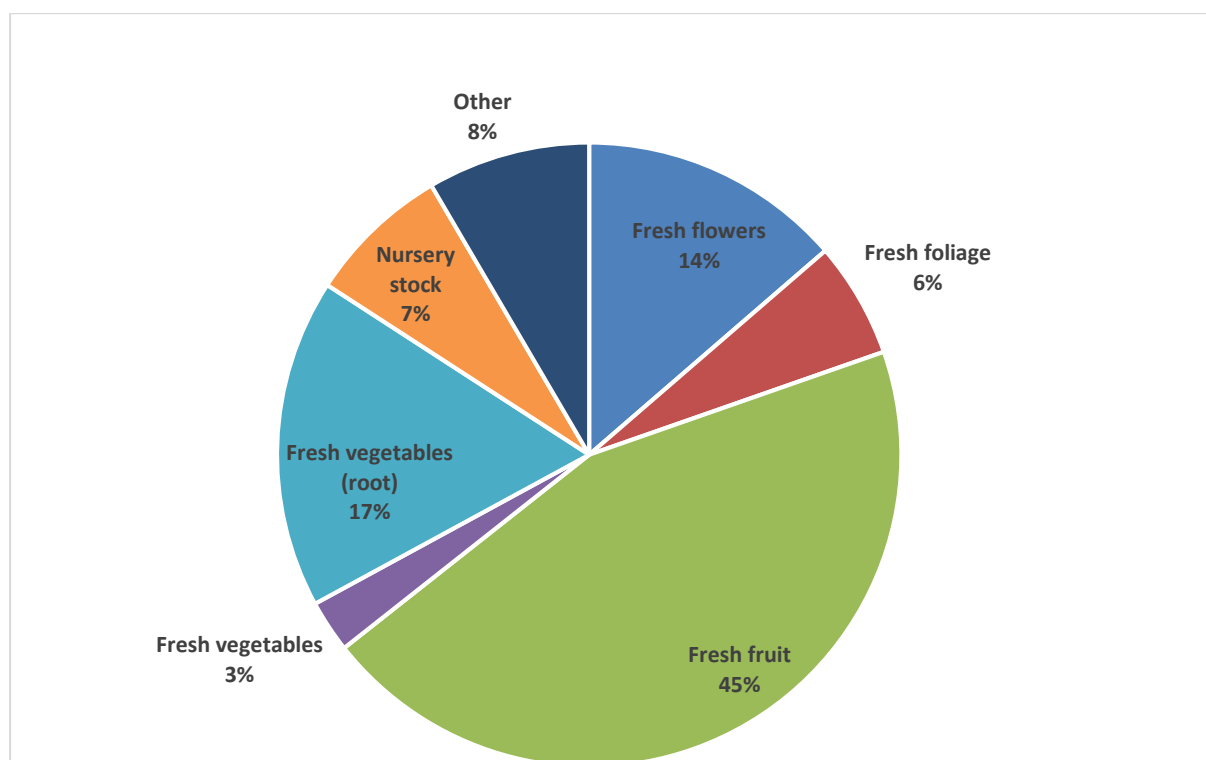
A total of 22 genera of intercepted mealybugs were identified (Table 3.2; Appendix D). The most frequently intercepted genera, in descending order, were *Paraputo*, *Pseudococcus* and *Planococcus*, followed by *Crisicoccus*, *Dysmicoccus*, *Phenacoccus*, *Nipaecoccus*, *Ferrisia* and *Paracoccus*. Note that species of *Paraputo* were mainly intercepted on taro from Pacific countries.

A total of 40 mealybugs were identified to species level (Table 3.2; Appendix D). The most frequently intercepted species, in descending order, were *Pseudococcus longispinus*, *Planococcus citri* and *Planococcus minor*, followed by *Pseudococcus calceolariae*, *Pseudococcus viburni*, *Planococcus ficus* and *Pseudococcus jackbeardsleyi*. The quarantine status and/or status as a virus vector for these 40 species are presented in Table 11.1 of Appendix D. Twenty of these species are quarantine pests for Australia and six are regional pests for Western Australia. Thirteen species in total are virus vectors.

The main commodities on which mealybugs were intercepted by Australia in the last 30 years (1986–2015) are presented in Figure 3.1. Forty-five per cent were intercepted on various forms of fresh fruit, most frequently on mangosteen, betel fruit, persimmon, mango, blueberry, papaya, pomegranate, kiwifruit, lychee, longan, citrus and pineapple. Seventeen per cent were on root vegetables, mainly taro and yam, and three per cent on other vegetable including asparagus and capsicum. One-fifth of mealybug interceptions were on cut-flowers (14 per cent) and foliage (six per cent); interceptions were most common on roses, followed by orchids, *Anthodium*, *Hypericum* and *Chrysanthemum*. About seven per cent were found on a variety of nursery stock,

including *Dracaena* spp., bromeliads and cactus. The remaining eight per cent were from a number of other plant products such as herbs, bulbs and tubers (Figure 3.1).

Figure 3.1 Commodity groups on which mealybugs were intercepted by Australia (1986–2015)



Mealybug interceptions (International data)

Mealybugs are frequently intercepted on plant material in international trade by other countries, although only some countries make the interception records publicly available. Detailed information on mealybug interceptions is included in Appendix B, indicating that 157 mealybug species have been identified and reported in international trade.

The USDA/APHIS published an online identification tool for scale insects of quarantine significance, in which the history of quarantine interceptions of the species by APHIS is summarised in fact sheets, including 99 species of mealybugs (Miller et al. 2014a; Rung et al. 2006). In addition, mealybugs intercepted by the US have also been studied and recorded in material examined in 'Mealybugs of Southern Asia' (Williams 2004) and 'Mealybugs of Central and South America' (Williams & Granara de Willink 1992). Some of the specimens were intercepted many years ago but were only identified by the authors when material was made available during their studies. In total, 166 species of mealybugs were intercepted by the US from its trading partners in different parts of the world, particularly Asia and South America (Appendix B).

Ji et al. (2010) published a list of 13 mealybug species intercepted by South Korea on plant material from China from 2000 to 2009. Tokihiro (2006) reported Japan's interceptions of seven mealybug species, mainly from countries or regions where the pests were not previously known to occur.

Interceptions of mealybugs by other countries including UK, France, India, Russia, New Zealand, Netherlands and Israel have also been recorded in the mealybug monographs (Williams 2004;

Williams & Granara de Willink 1992) when the material was made available to the authors (Appendix B).

Australian and international interceptions of mealybugs suggest that mealybugs will continue to be present on plant import pathways as long as trade is occurring. A significant number of the intercepted mealybug species are of biosecurity concern for Australia (Table 11.1, Appendix D).

Summary of importation

Pest mealybugs have been reported worldwide, including in countries that Australia trades with, on a wide range of host plants, including many important agricultural and horticultural crops and commodities for export such as fruit, vegetables, cut-flowers and foliage. Mealybugs are small and can hide in plant material such as the calyx of fruit. Such factors make detection of mealybugs difficult during quality control inspections for export commodities. Microscopic examination can be helpful in some instances, and dissection may be required for some commodities. These methods are not necessarily used during export quality control inspections, which instead tend to focus on grading produce according to size, colour and appearance. At best, removal of distorted or damaged products during export quality control inspections may remove some, but not all, mealybugs from the plant import pathway. Mealybugs associated with plant products are likely to survive international transportation, as evidenced by the 157 mealybug species recorded as intercepted on plant material in international trade (Appendix B).

Notwithstanding the pathway-dependent factors, the indicative likelihood of importation for pest mealybugs arriving in Australia as a result of the import of fresh fruit, vegetables, cut-flowers and foliage is considered to be high. This assessment is consistent with those for 32 of the 37 pest mealybug species in previous risk assessments conducted by Australia in 30 PRAs on 16 commodities from 16 countries (Appendix C).

Likelihood (indicative) of distribution

The likelihood (indicative) that a mealybug quarantine pest will be distributed within Australia in a viable state following its importation on the plant import pathway and subsequently transfer to a susceptible host is assessed as **Moderate**.

The supporting evidence for this assessment is provided.

Transport and distribution

Fresh fruit, vegetables, cut-flowers and foliage infested with mealybugs would be expected to be distributed for retail sale to multiple destinations within the PRA area, so a proportion of these commodities are likely to reach areas with susceptible host plants.

During transport and distribution, these commodities may be kept at cool temperatures. However, the perishable nature of these commodities mean transit times will be relatively short, and transit temperatures are unlikely to be lethal for mealybugs as they are able to tolerate cold temperature (Abbas et al. 2010; Hoy & Whiting 1997). At retail outlets, these commodities may be displayed at ambient temperature that would support the survival and development of mealybugs.

Assessment of the likelihood of distribution must consider whether pest mealybugs can enter the external environment during the process of unpacking, transportation and retail sale, and/or

from wastes disposed by retailers and individual consumers. Although cross-contamination among host commodities could occur, it is considered that mealybugs are unlikely to be successful in entering the external environment during unpacking in warehouses and during transportation to retail outlets, or at point of sale, because these activities are undertaken within an indoor environment.

The majority of waste resulting from the imported commodities is likely to be disposed as municipal solid waste (MSW) to be processed accordingly, including into landfill, or to a lesser extent by commercial composting as green waste (Atalia et al. 2015; EPHC 2009). A mealybug is not likely to be able to enter the external environment through the MSW stream. The most likely scenario for mealybugs to enter the external environment is through the disposal of waste by individual consumers, or from waste from retail activities before it enters the MSW stream.

Waste production and disposal

Live mealybugs on the plant import pathway could enter the external environment as a result of disposal of waste generated through the consumption of fruit and vegetables, and by discarding of used cut-flowers and foliage. The infested material would be disposed, for example, in compost, green waste, general household and commercial waste, or on roadsides and in parks by individual consumers. Disposal of this waste will almost certainly occur at numerous locations throughout the PRA area, especially for commodities consumed or used by households.

As waste deteriorates, mealybugs on the waste disposed in the external environment will need to find a suitable host quickly. Eggs could hatch into first instars on the waste. All stages of mealybug nymphs and adult females are able to walk and wander around. However, the mobility of mealybugs differs between different life stages, with the crawlers being most active and individuals then becoming progressively less mobile as they develop into later life stages. Adult males usually have a pair of wings, but they do not feed and are fragile, and have a life span of only a few days in which to find a female with which to mate.

Crawler behaviours

As the crawlers are the most active life stage, and thus would be the most likely to reach a host plant via their own movement, it is important to understand their behaviours.

Crawler behaviours of mealybugs are considered to be the same as, or at least very similar to, those of the other members of the superfamily Coccoidea. To date, there has been no comprehensive review of crawler behaviours specific for mealybugs. However, crawler behaviours of Diaspididae have been assessed by Koteja (1990) and Greathead (1990), and those of Coccidae by Marotta (1997) and Greathead (1997). Relevant evidence for crawler behaviours of other Coccoidea is considered to be equally applicable to those of mealybugs in cases where there is no specific information for mealybugs.

Duration of crawler life-stage

Studies on the duration of different life stages of mealybugs have generally been done in the laboratory. Studies have most commonly been carried out at constant temperatures ranging from 15 °C to 40 °C, under conditions of 60 to 80 per cent relative humidity, and at various photoperiod combinations. Studies of these types have been carried out for many mealybug species, including *Maconellicoccus hirsutus* (Chong, Roda & Mannion 2008), *Paracoccus marginatus* (Amarasekare et al. 2008), *Phenacoccus madeirensis* (Chong, Oetting & van Iersel

2003), *Phenococcus solenopsis* (Fand et al. 2014; Prasad et al. 2012), *Planococcus citri*, *Planococcus kraunhiae* and *Pseudococcus citriculus* (Arai 1996), and *Pseudococcus cryptus* (Kim, Song & Kim 2008). These studies demonstrate that the development of mealybug crawlers varies for different species and at different temperatures. The lower threshold temperatures for development range from 7.7 °C to 15.2 °C for different species, and the higher threshold is from 30 °C to 40 °C. The crawler period can last for as little as 3 days at 40 °C to as long as 25.3 days at 18 °C.

It is noted that these studies were undertaken in the laboratory environment and the crawlers were fed. In the external environment there would be many other factors that could influence the survival and/or development of a crawler, such as variable temperatures and humidity, and availability of host plants (Beardsley & Gonzalez 1975).

Dispersal phase of crawlers

To date, most studies of crawler dispersal have been undertaken using insects on their host plants. The dispersal phase of crawlers may be different between the mealybugs and other Coccoidea.

As for development, the dispersal phase of a crawler may differ from species to species, and be influenced strongly by environmental factors. Beardsley and Gonzalez (1975) recognised three factors that would primarily control the dispersal and settling behaviour of Diaspididae crawlers (i) innate behaviour to initiate wandering and settling, (ii) availability of acceptable settling sites and (iii) ambient environmental conditions. These factors were proposed for diaspidids in situations where the crawlers were on a host plant; they are considered likely to also be applicable for mealybugs in the current scenario. However, when these factors are used to assess situations where crawlers are associated with disposed waste, the second factor (availability of acceptable settling sites) needs to be assessed to consider how a crawler on disposed waste could migrate to an acceptable site on a suitable host plant some distance away.

Cornwell (1956) made very detailed observations on the migration of *Pseudococcus njalensis* using cacao as host. These observations indicated that crawlers are capable of walking quite rapidly for long distances over smooth surfaces, but also that their speed is significantly reduced by short periods of starvation. Coarse surfaces also had a significant effect on the movement of mealybugs; soil surface with cacao leaf litter had greater influence on nymphs than on adults. Mealybugs soon became incapable of movement when starved for a few days, and the majority died within a week. The mortality of unfed first- and second instars of *Pseudococcus njalensis* was about 90 per cent after four days (Cornwell 1956). Mealybug crawlers are vulnerable, and like those of diaspidids, have relatively small energy reserves (Koteja 1990), and are therefore unlikely to be capable of walking for prolonged periods.

The dispersal phase of crawlers of the Coccidae may last from several hours to several days (Marotta 1997), and 80 per cent settle within 24 hours (Greathead 1997). A majority of Diaspididae crawlers also settle in the first day (Beardsley & Gonzalez 1975; Greathead 1990) although some may move for several days (Koteja 1990). Therefore, it seems that most crawlers would have enough stored energy to travel for several to 24 hours before settling to feed.

There is no specific study on the behaviours of mealybug crawlers associated with waste. Unlike on the host plant, there would be no suitable settling sites available on the waste. Suitable host

plants and/or settling sites would only be available at a distance away from the waste. Whether or not a crawler will find an acceptable settling site on a host away from the waste will depend on the mobility of the crawler, and how far the available host is from the waste. Success is also likely to be affected by environmental factors at the time of dispersal.

Walking speed of a crawler

There are apparently very few studies on the walking speed of a crawler. Cornwell (1956) indicated that crawlers of *Pseudococcus njalensis* were able to walk at a rate of about 5.7 cm (2.24 in) per minute over paper, when in motion. Washburn and Frankie (1981) found that crawlers of *Pulvinariella mesembryanthemi* (Vallot) in the family Coccidae walked at an average speed of 4.32 cm per minute (0.72 ± 0.22 mm per second) on its iceplant host.

Distance travelled by a crawler

There are no data on the distance a mealybug can travel from disposed waste in order to find a host. As noted, crawlers can walk at speeds of 4.32 cm to 5.7 cm per minute, however these speeds are not likely to be reproduced when mealybugs disperse from disposed waste, as the surface(s) they would travel over can be expected to be more difficult to traverse. However, the dispersal phase of most crawlers in the Coccidae and Diaspididae can last from several hours to 24 hours (Greathead 1997; Marotta 1997), while crawlers of mealybugs can disperse throughout their entire life stage. Many suitable host plants for mealybugs are available at ground level and could be within the walking range of crawlers. As an example, if a crawler were to move for 3 hours (180 minutes) at 2 cm per minute it could travel 360 cm or 3.6 metres. Thus, it is considered feasible that crawlers would be able travel to a nearby host during their dispersal phase.

Experimental observations of mealybug migration in the field were also carried out for *Pseudococcus njalensis* by Cornwell (1956). To date, this may be the most relevant study to assist an assessment of how mealybugs on disposed waste could find a host. The experiment firstly compared the migration impact of movement on a smooth plywood surface compared with soil with cacao litter. It concluded that soil with cacao leaf litter had a marked effect on the mobility of mealybugs; the number of mealybugs that migrated over soil with cacao litter was less than 6 per cent of those that moved over the smooth plywood surface. Most of the migrated mealybugs (95 percent on plywood and 80 per cent on soil) were crawlers.

The experiment then tested the distance of mealybug travel from slash piles of cacao trees to target cacao twigs placed around the piles. *Pseudococcus njalensis* was observed to have walked about 1.2 m over cacao leaf litter and 60 cm over bare soil after three days (Cornwell 1956). Analysis of the results indicated that mealybug migration from the slash piles did occur, and that there was a rapid decrease in the number of mealybugs captured at greater distances from the piles. When the distance was doubled, the mealybug number was reduced to about one third. The analysis concluded that *Pseudococcus njalensis* would not travel more than 7.3 metres from slash piles.

It is recognised that this study was for one mealybug species, and carried out using slash piles of cacao. Other species may be able to travel greater or lesser distances on soil surfaces. Also, mealybugs may behave differently when travelling from disposed waste as compared to leaving slash piles of their hosts. Nevertheless, the study supports the contention that mealybugs leaving

disposed waste could travel some distance to find a suitable host. In addition, live host plants near disposed waste may release chemicals to attract the insects.

It is concluded that mealybug crawlers would have the ability to find a suitable host or settling site from disposed waste if the host plant is in reasonably close proximity, and environmental conditions are suitable.

Wind dispersal of crawlers

Crawlers are tiny and could also be passively transferred to a host plant with the assistance of wind. There are many studies to indicate that crawlers can be dispersed by air currents (Greathead 1990; Gullan & Kosztarab 1997), but this factor is likely to be less relevant in assessment of likelihood of distribution, and more relevant in assessment of likelihood of spread. This conclusion is made on the basis that discarded waste is most likely to be at or near ground level, so that crawlers on the waste are less likely to be in a position to become airborne at the distribution step.

Thus crawlers are considered most likely to reach nearby host plants through their own movements, and less likely to do so via airborne means. Hosts such as grasses, daisies and sedges that are on or close to ground level are considered most likely to be at risk of infestation by mealybugs from disposed wastes.

Behaviours of other life stages

Unlike other Coccoidea, the second and third instar nymphs and adult females of mealybugs have functional legs and can move around, as shown by Cornwell (1956), although they may not be as active as the crawlers. Thus, they too could find a suitable host away from disposed wastes through their own abilities. It has been observed that 90 per cent of unfed second instars of *Pseudococcus njalensis* died in four days, and 90 per cent of unfed adults died in 8.5 days (Cornwell 1956). This length of survival is considered to leave enough time for individuals to reach a host located in reasonable proximity.

Adult females of *Pseudococcus njalensis* were observed to travel at a mean speed of 5.18 cm per minute over paper, but this was reduced to 3.35 cm per minutes after starvation (Cornwell 1956). Even under such circumstances, adult females are therefore considered to have the potential to travel to a nearby host plant.

In addition, Cornwell (1956) showed that when cut cacao started to wilt it stimulated the reproduction of *Pseudococcus njalensis*. From this it can be extrapolated that deteriorating waste may also stimulate the reproduction of adult mealybugs, resulting in production of additional crawlers.

Host detection and selection

It is further necessary to consider how mealybugs could locate a host in the environment, including whether they can detect a host from a distance, and how far that distance might be.

Phytophagous insects select their hosts by a sequence of behavioural responses to an array of stimuli associated with host and non-host plants (Visser 1986). Phytophagous insects possess sensory receptors, mainly located on their antennae, which enable them to perceive these stimuli. Potential plant stimuli include various visual, mechanical, gustatory and olfactory

characteristics. Host-produced olfactory kairomones play an important role in enabling insects to recognise host plants at a distance using olfactory receptors (Bruce, Wadhams & Woodcock 2005).

The role of plant odours in host selection can be traced in the orientation of phytophagous insects toward particular plants, and in the ultimate recognition of host plants for feeding and oviposition. Plant odours are attractive to both adults and immatures (Visser 1986). Aphids (Chapman, Bernays & Simpson 1981; Pettersson 1970, 1973), whiteflies (Vaishampayan, Waldbauer & Kogan 1975), and rice brown planthoppers (Obata et al. 1983) are attracted to host plant odours by use of their olfactory receptors. Olfactory receptors are also present on mealybugs and have been examined for *Planococcus citri* (Salama & Saleh 1971), *Phenacoccus aceris* (Koteja 1980) and *Phenacoccus manihoti* (Le Ru et al. 1995; Le Rü et al. 1995). The antennal and labial sensillae of *Phenacoccus manihoti* crawlers most probably mediate orientation towards its cassava host (Calatayud & Le Rü 2006).

Although there are no data on how far mealybugs can detect host plants, it is feasible that all life stages of mealybugs have the potential to find a host in close proximity.

Climatic factors

Climatic factors such as temperature and humidity will influence a mealybug's ability to reach a suitable host from disposed waste. The degree of influence will depend on the species, for example, whether it is a tropical, subtropical or temperate species. Australia's climate includes tropical, subtropical, temperate and cool temperate regions (Bureau of Meteorology 2011), and different parts of Australia have climatic conditions suitable for different mealybug species.

Available host plants

Mealybugs feed on a variety of plants from angiosperm, gymnosperm and fern families, with most species feeding on herbaceous plants, especially those from the large family Poaceae (Table 2.3). Mealybugs can be monophagous (feeding on a single plant genus), oligophagous, (feeding on different genera in a single plant family), or polyphagous (feeding on genera in different plant families). Based on these criteria, 74 per cent (130 species) of the 175 mealybug species included in Table 2.4 are polyphagous, with only about 10 per cent (17 species) oligophagous and 16 per cent (28 species) monophagous. The economically important species are usually highly polyphagous. For example, the citrus mealybug *Planococcus citri* has been found on 250 species in 191 genera of 82 plant families (García Morales et al. 2018), and is a pest of subtropical and tropical crops such as citrus (*Citrus* spp.), persimmon (*Diospyros kaki*), banana (*Musa paradisiaca*) and custard apple (*Annona* spp.), and is also a pest on various types of indoor plants.

Most importantly, a large number of mealybug hosts are herbaceous plants, such as grasses (Poaceae), sedges (Cyperaceae) and daisies (Asteraceae) that are likely to be accessible at ground level, and could be available near disposed waste. For example, Bermuda grass (also known as Couch grass, *Cynodon dactylon*) is a stalwart of backyards and sporting fields nationwide, and is a known host of 10 quarantine mealybug species. Common nutsedge (*Cyperus rotundus*) is a perennial weed that is often found in turf and is a host of six quarantine mealybug species. Common dandelion (*Taraxacum officinale*) is found in lawns and along roadsides and is a host of two quarantine mealybug species.

In addition, many mealybugs also feed on roots of plants, which could be easily accessible near disposed waste. In fact, all members of the ground mealybug group, the family Rhizoecidae, are associated with roots and six species of the family are included in Table 2.4 as quarantine mealybugs. Members of Rhizoecidae have been recorded on a diverse range of host plants (Table 2.3), including Poaceae and Asteraceae species, which are widespread in backyard, roadside and park environments. Many species are highly polyphagous, such as *Rhizoeus falcifer* which has been reported on 64 genera in 38 families of host plants, including Bermuda grass.

In addition, in laboratory studies many mealybug pest species have been successfully reared on alternative hosts, such as potato sprouts or pumpkins (Mani & Shivaraju 2016c), which are not colonised easily by mealybugs in the field. This suggests that mealybugs may also be able to survive on other unreported host plants.

It is concluded that suitable host plants are readily available in the Australian environment, and would be exposed to potential infestation by mealybugs from disposed waste.

Summary of distribution

Pest mealybugs imported with fresh fruit, vegetables, cut-flowers and foliage would likely survive transportation, retail sale, and waste disposal. Mealybugs are most likely to enter the external environment through the disposal of wastes by retailers and individual consumers. All nymph stages and adult females of mealybugs are able to move and walk around, but the most active stage is the crawler stage, which would be the most likely life stage to reach a host plant through its own activity. A large number of mealybug hosts are herbaceous, and many are close to or at ground level and potentially in close proximity to disposed waste in backyards, roadsides and parks. As noted, disposed wastes would deteriorate quickly, so that mealybugs would need to find a suitable host in a limited timeframe.

Notwithstanding the pathway-dependent factors, the indicative likelihood of distribution, that is, the likelihood that pest mealybugs will be distributed to a host plant in Australia as a result of the import of fresh fruit, vegetables, cut-flowers or foliage is considered to be Moderate. This assessment is consistent with those for 36 of the 37 pest mealybug species in previous risk assessments undertaken by Australia, noting that the only other species assessment was High (Appendix C).

3.3 Likelihood of establishment

The likelihood that a mealybug quarantine pest will establish within Australia, following entry on the plant import pathway is assessed as **High**.

Establishment is defined as the '*perpetuation for the foreseeable future, of a pest within an area after entry*' (FAO 2017b).

The supporting evidence for this assessment is provided.

Availability of suitable hosts, alternate hosts and vectors in the PRA area

As noted under pest categorisation and distribution, many mealybug pests are polyphagous and can feed on a wide range of host plants. These hosts are widely available in Australia as agricultural and horticultural crops and include such as apple, banana, citrus and grapes, and

garden and weed plants. For example, *Pseudococcus cryptus* has been recorded from 35 host plant families.

Mealybugs do not require a vector for their establishment in the PRA area.

Suitability of the environment

Australia's climate includes tropical, subtropical, temperate and cool temperate regions (Bureau of Meteorology 2011). Agricultural crops and horticultural fruit trees are grown in many parts of Australia and the ecological conditions in these areas are similar to those of the countries or regions where the pest mealybugs are currently present. Therefore suitable environments are available in Australia for the establishment of mealybugs.

Reproductive strategies and potential for adaptation

Most mealybug species reproduce sexually, and some parthenogenetically, due to the advantage of maintaining a superior genotype, an increased reproductive output and/or the ability to reproduce without males (Franco, Zada & Mendel 2009; Gullan & Kosztarab 1997). Most mealybugs lay eggs outside their body, but some species are ovoviviparous—that is, eggs are produced and hatched inside the female's body to release live crawlers (Franco, Zada & Mendel 2009).

There are no specific sex chromosomes in mealybugs and sex is probably determined by a functional haploid/diploidy mechanism. This means that the sex of offspring appears to be dependent on the behaviour of a set of chromosomes instead of a single chromosome (Franco, Zada & Mendel 2009). The embryo will develop into a male if chromosomes from the father become heterochromatic during the cleavage stage of embryogenesis, and it will develop into a female if none of the chromosomes become heterochromatic (Sanchez 2008). The maternal genome determines and controls the heterochromatisation of the inherited paternal chromosomes. Thus, females have two functional chromosomal complements, while males are structurally diploid but functionally haploid (Sanchez 2008).

Temperature and the age of the mother have also been reported to influence the sex determination of progeny and, consequently, the sex ratio in mealybugs (Nelson-Rees 1960). The effect is attributed to a change in the ratio of the number of oocytes with or without the presumptive maternal factor (Sanchez 2008).

In theory, a single mated female for most mealybug species or a single unmated female for the parthenogenetic species would be able to initiate a population. The likelihood of establishment for mealybugs would increase with pioneer population size and rates of incipient infestations and would be positively associated with the numbers of founding individuals, thus the more individual mealybugs enter with the commodities, the higher the likelihood they will establish successfully.

In summary, the ability to utilise either a sexual or asexual reproductive strategy enables mealybugs to take advantage of new environments for establishment.

Cultural practice and control measures

The management of pest mealybugs on agricultural and horticultural crops usually involves a variety of measures, a strategy commonly known as integrated pest management (IPM). Chemical control is usually one of the components of IPM, but is only be employed when

required. Given that these measures are applied to existing pest species for commercial crops, they may also have some impact on newly introduced exotic species. However, as many economically important mealybugs are highly polyphagous, they are likely to also occur in non-commercial environments where the cultural practices and control measures used in commercial crops would not have any impact.

Summary of establishment

Factors such as wide availability of host plants in the natural environment, and as garden plants and agricultural and horticultural crops, suitability of climatic conditions, use of effective reproductive strategies including parthenogenesis for some species, and probability that initial populations in the natural environment will not be noticed and/or managed at an early stage, all support a likelihood of establishment of high. This assessment is consistent with those for 35 of the 37 mealybug species in previous assessments conducted by Australia (the other two species were assessed as having a Moderate likelihood of establishment) (Appendix C).

3.4 Likelihood of spread

The likelihood that a mealybug quarantine pest will spread within Australia, following its establishment is assessed as **High**.

Spread is defined as '*the expansion of the geographical distribution of a pest within an area*' (FAO 2017b).

The supporting evidence for this assessment is provided.

Suitability of the natural and/or managed environment for natural spread of the pest

The same or similar environmental conditions to where pest mealybugs currently occur are available for the natural spread of pest mealybugs throughout Australia.

Greenhouse environments have also been shown to be suitable in aiding the spread of some mealybugs. Like other countries, Australia uses greenhouses to produce many crops such as tomatoes, capsicum, cucumber and eggplant (Ausveg 2014), which are hosts of mealybugs.

Presence of natural barriers

Natural barriers exist between different areas within Australia. Arid areas and long geographic distances exist between the east and the west, for example, the Nullarbor Plain. The Bass Strait separates the mainland from Tasmania. Climatic differentials occur between the north and the south. It would be difficult for mealybugs to naturally disperse via the movement of crawlers (first instar nymphs) from one area to another. However, at least some mealybugs might be able to overcome some natural barriers. Although rare, airborne scale crawler dispersal it has been assumed to occur and has been used to explain some unexpected mealybug incursions that occur at longer distance from known sources of infestation, such as up to 260 Km inland from an infested area on the Kenyan coast (Greathead 1990; Gullan & Kosztarab 1997).

The potential for movement with commodities or conveyances

Pest mealybugs can be spread on fresh plants and/or cuttings, as mealybugs are easily concealed under bracts and in buds and leaf bases.

Mealybugs may also be spread between production areas on the clothes of people who have been in direct contact with infested material. This type of spread may deposit mealybugs directly into new uninfested areas at a faster rate than mealybugs could naturally spread.

Intended use of the commodity

The intended uses of commodities and live plants derived from the large number of potential hosts, such as fresh fruit, vegetables, cut-flowers and foliage, cereal crops, and propagative material are likely to include human consumption, decoration, nursery stock and animal feeds. These commodities and live plants would be moved around the country, and this assists spread of eggs, nymphs and adults of associated mealybugs.

Dispersal and potential vectors of the pest in the PRA area

Pest mealybugs do not require a vector for dispersal. Their dispersal is actively through the mobility and passively through other means including wind and human activities.

The main dispersal stage is the newly emerged crawlers, which actively seek suitable feeding sites by walking. As discussed previously under the likelihood of distribution, the dispersal capability of crawlers by walking is limited, and local in nature (Cornwell 1956) by their finite energy reserves (Koteja 1990), by terrain over which they must move, and by high mortality if they remain unfed (Cornwell 1956).

There is evidence that crawlers of scale insects and mealybugs can be dispersed passively by the wind, even though mortality is very high. Passive dispersal by wind has been reported to range from several metres to a few kilometres, or more (Greathead 1990; Gullan & Kosztarab 1997). Once airborne, the trajectory of a crawler is likely to be erratic because of the influence by air turbulence caused by wind up- and down-drifts (Pedgley 1982).

Apart from wind, other factors such as water, soil, human and animals may also aid the passive dispersal of mealybugs (Franco, Zada & Mendel 2009). In addition, crawlers of some ant-attended mealybugs are carried to new feeding sites by colony-founding queen ants (Gullan & Kosztarab 1997).

Potential natural enemies of the pest in the PRA area

The most common natural enemies of mealybugs include parasitic wasps, arthropod predators and entomopathogenic fungi (Franco, Zada & Mendel 2009). For parasitic wasps, the important genera include *Gyranusoidea*, *Pseudaphycus*, *Coccidoxenoides*, *Leptomastidea*, *Leptomastix* and *Tetracnemoidea* (Franco, Zada & Mendel 2009)—the last four genera have species reported from Australia.

The beetle family Coccinellidae can feed on a wide range of food sources but some genera, including *Brumus*, *Cryptolaemus*, *Diomus*, *Nephus* (now *Scymnus*) and *Orcus*, prefer to prey on mealybugs (Franco, Zada & Mendel 2009). These genera or their related genera are reported in Australia. Other mealybug predators include lacewings (Neuroptera: Hemerobiidae) and gall midges (Diptera: Cecidomyiidae).

However, these natural enemies are unlikely to have significant impact on the spread of introduced species because they can also use local mealybugs as food sources, and would not specifically target the introduced mealybugs.

Summary of spread

The suitability of natural and/or managed environments including greenhouses, the ability for short-range dispersal by crawlers, potential for long-range dispersal by wind and human activities allowing natural barriers to be overcome, all support a likelihood of spread of High, which is consistent with all previous assessments conducted by Australia on 37 pest mealybug species (Appendix C).

3.5 Overall likelihood of entry (indicative), establishment and spread

The overall likelihood of entry, establishment and spread is determined by combining the likelihoods of entry (indicative), of establishment and of spread using the matrix of rules shown in Appendix A. These likelihoods are summarised in Table 3.3.

The overall likelihood that a mealybug quarantine pest will enter Australia on the plant import pathway, be distributed in a viable state to a susceptible host, establish in Australia and subsequently spread within Australia is assessed as **Moderate**.

Table 3.3 Overall likelihood of entry (indicative), establishment and spread for mealybugs

Step	Likelihood
Importation (indicative)	High
Distribution (indicative)	Moderate
Overall likelihood of entry (indicative)	Moderate
Establishment	High
Spread	High
Overall likelihood estimate (indicative)	Moderate

3.6 Consequences

The overall consequences for a mealybug quarantine pest are estimated to be **Low**.

The potential consequences of the establishment of a mealybug quarantine pest in Australia have been estimated according to the method described in Appendix A.

Impact scores for consequences are summarized in Table 3.4.

Table 3.4 Summary of consequences for mealybugs

Consequences criterion	Impact (magnitude and geographic scale)	Impact score
Direct impact on plant life or health	Major significance at the local level	D
	Significant at the district level	
	Minor significance at the regional level	
Direct impact on other aspects of the environment	Minor significance at the local level	B
Indirect impact on eradication and control	Major significance at the local level	D
	Significant at the district level	
	Minor significance at the regional level	
Indirect impact on international trade	Major significance at the local level	D
	Significant at the district level	
	Minor significance at the regional level	

Indirect impact on domestic trade	Significant at the local level Minor significance at the district level	C
Indirect impact on environment	Minor significance at the local level	B
Overall consequences rating		Low

The assessment of consequences considered only the impacts caused by a mealybug quarantine pest. It did not consider any additional impacts caused by viruses that they may transmit. A separate risk assessment was undertaken for these viruses (Chapter 4).

The overall consequences rating of low for a mealybugs quarantine pest is consistent with all previous assessments conducted by Australia.

The supporting evidence for this assessment is provided.

Direct impact on plant life or health

Impact score is estimated as **D**.

The direct impact of a pest mealybug on plant life or health would be of major significance at the local level, significant at the district level, and of minor significance at the regional level, which has an impact score of 'D'. This is because the impact would be expected to threaten economic viability through a large decrease in production of infested crops at the local level. Damage caused by pest mealybugs includes weakening plant vigour to decrease yield and impacting the appearance of produce to reduce market value. Secondary impacts are caused by sooty mould development resulting from honeydew secretion. The impact on plant industries is expected to be significant at the district level and of minor significance at the regional level because these industries within a state or territory are usually diverse in composition of hosts and physically dispersed.

This impact score is consistent with all previous risk assessments of mealybugs conducted by Australia.

As mentioned in pest categorisation, many mealybugs are polyphagous and feed on numerous plants including important agricultural and horticultural crops. The damage of mealybugs on plants is caused by sap sucking, weakening plant vigour to decrease yield. Secondary impacts are caused by sooty mould development associated with honeydew secretion.

Mealybugs can be serious pests of crops such as apples, bananas, cassava, citrus, cocoa, coffee, grapes, mango, mangosteens, longan, lychees, orchids, pineapples, taro, capsicum and zucchini (Mani & Shivaraju 2016e; Miller, Miller & Watson 2002; Williams & Granara de Willink 1992; Williams & Watson 1988b). When populations reach high numbers, the severity of their damage can be considerable, reducing growth and sometimes killing the host plants (Williams & Granara de Willink 1992). Given that pest mealybugs are often polyphagous, a single mealybug species can be a pest for many host plants; for example, *Dysmicoccus neobrevipes* is recorded as damaging banana, pineapples, citrus, cocoa and coffee (Williams & Granara de Willink 1992).

Australia has significant primary industries with many host crops which are subject to attack by mealybugs. For horticulture, Australia's annual gross value of production (GVP)—the value of

production at the point of sale in 2014–15 was valued at \$3,855 million (ABS 2016), which included commodities such as apples, bananas, citrus, pears, stone fruit and table grapes. Vegetable production was valued at \$3,350 million (ABS 2016), which included beans, capsicum, cucumbers and lettuce. Cut-flowers were valued at \$296 million (ABS 2016). However, the actual impact on these industries caused by a given mealybug would not be expected to equate to the full extent of these GVP values.

Direct impact on other aspects of the environment

Impact score is estimated as **B**.

The direct impact of a pest mealybug on other aspects of the environment would be of minor significance at the local level, and indiscernible at the district, regional and national levels, which has an impact score of 'B'. This is because they may have a minor impact on native mealybugs, or compete for resources locally with these organisms. On rare occasions, mealybugs have been shown to have the capacity to kill trees.

This impact score is consistent with those of 27 of the 37 pest mealybug species in the previous risk assessments conducted by Australia (four species were classified as having an impact score of A, and six as having a score of C).

Although a rare occurrence, some species of mealybugs have shown themselves to be able to kill trees and thus alter the amenity landscape. In India, *Dysmicoccus neobrevipes* has been reported to have attacked over 2000 street trees (*Albizia saman*) in Mumbai since 2010 with over a thousand trees killed due to mealybug attack (Dutta 2014; Thomas 2015). The trees were 40–50 years old and were important street trees in the city.

In addition, some species of pest mealybugs may have some impact on native mealybug fauna through competition for the same or similar resources.

Indirect impact on eradication and control

Impact score is estimated as **D**.

The indirect impact of a pest mealybug on the basis of associated eradication and control activities would be of major significance at the local level, significant at the district level, and of minor significance at the regional level, which has an impact score of 'D'. This is because the impact would be expected to threaten economic viability through a large increase in costs for containment, eradication and control at a local level. Containment and eradication activities are costly, and would also cause significant disruption to agribusiness and associated trades at the district level. The costs associated with the initial response to an incursion and ongoing control of the introduced pest, including any additional research requirement, would be expected to be of minor significance at the regional level.

This impact score is consistent with those of 29 of the 37 pest mealybug species in the previous risk assessments conducted by Australia (two species were assessed as having an impact score of B, and six species as having a score of C).

In Australia, an exotic pest incursion will trigger an immediate response by Australian federal, state and territory governments and relevant industries, and there are costs involved with this

response (Plant Health Australia 2013). The initial response includes consideration of the feasibility of eradication of the pest from Australia.

To date, there have been no attempts to try to eradicate exotic mealybugs in Australia, as when the pests were detected they had already established and spread to a wide area, and eradication was considered not feasible.

The difficulty of eradicating mealybug pests results from factors including their wide range of host plants, capacity for dispersal of crawlers by wind and through spread on infested plant material and commodities, as well as the commonly delayed period to detection.

Once exotic pest mealybugs become established and eradication is not considered possible, it is necessary to control and manage the pests on an ongoing basis. Control of pest mealybugs usually involves integrated pest management (IPM), which incorporates cultural, physical, biological and chemical control methods. In the IPM program, chemical control is reserved for suppressing large pest population sizes when cultural, physical and/or biological measures become ineffective. In Australia, examples of IPM programs implemented specifically for mealybug pests or as part of the management strategy include control on grape vines for *Pseudococcus calceolariae*, *Pseudococcus longispinus* and *Pseudococcus viburni* in New South Wales (Braybrook 2012), on ornamentals for *Planococcus citri*, *Pseudococcus longispinus* and *Rhizococcus falcifer* in Queensland (Goodwin et al. 2000), on apples and pears for *Pseudococcus longispinus* in Australia (APAL 2009), and on citrus for *Pseudococcus calceolariae* (Baker & Keller 1998).

The presence of a new pest in any agricultural and horticultural cropping system will likely require initial investigation and ongoing additional research to determine what modifications to existing management regimes are required, and to evaluate their effectiveness. In Australia, such research is often funded under shared government and industry arrangements and may take years to complete.

Indirect impact on International trade

Impact score is estimated as **D**.

The indirect impact of a pest mealybug on international trade would be of major significance at the local level, significant at the district level, and of minor significance at the regional level, which has an impact score of 'D'. This is because the impact would be expected to threaten economic viability through loss of trade and export markets at the local level. It is likely that trading partners would review their phytosanitary requirements for exported host commodities, including the possibility of suspending or stopping trade or imposing phytosanitary measures for pest mealybugs that are not currently present in their countries. Australia is a significant exporter of agricultural commodities. If trade was to be suspended or stopped, it would be expected to have a significant impact on affected industries at the district level. The relevant state or territory government would also have to expend resources to support affected industries and assist in regaining market access, which would have a minor impact at the regional level.

This impact score is consistent with those of 32 of the 37 pest mealybug species in previous risk assessments conducted by Australia (four species were assessed as having an impact score of B, and one species as having an impact score of C).

Although pest mealybugs have been recorded in Australia (Williams 1985b), many recognised pest species are not present in Australia. If introduced, they might have an impact on Australia's export markets in countries where these mealybug species currently do not occur.

Whether the pest mealybug species was able to transmit pathogens of biosecurity concern could be another factor that might be considered by trading partners.

Many countries require phytosanitary measures to mitigate the risk posed by their quarantine mealybugs. Australia is a significant exporter of agricultural and horticultural commodities, including hosts of pest mealybugs. Should exotic mealybugs become established on crops grown for export markets, Australia's trading partners may impose phytosanitary measures, typically inspection and treatment if mealybugs are present, resulting in additional export costs and/or disruption to the existing trade.

Indirect impact on domestic trade

Impact score is estimated as **C**.

The indirect impact of a pest mealybug on domestic trade would be significant at the local level and of minor significance at the district level, which has an impact score of 'C'. This is because the impact would be expected to threaten economic viability through a large reduction of trade or loss of domestic markets at the local level. Biosecurity measures would be enforced to prevent the movement of infested plant material out of the initial incursion area, which would have significant economic impacts on plant industries and business at the district level. The introduction of a new pest to a state or territory would be likely to disrupt interstate trade due to biosecurity restrictions on the domestic movement of affected commodities. This would be expected to be of minor significance at the regional level.

This impact score is consistent with those of the majority of the 37 pest mealybug species in previous risk assessments conducted by Australia.

If an exotic mealybug species is detected in Australia, initially it is likely to be restricted to a relatively small area. Previous detections of mealybug incursions support this assertion, which has also been the case for pests in other groups such as papaya fruit fly (Cantrell, Chadwick & Cahill 2002). Quarantine measures would be enforced to prevent the movement of plant material out of the incursion area, and this would have an economic impact on plant industries and business.

Australian states and territories have their own domestic biosecurity restrictions for pests of concern for their jurisdictions. An intergovernmental body, the Subcommittee on Domestic Quarantine and Market Access (SDQMA), has been established to ensure that the development of domestic market access conditions for plants and plant products in Australia is technically justified, coordinated and harmonised, and consistent with Australia's international import and export conditions and policies (SDQMA 2014). When an exotic pest is detected and its distribution is limited in area, this body can restrict intra- and/or inter-state movement of affected commodities to prevent the pest's spread. Such a restriction would clearly impact on domestic trade.

Indirect impact on environment

Impact score is estimated as **B**.

The indirect impact of a pest mealybug on the environment would be of minor significance at the local level, and indiscernible at the district, regional and national levels, which has an impact score of 'B'. This is because the introduction of a new pest mealybug may result in the additional use of pesticides for its control, and thus additional spray drift, causing minor damage to the local environment.

This impact score is consistent with those of 35 of the 37 pest mealybug species in previous assessments conducted by Australia (two species were assessed as having an impact score of A).

Increased pesticide use required to manage new mealybug species could affect the environment. Spray drift of pesticide application can result in soil toxicity, runoff and water system contamination (APVMA 2008; NSW DPI 2012). The Australian Pesticides and Veterinary Medicines Authority (APVMA) defines spray drift as the physical movement of spray droplets (and their dried remnants) through the air from the nozzle to any off-target site at the time of application or soon thereafter (APVMA 2008). Spray drift has been implicated with the decline of some butterflies in Australia (Sands & New 2002). Soil toxicity in agricultural systems is reported in the US to inhibit germination and lead to elevated pesticide residues in plants (Dalvi & Salunkhe 1975), possibly leading to issues with maximum residue limits (MRLs) and saleability of crops. Runoff and leaching may affect biodiversity in aquatic ecosystems (NSW DPI 2012).

3.7 Unrestricted risk estimate (indicative)

Unrestricted risk is the result of combining the overall likelihood of entry, establishment and spread (Table 3.3) with the estimate of consequences (Table 3.4). Likelihoods and consequences are combined using the risk estimation matrix in Appendix A. The unrestricted risk (indicative), for mealybugs that are quarantine pests for Australia, is given in Table 3.5, and is assessed as **Low**.

Table 3.5 Unrestricted risk estimate (indicative) for mealybugs

Risk component	Rating
Overall likelihood of entry (indicative), establishment and spread	Moderate
Consequences	Low
Unrestricted risk (indicative)	Low

This unrestricted risk estimate (indicative) is consistent with those of 32 of the 37 pest mealybug species previously assessed by Australia (five species were assessed as having an unrestricted risk estimate of Very low; on two occasions the same species was assessed as having a different unrestricted risk estimate due to a difference in the likelihood of importation on different plant import pathways).

4 Pest categorisation of viruses transmitted by mealybugs

4.1 Introduction

The pest categorisation process identifies pests with the potential to be on the plant import pathway that are quarantine pests for Australia, and as a result require pest risk assessment. A quarantine pest is 'a pest of potential economic importance to the area endangered thereby and not yet present there, or present and not widely distributed and officially controlled' (FAO 2017b).

4.2 Substantiation of virus transmission by a mealybug species

The potential associations between viruses and the mealybug species suspected to transmit them are presented in Tables 12.1 and 12.2 of Appendix E. These associations, together with selection criteria (Table 4.1), provide the rationale for the inclusion or exclusion of viruses in the pest categorisation process presented in Table 13.1 of Appendix F.

Table 4.1 Criteria for the inclusion of viruses transmitted by mealybugs in pest categorisation

Criterion	Description
1	The virus species is proven to be transmitted by a specific mealybug species, or
2	A former virus species that was revised and split into new virus species, and the mealybug(s) identified as vectors of the original virus species were assigned to the new virus species, and
3	The virus species identified by criterion 1 or 2 is recognised by the International Committee on Taxonomy of Viruses (ICTV 2017)

Viruses were only included in the pest categorisation process where it could be substantiated that they were transmitted by a specific mealybug species. On several occasions, detailed analysis of the literature revealed no tangible evidence for this, or the association was considered ambiguous. Substantiation was also complicated in some situations by revision to the virus taxonomy. For example, many references report mealybugs as capable of transmitting 'banana streak virus' (BSV). However, in the last 10 years, taxonomic reassessment has resulted in splitting of this virus into three species, and as a result 'banana streak virus' has become an invalid name, hence abandoned. To ensure that all mealybugs that were reported to transmit the original 'banana streak virus' were considered during pest categorisation, all known mealybug vectors of BSV were designated as associated with each of the three species into which BSV was split, namely *Banana streak GF virus*, *Banana streak MY virus* and *Banana streak OL virus* (Appendix E). A similar situation exists with respect to 'sugarcane bacilliform virus' (SBV). In this case, all mealybugs reported to transmit SBV, have been designated as associated with the two species into which SBV was split: *Sugarcane bacilliform IM virus* and *Sugarcane bacilliform MO virus*. Additionally, there are several newly reported virus species where a specific vector has not yet been identified.

The taxonomy of the virus family *Closteroviridae*, including of grapevine-infecting members of the genus *Ampelovirus*, was recently reviewed (Martelli et al. 2012). As a result, several previously considered distinct, or tentative Grapevine leafroll-associated viruses (GLRaV), namely viruses 5, 6, 9, Pr, De and Car became synonyms of GLRaV-4. A significant factor in this revision was a change in the minimum amino acid sequence identity required for the demarcation of distinct *Ampelovirus* species, which was revised from 90 per cent to 75 per cent, allowing a 25 per cent divergence in three taxonomically relevant genes (King et al. 2012;

Martelli et al. 2012). A previous pest risk assessment of grapevine propagative material (DAFF 2013d), acknowledged the anticipated taxonomic revision, but at that time considered several of these now synonymous species as being separate. The current taxonomy supersedes this earlier decision.

4.3 Process of pest categorisation of viruses transmitted by mealybugs

The pest categorisation process is described in Appendix A.

Pest categorisation confirms the identity of a pest, its absence or presence and regulatory status within the PRA area, its potential for establishment and spread, and its potential for economic and environmental consequences in the PRA area (FAO 2017c).

The components of this pest categorisation process for viruses are presented in Table 13.1 of Appendix F and the outcome is summarised in Chapter 4.4.

4.4 Conclusion of pest categorisation of viruses transmitted by mealybugs

A total of 26 viruses that are transmitted by mealybugs were considered in the pest categorisation process (Table 13.1 of Appendix F), and the results of this process are presented in Table 4.2.

Nine viruses that are transmitted by mealybugs were identified as quarantine pests for Australia, namely BSVNV, CSSV, CiYMV, ComYMV, DBALV, GVB 'corky bark' strains, KTSV, PYMoV and SCBMOV. Seventeen other viruses were assessed not to be quarantine pests for Australia because they are present in the PRA area and not under official control.

Table 4.2 Outcome of pest categorisation of viruses transmitted by mealybugs

Virus species	Acronym	Consider further as quarantine pest
<i>Banana streak GF virus</i>	BSGFV	No
<i>Banana streak MY virus</i>	BSMYV	No
<i>Banana streak OL virus</i>	BSOLV	No
<i>Banana streak VN virus</i>	BSVNV	Yes
<i>Cacao swollen shoot virus</i>	CSSV	Yes
<i>Citrus yellow mosaic virus</i>	CiYMV	Yes
<i>Commelina yellow mottle virus</i>	ComYMV	Yes
<i>Dioscorea bacilliform AL virus</i>	DBALV	Yes
<i>Grapevine leafroll-associated virus 1</i>	GLRaV-1	No
<i>Grapevine leafroll-associated virus 3</i>	GLRaV-3	No
<i>Grapevine leafroll-associated virus 4</i>	GLRaV-4	No
<i>Grapevine virus A</i>	GVA	No
<i>Grapevine virus B</i>	GVB 'corky bark' strains	Yes
<i>Grapevine virus E</i>	GVE	No
<i>Kalanchoe top-spotting virus</i>	KTSV	Yes
<i>Little cherry virus 2</i>	LChV-2	No
<i>Pineapple bacilliform comosus virus</i>	PBCoV	No

Virus species	Acronym	Consider further as quarantine pest
<i>Pineapple bacilliform erectifolius virus</i>	PBErV	No
<i>Pineapple mealybug wilt-associated virus 1</i>	PMWaV-1	No
<i>Pineapple mealybug wilt-associated virus 2</i>	PMWaV-2	No
<i>Pineapple mealybug wilt-associated virus 3</i>	PMWaV-3	No
<i>Piper yellow mottle virus</i>	PYMoV	Yes
<i>Schefflera ringspot virus</i>	SRV	No
<i>Sugarcane bacilliform IM virus</i>	SCBIMV	No
<i>Sugarcane bacilliform MO virus</i>	SCBMOV	Yes
<i>Taro bacilliform virus</i>	TaBV	No

Pest categorisation identified twenty-four mealybug species that transmit viruses, namely *Dysmicoccus boninsis*, *D. brevipes*, *D. neobrevipes*, *Dysmicoccus* sp. nr. *texensis*, *Ferrisia gilli*, *F. virgata*, *Formicococcus celtis*, *F. njalensis*, *Heliococcus bohemicus*, *Paracoccus burnerae*, *Phenacoccus aceris*, *P. hargreavesi*, *Planococcus citri*, *P. ficus*, *P. kenya*, *P. minor*, *Pseudococcus comstocki*, *P. concavocerarii*, *P. elisae*, *P. longispinus*, *P. maritimus*, *P. solomonensis*, *P. viburni* and *Saccharicoccus sacchari*.

Eighteen of the twenty-four mealybug species that transmit viruses are quarantine pests for Australia, and are currently regulated. Six additional mealybug species are not currently regulated, namely *Dysmicoccus brevipes*, *Ferrisia virgata*, *Planococcus citri*, *P. longispinus*, *P. viburni* and *Saccharicoccus sacchari*. Collectively, these six species have the potential to transmit a total of nine of quarantine pest viruses (Table 13.1 of Appendix F).

Viruses that are quarantine pests for Australia require further consideration in this risk analysis to determine if additional measures are required to manage their risk, especially where the mealybugs that transmit them are not currently regulated.

5 Pest risk assessment of viruses transmitted by mealybugs

5.1 Introduction

Pest categorisation (Chapter 4) identified eight badnaviruses plus GVB ‘corky bark’ strains as quarantine pests for Australia (Table 5.1). These viruses require further pest risk assessment.

Table 5.1 Viruses transmitted by mealybugs that require pest risk assessment

Virus	Acronym
BADNAVIRUS	
<i>Banana streak VN virus</i>	BSVNV
<i>Cacao swollen shoot virus</i>	CSSV
<i>Citrus yellow mosaic virus</i>	CiYMV
<i>Commelina yellow mottle virus</i>	ComYMV
<i>Dioscorea bacilliform AL virus</i>	DBALV
<i>Kalanchoe top-spotting virus</i>	KTSV
<i>Piper yellow mottle virus</i>	PYMoV
<i>Sugarcane bacilliform MO virus</i>	SCBMOV
VITIVIRUS	
<i>Grapevine virus B</i> ‘corky bark’ strains	GVB ‘corky bark’ strains

At various steps in this risk assessment, badnaviruses and GVB ‘corky bark’ strains were either considered independently or as a group, as appropriate, on grounds that include:

- their transmission by mealybugs, and
- their common viral forms
- the dominance of research focusing on only a few well known viruses, and the need to extrapolate to and from other related viruses.

It was necessary to differentiate between badnaviruses and GVB ‘corky bark’ strains to estimate their overall consequence ratings. The information presented in this risk assessment applies to all the quarantine viruses being assessed, unless specifically indicated otherwise.

Badnaviruses

Badnaviruses (Family *Caulimoviridae*) are bacilliform particles with a circular double stranded DNA genome of about 7 to 8 kb, with three to seven open reading frames (ORFs), depending on the species (King et al. 2012). Badnaviruses are pararetroviruses, with a reverse transcription stage in their replication cycle. Their replicative strategy differs from retroviruses which require integration into the host genome for replication, although some badnaviruses have been found integrated within the genome of their hosts—in this case being termed an endogenous pararetrovirus (Gayral & Iskra-Caruana 2009; Harper et al. 1999; Iskra-Caruana et al. 2015; Lheureux et al. 2007; Lockhart et al. 1997b).

Badnaviruses may represent an emerging biosecurity risk, with several new badnaviruses described in recent years (Bhat, Hohn & Selvarajan 2016). There are 40 badnavirus species recognised by the ICTV (2017), with an additional 22 described (Bhat, Hohn & Selvarajan 2016).

In contrast, only 16 badnaviruses were known 20 years ago (Brunt et al. 1996). This increase in number and knowledge has resulted in considerable modification to their taxonomy, and introduced uncertainty about the specific details of some earlier studies. However, each badnavirus species has a relatively narrow host plant range, a position that has remained fairly consistent, even with the discovery of new species.

Grapevine virus B ‘corky bark’ strains

Grapevine virus B is a *Vitivirus* (Family *Betaflexiviridae*). Vitiviruses possess non-enveloped flexuous filamentous particles with a linear positive sense single-stranded RNA genome of about 7.5 kb (King et al. 2012), and five open reading frames (ORFs) (Al Rwahnih et al. 2012; du Preez et al. 2011). Vitiviruses are predominantly known as pathogens of grapevine, from which they derive their name. Of the nine described *Vitivirus* species, five are known from grapevine: *Grapevine virus A* (GVA), *Grapevine virus B* (GVB), *Grapevine virus D* (GVD), *Grapevine virus E* (GVE), and *Grapevine virus F* (GVF).

Entry, establishment and spread, and consequences of these mealybug-transmitted viral pathogens are estimated according to the method described in Appendix A.

5.2 Likelihood (indicative) of entry

The overall likelihood (indicative) that a quarantine pest badnavirus or GVB ‘corky bark’ strains will enter Australia on the plant pathway is assessed as **Very low**.

Entry is defined as the movement of a pest into an area where it is not yet present, or present but not widely distributed and being officially controlled (FAO 2017b).

The likelihood of entry is considered in two parts, the likelihood of importation and the likelihood of distribution, which consider pre-border and post-border issues, respectively. The overall likelihood of entry is determined by combining the likelihood of importation with the likelihood of distribution using the matrix of rules provided in Appendix A.

In this Group PRA, the likelihood of entry of the quarantine viruses transmitted by mealybugs is assessed as indicative because it is not linked to a specific plant import pathway.

The likelihood of importation and likelihood of distribution are influenced by a range of factors. Most of these factors can be considered fully at the group level, but some cannot (see Appendix A). These factors were considered in this Group PRA based on extensive historic and contemporary analysis of the plant pathway.

Entry is also conditional on the virus and the mealybugs that transmit them being present in the export region. Appendix G summarises the known global distributions of mealybug-transmitted viruses and the mealybugs that transmit them. However, these details may be subject to periodic revision.

If this Group PRA is applied to a specific pathway, these factors must be verified on a case-by-case basis, as appropriate. Until this occurs, the likelihood of pest entry in this Group PRA is indicative only, and potentially subject to revision.

Entry scenario

This risk assessment considers the risk that a viruliferous mealybugs could facilitate the entry of a virus into Australia on the plant import pathway.

Likelihood (indicative) of importation

The likelihood (indicative) that a quarantine pest badnavirus or GVB ‘corky bark’ strains will be imported into Australia on the plant import pathway is assessed as **Low**.

The supporting evidence for this assessment is provided.

Association with export crops

Many mealybug species are important pests of agricultural and horticultural crops (Miller et al. 2006; Williams 2004; Williams & Granara de Willink 1992). Evidence for a close association of mealybug species with crops that comprise the plant pathway was presented in Chapter 3.2, and this relationship is also relevant to viruliferous mealybugs.

Mealybugs and the viruses they transmit can be sustained on ‘volunteer’ plants (cultivated species growing wild or contaminating other crops), or on nearby crops, to provide a source of viruliferous mealybugs and infection of export crops. Therefore, the risk that a virus may be imported into the PRA area results from the acquisition of the virus by a mealybug when it feeds on virus-infected plant tissues, and its subsequent presence on the exported commodity. However, there are three possible scenarios for the association of a viruliferous mealybug with an export crop, namely (i) the export crop is not a host plant species for the virus(es) under consideration, (ii) it is a host but not virus infected, or (iii) it is a host that is virus infected.

Mealybugs have a semi-persistent mode of virus transmission, retaining virus and remaining infective for only a few days (supporting evidence is presented later in this risk assessment). A viruliferous mealybug that prior to harvest arrived in an export crop that was a non-host for the virus it carried would rapidly lose the virus without any further source of re-infection. Therefore, for such a mealybug to be viruliferous at the time of harvest, it would need to have reached the export crop within a relatively restricted period of a few days prior to harvest.

If the export crop was virus-free and a host species of the virus, the viruliferous mealybug could infect the crop with virus, and if that mealybug continued to feed in the same location, it is possible that it could remain viruliferous by reacquiring the virus from the local site of infection. However, it would take time for the virus to replicate and spread throughout the host plant before it would be available to be acquired by other mealybugs feeding on that plant. Thus it is much more likely that a viruliferous mealybug would be imported into the PRA area when the export crop is a host of the virus, with an established prevalence of virus infection and infestation of vector-competent viruliferous mealybugs.

Host plants of quarantine pest badnaviruses include *Adansonia*, banana, Betel vine, black and long pepper, cacao, *Ceiba*, *Cola*, *Citrus* spp. (lemon, lime, pumelo, sweet and sour orange, grapefruit), *Commelina diffusa*, *Dioscorea alata*, *Kalanchoe blossfeldiana* and sugarcane (Table 13.1 of Appendix F). Thirteen mealybug species are proven to transmit quarantine pest badnaviruses. These species are *Dysmicoccus boninsis*, *D. brevipes*, *Ferrisia virgata*, *Formicococcus celtis*, *F. njalensis*, *Phenacoccus hargreavesi*, *Planococcus citri*, *P. kenya*, *P. minor*, *P. concavocerarii*, *P. elisae*, *P. longispinus*, and *Saccharicoccus sacchari* (Table 12.2 of Appendix E).

Grapevine virus B 'corky bark' strains infect only grapevines. Four mealybug species are proven to transmit GVB. These species are *Phenacoccus aceris*, *Planococcus ficus*, *Pseudococcus longispinus* and *Pseudococcus viburni* (Table 12.2 of Appendix E).

The association between mealybugs and the viruses they vector is complex. A single mealybug species can vector many viruses. For example, *Planococcus citri* is recorded to transmit 16 virus species (Table 13.2). Conversely, one virus may be transmitted by many mealybug species—CSSV is vectored by 9 mealybug species, including the cosmopolitan phytophagous species *Dysmicoccus brevipes*, *Ferrisia virgata*, *Planococcus citri* and *Pseudococcus longispinus* (Table 12.1 of Appendix E).

Mealybug eggs, nymphs and adult females are all relatively small—about 0.3 mm for eggs to a maximum of 8 mm for adults. They can often be found in crevices and protected spaces, such as under the calyx of fruit. This makes them difficult to detect during routine commercial harvest and packing house inspections.

While mealybug nymphs and adult females are capable of acquiring and transmitting plant viruses, adult males have no functional mouthparts and hence cannot transmit viruses (Williams 2004). In addition, females are not known to pass viruses to their offspring by transovarian means (Tsai et al. 2008). As a result, the presence of mealybug eggs or adult males does not provide a pathway for the importation of these viruses.

Mealybug interceptions

Combined Australian and international records show that mealybugs are repeatedly and globally intercepted on fresh fruit, vegetables, cut-flowers and foliage (Appendix B). This information shows that 19 of the 24 mealybug species known to transmit viruses have been reported as being intercepted on the plant import pathway within global trade.

Australian interception records indicate that 13 mealybug species that transmit viruses have been intercepted at the border (Table 11.1 of Appendix D). Nine of those species transmit one or more of the quarantine viruses identified in this report (Table 5.2). The three mealybugs species most frequently identified were *Pseudococcus longispinus*, *Planococcus citri* and *Planococcus minor*, which collectively vector nine quarantine pest viruses. The mealybugs that were identified to species level represent about 10 per cent of those intercepted over this period.

Table 5.2 Mealybugs that transmit quarantine viruses intercepted by Australia (1986-2015)

Species	Interceptions	Quarantine pest viruses transmitted
<i>Dysmicoccus boninsis</i>	1	SCBMOV
<i>D. brevipes</i>	2	CSSV
<i>Ferrisia virgata</i>	6	CSSV and PYMoV
<i>Planococcus citri</i>	50	BSVNV, CSSV, CiYMV, ComYMV, DBALV, KTSV, PYMoV and SCBMOV
<i>P. ficus</i>	8	GVB
<i>P. minor</i>	44	PYMoV
<i>Pseudococcus longispinus</i>	83	CSSV and GVB
<i>P. viburni</i>	11	GVB
<i>Saccharicoccus sacchari</i>	2	SCBMOV

The interception of mealybug species that transmit quarantine pest viruses provides compelling evidence of the close association of these species with crops that form part of the plant import pathway, and their potential to facilitate virus entry.

It is expected that the observed trends in mealybug interceptions on the plant import pathway are likely to continue.

Modes of virus transmission by insects

The majority of plant viruses are vectored by insects—reviewed by Ng and Falk (2006), Hogenhout et al. (2008), Whitfield, Falk and Rotenberg (2015) Whitfield, Falk and Rotenberg (2015), and Fereres and Raccach (2015).

There are three broad modes of virus transmission by insects—non-persistent, semi-persistent and persistent. Persistent transmission is further subdivided into two categories based on whether the virus enters the insect’s circulatory system and replicates—termed propagative circulative or non-propagative circulative (Table 5.3).

Table 5.3 Characteristics of the modes of virus transmission by insects

Features	Mode of transmission		
	Non-persistent	Semi-persistent	Persistent
Circulation	Non-circulative	Non-circulative	Circulative (propagative or non-propagative)
Retention period	Few hours	Few days	Days to months
Acquisition and inoculation access periods	Seconds/minutes	Hours	Hours to days
Latent period	Not required	Not required	Required

The characteristics of each mode of virus transmission by insects are the consequence of:

- the period of time needed for the virus to be acquired (acquisition access period—AAP)
- whether the virus enters the insect’s circulatory system, and if so, whether it is propagated
- whether a period of time is necessary before the virus can be transmitted (latent period)

- the period of time post virus acquisition for which the insect is viruliferous (retention period)
- the period of time needed for a virus to be transmitted to a susceptible host (inoculation access period—IAP).

Hemipteran insects, including mealybugs, have piercing-sucking mouthparts with a needle-like stylet bundle consisting of two mandibular and two maxillary stylets that form two canals—a narrower channel for saliva delivery, and a wider food channel for the ingestion of plant sap. The food canal connects with the foregut, which comprises the pre-cibarium, the cibarium which is equipped with a muscular pump, and the oesophagus from where the alimentary tract connects the midgut and then the hindgut (Herrbach et al. 2017).

Mode of virus transmission by mealybugs

Mealybugs are reported to have a semi-persistent mode of virus transmission (Andret-Link & Fuchs 2005; Bertin et al. 2016; Fereres & Raccach 2015; Nault 1997; Tsai et al. 2008), including for ampeloviruses, badnaviruses and vitiviruses (King et al. 2012). Persistence characteristics and the mode of transmission for members of a given virus genus are fairly consistent (Andret-Link & Fuchs 2005; Fereres & Raccach 2015; Nault 1997).

In one possible exception, Cid et al (2007) reported that *Planococcus citri* accumulated the Ampelovirus *Grapevine leafroll-associated virus 3* (GLRaV-3) within its primary salivary glands, which they concluded as being reflective of a circulative non-propagative mode of transmission. However, consistent with a semi-persistent mode of transmission, GLRaV-3 was not detectable after four days of *P. citri* being fed on virus-free leaves (Cid et al. 2006). GLRaV-3 has been described by other authors as having a semi-persistent mode of transmission by *P. ficus* (Tsai et al. 2008).

For a semi-persistent mode of virus transmission, the virus AAP and IAP are relatively short, there is no latent period, the virus is not propagated within its vector, and nor does it pass through the gut wall into the circulatory system (the haemocoel). Instead the virus remains associated with the epicuticle that lines the stylets (mouthparts) and/or the foregut (the anterior part of the alimentary canal), and is available for consequent transmission to a host plant during feeding activities (Hogenhout et al. 2008).

Viruliferous mealybug prevalence

The prevalence of viruliferous mealybugs at harvest is primarily determined by two factors, namely, the prevalence of the virus in the crop, and the rate of virus acquisition by the mealybug. Virus prevalence in the field can vary greatly. In vineyards in southern Italy, GVB incidences of 16 per cent have been reported (Bonavia et al. 1996), while in a study in Chile, 2,535 vines were tested for a range of viruses, with less than 1 per cent positive for GVB (Fiore et al. 2008). *Citrus yellow mosaic virus* is only found in India, where about 25 per cent of citrus production occurs in Andhra Pradesh, and where the incidence of CiYMV ranges from about 8 to 38 per cent (Naga et al 2014).

Mealybug-transmitted viruses are known only to be vectored by a small number of species, and in some cases by only a single species. Acquisition rates are typically around 25 to 50 per cent. For example, studies by Kubiriba et al. (2001) of the former 'banana streak virus' reported virus acquisition rates from banana leaves of 28 to 32 per cent for *Saccharicoccus sacchari*, and 26 to

48 per cent for *Dysmicoccus brevipes*; it should be noted however that the life stages of the mealybugs were not stated. However, in other studies, early instars were reported to transmit 'banana streak virus' more efficiently than later instars (Su 1998). Bertin et al. (2016), working with combinations of three grapevine viruses (GLRaV-1, GLRaV-3 and GVA) and *Planococcus ficus* and *P. citri* observed acquisition rates of between 33 to 52 per cent. Consequently, not all susceptible host plants in a crop will be infected, nor will all mealybugs capable of acquiring a given virus within a population become viruliferous.

Virus acquisition by mealybugs is unlikely to occur post-harvest

Pre-harvest, mealybugs can probably acquire viruses from most plant structures, with the likely exception of seeds (Roivainen 1980). They often acquire viruses from leaf, petiole and stem tissues, as these structures are the primary feeding sites for many species (Tsai et al. 2011). Mealybugs were reported to acquire CSSV from cocoa pods, but this study referred to virus acquisition pre-harvest (Posnette & Strickland 1948; Roivainen 1980).

There is no evidence of mealybugs acquiring a virus from produce post-harvest. There is limited evidence of other hemipteran species acquiring viruses from post-harvest fruit under laboratory conditions. For example, aphids were reported to acquire *Plum pox virus* from peach fruit and transmit it to seedlings (Gildow et al. 2004; Labonne & Quiot 2001) and *Bemisia tabaci* acquired *Tomato yellow leaf curl virus* from tomato fruit (Delatte et al. 2003). In contrast, Polston et al (2006) concluded that whiteflies were unable to acquire *Tomato yellow leaf curl virus* from capsicum fruit. Lecoq et al. (2003) reported post-harvest transmission, under experimental field conditions, of *Papaya ringspot virus* and *Zucchini Yellow virus* from infected intact melon fruits to test plants, possibly by aphids that were seen probing the fruit.

Without precluding the prospect of virus acquisition pre-harvest by other insects, the lack of any evidence that mealybugs can acquire virus from post-harvest produce, and the limited evidence that this occurs with other hemipteran species, suggests that even if feasible, this would likely be a rare event for mealybugs. Therefore, a mealybug is assessed as most likely to acquire a quarantine pest virus pre-harvest. This has implications for the risk assessment because the calculation of the virus retention period by a mealybug could be considered to commence at harvest. However, temperature can influence the development of mealybugs, and as a result, this may influence the virus retention period of mealybugs.

Effect of temperature on the development of mealybugs

Plant import pathway commodities typically arrive in Australia as non-refrigerated air freight, most of which are subject to cold storage both before and after air transportation, though refrigerated sea transport is also used for a number of commodities, such as citrus fruit and table grapes.

Post-harvest, perishable plant produce respire, taking in oxygen and releasing carbon dioxide and heat, and transpire, losing water. Fruits, especially climacteric fruits, also release ethylene during their development. Regulating post-harvest temperature and atmospheric conditions reduces the rate of deterioration of perishable produce, which is a commercial imperative (Brecht et al. 2003; Kader 2002, 2003; Wu 2010). Most leafy vegetables and temperate fruits are not chill-sensitive and can be stored between 0 °C to 4 °C, but many tropical and subtropical fruit and some root vegetables are chill-sensitive, and are often stored at 5 °C to 10 °C, or above (Kader 2002). Produce may also be expected to be exposed to fluctuations in temperature

during handling, transportation and storage; this is most likely to occur at retail outlets where some produce may encounter temperatures at or near ambient (Brecht et al. 2003).

Many mealybug species overwinter as second-instar nymphs, although for some species eggs, first-instars, and adult females can perform this function (Miller 2005). Franco et al. (2009) provide examples, including of *Pseudococcus maritimus* overwintering as eggs and first-instars under bark, and *Pseudococcus viburnum* overwintering within bark crevices as first instars, but rarely as second or third instars. In the USA, the main overwintering life stage for *Planococcus citri* is eggs (Kerns, Wright & Loghry 2015). Live mealybugs are also regularly intercepted on the plant import pathway under chilled conditions (Appendix B and Appendix D).

Temperature has a significant influence on the development of mealybugs (Amarasekare et al. 2008; Chong, Roda & Mannion 2008; Goldasteh et al. 2009; Santa-Cecilia et al. 2011; Sreedevi et al. 2013; Walton & Pringle 2005). Mealybug first-instar nymphs (crawlers) are known as the principal dispersal life stage (Ross, Pen & Shuker 2010). For that reason, they have particular importance to the likelihood of entry of a virus via a mealybug vector.

Goldasteh et al. (2009) studied the influence of temperature, ranging from 10 °C to 37 °C, on the development of *Planococcus citri* when held on coleus plants at 60 to 70 per cent relative humidity. Females and males successfully developed from eggs into adults at temperatures ranging from 15 °C to 32 °C, and from 18 °C to 32 °C, respectively. The time period required for this to occur progressively increased with decreasing temperatures below 25 °C. The period of first-instar development increased as temperature decreased—for those that developed as females, this was 16.14 ± 0.40 days at 15 °C, compared with 4.02 ± 0.07 days at 25 °C. For those that became males, this was 9.50 ± 0.24 days at 18 °C, compared to 3.03 ± 0.2 days at 25 °C. Nymph survival was optimal for all instars at 25 °C. All first instars died at 10 °C or 12 °C; the time period over which this occurred was not specified.

The lower temperature threshold for the development of *Pseudococcus longispinus* was estimated at about 8 °C (Santa-Cecilia et al. 2011). The development period for first instars was longer at lower temperatures— 32.2 ± 2.7 days at 15 °C compared with 9.8 ± 0.2 days at 25 °C. Mortality of first instars was 62.5 per cent at 15 °C, and 0 per cent at 25 °C; but the time period over which this occurred was not specified.

The lower temperature threshold for the development of *Planococcus ficus* was estimated at about 16.6 °C (Walton & Pringle 2005). The development period for first instars was longer at lower temperatures— 5.5 ± 0.1 days at 18 °C compared with 2.2 ± 0.1 days at 25 °C.

From these results it can be concluded that if plant produce is subjected to periods of lower temperatures during processes of transport and entry, this is likely to inhibit normal mealybug development, including that of the first instars, and this may prolong the virus retention period. It could also be inferred that mealybug metabolic rate and normal behaviours may be suppressed, including of feeding, adding further weight to the assessment that mealybugs are unlikely to acquire a virus from post-harvest produce. It is also plausible that prolonged exposure of mealybugs to lower temperatures may result in significant crawler mortality.

Virus retention by mealybugs

The virus retention period of mealybugs is predominantly reported (Table 5.4) to be no more than four days, and often much less, based on a range of studies (Bertin et al. 2016; Lister 1953;

Muturi et al. 2016; Posnette & Robertson 1950; Roivainen 1976; Tsai et al. 2008). However, these studies were almost always undertaken at ambient temperatures, and may not accurately represent the virus retention period at the lower temperatures expected during storage and transport on the plant import pathway.

Table 5.4 Virus retention period by mealybugs

Reference	Virus	Vector	Life stage and post-AAP conditions	Detection Method	Retention period
Posnette and Robertson (1950)	CSSV	<i>Planococcus citri</i>	Nymphs, fasted	Transmission	1.5 d
–	CSSV	<i>Formicococcus njalensis</i>	Nymphs, fasted	Transmission	1.5 d
Lister (1953)	CSSV	<i>F. njilensis</i>	Adults, fasted	Transmission	~2 d
–	CSSV	–	L1, fasted	Transmission	1 d
Roivainen (1976)	CSSV	<i>F. njilensis</i>	Nymphs, fasted	Transmission	4 d
Tsai et al. (2008)	GLRaV-3	<i>P. ficus</i>	L1, fed on virus non-host	Transmission	3 d
–	GLRaV-3	<i>P. ficus</i>	L1, fed on virus non-host	Immuno-capture PCR	2 d
Muturi et al. (2016)	Former 'BSV'	<i>Paracoccus burnerae</i>	L1, fed on virus non-host	RCA (Rolling circle amplification)	4 d
Bertin et al. (2016)	GVA, GLRaV-1, GLRaV-3	<i>P. citri</i> and <i>P. ficus</i>	L1, fed on virus non-host	PCR	3 to 4 d

Occasionally, longer virus retention periods by mealybugs have been reported, such as 5 days (Kubiriba et al. 2001), 6 days (Obok, Wetten & Allainguillaume 2014), and 8 days (Krüger et al. 2015). However, some aspects of these studies appear questionable. Kubiriba et al. (2001) incubated ELISA plates overnight and discerned positive virus retention based on an absorbance value twice that of the negative control. However, observed values were often very close to cut-off values, at times requiring consideration to three decimal places, and were vulnerable to subjective interpretation. Obok, Wetten and Allainguillaume (2014) concluded retention at 6 days based on a PCR product that was abruptly much greater than all preceding values, and comparable to that of the positive control, implying a false positive. The results published by Krüger et al. (2015) appear as an extreme outlier to the virus retention periods of mealybugs reported in all other studies.

In a semi-persistent, non-circulative mode of virus transmission, a virus is understood not to be retained by a mealybug through a moult (ecdysis) (Fereres & Raccach 2015; Hogenhout et al. 2008). The virus particles are thought to remain attached to the cuticle lining of the mouthparts (stylet channel) or the foregut (Fereres & Raccach 2015). When a mealybug moults, these structures are cast off and any attached virions are lost (Andret-Link & Fuchs 2005; Fereres & Raccach 2015; Nault 1997). Moults occur on the transition between each life stage as a mealybug develops. For example, in several studies CSSV was observed not to be retained by mealybugs through a moult (Cabaleiro & Segura 1997b; Longworth & Entwistle 1965; Martini 1959). Roivainen (1971) reported that *Formicococcus njalensis* retained CSSV through an L1 to L2 moult in 3 of 8 replicate experiments, based on a 5 day AAP and virus transmission by a total of 35 of 259 moulted individuals and 45 of 254 unmoulted individuals (13.5 and 17.7 per cent, respectively). Even if mealybugs can retain virus in some situations through a moult, the

majority are nevertheless expected to become non-viruliferous. No study has assessed virus retention through multiple moults.

Summary of importation

The pest risk assessment for mealybugs (Chapter 3) gave an indicative likelihood of importation for mealybugs of High. If a mealybug-transmissible virus was present in the export production area, a viruliferous mealybug may also be present.

Mealybugs have a semi-persistent mode of virus transmission and will usually retain a virus for no more than four days. A viruliferous mealybug that arrived within an export crop that was a non-host for the virus it carried would rapidly lose the virus without a source of re-infection. For such a mealybug to be viruliferous at the time of harvest, it would need to have arrived within the non-host export crop within a relatively restricted period of a few days prior to harvest. A viruliferous mealybug that arrived within an uninfected host export crop could remain viruliferous if it infected a plant and continued to feed, thus reacquiring the virus from a localised site of infection. However, it is much more likely that a viruliferous mealybug would be imported into the PRA area when the export crop is a virus host species with an established prevalence of virus infection and an accompanying viruliferous mealybug vector infestation.

Mealybugs are relatively small, and difficult to detect during routine commercial harvest and packing house inspections; mealybug species that transmit viruses are regularly intercepted on the plant import pathway, providing strong evidence of their close association with these crops, and their potential to facilitate virus entry.

Not all susceptible host plants within a crop will be infected by virus, and not all mealybugs capable of transmitting a given virus within a population are likely to become viruliferous. Neither eggs nor adult males present a pathway for virus entry. Although there may be rare exceptions, mealybugs usually do not retain viruses through moults, and their virus retention period is predominantly reported as four days or less.

There is no evidence of virus acquisition by mealybugs from produce post-harvest. Therefore, the virus retention period of mealybugs could be calculated from point of harvest. However, produce is subjected to reduced temperatures during periods of the entry process, which is likely to impede normal mealybug development and behaviours, including moulting and feeding. This may prolong the virus retention period of mealybugs beyond that reported at ambient temperatures.

As a result of consideration of the factors discussed, the (indicative) likelihood of importation is assessed as Low.

Likelihood (indicative) of distribution

The likelihood (indicative) that a quarantine pest badnavirus or GVB 'corky bark' strains will be distributed in a viable state in Australia following their importation on the plant import pathway and subsequently be transfer to a susceptible host is assessed as **Very low**.

The supporting evidence for this assessment is provided.

Viruliferous and non-viruliferous mealybugs do not differ in capability to disseminate

Viruliferous and non-viruliferous mealybugs are not expected to differ in their capability to disseminate. The pest risk assessment for mealybugs (Chapter 3) provided an indicative assessment of the likelihood of distribution of mealybugs as Moderate. This sets the maximum likelihood of distribution of an imported virus to a susceptible host plant (the end point of distribution), via a viruliferous mealybug. Initially, the likelihood of distribution of a virus is influenced by the characteristics of the mealybug that transmits it, including small size, cryptic behaviour and survival strategies.

Plant produce would be distributed via the import pathway wholesale and retail supply chains, and transport and storage conditions are not expected to preclude viable viruliferous mealybug distribution to the point of retail sale.

As discussed in Chapter 3, mealybugs are most likely to enter the environment following the disposal of waste, which is expected to occur at multiple locations throughout Australia. However, most of this waste would be likely to be held in rubbish bins for several days before collection and then disposed as municipal solid waste (MSW) to be processed accordingly, including landfill, or to a lesser extent by commercial composting as green waste (Atalia et al. 2015; EPHC 2009). The eventuality that a mealybug would persist through the MSW stream, and then gain access to a susceptible host is improbable. However, it is conceivable that a lesser quantity of mealybug-infested waste could enter the environment by other means, for example, through waste disposal in a domestic compost bin or as produce discarded on the ground. After disposal, most of this waste would be expected to deteriorate rapidly, or be consumed by wildlife, resulting in the likely death of less mobile mealybug life stages.

Mealybug life-stage and sex influences dispersal

The mobility of mealybugs differs between life-stages and sexes. First instar crawlers are almost certainly the life-stage most capable of dispersal (Barrass, Jerie & Ward 1994; Daane et al. 2012). However, if instars hatched from eggs present on post-harvest produce, they would not be viruliferous because mealybugs are not known to pass viruses transovarially (from parent to offspring), and as discussed previously, subsequent virus acquisition from post-harvest produce is considered unlikely.

Although still capable of movement, female mealybugs become progressively less mobile as they mature, and later instars and adults are less likely to disperse long distances unaided. Adult males are short lived, and may have a single pair of wings, or be wingless and morphologically degenerate (Williams 2004). However, adult males are incapable of virus acquisition or transmission because they have no functional mouthparts.

Thus, the mealybug life stage most likely to be viruliferous and capable of finding a susceptible host plant is the first instar nymph, irrespective of whether they are female or male. Other life stages are either incapable or less capable of dispersal and of distributing a virus to a susceptible host. Therefore, both the durability and distance over which crawlers can disperse is of greatest relevance.

Dispersal of mealybugs by walking

The crawler life stage of Coccoidea share characteristics including of small size and role as the primary dispersal life stage. They are considered unlikely to be capable of walking for prolonged

periods before they must feed, because of their relatively small energy reserves (Koteja 1990). *Pseudococcus njalensis* first instar nymphs were reported to crawl at a rate of about 5.7 cm per minute over paper, and that this life-stage comprised about 78 per cent of those that were mobile (Cornwell 1956). Labelled mealybug populations of up to 5,000 insects were studied under field conditions. After 3 days, the farthest distance any life stage moved from cacao slash piles was about 1.2 m over cacao leaf litter, and 60 cm over bare soil (Cornwell 1956). Traversing over soil was a greater impediment to nymphs than adults. In another experiment, the mortality of unfed first- and second instars after 4 day was about 90 per cent, and migrating nymphs were observed not to exhibit any marked directional orientation (Cornwell 1956).

Cornwell (1958) found that *P. njalensis* first-instar nymphs comprised about 92 per cent of the mobile population within the cacao tree canopy, and moved up to 8.5 m in search of new feeding sites, with dispersal increasing proportionally with the number of canopy bridges. Thus, mobility within the canopy may be better than on the ground, but is still limited to a relatively short distance. Studies of GLRaV-3 (Habibi & Nutter 1997) and GVB (Tanne et al. 1996) reported that the spatial pattern of mealybug-mediated virus spread within vineyards clustered around adjacent vines within rows rather than between rows, concluding it was likely that it reflected crawler dispersal occurring vine-to-vine via canopy bridges. *Pseudococcus maritimus* first-instars were reported to disperse less than one metre on grapevines, which was probably influenced by the ease of accessibility to suitable feeding sites (Grasswitz & James 2008).

As a result, dispersal by walking is assessed as unlikely to result in a viruliferous mealybug finding a susceptible host plant, other than if it were located within close proximity.

Airborne dispersal of mealybugs

Mealybug-infested waste discarded into the environment is most likely to be at or near ground level. Crawlers of Coccoidea are less likely to become and remain airborne for an extended period from ground level, relative to their potential to become airborne from an elevated position, such as from within a tree canopy—an improbable scenario during distribution. Crawlers of different species can exhibit either active or inactive dispersal behaviours, promoting or impeding them from becoming airborne (Hanks & Denno 1998; Washburn & Washburn 1984). However, such behaviour is likely to be of most significance where dispersal occurs from elevated structures.

Generally, horizontal dispersal distance can be estimated by $D = Uh/s$, where 'D' is the horizontal distance travelled downwind, 'U' is the wind speed, 'h' is the height of release, and 's' is the settling rate (Pasek 1988). Once airborne, a crawler would be prone to drift downwards under the influence of gravity, but its buoyancy is influenced by its size, mass and shape. However, it is acknowledged that their trajectory while airborne is also likely to be erratic because of air turbulence caused by up- and down-drifts (Pedgley 1982).

Hanks and Denno (1998) analysed non-standardized data from a range of field studies on windborne crawler dispersal. They concluded that distribution would likely be Negligible over distances greater than 100 m, and that the typically observed relatively short distances travelled by most windborne crawlers implied that aerial dispersal mainly assists relatively localised dispersal within a cluster of hosts rather than between clusters of hosts. Consistent with this view, over multiple years the spatio-temporal spread of mealybug-vectored grapevine viruses shows aggregation or clustering of infected vines between adjacent vines within a row and

across adjacent rows (Naidu et al. 2014). That is, aerial dispersal from the primary source of virus infection is relatively limited and localised. In agreement, Grasswitz and James (2008) reported aerial dispersal of *Pseudococcus maritimus* nymphs from grapevines to traps set at a height of 1.2 m (level with the vine's main lateral trunk) was most frequently less than 3 m, with few being transported to a distance of 8 m.

In consideration of these data, airborne dispersal during distribution is assessed as most likely to result in a viruliferous mealybug accessing a susceptible host plant over only a relatively limited distance, on a scale of metres to tens of metres.

Time elapsed and conditions during distribution

Mealybugs are most likely to acquire a virus pre-harvest, and at ambient temperatures the virus retention period for mealybugs is likely to be in the order of a few days. However, low temperatures are expected to delay mealybug development, including that of first instars, which may influence the virus retention period.

Hosts of the viruses under consideration in this risk assessment include banana, citrus and grapes. The recommended storage temperatures and estimated storage life of these commodities differ. For example, for banana these are about 13 °C to 15 °C for 7 to 28 days, limes 9 °C to 11 °C for 42 to 56 days, oranges 0 °C to 9 °C for 56 to 84 days, grapes 0 °C to 0.5 °C for 14 to 56 days, and for cherries –1 °C to 0.5 °C for 14 to 21 days (El-Ramady et al. 2015). Transportation and storage periods for such commodities may be in the order of weeks before retail sale, consumption, and the generation and disposal of infested waste.

Virus host plant accessibility

Badnavirus hosts such as banana, citrus and sugarcane are grown in commercial and domestic cultivation, or are present elsewhere in the environment, such as the native species *Commelina diffusa* (Bostock & Holland 2007) in Australia. Most of these host species are woody or perennial plants (Table 13.1 of Appendix F) and are grown year round within tropical and temperate Australia.

Grapevine virus B only infects grapevines. Grapevines are deciduous woody plants mainly grown under commercial and domestic cultivation within temperate regions of Australia.

Differing host plant ranges between mealybug species and the viruses they transmit

Most mealybug species that transmit quarantine pest viruses are polyphagous, with markedly wider host plant ranges than those of the viruses they vector (Table 5.5). For example, *P. citri* has about 250 host plant species (García Morales et al. 2018), whereas each of the viruses it is capable of transmitting is restricted to at most a few species.

Table 5.5 Comparative host ranges of selected mealybug species and the viruses they transmit

Mealybug	Host plants			Virus	Host plants	
	families	genera	species		number	hosts
<i>Dysmicoccus boninsis</i>	11	31	69	SCBMOV	1	sugarcane
<i>Dysmicoccus brevipes</i>	58	140	197	CSSV	4	cacao, cola, ceiba, adansonia
<i>Ferrisia virgata</i>	78	204	278	CSSV	4	cacao, cola, ceiba, adansonia
–	–	–	–	PYMoV	3	black/long pepper, betel vine

Mealybug	Host plants			Virus	Host plants	
	families	genera	species	acronym	number	hosts
<i>Planococcus citri</i>	82	191	250	BSVNV	1	banana
–	–	–	–	CSSV	4	cacao, cola, ceiba, adansonia
–	–	–	–	CIYMV	6	orange (sweet), orange (sour), pumelo, lime, lemon, grapefruit
–	–	–	–	ComYMV	1	<i>Commelina diffusa</i>
–	–	–	–	DBALV	1	<i>Dioscorea alata</i>
–	–	–	–	KTSV	1	<i>Kalanchoe blossfeldiana</i>
–	–	–	–	PYMoV	3	black/long pepper, betel vine
–	–	–	–	SCBMOV	1	sugarcane
<i>Pseudococcus ficus</i>	23	28	35	GVB	1	grapevine
<i>Planococcus minor</i>	71	193	249	PYMoV	3	black/long pepper, betel vine
<i>Pseudococcus longispinus</i>	82	157	214	CSSV	4	cacao, cola, ceiba, adansonia
–	–	–	–	GVB	1	grapevine
<i>Pseudococcus viburni</i>	89	236	330	GVB	1	grapevine
<i>Saccharicoccus sacchari</i>	1	8	13	SCBMOV	1	sugarcane

For a given mealybug species, host plants that are non-virus hosts comprise a wide range of crop, ornamental and naturalised species (García Morales et al. 2018) commonly grown within commercial, residential and natural environments within Australia. For example, the non-virus host plants of several key mealybug vector species include for:

- *Planococcus citri*—*Mangifera indica* (mango), *Ananas comosus* (pineapple), *Cucumis melo* (Melo), *Oryza sativa* (rice), *Prunus dulcis* (almond), *Solanum lycopersicum* (tomato), *Solanum tuberosum* (potato), *Medicago sativa* (lucerne), *Glycine max* (soybean), *Trifolium alexandrinum* (clover), *Ficus*, *Bougainvillea*, *Pittosporum*, *Euonymus*, *Hibiscus*
- *Planococcus minor*—*Ananas comosus* (pineapple), *Brassica oleracea* (cabbage), *Brassica rapa*, *Cucumis melo* (melon), *Cucumis sativus* (cucumber), *Glycine max* (soybean), *Phaseolus vulgaris* (beans), *Persea americana* (avocado), *Psidium guajava* (guava), *Passiflora edulis* (passion fruit), *Zea mays* (maize), *Capsicum annuum* (peppers), *Solanum lycopersicum* (tomato), *Zingiber officinale* (ginger), *Ficus*, *Dahlia*, *Impatiens*, *Euphorbia*, *Pelargonium*, *Jasminum officinale*
- *Pseudococcus longispinus*—*Mangifera indica* (mango), *Ananas comosus* (pineapple), *Asparagus officinalis*, *Punica granatum* (pomegranate), *Olea europaea* (olive), *Capsicum annuum* (peppers), *Solanum melongena* (eggplant), *Eucalyptus tereticornis*, *Magnolia*, *Ficus*, *Myrtus communis*, *Philodendron*, *Euonymus*, *Pittosporum*
- *Pseudococcus maritimus*—*Medicago sativa* (lucerne), *Trifolium* sp., *Solanum melongena* (eggplant), *Magnolia*, *Sambucus*, *Liquidambar styraciflua*, *Grevillea*.
- *Pseudococcus viburni*—*Actinidia* (kiwifruit), *Mangifera indica* (mango), *Allium sativum* (garlic), *Ananas comosus* (pineapple), *Brassica*, *Medicago sativa* (lucerne), *Glycine max* (soybean), *Passiflora edulis* (passion fruit), *Zea mays* (maize), *Solanum lycopersicum* (tomato), *Solanum tuberosum* (potato), *Trifolium fragiferum* (clover), *Ficus*, *Bougainvillea*, *Buxus*, *Euonymus*, *Pittosporum*, *Eucalyptus*.

The markedly different host plant ranges of mealybug species and the viruses they vector, along with the expected accessibility of these non-virus host species relative to virus hosts is likely to result in a high likelihood of a viruliferous mealybug being distributed to a plant species that is not a host of the virus it carries. In this scenario, virus distribution to a susceptible host would fail. This is a substantial factor moderating the likelihood of distribution for viruses.

Summary of distribution

The pest risk assessment for mealybugs (Chapter 3) gave an indicative likelihood of distribution for mealybugs of Moderate. This sets a maximum likelihood value for distribution of a viruliferous mealybug. Viruliferous and non-viruliferous mealybugs are not expected to differ in their capability to disseminate, and may be distributed in a viable state around Australia on imported produce via wholesale and retail supply chains.

Recommended storage temperatures and the duration of estimated storage life of host commodities, if realised, may lead to first instar mortality. However, it is likely that at least a proportion of viruliferous mealybugs will remain viable. Reduced temperatures impact mealybug development, and it is expected that commodities will be transported and stored at chilled temperatures before retail sale, consumption, and the generation and disposal of infested waste.

Mealybugs are most likely to enter the environment following the disposal of waste, which is expected to occur at multiple locations throughout Australia. However, most of this waste would be disposed as municipal solid waste and processed accordingly. The prospect that a mealybug would persist through this waste stream, and then access a susceptible host is considered improbable. A smaller quantity of mealybug infested waste could enter the environment by other means, but after disposal, most of this waste would be expected to deteriorate rapidly, and/or be consumed by animals, resulting in the probable death of, at least, the less mobile mealybug life stages.

The mobility of mealybugs differs between life-stages and sexes. If present, eggs and adult males do not present a pathway for the entry of viruses. First instar crawlers are almost certainly the most capable of dispersal, but their dispersal by walking and becoming airborne is limited and likely to result in relatively local dispersal. At ambient temperatures, crawlers have limited energy reserves, and if unfed, become incapable of movement and die after a few days. At ambient temperatures the virus retention period of mealybugs is measured in days. As a result there is a very narrow window for crawlers to find a host before they perish and/or their infectivity is lost.

There is a substantial disparity between the respective host ranges of quarantine pest viruses and the mealybug species that transmit them. It is expected that a large proportion of viruliferous mealybugs would find a plant host species that is not a host of the virus it carries, and that virus distribution to a susceptible host would thus fail.

In consideration of these factors, the (indicative) likelihood of distribution is assessed as Very low.

5.3 Likelihood of establishment

The likelihood that a quarantine pest badnavirus or GVB ‘corky bark’ strains will establish within Australia following their entry on the plant import pathway is assessed as **Moderate**.

Establishment is defined as the ‘perpetuation for the foreseeable future, of a pest within an area after entry’ (FAO 2017b).

The supporting evidence for this assessment is provided.

Virus perpetuation

Viruses need a host in which to replicate, and their ‘*perpetuation for the foreseeable future*’ usually necessitates that they continuously cycle from plant to vector and back again.

In many circumstances, the failure of the mealybug vector to establish is likely to result in the failure of the virus it transmits to establish, because the virus would not be perpetuated beyond the life-cycle of an individual host plant. Without a reservoir of virus infection in a host plant, the virus would also be rapidly lost from the vector population. However, some host plant species can propagate naturally vegetatively, or may be manually propagated and thus promote virus perpetuation. Several badnaviruses are seed transmissible, including CSSV, ComYMV and PYMoV, and KTSV is both seed and pollen transmissible (Bhat, Hohn & Selvarajan 2016; Hearon & Locke 1984). Therefore, these viruses have mechanisms that could facilitate their establishment independently of that of their mealybug vector. Furthermore, mealybug species that transmit some, but not all of the quarantine pest viruses are already present within Australia, and they could facilitate virus establishment, under certain circumstances. Consequently, the likelihoods of mealybug and virus establishment are not always correlated events.

There are four possible outcomes when considering virus establishment via a viruliferous mealybug in Australia: (i) a virus and its introducing mealybug vector establish; (ii) only the virus establishes; (iii) only the mealybug vector establishes; or (iv) neither establish.

Virus establishment via a viruliferous mealybug

The pest risk assessment for mealybugs (Chapter 3) provided a likelihood of establishment for mealybugs of High. Factors supporting this conclusion included their broad host range, and reproductive and adaptive survival strategies.

Viruliferous and non-viruliferous mealybugs are not expected to differ in their capability to establish, and commercial agricultural practices within Australia would be unlikely to prevent their establishment.

Host plant accessibility

A premise of the pest risk assessment process is that previous critical steps have already occurred—in this instance, meaning that the virus has been imported, distributed to, and transferred to a susceptible host. Therefore, an already explored and substantial moderating factor for virus distribution (Chapter 5.2), namely the markedly different host plant ranges of mealybug species and the viruses they vector, is assumed to have already been overcome prior to assessment of the likelihood of establishment.

Most host plant species of mealybug-vectored viruses are woody or perennial plants, such as citrus and grapevines (Table 13.1 of Appendix F), and potentially relatively long-lived. In a commercial setting, these crops are likely to be grown as mass plantings, which is conducive to virus establishment. Illustrating this point is the spatio-temporal spread of mealybug-vectored grapevine viruses as aggregations or clusters of infected vines (Naidu et al. 2014). The longevity of these hosts also tends to support virus establishment in non-commercial settings, although potential hosts in domestic locations are likely to be relatively more dispersed.

Virus acquisition and transmission

As discussed (Chapter 5.2), not all susceptible mealybugs that are exposed to a virus infected host will become viruliferous, or subsequently transmit a virus to a susceptible host plant. The likelihood that a virus will be perpetuated for the foreseeable future would be influenced by both virus acquisition and transmission efficiency rates. A decrease in the efficiency in either or both may substantially moderate the likelihood of establishment of a virus, via transmission by a viruliferous mealybug.

Mealybugs already present within Australia that transmit quarantine viruses

Several mealybugs already present within Australia can transmit badnaviruses. These mealybugs include *Dysmicoccus boninsis*, *D. brevipes*, *Ferrisia virgata*, *Planococcus citri* and *Saccharicoccus sacchari*. Collectively these species transmit six quarantine pest badnaviruses, namely SCBMov, ComYMV, DBALV, PYMoV, CiYMV and KTSV (Table 4.2). Two mealybug species that transmit GVB, *Pseudococcus longispinus* and *P. viburni*, are also present in Australia (Table 4.2). In a scenario where the mealybug that facilitated the entry of a virus failed to establish, the presence of a vector-competent local mealybug species could facilitate the establishment (and subsequently spread) of these viruses in Australia.

Other insects that transmit quarantine viruses

One badnavirus, PYMoV, is transmitted by *Diconocoris distanti* (de Silva, Jones & Shaw 2002), but this species is not known to occur in Australia. Ahlawat et al. (1985) reported that CiYMV could be experimentally transmitted by the aphids *Myzus persicae* and *Aphis craccivora*, but this has not been reported to occur in the field. These aphid species are present in Australia, and if this were confirmed, could facilitate CiYMV establishment (and subsequently spread) in Australia. GVB 'corky bark' strains are not known to be transmitted by insects other than mealybugs.

Previous virus establishment events within Australia

Several badnaviruses have already established in Australia, including BSIMV, BSMYV, BSOLV, SCBIMV, SRV and TaBV (Table 13.1 of Appendix F). Non-GBV 'corky bark' strains have also established in Australia (Table 13.1 of Appendix F). Although the pathway(s) for their entry cannot be identified with certainty, this provides evidence that the Australian environment can support the establishment of viruses of this group, and that their host plants were accessible.

Summary of establishment

The pest risk assessment for mealybugs (Chapter 3) provided a likelihood of establishment for mealybugs of High. Factors supporting this assessment included their broad host range, reproductive and adaptive survival strategies. Viruliferous and non-viruliferous mealybugs are not expected to differ in their capability to establish.

A key moderating factor on virus distribution, namely, the markedly different host plant ranges of mealybug species and the viruses they vector, has already been overcome prior to consideration of viral establishment. In addition, virus host plant species are long-lived, and in a commercial setting are likely to be grown as mass plantings, which is conducive to virus establishment. The longevity of hosts may also assist virus establishment in non-commercial settings where potential host plants are likely to be more dispersed.

If a mealybug that facilitated entry of a virus failed to establish, virus establishment is likely also to fail in most circumstances. However, it is possible that another established mealybug species may facilitate virus establishment (and subsequent spread) of some, but not all of these viruses. Some viruses are also seed- and/or pollen-transmissible, and in some cases hosts may also propagate vegetatively, either by unaided or assisted means.

In some circumstances, virus acquisition and transmission efficiency may influence the likelihood of virus establishment. Not all susceptible host plants within a crop become infected by a virus, and not all mealybugs capable of transmitting a given virus within a population are likely to become viruliferous. As mealybugs have a semi-persistent mode of virus transmission, the vector population would rapidly become non-viruliferous because virus titre within the host plant would take time to build up to levels that could be re-acquired by the vector population. It is probable that a virus will fail to establish within a susceptible host—on many occasions. This is particularly likely to occur where viral infection is still limited to a single, or a few plants. In such a scenario, without a source of virus infection, the mealybug population would rapidly become non-viruliferous. However, comparable viruses have established within Australia, signifying that the potential exists, in some situations at least.

In consideration of these factors, the likelihood of establishment is assessed as Moderate.

5.4 Likelihood of spread

The likelihood that a quarantine pest badnavirus or GVB ‘corky bark’ strains will spread within Australia following their establishment is assessed as **Moderate**.

Spread is defined as ‘the expansion of the geographical distribution of a pest within an area’ (FAO 2017b).

The supporting evidence for this assessment is provided.

In assessing the likelihood of spread, the premise is that the virus has already established. For the virus to establish in the field, ordinarily either the introducing mealybug vector has established, and/or a local mealybug vector is available to facilitate establishment. That both the virus and its vector are expected to be present within Australia provides an enduring source of infection, and the primary means of spread. Infected propagative plant materials also provide an additional pathway for the spread of these viruses.

Viruses can spread via (i) viruliferous mealybugs or (ii) the movement of infected plants and propagative materials.

The pest risk assessment for mealybugs (Chapter 3) provided a likelihood of spread for mealybugs of High. Factors supporting this conclusion included mealybug crawler dispersal by walking or by being airborne, or as contaminants on nursery-stock, vehicles or clothes.

Viruliferous and non-viruliferous mealybugs are not expected to differ in their capacity to spread.

Virus spread via a viruliferous mealybug

First instar crawlers are likely to be the primary life stage for dispersal (Barrass, Jerie & Ward 1994; Daane et al. 2012). As discussed (Chapter 5.2), viruliferous crawlers can disperse via (i) walking, and/or (ii) becoming airborne.

The dispersal capability of crawlers by walking is very limited, and local in nature (Cornwell 1956). Crawler dispersal is expected to be limited by their finite energy reserves (Koteja 1990), restricted by the terrain over which they must move, and subject to high mortality if they remain unfed (Cornwell 1956).

Airborne dispersal of crawlers can contribute to relatively localised dispersal (Grasswitz & James 2008; Hanks & Denno 1998) during distribution. However, in considering the likelihood of spread, it is anticipated that mealybugs are more likely to access the elevated canopy of host plants, from where they could become airborne. Established mealybug populations are also likely to be at considerably higher population densities than those expected to be present at the distribution step. Therefore, the potential number of crawlers available to become airborne, and the probable distance over which they will disperse, are likely to be greater. For example, Barrass, Jerie and Ward (1994) observed the aerial dispersal of *Pseudococcus longispinus* first instars from infested 4.5 m high trees to 3 m high traps placed at a distance 10 m. From their studies they predicted a dispersal range of about 50 km, given a constant wind run of 24 h.

Similarly, the observed airborne dispersal of scale insect crawlers of *Aonidiella aurantii* was at least 300 m from an infested grove of lemon trees (Willard 1974, 1976), and for *Matsuccoccus resinosa* this was at least 1.6 km from the canopy of red pine trees (Stephens & Aylor 1978).

Although assumed to be rare, it has been accepted that airborne crawler dispersal may also occur over much greater distances; this effect was used to explain some unexpected mealybug incursions that occur at longer distance from known sources of infestation, such as up to 260 km inland from an infested area on the Kenyan coast (Greathead 1990; Gullan & Kosztarab 1997).

Virus spread via infected propagative plant material

Propagative plant material is a significant pathway for the spread of plant pests. Several hosts, such as citrus and grapevine are likely to be present in plant nurseries servicing both commercial and domestic activities. Large volumes of whole plants and other propagative material are traded across Australia. Infected plants and propagative material is also likely to be traded if, for instance, virus disease expression is localised, rather than systemic, or is present as an asymptomatic infection.

In addition to propagative plant material being infected, this material may be infested with viruliferous mealybugs when traded, further enabling virus spread. The possibility that viruliferous mealybugs could be dispersed as contaminants on propagative plant material would be facilitated by factors that include mealybug's small size, cryptic habits, and survival and dispersal strategies.

Spread of viruses via infected propagative plant material, or via infestation with viruliferous mealybugs, would be aided by the extensive wholesale and retail supply chains that exist in

Australia for the movement of this material. However, commercially produced plants or other propagative material with easily observable virus disease (or infestation) symptoms may be unmarketable. In addition, the interstate movement of a range of plants species is subject to domestic biosecurity arrangements within Australia. These factors would be expected to moderate the likelihood of spread via this pathway, but it is plausible that it could remain a pathway for virus spread.

Badnaviruses can also spread via propagative plant material when they integrate into their host plant's genome. However, integration is fragmented, and commonly cannot reconstitute itself into an infective episomal form (Bhat, Hohn & Selvarajan 2016). While some badnaviruses are known to be able to reform infective viruses when exposed to abiotic stresses (Meyer et al. 2008), these viruses are not the subject of this risk assessment.

Virus retention period within mealybugs

As discussed (Chapter 5.2), mealybugs are reported to have a semi-persistent mode of virus transmission (Andret-Link & Fuchs 2005; Bertin et al. 2016; Fereres & Raccach 2015; Nault 1997; Tsai et al. 2008). The virus retention period by mealybugs at ambient temperatures is mostly reported to be no more than about four days, and often much less (Bertin et al. 2016; Lister 1953; Muturi et al. 2016; Posnette & Robertson 1950; Roivainen 1976; Tsai et al. 2008). Therefore, it is feasible that a significant proportion of viruliferous mealybugs may become non-viruliferous as they disperse to find a new host.

Host plant accessibility

As discussed (Chapters 2 and 5.2), most mealybug species that transmit quarantine pest viruses are polyphagous, with markedly wider host plant ranges than the viruses that they vector (Table 5.6). The markedly different host plant ranges of the mealybug species and the viruses they vector, along with the expected relative accessibilities of these non-virus host species in comparison to virus hosts, is likely to result in viruliferous mealybugs being dispersed to a plant species that is not a host of the virus it carries. In this scenario, virus spread to a susceptible host would fail, moderating the capacity for spread via a viruliferous mealybug. However, this is a lesser constraint on spread than on distribution, because the size of the established population of mealybugs potentially available to disperse is expected to be much greater, and failure of an individual viruliferous mealybug to find a suitable host is much less significant on outcome.

Australian environment

The Australian environment has demonstrably supported the spread of related viruses. However, Australia's agricultural production is diverse in composition and physically dispersed. Natural barriers exist between different production areas within Australia. Arid areas and long geographic distances exist between the east and the west of the continent, for example, the Nullarbor Plain, and Bass Strait separates the mainland from Tasmania. Climatic differentials also occur between the north and the south of the continent. It would be difficult for viruliferous mealybugs to naturally disperse via the movement of crawlers from one distant area to another.

Summary of spread

The pest risk assessment for mealybugs (Chapter 3) provided a likelihood of spread of mealybugs as High. Factors supporting this conclusion included mealybug crawler dispersal by

walking, becoming airborne, or as contaminants on nursery-stock, vehicles or clothes. Viruliferous and non-viruliferous mealybugs are not expected to differ in their capacity to spread. Further potential pathways for virus spread are through infected nursery-stock (including propagative plant materials), and for a few badnaviruses, by seed and pollen transmission.

Virus spread via infected propagative plant material, or its infestation with viruliferous mealybugs, would be aided by the extensive wholesale and retail supply chains that exist. However, commercially produced plants or other propagative material with easily observable virus disease (or infestation) symptoms may be unmarketable. In addition, the interstate movement of a range of plants species is subject to domestic biosecurity arrangements within Australia.

The dispersal ability of crawlers by walking is very limited. Relative to the situation at the distribution stage, the likely number of crawlers available to become airborne is substantially larger at the stage of spread, and the probable distance over which they may disperse is greater because the established population can access elevated plant structures. However, crawlers have a relatively short lifespan, and are likely to suffer high mortality during dispersal. Additionally, the virus retention period by mealybugs at ambient temperatures is no more than about four days, and often much less. A proportion of viruliferous mealybugs are likely to become non-viruliferous during dispersal before they find a suitable virus host.

The different host plant ranges of mealybug species and the viruses they vector, along with the expected relative accessibilities of non-virus host species relative to virus hosts, is likely to result in viruliferous mealybugs being dispersed to a plant species that is not a virus host, resulting in failure of virus spread. However, because of the greater population size available to disperse, failure of an individual viruliferous mealybug to find a suitable virus host is a less significant moderating factor than at the distribution stage.

Australia's agricultural production is diverse in composition and physically dispersed, and natural barriers exist between different production areas. Climatic differentials also occur between the north and south of the continent. It would be difficult for viruliferous mealybugs to naturally disperse via the movement of crawlers from one distant area to another. However, related viruses have spread within Australia, signifying that the potential exists in some situations.

In consideration of these factors, the likelihood of spread of mealybug vectored quarantine viruses is assessed as Moderate.

5.5 Overall likelihood (indicative) of entry, establishment and spread

The overall likelihood (indicative) that a quarantine pest virus carried by a mealybug will enter Australia on the plant import pathway, be distributed in a viable state to a susceptible host, establish in Australia, and subsequently spread within Australia is assessed as **Very low**.

The overall likelihood of entry, establishment and spread is determined by combining the likelihoods of entry (indicative), of establishment, and of spread using the matrix of rules shown in Appendix A. These likelihoods are summarised in Table 5.6.

Table 5.6 Likelihood of entry (indicative), establishment and spread for mealybug-vectored viruses

Step	Likelihood for	
	Badnaviruses	GVB 'corky bark' strains
Importation (indicative)	Low	Low
Distribution (indicative)	Very low	Very low
Overall likelihood of entry (indicative)	Very low	Very low
Establishment	Moderate	Moderate
Spread	Moderate	Moderate
Overall likelihood estimate (indicative)	Very low	Very low

5.6 Consequences

The overall consequences ratings for:

- Badnaviruses is estimated to be **Moderate**
- GVB 'corky bark' strains is estimated to be **Moderate**.

The potential consequences of the establishment of quarantine pest viruses in Australia have been estimated according to the method described in Appendix A. Impact scores for consequences ratings are summarised in Table 5.7 for badnaviruses and Table 5.8 for GVB 'corky bark' strains.

Table 5.7 Summary of consequences for badnaviruses

Consequences criterion	Impact (magnitude and geographical scale)	Impact score
Direct impact on plant life or health	Major significance at the district level	E
	Significant at the regional level	
	Minor significance at the national level	
Direct impact on other aspects of the environment	Indiscernible at the local, district, regional and national levels	A
Indirect impact on eradication and control	Major significance at the district level	E
	Significant at the regional level	
	Minor significance at the national level	
Indirect impact on international trade	Major significance at the local level	D
	Significant at the district level	
	Minor significance at the regional level	
Indirect impact on domestic trade	Major significance at the local level	D
	Significant at the district level	
	Minor significance at the local level	
Indirect impact on environment	Indiscernible at the local, district, regional and national levels	A
Overall consequences rating		Moderate

Table 5.8 Summary of consequences for GVB ‘corky bark’ strains

Consequences criterion	Impact (magnitude and geographic scale)	Impact score
Direct impact on plant life or health	Major significance at the district level Significant at the regional level Minor significance at the national level	E
Direct impact on other aspects of the environment	Indiscernible at the local, district, regional and national levels	A
Indirect impact on eradication and control	Major significance at the district level Significant at the regional level Minor significance at the national level	E
Indirect impact on international trade	Major significance at the local level Significant at the district level Minor significance at the regional level	D
Indirect impact on domestic trade	Major significance at the local level Significant at the district level Minor significance at the regional level	D
Indirect impact on environment	Indiscernible at the local, district, regional and national levels	A
Overall consequences rating		Moderate

These assessments of consequences considered only the impacts caused by badnaviruses or GVB ‘corky bark’ strains transmitted by mealybugs. It did not consider any additional impacts caused by the mealybugs that transmit them. A separate risk assessment was undertaken for mealybugs (Chapter 3).

The supporting evidence for this assessment is provided.

Direct impact on plant life or health

Impact scores are estimated for:

- Badnaviruses as **E**
- GVB ‘corky bark’ strains as **E**.

The direct impact of a badnavirus or of GVB ‘corky bark’ strains on plant life or health would be of major significance at the district level, significant at the regional level, and of minor significance at the national level, which has an impact score of ‘E’. This is because the impact would be expected to threaten economic viability through a large decrease in production of infected crops at the district level of a state or territory. Badnaviruses typically cause chlorotic mottles, necrotic streaks, deformed leaves and stunting. GVB ‘corky bark’ strains cause pitting, grooving and necrosis that reduces vine vigour, and can lead to vine death. Once infected a host plant will typically continue to be impacted for life. Infection typically reduces commercial yields, quality and/or marketability, but in the worst case scenario, near complete crop failures have been recorded. Industries are expected to be impacted significantly at the regional level. This would be of minor significance at the national level because Australia’s agricultural production is diverse in composition and physically dispersed, and not all areas of production in a given commodity are expected to be impacted.

Host crops

Badnaviruses cause significant economic consequences to crop production globally (Bhat, Hohn & Selvarajan 2016; Borah et al. 2013). This impact includes host plant species that comprise the plant import pathway, as illustrated and referenced in the pest categorisation for viruses transmitted by mealybugs (Appendix F). Examples of economically significant crops affected by badnaviruses include banana, cacao, piper, citrus and sugarcane.

Grapevine virus B is a *Vitivirus*. Vitiviruses are known around the world, predominantly for their involvement in the rugose wood disease complex of grapevine (Martelli 1993). The relationship between GVB and ‘corky bark’ disease (or ‘corky rugose wood’) is well documented (Bonavia et al. 1996). *Grapevine virus B* and ‘corky bark’ disease cause economic consequences to grapevines by impacting plant vigour and yield (Bonavia et al. 1996; Teliz et al. 1980), and as referenced in the pest categorisation for viruses transmitted by mealybugs (Appendix F).

Symptoms and disease incidence

Badnaviruses typically cause chlorotic mottles, necrotic streaks, deformed leaves and stunting (Borah et al. 2013), reducing commercial yields, quality and marketability. Badnaviruses affecting bananas generally cause chlorotic or necrotic streaks running parallel to the leaf veins, but can cause splitting of the pseudostem. In Australia, losses of seven per cent, with delays in harvest of about three weeks, have been reported (Daniells, Geering & Thomas 1998). In West Africa up to 90 per cent crop losses from badnaviruses in bananas have been reported (Lassoudière 1979). In India CiYMV is particularly common in sweet orange; in situations where disease incidence ranged from 10 to 70 per cent, fruit yields were reduced by 77 per cent, and some orchards experienced such declines that they were abandoned (Ahlawat et al. 1996a). Sugarcane-infecting badnaviruses have been recorded in most sugarcane growing regions of the world; in this crop they cause mild leaf freckling, but the extent of yield losses are not reported (Autrey et al. 1992). PYMoV causes vein-clearing, leaf distortion and interveinal chlorotic mottles (Lockhart et al. 1997a). In India, the incidence of PYMoV infection has been recorded to be 100 per cent in black pepper crops (Bhat et al. 2003).

Disease symptoms caused by GVB ‘corky bark’ strains commonly manifest at the graft union; in overview they include pitting, grooving and necrosis that reduces the vigour of the plant, resulting in reduced yield and poor quality fruit, and can lead to vine death (Bonavia et al. 1996; Tanne, Dubitzky & Bazak 1990). Teliz et al (1980) reported 35 to 76 per cent yield loss of the table grape variety ‘Cardinal’ in the Mexican state of Aguascalientes, noting that losses were higher on older vines.

Australian gross crop value

Assessing only the scale of selected industries known to be ‘at risk’ for viruses transmitted by mealybugs, Australia’s annual gross value of production (GVP)—the value of production at the point of sale—for these host crops in Australia are summarised. However, the actual impact on these industries caused by a given virus would not be expected to equate to the full extent of these GVP values.

Badnaviruses: For the FY 2014–15 the GVP of sugarcane was \$1.3 billion, citrus \$507.5 million and banana \$455 million (ABS 2016). Values of these examples of badnavirus hosts thus total

about \$2.3 billion. In addition, the Australian nursery-stock industry could also be impacted; for example, citrus propagative material is traded extensively across Australia.

GVB: For the FY 2014–15 the GVP of grapes for wine was \$764.8 million and \$343.3 million for grapes for other uses, giving a total value of potentially ‘at risk’ grape industries of about \$1.1 billion (ABS 2016).

Direct impact on other aspects of the environment

Impact scores are estimated for badnaviruses and GBV corky strains as **A**.

The direct impact of a virus on other aspects of the environment would be indiscernible at the local, district, regional and national levels, which has an impact score of ‘A’. These viruses are all reported only from cultivated hosts, with no evidence of them infecting native flora.

Weeds

Internationally, there is evidence to suggest these viruses have weed species as hosts. While movement of these viruses into weed species in Australia may be conceivable, any impact on weed species in the environment is unlikely to cause significant negative consequences.

Native flora

Badnaviruses: These viruses are unlikely to have a significant impact on native flora. One exception may be for CiYMV, which may have potential to infect native citrus in Australia, noting that this virus has been reported on a range of cultivated citrus varieties within India (Ahlawat et al. 1996a). Another exception may be ComYMV; in an overseas study (Lockhart & Khaless 1988), ComYMV was isolated from *Commelina diffusa*, which is an Australian native species that grows from tropical Queensland down the east coast of Australia to Victoria. However, no information about the virus impact on this plant species was provided. Members of this genus also include weedy species.

GBV: *Grapevine virus B* ‘corky bark’ strains are unlikely to have a significant impact on native flora. Although there are no native *Vitis* species in Australia, there are related Vitaceae belonging to the genera *Cayratia*, *Cissus*, *Parthenocissus* and *Tetrastigma* (Herbison-Evans & Ashe 2009) that could be affected by vitiviruses. However, there are no records of any of the vitiviruses present in Australia (GVA, GVB or GVD) affecting these plants, so it seems unlikely that ‘corky bark’ strains of GVB could affect native members of the Vitaceae.

Indirect impact on eradication and control

Impact scores are estimated for:

- Badnaviruses as **E**
- GVB ‘corky bark’ strains as **E**.

The indirect impact of a badnavirus or of GVB ‘corky bark’ strains on eradication and control would be of major significance at the district level, significant at the regional level, and of minor significance at the national level, which results in an impact score of ‘E’.

It is expected that efforts would be taken to contain and possibly eradicate an incursion of a quarantine pest virus within Australia. The economic viability of production would be

threatened through a large increase in costs for containment, eradication and control at the district level for a badnavirus or for GVB ‘corky bark’ strains. These actions would also cause significant disruption to agribusiness and associated trades within the affected area.

Should eradication and containment fail, commercial production practices would need to change to mitigate the impact from a virus, as infected plants would need to be removed and destroyed because no other control measure would be possible. The costs associated with the initial response to an incursion and the ongoing control of the introduced pest, including any additional research requirements, would be expected to be significant.

Containment and eradication

Australia has emergency response systems and protocols in place to respond appropriately to plant pest incursions. There is a formal, legally binding agreement between Plant Health Australia, the Australian Government, all state and territory governments and plant industry signatories, covering the management and funding of responses to Emergency Plant Pests—the Emergency Plant Pest Response Deed (PHA 2015). Under this framework, it is possible that biosecurity action(s) would be taken to contain and possibly attempt to eradicate an incursion of a quarantine virus within Australia.

In the case of Badnaviruses, attempts have been made internationally to contain or eradicate badnaviruses. For example, in Ghana, attempts to eradicate CSSV began in 1946. This failed eradication attempt was costly, with about 200 million trees removed, and as a result millions of dollars lost in production (Dzahini-Obiatey, Domfeh & Amoah 2010). Any action in response to a badnavirus incursion, whether successful or not, would undoubtedly be costly and cause significant disruption to impacted agribusiness and associated trades.

Commercial production

Should containment and eradication of one or more of these viruses be attempted and fail, industry might need to adjust production practices to mitigate their impact. This is likely to have cost implications. It is likely that some Australian scientific research effort may be diverted, post-incursion, into further resolving the virus epidemiology and appropriate production and pest management responses within the Australian context.

Indirect impact on international trade

Impact scores are estimated for:

- Badnaviruses as **D**
- GVB ‘corky bark’ strains as **D**.

The indirect impact of a badnavirus or of GVB ‘corky bark’ strains on international trade would be of major significance at the local level, significant at the district level, and of minor significance at the regional level, which has an impact score of ‘D’.

These viruses are all considered global pests. It is likely that trading partners may review their phytosanitary requirements for affected exported host commodities, including the possibility of suspending or stopping trade. Market access would need to be re-established. This could be expected to threaten economic viability through loss of trade and export markets. If trade is suspended or stopped, it is expected to have significant impact on host crop industries. The state

or territory government would have to spend resources to support affected industries and assist in regaining market access, which would have minor impact at the regional level.

These viruses are considered major global pests (Bhat, Hohn & Selvarajan 2016; Bonavia et al. 1996; Borah et al. 2013; Hadidi et al. 2011). In response to these viruses being identified in Australia's agricultural sectors, it is likely that trading partners would review their phytosanitary requirements for affected export commodities. Trading partners might close, at least transiently, existing market access and/or impose additional measures, consistent with their rights and obligations under the WTO SPS Agreement. Maintaining or re-establishing market access in response to trading partners' actions would place an additional resource burden on Australia's National Plant Protection Organisation (NPPO) and supporting biosecurity structures. Reduced export value and/or increased costs associated with the production and export of affected commodities would be expected. Additionally, future market access for these commodities might be more difficult and costly. Possibly, existing and/or future export trade in a range of affected host commodities could become uneconomical. Australia's response to any such potential action would be within the context that fruit is not likely to be a pathway for these viruses, and the conclusions of this analysis with respect to the likelihood that these viruses may be carried by a mealybug vector.

Badnavirus: The introduction of a quarantine pest badnavirus, such as *Citrus yellow mosaic virus*, which is currently only present in India, would have the potential to impact citrus exports. In the FY 2014–15, 160,894 tonnes of citrus with a value of \$206.2 million were exported from Australia to markets including Hong Kong, Japan, China, Malaysia, Indonesia, Singapore, Canada, China, New Zealand and Thailand (HIA 2016).

GVB: The hosts of GVB 'corky bark' strains are grapevines. Neither fresh table grapes or wine made from grapes are pathways for GVB. However, the presence of the virus and its vector could lead to restrictions. A total of 84,103 tonnes of table grapes with a value of \$240.2 million were exported in the FY 2014–15 (HIA 2016). The main export markets for fresh table grapes are Hong Kong, Indonesia, Singapore, United Arab Emirates and Thailand, countries in which GVB 'corky bark' strains are not present. GVB 'corky bark' strains are present in Israel, Japan, Europe and the Americas.

The indirect impact on international trade could lead to produce destined for export being sent onto the domestic market. In the short term, this might lower the domestic market price of affected commodities. However, industry adjustment would be expected in line with demand.

Indirect impact on domestic trade

Impact scores are estimated for:

- Badnaviruses as **D**
- GVB 'corky bark' strains as **D**.

The indirect impact of a badnavirus or of GVB 'corky bark' strains on domestic trade would be of major significance at the local level, significant at the district level, and of minor significance at the regional level, which has an impact score of 'D'.

Biosecurity measures would be enforced to prevent the movement of plant material out of the initial incursion area, which would be likely to have significant economic impact on plant

industries and business. The introduction of a new pest to a state or territory would disrupt interstate trade due to the biosecurity restrictions on the domestic movement of the host commodities.

Regional Biosecurity

In addition to Australia's international biosecurity activities, Australia operates a biosecurity system at state and territory level, which regulates domestic (interstate) movement of a range of plants and plant produce to mitigate the risk from regional pests. The introduction of a virus into Australia's agricultural/horticultural sectors would be expected to result in domestic movement restrictions on affected host commodities. Disruption to trade is likely to be significant to growers and the production areas affected. Compliance with domestic biosecurity requirements would impose additional costs on the agricultural/horticultural sectors. Depending on the specific circumstance, this might render part of existing and/or future interstate trade in affected commodities uneconomic. However, it is plausible that the introduced virus would establish and spread in multiple states/territories, over time mitigating part of this impact as the biosecurity requirements between affected regions equalised.

Indirect impact on the environment

Impact scores are estimated for:

- Badnaviruses as **A**
- GBV 'corky bark' strains as **A**.

The indirect impact of these viruses on environmental and non-commercial factors would be indiscernible at the local, district, regional and national levels, which results in an impact score of 'A'. No evidence was found indicating these viruses would have any significant indirect consequences on environmental and non-commercial activities.

Summary of consequences

Internationally, the quarantine viruses transmitted by mealybugs can cause significant economic consequences to fruit, vegetable, and nursery-stock production. Infection by these viruses typically reduces the commercial yields, quality or marketability of their hosts, but in the worst case scenario, near complete crop failures have been recorded.

Australian crops/sectors most at risk includes sugarcane, banana and citrus with combined annual GVPs of about \$2.1 billion and grapes with GVP of about \$1.2 billion. However, the actual impact on these industries caused by any given virus would not be expected to equate to the full extent of these GVP values. There is no evidence that these viruses would have a significant impact on the Australian natural environment. Indirect consequences would be expected in response to an incursion, including resourcing of containment and eradication efforts. Should containment and eradication fail, industry is ultimately likely to be able to adjust, but scientific research may be required to assist with this, with associated costs. Domestic and international trade in host crops is also likely to be disrupted, with potential for loss of markets and/or increased production and biosecurity compliance costs.

The impact scores for these viruses are summarised for badnaviruses in Table 5.7 and for GVB ‘corky bark’ strains in Table 5.8, following their entry, establishment and spread, as discussed under each criterion.

5.7 Unrestricted risk estimate (indicative)

Unrestricted risk is the result of combining the overall likelihood of entry (indicative), establishment and spread (Table 5.6) with the estimate of consequences (Tables 5.7 and 5.8). Likelihoods and consequences are combined using the risk estimation matrix in Appendix A. The unrestricted risk, for quarantine viruses transmitted by mealybugs is given in Table 5.9.

Table 5.9 Unrestricted risk estimate (indicative) for quarantine viruses transmitted by mealybugs

Risk component	Rating for	
	Badnaviruses	GVB ‘corky bark’ strains
Overall likelihood of entry (indicative), establishment and spread	Very low	Very low
Consequences	Moderate	Moderate
Unrestricted risk (indicative)	Very low	Very low

This PRA identified nine quarantine viruses (Table 5.1), eight badnaviruses and GVB ‘corky bark’ strains as quarantine pests for Australia. For the plant pathway, all of these viruses had an unrestricted risk estimate (indicative) that achieves the ALOP for Australia. Consequently, no additional risk management measures are required these viruses or the mealybugs that transmit them on the plant import pathway.

6 Key findings

6.1 Pest categorisation of mealybugs

The pest categorisation process determines whether a pest has the characteristics of a quarantine pest (FAO 2017b). Based on the selection criteria, 192 species were identified as mealybug pests of potential biosecurity significance to Australia (Table 9.1). A total of 175 species were considered further in the pest risk assessment: 169 species were deemed to be quarantine pests (Table 2.4) and six additional species were vectors of quarantine viruses but were not themselves quarantine pests. Eighteen species were both quarantine pests and vectors of viruses.

6.2 Pest categorisation of viruses transmitted by mealybugs

Virus species known to be transmitted by mealybugs were identified for pest categorisation. Twenty-six viruses are naturally transmitted by 24 mealybug species. Nine of these viruses were identified as quarantine pests for Australia and were considered further in the pest risk assessment.

6.3 Outcomes of pest risk assessments

This Group PRA undertook a pest risk assessment for mealybugs (Pseudococcidae, Putoidae and Rhizoecidae) as a group, and for the nine quarantine viruses transmitted by mealybugs.

Unrestricted risk estimates were calculated for each pest group by combining their respective overall likelihoods of entry, establishment and spread, with an estimate of consequences, and are summarised in Table 6.1.

Table 6.1 Summary of unrestricted risk estimates (indicative)

Risk Component	Mealybugs	Badnavirus	GVB 'corky bark' strains
Overall likelihood of entry (indicative), establishment and spread	Moderate	Very low	Very low
Consequences	Low	Moderate	Moderate
Unrestricted risk (indicative)	Low	Very low	Very low

The unrestricted risk estimates (indicative) for the mealybug pests (Table 3.5) was assessed as Low. An unrestricted risk of Low does not achieve the ALOP for Australia. Therefore, risk management measures would be required for these pests in specific trade pathways when the unrestricted risk estimate (indicative) has been verified to be Low.

The unrestricted risk estimate (indicative) for viruses transmitted by mealybugs in the badnavirus group and for *Grapevine virus B* 'corky bark' strains were assessed as Very low. An unrestricted risk estimate of Very low or Negligible achieves the ALOP for Australia. Consequently, no additional risk management measures are required these viruses or the mealybugs that transmit them on the plant import pathway.

6.4 No regulatory changes to mealybugs that transmit viruses

Since the unrestricted risk estimates for the viruses transmitted by mealybugs achieve the ALOP for Australia, no additional risk management measures are required for the mealybug species

that transmit these viruses. The six non-quarantine mealybug pests that transmit viruses are therefore proposed to continue to be non-regulated.

7 Pest risk management

The Group PRA has identified mealybug quarantine pests and viruses transmitted by mealybugs of biosecurity importance to Australia. However, the quarantine pest viruses transmitted by mealybugs did not require pest risk management on the plant import pathway to achieve the ALOP for Australia.

Imported commodities infested with quarantine pest mealybugs will be regulated to reduce the risk of establishment of these organisms in Australia. Regulation will be in accordance with this pest risk analysis and any other relevant commodity-based PRAs.

Measures are required to reduce the risk on such commodities to achieve the ALOP for Australia. Verification, such as inspection, will provide assurance that Australia's import conditions have been met and ALOP achieved.

This chapter identifies measures for mealybug quarantine pests and alternative risk management options that may be considered on a case-by-case basis when developing new import conditions for specific commodities, or reviewing existing import conditions for commodities that are currently traded.

7.1 Measures for quarantine mealybugs

Freedom from quarantine mealybugs

Measures are required if the indicative unrestricted risk estimate given in this Group PRA is verified for a specific commodity pathway and the ALOP for Australia is not achieved.

Measures are applied to ensure that goods in consignments are free from quarantine mealybugs. This will reduce the risk posed by quarantine mealybugs to an acceptable level.

Importers and NPPOs, as appropriate, are responsible for ensuring imported goods are presented that meet Australia's import conditions. Australia's requirements for freedom from quarantine mealybugs means that these mealybugs are either absent, or if present, dead or sterile, and thus unable to establish. This outcome can be achieved through commercial production practices and/or phytosanitary treatments.

Imported goods that are frequently found to be infested with mealybugs may be subject to mandatory treatment. Methyl bromide fumigation is an effective treatment currently used for quarantine pest mealybugs. Both the rate and duration of fumigation with methyl bromide are commodity specific. There are also alternative less commonly used, but potentially available, measures as outlined in Chapter 8 (Appendix A).

Any treatment applied to imported food must also meet Australia's food safety requirements

Verification

Verification measures, such as inspection, are required to provide assurance that Australia's import conditions and ALOP have been met. Additional verification may be required on a case-by-case basis. For example, evidence may be required to verify operational procedures have been undertaken where they are critical risk management control points in a managed pathway or part of a systems approach.

Pre-export inspection

Many fresh fruit, vegetable, cut-flower and foliage commodities are visually inspected pre-export by the exporting country NPPPO to verify that consignments are free from quarantine and regulated pests.

Where this is a required import condition, pre-export visual inspection must be undertaken by the NPPPO or under its authority in accordance with ISPM 23: *Guidelines for inspection* (FAO 2016f) and consistent with the principles of ISPM 31: *Methodologies for sampling of consignments* (FAO 2016h).

An international phytosanitary certificate (IPC) may be required on a case-by-case basis. The requirements for phytosanitary certificate are set out in ISPM 12: *Phytosanitary certificates* (FAO 2016d) and ISPM 7: *Phytosanitary certification system* (FAO 2016b).

On-arrival verification

The majority of fresh fruit, vegetables, cut-flowers and foliage imported into Australia are visually inspected by the department on arrival. This inspection verifies that imported goods comply with Australia's import conditions.

Consistent with the principles of ISPM 31: *Methodologies for sampling of consignments* (FAO 2016h), Australia's standard biosecurity sampling protocol requires inspection of 600 units for quarantine pests from systematically selected random samples from each homogeneous consignment or lot. If no pests are detected by the inspection, this size sample achieves a confidence level of 95 per cent that not more than 0.5 per cent of the units in the consignment are infested or infected. The level of confidence depends on each unit in the consignment having similar likelihood of being affected by a quarantine or regulated pest and the inspection technique being able to reliably detect all these pests in the sample. If no live pests are detected in the sample, the consignment is considered to be free from quarantine and regulated pests.

Any consignment that fails to meet Australia's import conditions will be subject to suitable remedial treatment where an effective treatment is available and biosecurity risks associated with applying the treatment can be effectively managed, or the imported consignment will be exported or destroyed.

The department reserves the right to suspend imports and conduct an audit of the risk management system if consignments are repeatedly non-compliant. Imports will recommence only when the department is satisfied that appropriate corrective action has been undertaken.

Additional operational procedures

Additional operational procedures may be required on a case-by-case basis for specific plant import pathways, such as:

- A system of traceability to source, where the objective is to ensure that export commodities are of commercial quality, that export sources can be identified, and prospective corrective action can be targeted if live pests are intercepted.
- Registration of packing house and treatment providers and auditing of procedures, where the objective is to ensure that export commodities are sourced only from packing houses and

treatment providers processing commercial quality export commodities approved by the NPPO, and that treatment providers competently manage target pests.

- Packaging and labelling, where the objective is to ensure that export packing houses and treatment providers (where applicable) ensure packaging is suitable to maintain the phytosanitary status of the export consignment, and labelling is sufficient for the purposes of trace-back.
- Specific conditions for storage and movement, where the objective is to ensure that export commodities that have been treated and/or inspected are kept secure and segregated at all times from other commodities for domestic or other markets, and from untreated/non pre-inspected product, to prevent mixing or cross-contamination.

7.2 Alternative options

Import conditions are developed and reviewed on a case-by-case basis for specific plant import pathways.

Australia recognises the principle of equivalence, namely, *‘the situation where, for a specified pest risk, different phytosanitary measures achieve a contracting party’s Appropriate Level of Protection’* (FAO 2017b). ISPM 24 (FAO 2017d) provides *Guidelines for the determination and recognition of equivalence of phytosanitary measures*. Where formal recognition of equivalence is required, the NPPO of the exporting country must provide a technical submission detailing relevant evidence for the proposed measures.

In regard to treatments, alternative options may be available, such as irradiation. Annex 19 of ISPM 28 (FAO 2016g) specifies a minimum absorbed irradiation dose of 231 Gy for the sterilisation of adult females of *Dysmicoccus neobrevipes*, *Planococcus lilacinus* and *Planococcus minor*. In relation to food, the Food Standards Australia New Zealand Code *‘Standard 1.5.3, Irradiation of Food’* permits an absorbed irradiation dose between 150 to 1,000 Gy (gray) as a phytosanitary measure that can be applied to a range of fruit and vegetables within Australia, subject to approval on a commodity-specific basis (FSANZ 2015).

- A number of other ISPMs provide guidance on pest risk management. These may be used as appropriate to achieve the objective of freedom from quarantine pest mealybugs.
- ISPM 4: Requirements for the establishment of pest free areas (FAO 2017a)
- ISPM 10: Requirements for the establishment of pest free places of production and pest free production sites (FAO 2016c)
- ISPM 14: The use of integrated measures in a systems approach for pest risk management (FAO 2017a)
- ISPM 22: Requirements for the establishment of areas of low pest prevalence (FAO 2016e).

7.3 Review of policy

The department reserves the right to review this Group PRA for mealybugs and the viruses they transmit on the plant import pathway if there is reason to believe that the pest or phytosanitary status of these organisms has changed, or is likely to change. Similarly, a review may be required, for example, where scientific evidence or other information subsequently becomes available which improves knowledge of, or decreases uncertainty in treatment efficacy and/or the equivalence of particular measures.

8 Appendix A: Group Pest Risk Analysis method

This chapter sets out the method used for the Group pest risk analysis (Group PRA) in this report.

The International Plant Protection Convention (IPPC) defines PRA as ‘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 2017b). A pest is ‘any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products’ (FAO 2017b).

International Standard for Phytosanitary Measures (ISPM) 2: Framework for pest risk analysis (FAO 2016a), states that ‘organisms may ... be analysed individually, or in groups where individual species share common characteristics’. This is the basis for the Group PRA in which organisms are grouped if they have shared common characteristics (with reference to their biosecurity significance), similar likelihoods of entry, establishment and spread and comparable consequences.

This Group PRA is not linked to any specific market access request. It is intended to be a ‘building block’ that can be used to review existing trade pathways or it can be applied to prospective ones for which a specific PRA is required, as appropriate.

When linked to a specific trade pathway using the rules set out in the report, it will be consistent with the principles of the International Standards for Phytosanitary Measures (ISPMs), including ISPM 2: Framework for Pest Risk Analysis (FAO 2016a) and ISPM 11: Pest Risk Analysis for Quarantine Pests (FAO 2017c) and the requirements of the SPS Agreement (WTO 1995).

The Department of Agriculture and Water Resources recognises there may be exceptional circumstances where risk differs significantly from the group. If technically justified, a specific risk assessment would be undertaken where such exceptions exist. The proposed approach is to confirm the applicability of this Group PRA when it is applied to a specific trade pathway.

A glossary of the key terms used in this Group PRA is provided at the back of this report.

This Group PRA was undertaken in three consecutive stages: initiation, pest risk assessment and pest risk management.

Stage 1: Initiation

This group pest risk analysis was initiated by the department.

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

This Group PRA considered all members of the three insect families Pseudococcidae, Putoidae and Rhizocidae (commonly referred to as mealybugs) that are associated with fresh fruit, vegetables and cut-flowers or foliage imported into Australia as commercial consignments from any country. These are referred to as the plant import pathway in this report. The Group PRA also deals with viruses transmitted by mealybugs.

For this risk analysis 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.

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 magnitude of associated potential economic consequences' (FAO 2017b).

In this Group PRA, the pest risk assessment was undertaken in several interrelated phases.

Pest Categorisation of mealybugs

The pest categorisation process identifies pests with the potential to be on the plant import pathway that are quarantine pests for Australia and as a result require pest risk assessment. A quarantine pest is 'a pest of potential economic importance to the area endangered thereby and not yet present there, or present and not widely distributed and officially controlled' (FAO 2017b).

Pest categorisation in the Group PRA was undertaken for mealybugs and for the viruses transmitted by mealybugs.

Factors considered in the pest categorisation of both the mealybugs species and all the viruses they transmitted were:

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

The results of pest categorisation are given in Tables 2.4 for mealybugs, and Table 4.3 for viruses. The quarantine mealybug and virus pests identified during categorisation were carried forward for pest risk assessment.

Assessment of the likelihood 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 2017c). The SPS Agreement (WTO 1995) uses the term likelihood rather than probability for these estimates. In qualitative PRAs, the Department of Agriculture and Water Resources uses the term 'likelihood' for the descriptors it uses for its estimates of the likelihood of entry, establishment and spread. The use of the term 'probability' is limited to the direct quotation of ISPM definitions.

A summary of this process is given in this chapter, followed by a description of the qualitative methodology used in this pest risk analysis.

This Group PRA initially considered the likelihood of importation and the likelihood of distribution (and therefore entry) in the terms of likely commercial conditions and procedures based on extensive contemporary and historic analysis of the plant import pathway. For this reason, the likelihood of entry in this Group PRA is indicative only and potentially subject to revision when all trade related factors are known. Accordingly, these factors must be verified, on a case-by-case basis, as part of a specific market access request.

Factors considered in assessing the ratings for likelihood of establishment and spread and the estimate of consequences are independent of entry pathway, being based on pest biology, environmental conditions and other commercial practices within Australia. Consequently, these ratings can be applied to all plant import pathways.

Likelihood of entry

The likelihood of entry describes the likelihood that a quarantine pest will enter Australia as a result of trade associated with the plant import pathway, be distributed in a viable state in the PRA area and be transferred to a susceptible host.

Entry is defined as the movement of a pest into an area where it is not yet present, or present but not widely distributed and being officially controlled (FAO 2017b).

For the purpose of considering the likelihood of entry, the Department of Agriculture and Water Resources divides this step into two components:

- likelihood of importation—the likelihood that a pest will arrive in Australia when a given plant import pathway commodity is imported.
- likelihood of distribution—the likelihood that the pest will be distributed, as a result of the processing, sale or disposal of a plant import pathway commodity, in the PRA area and subsequently transfer to a susceptible part of a host.

The overall likelihood of entry is determined by combining the likelihood of importation with that of likelihood of distribution.

Factors considered in the likelihood of importation include:

- distribution and incidence of the pest in the source area
- occurrence of the pest in a life-stage that could be associated with the commodity
- mode of trade (for example, bulk, packed)
- 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 applied to consignments during transport and storage in the country of origin, and during transport to Australia.

Factors considered in the likelihood of distribution include:

- commercial procedures applied to consignments during distribution in Australia
- dispersal mechanisms of the pest, including vectors, to allow movement from the pathway to a 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 hosts
- time of year at which import takes place
- intended use of the commodity
- risks from by-products and waste.

Likelihood of establishment

Establishment is defined as the ‘perpetuation for the foreseeable future, of a pest within an area after entry’ (FAO 2017b). In order to estimate the likelihood of establishment of a pest, reliable biological information (for example, lifecycle, host range, epidemiology and survival) 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 occurs and expert judgement used to assess the likelihood of establishment.

Factors considered in the likelihood of establishment include:

- availability of hosts, alternative hosts and vectors
- suitability of the natural and/or managed environment
- reproductive strategy and potential for adaptation
- minimum population needed for establishment
- cultural practices and control measures.

Likelihood of spread

Spread is defined as ‘the expansion of the geographical distribution of a pest within an area’ (FAO 2017b). The likelihood 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 likelihood 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 compared with that in the areas where the pest currently occurs and expert judgement used to assess the likelihood of spread in the PRA area.

Factors considered in the likelihood of spread include:

- suitability of the natural and/or managed environment
- presence of natural barriers
- potential for movement with commodities, conveyances or by vectors
- intended end-use of the commodity
- potential vectors of the pest in the PRA area

- potential natural enemies of the pest in the PRA area.

Assigning likelihoods for entry, establishment and spread

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 8.1). Descriptive definitions for these descriptors and their indicative ranges are given in Table 8.1. The indicative ranges are only provided to illustrate the boundaries of the descriptors and are not used beyond this purpose in qualitative PRAs. These indicative ranges provide guidance to the risk analyst and promote consistency between different pest risk assessments.

Table 8.1 Nomenclature for likelihoods

Likelihood	Descriptive definition	Indicative range
High	The event would be very likely to occur	$0.7 < \text{to} \leq 1$
Moderate	The event would occur with an even likelihood	$0.3 < \text{to} \leq 0.7$
Low	The event would be unlikely to occur	$0.05 < \text{to} \leq 0.3$
Very low	The event would be very unlikely to occur	$0.001 < \text{to} \leq 0.05$
Extremely low	The event would be extremely unlikely to occur	$0.000001 < \text{to} \leq 0.001$
Negligible	The event would almost certainly not occur	$0 < \text{to} \leq 0.000001$

Combining likelihoods

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 8.2). 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 likelihood of importation is assigned a descriptor of 'Low' and the likelihood of distribution is assigned a descriptor of 'Moderate', then they are combined to give a likelihood of 'Low' for entry. The likelihood for entry is then combined with the likelihood assigned for establishment of 'High' to give likelihood for entry and establishment of 'Low'. The likelihood for entry and establishment is then combined with the likelihood assigned for spread of 'Very low' to give the overall likelihood for entry, establishment and spread of 'Very low'. This can be summarised as:

Importation x distribution = entry [E]	Low x Moderate = Low
[E] x establishment = [EE]	Low x High = Low
[EE] x spread = [EES]	Low x Very low = Very low

Table 8.2 Matrix of rules for combining 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.

The department 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 the Department of Agriculture and Water Resources 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 the Department of Agriculture and Water Resources has an obligation to review the risk analysis and, if necessary, provide updated policy advice.

In assessing the volume of trade in this risk analysis the department assumed that a substantial volume of trade will occur.

Assessment of potential consequences

The objective of the consequences assessment is to provide a structured and transparent analysis of the potential consequences if the pests 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 2017b) and ISPM 11 (FAO 2017c).

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
- international trade
- domestic 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 chapter 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 consequences 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) using Table 8.3.

Table 8.3 Decision rules for determining consequences impact score

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

Note: In earlier qualitative PRAs, 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 to F has been changed to become B to G and a new lowest category A ('indiscernible' at all four levels) was added. The rules for combining impacts in Table 8.4 were adjusted accordingly.

Table 8.4 Decision rules for determining the overall consequences rating for each pest

Rule	The impact scores for consequences of direct and indirect criteria	Overall consequences 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

The overall consequences for each pest is achieved by combining the qualitative impact scores (A–G) for each direct and indirect consequences using a series of decision rules (Table 8.4). These rules are mutually exclusive, and are assessed in numerical order until one applies.

Estimation of the unrestricted risk

Once the assessments of the likelihood of entry, establishment and spread and potential consequences are completed, the unrestricted risk can be determined for each group of pests. This is determined by using a risk estimation matrix (Table 8.5) to combine the estimates of the likelihood of entry, establishment and spread and the overall consequences of pest establishment and spread. Therefore, risk is the product of likelihood and consequences.

When interpreting the risk estimation matrix, note the descriptors for each axis are similar (for example, 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.

Table 8.5 Risk estimation matrix

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

Appropriate level of protection (ALOP) for Australia

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. The ALOP for Australia reflects community expectations through government policy, and 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 8.5 marked ‘Very low risk’ represents the ALOP for Australia.

Stage 3: Pest risk management

Pest risk management describes the process of identifying and implementing phytosanitary measures to manage risks to achieve the ALOP for Australia, 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 does not achieve the ALOP for Australia, 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 the restricted risk achieves the ALOP for Australia.

ISPM 11 (FAO 2017c) 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 likelihood of entry of the pest.

Examples given of measures commonly applied to traded commodities include:

- options for consignments, include 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, including 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, including pest-free area, pest-free place of production or pest-free production site
- options for other types of pathways, including consider natural spread, measures for human travellers and their baggage, cleaning or disinfestation of contaminated machinery
- options within the importing country, including 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 unrestricted risk estimate does not achieve the ALOP for Australia. These are presented in the 'Pest Risk Management' chapter of this report.

9 Appendix B: Pest categorisation of mealybugs

In this Group PRA, pest categorisation was undertaken in each column as described.

Column 1 indicates the identity of the pest. The most recent valid scientific name is used, and some junior synonyms are also indicated when information related to the synonym is commonly found in the literature.

Column 2 gives the reason(s) why the species is included within the categorisation table, based on the selection criteria set out in Table 2.1.

Column 3 provides a global distribution for the species.

Column 4 assesses the species absence or presence and its regulatory status within the PRA area. Information was based on the published literature, including verifying the regulatory status of the species by accessing publically available plant quarantine legislation and manuals by the states and territories.

Column 5 includes host plants, plant parts affected and/or previous pathway assessment(s). Information for host plants and plant parts affected by the pest is summarised. Species identified by Australian industries as a high priority pest in relevant industry biosecurity plans are also indicated in this column.

Column 6 summarises interception events from Australia and other countries. Australian interception events are based on data within Appendix D, where 40 mealybug species were identified from a small proportion (10 per cent) of the 3,101 interception events. Interception records for other countries are mostly from the USA.

Column 7 identifies species requiring further assessment as a quarantine pest. If the pest is not present in Australia or present but under official control, it is considered further.

Note that the potential for establishment and spread, and potential for economic and environmental consequences in the PRA area were not presented for individual species in the categorisation table. Rather they were addressed for all the pest mealybugs as a group in sections 2.4 and 2.5, respectively. The determination of the quarantine status of each species (Column 7) took account of information in sections 2.4 and 2.5.

Column 8 identifies species requiring further assessment as a vector of a virus. All mealybug species reported to transmit viruses were considered further.

Table 9.1 Pest categorisation of mealybugs

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
PSEUDOCOCCIDAE							
<i>Anisococcus crawii</i> (Coquillett)	1	USA (García Morales et al. 2018; McKenzie 1967)	No record found (García Morales et al. 2018)	On four species of <i>Salvia</i> (Lamiaceae) and <i>Haplopappus pinifolius</i> (Asteraceae) (García Morales et al. 2018)	Intercepted in Australia on foliage in air baggage; on foliage of <i>Cynodon</i> sp. in air cargo; and on foliage of unknown plant and coconut in air baggage	Yes	No
<i>Antonina graminis</i> (Maskell)	1, 4, 5	Worldwide (García Morales et al. 2018; Kaydan & Kozár 2010; Matile-Ferrero & Étienne 2006; McKenzie 1967; Miller 2005; Moghaddam 2006; Suresh & Mohanasundaram 1996; Williams & Miller 2002)	Yes, NT, Qld, SA and WA (García Morales et al. 2018; Government of Western Australia 2015; Williams 1985a)	Mainly on stem bases and the rhizomes of grasses of numerous species of Poaceae including sugarcane and <i>Sorghum</i> (García Morales et al. 2018; Kaydan & Kozár 2010; Moghaddam 2006; Williams 1970, 2004)	Adult intercepted in Australia on <i>Cynodon</i> spp. for nursery stock On grass from the Philippines to San Francisco, USA (Williams 2004); on a diversity of grass hosts from nearly any warm part of the world to the USA (Miller et al. 2014a)	No	No
<i>Antonina maritima</i> Ramakrishna Ayyar	4	India and Sri Lanka (García Morales et al. 2018; Suresh & Mohanasundaram 1996)	No record found (García Morales et al. 2018)	On <i>Cyperus</i> , <i>Cynodon</i> and <i>Panicum</i> (García Morales et al. 2018; Williams 2004). Also on <i>Cenchrus glaucus</i> and <i>Cymbopogon martini</i> (Suresh & Mohanasundaram 1996)	–	Yes	No
<i>Antonina nakaharai</i> Williams & Miller	1	USA (Mainland and Hawaii), Asia and Europe (García Morales et al. 2018; Lee & Suh 2011; Miller 2005; Williams & Miller 2002)	No record found (García Morales et al. 2018)	In the axils of branches of many species of Poaceae (García Morales et al. 2018), including bamboos (Lee & Suh 2011; Williams & Miller 2002)	Intercepted before 1995 at USA ports of entry (Miller et al. 2014a); on a diversity of bamboo hosts from China and Japan to the USA (Miller et al. 2014a)	Yes	No
<i>Antonina pretiosa</i> Ferris	1	USA, Cuba, China and Indonesia (García Morales et al. 2018;	No record found (García Morales et al. 2018)	On the stems of bamboo, especially in the nodes and under the bracts, mainly	On bamboo from Cuba, Burma, China and the Philippines to the USA (Miller et al. 2014a)	Yes	No

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
<i>Antonina purpurea</i> Signoret	1	Gavrilov 2013; McKenzie 1967; Miller 2005; Miller, Miller & Watson 2002; Williams & Miller 2002) Europe (Green 1934; Sánchez-García & Ben-Dov 2010; Williams & Miller 2002)	No record found	bamboo species (McKenzie 1967; Ülgentürk, Porcelli & Pellizzari 2014; Williams & Miller 2002) and also a few other species of Poaceae (García Morales et al. 2018) On <i>Phyllostachys</i> , <i>Agropyrum</i> and a wide range of grass hosts (Green 1934; Williams & Miller 2002). Very common on Poaceae (Sánchez-García & Ben-Dov 2010)	On various grasses from France and Italy to the USA (Miller et al. 2014a)	Yes	No
<i>Antonina vietnamensis</i> Williams	1	Vietnam (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On bamboo (Williams 2004)	On bamboo from Vietnam to France (Miller et al. 2014a)	Yes	No
<i>Antonina zonata</i> Green	1	Asia (Ali 1967; García Morales et al. 2018; Williams & Miller 2002)	No record found (García Morales et al. 2018)	On several species of Poaceae including bamboo (García Morales et al. 2018; Williams & Miller 2002)	On bamboo from China to the USA (Miller et al. 2014a)	Yes	No
<i>Atrococcus paludinus</i> (Green)	1	Europe (Latvia, Turkey)(Kaydan et al. 2004; Malumphy & Ostrauskas 2008); Europe and Asia (García Morales et al. 2018)	No record found (García Morales et al. 2018)	On the leaves and at the bases of the stems of herbaceous woody plants (García Morales et al. 2018). Also on root of <i>Senecio</i> and other plants (Kaydan et al. 2004)	On <i>Codonopsis</i> from China to South Korea (Ji, Wu & Suh 2010)	Yes	No
<i>Brevennia rehi</i> (Lindinger)	1, 4	Worldwide, except Africa (García Morales et al. 2018; Miller 2005; Moghaddam 2006; Suresh & Mohanasundaram 1996)	Yes, NT, Qld (García Morales et al. 2018; Williams 1985a)	Beneath the leaf sheaths at the base of the host plants, on numerous species, mainly Poaceae (García Morales et al. 2018; Moghaddam 2006)	On grass hosts from India, Mexico, Puerto Rico and St. Thomas to the USA (Rung et al. 2006)	No	No

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
<i>Chaetococcus bambusae</i> (Maskell)	1	Worldwide (Beardsley 1966; García Morales et al. 2018; Gavrilov 2013; Hodges & Hodges 2004; Matile-Ferrero & Étienne 2006; Miller 2005; Miller, Miller & Watson 2002; Ülgentürk, Porcelli & Pellizzari 2014)	Yes, Qld (García Morales et al. 2018; Williams 1985a)	In groups on stem of the host beneath leaf sheath of many species of Poaceae (García Morales et al. 2018), including bamboo (Gavrilov 2013; Hodges & Hodges 2004; Ülgentürk, Porcelli & Pellizzari 2014)	On <i>Gigantochloa aspera</i> and <i>G. verticillata</i> from Indonesia and on bamboo from Sri Lanka to the USA (Williams 2004)	No	No
<i>Coccidohystrix insolita</i> (Green)	1, 4	Africa, Asia (China, Southern Asia), the Philippines, Guam and Western Samoa (García Morales et al. 2018; Lit, Caasi-Lit & Calilung 1998; Suresh & Mohanasundaram 1996)	No record found (García Morales et al. 2018)	On leaves and stems of a wide range of host plants (García Morales et al. 2018) including eggplant (Lit, Caasi-Lit & Calilung 1998), <i>Hibiscus</i> , <i>Abutilon</i> , <i>Clitoria</i> , <i>Cenchrus</i> , <i>Cynodon dactylon</i> and <i>Achyranthus aspera</i> (Suresh & Mohanasundaram 1996)	On <i>Schismatoglottis</i> sp. from the Philippines and on <i>Strongylodon</i> sp. from Thailand to Hawaii, USA and on unidentified plant from Vietnam to Los Angeles, USA (Williams 2004); adult female on young plant of <i>Alternanthera</i> sp. from Singapore to Japan (Tokihito 2006)	Yes	No
<i>Coccurea suwakoensis</i> (Kuwana & Toyoda)	5	China, Japan, North Korea and Russia (Danzig 2012; García Morales et al. 2018)	No record found (García Morales et al. 2018)	On branches and stems, near tips of twigs, females overwintering on basal part of trunk and in cracks of bark, on many host plants, including <i>Malus</i> , <i>Prunus</i> , <i>Rubus</i> and <i>Pyrus</i> (Danzig 2012; García Morales et al. 2018)	–	Yes	No
<i>Crisicoccus azaleae</i> (Tinsley) [as <i>Pseudococcus azalea</i> in (Fox-Wilson 1939)]	1, 5	USA and Japan (Fox-Wilson 1939; García Morales et al. 2018; Miller & Miller 2002)	No record found (García Morales et al. 2018)	On leaves and stems of azalea and two other hosts of Cupressaceae (Fox-Wilson 1939; García Morales et al. 2018; Miller & Miller 2002)	On azalea from Japan to the USA (Rung et al. 2006)	Yes	No

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
<i>Crisicoccus echinodes</i> Williams	1	The Philippines (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On <i>Lansium domesticum</i> and <i>Nephelium lappaceum</i> (Rung et al. 2006; Williams 2004)	On <i>Lansium domesticum</i> and <i>Nephelium lappaceum</i> from the Philippines to the USA (Miller et al. 2014a; Williams 2004)	Yes	No
<i>Crisicoccus hirsutus</i> (Newstead)	1	India (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	Described in a hollow bamboo with ant nests and reported from nine species of host plants in eight families (García Morales et al. 2018)	On <i>Mangifera indica</i> from India to New York and Boston, USA (Miller et al. 2014a; Williams 2004)	Yes	No
<i>Crisicoccus matsumotoi</i> (Siraiwa)	1, 5	Asia (Ezzat & McConnell 1956; García Morales et al. 2018; Park et al. 2010; Shiraiwa 1935; Williams 2004)	No record found (García Morales et al. 2018)	On a range of host plants (García Morales et al. 2018), including pear, Japanese maple, persimmon, walnut and fig (Ezzat & McConnell 1956; Park et al. 2010; Shiraiwa 1935) Assessed as on the pathway for Korean pear from South Korea (AQIS 1999b)	On <i>Codiaeum</i> sp. from the Philippines to Seattle, USA (Williams 2004); on <i>Chaenomeles</i> , <i>Codiaeum</i> , <i>Firmiana</i> and <i>Pyrus</i> from Japan and the Philippines to the USA (Miller et al. 2014a); on <i>Pyrus</i> from South Korea to the USA (Miller et al. 2014a)	Yes	No
<i>Crisicoccus pilosus</i> Ezzat & McConnell	1	India (Ezzat & McConnell 1956; García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On <i>Dahlia</i> sp. (García Morales et al. 2018; Williams 2004)	On <i>Dahlia</i> sp. from India to Hoboken, USA (Ezzat & McConnell 1956; Miller et al. 2014a; Williams 2004)	Yes	No
<i>Crisicoccus pini</i> (Kuwana)	1	USA, Asia and Europe (Danzig & Gavrilov 2010; Ezzat & McConnell 1956; García Morales et al. 2018; McKenzie 1967; Miller, Miller & Watson 2002)	No record found (García Morales et al. 2018)	On growing needles of <i>Pinus</i> species (Danzig & Gavrilov 2010; García Morales et al. 2018; McKenzie 1967)	On <i>Pinus</i> and <i>Taxus</i> from Japan to the USA (Miller et al. 2014a)	Yes	No
<i>Crisicoccus theobromae</i> Williams & Watson	1	Papua New Guinea and South Asia (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On four species of host plants in Punicaceae, Rubiaceae, Sapindaceae and Sterculiaceae	Adult, nymph and egg intercepted in Australia on piper betel	Yes	No

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
				(García Morales et al. 2018; Williams 2004)	On <i>Punica granatum</i> from Malaysia to Hawaii; on fruit of <i>Nephelium lappaceum</i> from the Philippines to the USA (Miller et al. 2014a; Williams 2004)		
<i>Dysmicoccus boninsis</i> (Kuwana)	1, 2, 4, 5	Worldwide (García Morales et al. 2018; Granara de Willink 2009; Matile-Ferrero & Étienne 2006; Miller 2005; Moghaddam 2006; Williams 2004; Williams & Granara de Willink 1992)	Yes, Qld (García Morales et al. 2018; Williams 1985a) Declared pest, prohibited by WA (Government of Western Australia 2018)	Beneath the leaf sheaths of sugarcane, on a wide range of host plants, mostly Poaceae but also on other plants (García Morales et al. 2018; Williams 1970; Williams & Watson 1988b); hosts include weeds such as <i>Lactuca</i> sp. (Moghaddam 2006)	Intercepted in Australia on grass for nursery stock in air cargo On sugarcane from nearly any warm part of the world to the USA; recently many interceptions from the Caribbean area but also from Africa, South America, Mexico and Southern Asia to the USA (Miller et al. 2014a)	Yes (WA)	Yes (Lockhart, Autrey & Comstock 1992)
<i>Dysmicoccus brevipes</i> (Cockerell)	1, 2, 4, 5	Worldwide (Beardsley 1959, 1993; Carter 1942; García Morales et al. 2018; Granara de Willink 2009; Ito 1938; Mani & Thontadarya 1987; Miller 2005; Watson & Kubiriba 2005; Williams & Granara de Willink 1992)	Yes, NSW, NT, Qld and WA (García Morales et al. 2018; Williams 1985a)	Highly polyphagous; on roots, leaves and natural cavities of a wide range of host plants including pineapple, bananas, sugarcane and rice (Beardsley 1959, 1993; García Morales et al. 2018; Ito 1938; Williams 1970); also found on some species of weeds (Pandey & Johnson 2006); on roots of <i>Melilotus indica</i> (Beardsley 1959); it has been reported as a pest of grapevine in India (Mani & Thontadarya 1987)	Adult and nymph intercepted in Australia on pineapple One of the most commonly intercepted mealybugs at U.S. ports of entry (Miller et al. 2014a); on <i>Saraca declinata</i> , <i>Ananas comosus</i> , <i>Ananas</i> sp., <i>Coffea canephora</i> , <i>Zea mays</i> and <i>Cyperaceae</i> from Indonesia to the USA; on <i>Ananas squamosa</i> from Laos to the USA; on <i>Ananas</i> sp. from Pakistan to India; from Malaysia on <i>Ananas</i> sp. to India and the USA; on <i>Araceae</i> to England and on <i>Nephelium lappaceum</i> to Hawaii; on <i>Areca catechu</i> , <i>Psidium guajava</i> , <i>Cocos nucifera</i> , <i>Ananas comosus</i> , <i>Mangifera indica</i> , <i>Kentia</i> sp., <i>Vanda sanderiana</i> , <i>Cyrtopodium</i>	No	Yes (Gambley et al. 2008a; Gambley et al. 2008b; Kirkpatrick 1950; Kubiriba et al. 2001; Meyer et al. 2008; Sether, Ullman & Hu 1998; Su 1999)

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
					<i>ciliare</i> , <i>Musa</i> and <i>Hedychium</i> from the Philippines to the USA; from Singapore on <i>Calathea</i> sp. and <i>Pandanus</i> sp. to the USA, and on <i>Ananas</i> sp. to India; from Sri Lanka on <i>Ananas comosus</i> , <i>Canna</i> sp. roots to the USA; on <i>Ananas</i> sp. to India and on an unknown host to England; from Thailand on <i>Ananas comosus</i> , <i>Cypripedium</i> sp., <i>Psidium</i> sp., <i>P. guajava</i> , <i>Zingiber</i> sp., <i>Areca catechu</i> , <i>Eugenia malaccensis</i> , Zingiberaceae, <i>Eriobotrya japonica</i> , <i>Annona</i> sp., <i>Nymphaea</i> sp. and <i>Piper nigrum</i> to the USA; from Vietnam on <i>Areca catechu</i> (Williams 2004); on <i>Ananas</i> , <i>Ficus</i> and <i>Rhapis</i> from China to South Korea (Ji, Wu & Suh 2010)		
<i>Dysmicoccus cocotis</i> (Maskell)	4	India and Pacific Islands (García Morales et al. 2018; Williams 1994)	No record found (García Morales et al. 2018)	On stems of coconut (<i>Cocos nucifera</i>) and also on <i>Calophyllum inophyllum</i> , <i>Roystonea regia</i> and <i>Pandanus odoratissimus</i> (García Morales et al. 2018; Williams 1994; Williams & Watson 1988b)	–	Yes	No
<i>Dysmicoccus finitimus</i> Williams	1	South Asia and Cocos Keeling Island (García Morales et al. 2018; Lit, Caasi-Lit & Laronia 2006; Williams 1994)	No record found (García Morales et al. 2018)	On <i>Areca catechu</i> , <i>Cocos nucifera</i> and <i>Corypha utan</i> (García Morales et al. 2018; Williams 1994, 2004)	On <i>Cocos nucifera</i> from Chagos Archipelago, the Philippines and Taiwan to the USA, and from India to Israel (Miller et al. 2014a; Williams 2004)	Yes	No
<i>Dysmicoccus grassii</i> (Leonardi)	1, 4, 5	Americas, Europe, Nigeria and Malaysia (Culik, Martins & Gullan 2006; García	No record found (García Morales et al. 2018)	On many host plants, including mango, papaya, acacia, banana, cacao, coffee and pineapple (Culik, Martins & Gullan 2006;	The most commonly intercepted species in the USA from tropical or subtropical localities on a wide diversity of hosts	Yes	No

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
[as <i>D. alazon</i> in (Williams & Granara de Willink 1992)]		Morales et al. 2018; Granara de Willink 2009; Miller 2005; Watson & Kubiriba 2005; Williams 2004; Williams & Granara de Willink 1992)		Culik, Ventura & dos S. Martins 2009; García Morales et al. 2018; Williams & Granara de Willink 1992) Assessed as on the pathway for pineapples - generic (AFFA 2002) and pineapples from Malaysia (DAFF 2012a)	especially coffee and cocoa (Miller et al. 2014a)		
<i>Dysmicoccus hambletoni</i> Williams & Granara de Willink	1	Costa Rica and Ecuador (García Morales et al. 2018; Granara de Willink 2009; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On roots of Araceae and Arecaceae (<i>Elaeis guineensis</i>) (García Morales et al. 2018; Williams & Granara de Willink 1992)	Intercepted from Ecuador to the USA (Miller et al. 2014a)	Yes	No
<i>Dysmicoccus lamsii</i> Williams	1	The Philippines (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On <i>Lansium domesticum</i> (Williams 2004)	On <i>Lansium</i> sp. and <i>L. domesticum</i> from the Philippines to the USA (Miller et al. 2014a; Williams 2004)	Yes	No
<i>Dysmicoccus lepelleyi</i> (Betrem)	1, 5	South Asia (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On a wide range of host plants, including mango, mangosteen, lychees and rambutan (García Morales et al. 2018; Williams 2004) Assessed as on the pathway for mangosteen from Indonesia (DAFF 2012b); lychees from Taiwan and Vietnam (DAFF 2013c)	Immature intercepted in Australia on mangosteen in air cargo On <i>Garcinia mangostana</i> from Cambodia to the USA; on <i>Nephelium lappaceum</i> , <i>Garcinia mangostana</i> , an unknown host and <i>Musa</i> from Indonesia to the USA; on <i>Dracaena</i> from Malaysia to Hawaii; on <i>Psidium guajava</i> , <i>Garcinia mangostana</i> and <i>Lansium domesticum</i> from the Philippines to the USA; on <i>Garcinia mangostana</i> from Singapore to the USA; on <i>Garcinia mangostana</i> , <i>Litchi</i>	Yes	No

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
					<i>sinesnsis</i> , <i>Nephelium lappaceum</i> from Thailand to the USA; on <i>Garcinia mangostana</i> , kaffir lime from Thailand to England; from Vietnam on <i>Musa</i> sp. to Russia, and on <i>Nephelium lappaceum</i> , <i>Annona cherimola</i> , <i>Annona</i> sp., <i>Garcinia mangostana</i> , <i>Nephelium litchi</i> , <i>Nephelium</i> sp. and <i>Psidium guajava</i> to the USA; on <i>Garcinia mangostana</i> from Korea and Taiwan to the USA (Miller et al. 2014a; Williams 2004)		
<i>Dysmicoccus mackenziei</i> Beardsley	1	Americas, Sri Lanka and Italy (García Morales et al. 2018; Granara de Willink 2009; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On many host plants, including banana, coffee, pineapple and other bromeliads (García Morales et al. 2018; Williams & Granara de Willink 1992)	On <i>Tilandsia</i> sp. from Sri Lanka to England (Williams 2004); on bromeliads from Central America and Mexico to the USA (Miller et al. 2014a)	Yes	No
<i>Dysmicoccus neobrevipes</i> Beardsley	1, 2, 4, 5	Pacific Islands, Americas, Asia, Italy and Sicily (Beardsley 1959, 1993; García Morales et al. 2018; Granara de Willink 2009; Malumphy, Ostrauskas & Pye 2008; Rohrbach et al. 1988; Williams 2004; Williams & Granara de Willink 1992)	No record found (Beardsley 1993; García Morales et al. 2018)	Highly polyphagous. On a wide range of host plants, including banana, citrus, pineapple and mangosteen (García Morales et al. 2018; Rohrbach et al. 1988; Williams 2004; Williams & Granara de Willink 1992). Also on <i>Alpinea purpurata</i> (red ginger), <i>Nothopanax</i> sp., <i>Thespesia populnea</i> , <i>Opuntia megacantha</i> and <i>Acacia farnesiana</i> (Beardsley 1959) Assessed as on pathway for Pineapples – generic (AFFA 2002); mangosteen from	Adult intercepted in Australia on <i>Sansevieria</i> spp. for nursery stock; on custard apple; adult and nymph intercepted on banana On <i>Annona reticulata</i> and <i>Musa coccinea</i> from India to the USA; on <i>Ananas comosus</i> from Malaysia to the USA; on <i>Nephelium lappaceum</i> from Pakistan to the USA; on bulbs of <i>Allium cepa</i> to England, <i>Annona reticulata</i> , <i>Annona squamosa</i> , <i>Annona</i> spp. <i>Garcinia mangostana</i> , Orchidaceae, <i>Musa</i>	Yes	Yes (Carter 1963; Sether & Hu 2002; Sether et al. 2012; Sether et al. 2005; Sether, Ullman & Hu 1998)

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
				Thailand (DAFF 2004b); bananas from the Philippines (Biosecurity Australia 2008b); pineapples from Malaysia (DAFF 2012a) Identified as high priority pest for the pineapple industry by Plant Health Australia	spp. <i>Mussaenda oona</i> , <i>Pandanus</i> sp., <i>Artocarpus altilis</i> , <i>Brassica oleracea</i> , <i>Mangifera indica</i> , <i>Lansium domesticum</i> , <i>Annona squamosa</i> , <i>A. musicata</i> , <i>A. cherimola</i> , <i>Manilkara zapota</i> , <i>Cocos nucifera</i> , <i>Colocasia esculenta</i> , <i>Psidium guajava</i> , <i>Aglaonema</i> sp., <i>Tamarindus indica</i> , <i>Syzygium malaccensis</i> from the Philippines to mainland USA; on 'Dona Aurua' <i>Annona squamosa</i> , <i>Psidium guajava</i> , <i>Agave</i> sp., <i>Ananas</i> sp. from the Philippines to Guam; on <i>Pandanus</i> sp. from Thailand to the USA; on <i>Garcinia mangostana</i> from Vietnam to the USA (Miller et al. 2014a; Williams 2004); on agave and tropical fruits from many areas in South America to the USA (Miller et al. 2014a); on <i>Schefflera</i> and <i>Yucca</i> from China to South Korea (Ji, Wu & Suh 2010)		
<i>Dysmicoccus nesophilus</i> Williams & Watson	5	Pacific Islands and Papua New Guinea (García Morales et al. 2018)	No record found (García Morales et al. 2018)	On wide range of host plants including citrus, mango, ficus, mangosteen and papaya (García Morales et al. 2018; Williams & Watson 1988b) Assessed as on pathway for papaya from Fiji	–	Yes	No
<i>Dysmicoccus orchidum</i> Williams	1	South and South East Asia (García Morales et al. 2018)	No record found (García Morales et al. 2018)	On many species of Orchidaceae including <i>Dendrobium</i> and <i>Phalaenopsis</i>	On <i>Vanda</i> sp. from India to the USA; <i>Bulbophyllum</i> sp. from Indonesia to the USA;	Yes	No

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
		et al. 2018; Williams 2004)		(García Morales et al. 2018; Williams 2004)	<i>Phalaenopsis</i> sp. from Malaysia to Honolulu; <i>Phalaenopsis grandiflora</i> roots and leaf, <i>P. amabilis</i> , <i>P. sandersana</i> , <i>P. luedemanniana</i> , <i>P. schilleriana</i> , <i>Cymbidium finlaysonianum</i> , <i>Grammatophyllum sriptum</i> , <i>Vanda boxallii</i> , <i>V. limbata</i> , <i>Dendrobium</i> sp., <i>D. dearei</i> , <i>D. aureum</i> , <i>D. schultsei</i> , <i>Phaius flavus</i> , orchid, Orchidaceae, <i>Phalaenopsis</i> , <i>P. aphrodite</i> , <i>Vanda coerulea</i> from the Philippines to the USA; on orchid, <i>Dendrobium</i> sp. from Thailand to the USA (Miller et al. 2014a; Rung et al. 2006; Williams 2004)		
<i>Dysmicoccus probrevipes</i> (Morrison)	1	Central and South America (García Morales et al. 2018; Granara de Willink 2009; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	Within swellings of host plants, including coffee (García Morales et al. 2018). Also <i>Cordia</i> sp., <i>C. alliodora</i> , <i>C. gerascanthus</i> , <i>Triplaris</i> sp. and <i>T. cumingiana</i> (Granara de Willink 2009; Williams & Granara de Willink 1992)	Intercepted from Central and South America to the USA (Miller et al. 2014a)	Yes	No
<i>Dysmicoccus</i> sp. nr. <i>texensis</i> [as <i>Dysmicoccus</i> sp. nr. <i>bispinosus</i> previously but <i>D. bispinosus</i> is now a junior synonym of <i>D. texensis</i> . (García Morales et al. 2018)]	1, 2	Central and South America (Miller et al. 2014a)	No record found (Miller et al. 2014a)	Present on roots, stems and leaves of host (Rung et al. 2006); on tropical plants, especially banana (Armijos 2004; Miller et al. 2014a)	Intercepted 33 times on a variety of hosts at U.S. ports-of-entry between 1995 and 2012; commonly intercepted on different tropical plants, especially banana from Central and South America (Rung et al. 2006)	Yes	Yes (Armijos 2004)

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<i>Dysmicoccus texensis</i> (Tinsley) [as <i>Dysmicoccus bispinosus</i> in (Matile-Ferrero & Étienne 2006; Miller, Miller & Watson 2002) and (Williams & Granara de Willink 1992)]	1, 4	Americas (García Morales et al. 2018; Granara de Willink 2009; Matile-Ferrero & Étienne 2006; Miller 2005; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On numerous host plants, including mango, acacia, banana, citrus (García Morales et al. 2018), <i>Cyperus</i> sp., <i>Coffea arabica</i> , <i>Abaca</i> sp. (Granara de Willink 2009), grapes (Pacheco da Silva et al. 2014), <i>cassava</i> (Matile-Ferrero & Étienne 2006)	–	Yes	No
<i>Dysmicoccus viatorius</i> Williams	1	The Philippines (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On fruit of <i>Lansium domesticum</i> , also on <i>Annona muricata</i> (García Morales et al. 2018; Williams 2004)	On <i>Lansium domesticum</i> (fruit), <i>Lansium</i> sp., <i>Annona muricata</i> , and many other interceptions from the Philippines to the USA (Miller et al. 2014a; Williams 2004)	Yes	No
<i>Dysmicoccus wistariae</i> (Green)	1, 5	Canada, USA, North Asia and Micronesia (Beardsley 1966; García Morales et al. 2018; Miller 2005; Park et al. 2010)	No record found (García Morales et al. 2018)	Overwinter as first instars in bark crevices (García Morales et al. 2018); on many host plants including <i>Malus</i> , <i>Prunus</i> and <i>Pyrus</i> (García Morales et al. 2018) Assessed on pathway for Fuji apples from Japan (AQIS 1998a) and Korean pear from South Korea (AQIS 1999b)	–	Yes	No
<i>Exallomochlus camur</i> Williams	1	Asia (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On eleven species of plants from nine families including persimmon, lychee, fig and cacao (García Morales et al. 2018; Williams 2004)	On <i>Sandoricum</i> sp., <i>Lansium domesticum</i> from Malaysia to the USA; <i>Lansium domesticum</i> , <i>Psidium guajava</i> , <i>Litchi</i> sp., <i>Annona</i> sp. from the Philippines to the USA; <i>Nephelium</i> sp. from Thailand to the USA; <i>Dyospyros</i> sp. from Korea to the USA; <i>Lansium domesticum</i> from	Yes	No

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<i>Exallomochlus hispidus</i> (Morrison)	1, 4, 5	South Asia (García Morales et al. 2018; Williams 2004; Williams & Miller 2010)	No record found (García Morales et al. 2018)	On stems and fruit of a wide range of host plants, including coconut, longan, figs, cacao, mangosteen and sugarcane (García Morales et al. 2018; Williams 2004; Williams & Miller 2010) Assessed as on pathway for mangosteen from Indonesia (DAFF 2012b)	Taiwan to the USA (Miller et al. 2014a; Williams 2004) Adult intercepted in Australia on fresh fruit From Indonesia, on <i>Garcinia mangostana</i> to England and France; on <i>Annona muricata</i> , <i>Garcinia mangostana</i> and <i>Nephelium lappaceum</i> to the USA; from Malaysia on <i>Nephelium lappaceum</i> to England and the USA; from the Philippines on <i>Lansium domesticum</i> and <i>Garcinia mangostana</i> to the USA; from Singapore on <i>Licula spinosa</i> , <i>Garcinia mangostana</i> , <i>Durio zibethinus</i> and <i>Theobroma cacao</i> to the USA; from Thailand on <i>Durio zibethinus</i> , <i>Durio</i> sp., <i>Garcinia mangostana</i> and <i>Nephelium lappaceum</i> to the USA; from Vietnam on <i>Garcinia</i> sp. to the USA (Miller et al. 2014a; Williams 2004)	Yes	No
<i>Exallomochlus liti</i> Williams	1	The Philippines (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On fruit of <i>Lansium domesticum</i> , <i>Musa</i> sp. and <i>Poikilospermum suaveolens</i> (Miller et al. 2014a; Rung et al. 2006; Williams 2004)	On fruit of <i>Musa</i> sp., fruit of <i>Lansium domesticum</i> , and <i>Poikilospermum</i> from the Philippines to the USA (Miller et al. 2014a; Williams 2004)	Yes	No
<i>Exallomochlus philippinensis</i> Williams	1	The Philippines (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On a small number of host plants including rambutan, Spanish lime and sapote (García Morales et al. 2018; Williams 2004)	On <i>Euphoria longana</i> , <i>Lansium domesticum</i> , <i>Manilkara zapota</i> , <i>Melicoccus bijugatus</i> , <i>Nephelium lappaceum</i> from the Philippines	Yes	No

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<i>Ferrisia gilli</i>	2	The USA (García Morales et al. 2018)	No record found (García Morales et al. 2018)	In orchards and vineyards in California (García Morales et al. 2018)	to the USA (Miller et al. 2014a; Williams 2004)	Yes	Yes (Wistrom et al. 2016)
<i>Ferrisia malvastrae</i> (McDaniel) [as <i>F. consobrina</i> in (Williams & Granara de Willink 1992)]	1, 4, 5, 6	Europe, Africa, South Asia, Pacific, USA (Donat et al.) and South America, (Culik, Martins & Gullan 2006; García Morales et al. 2018; Miller 2005; Walton & Pringle 2004a)	Yes, Qld (García Morales et al. 2018) Declared pest, prohibited by WA (Government of Western Australia 2018)	On a large number of host plants including citrus, mango, macadamia (García Morales et al. 2018), avocado, herbs and spices (García Morales et al. 2018) and grapevine (Walton & Pringle 2004a) Assessed as on pathway for mangoes from India (Biosecurity Australia 2008a)	Adult intercepted in Australia Intercepted in the USA (Miller et al. 2014a)	Yes (WA)	No
<i>Ferrisia virgata</i> (Cockerell)	1, 2, 4, 5	Americas, Europe, Africa, Asia and the Pacific (Abul-Nasir, Swailem & Dawood 1975; Brunt & Kenten 1962; Culik, Martins & Gullan 2006; García Morales et al. 2018; Gavrilo 2013; Hassan, Radwan & El-Sahn 2012; Lit, Caasi-Lit & Calilung 1998; Posnette & Strickland 1948; Suresh & Mohanasundaram 1996; Watson & Kubiriba 2005; Williams 1960) Note that some records of <i>Ferrisia</i>	Yes, Qld, NT, WA (García Morales et al. 2018; Government of Western Australia 2015; Williams 1985a)	Feeds on cacao beans and leaves (Posnette & Strickland 1948). Also found in sugarcane (Williams 1970), <i>chrysanthemum</i> (Abul-Nasir, Swailem & Dawood 1975), eggplant (Lit, Caasi-Lit & Calilung 1998), banana (Watson & Kubiriba 2005), guava, acacia, tomato, pomegranate (Suresh & Mohanasundaram 1996), coffee, cacao and mango (Kondo 2001) Assessed on pathway for citrus from Egypt (Biosecurity Australia 2002a); papaya from Fiji (Biosecurity Australia 2002b); lychee from China (DAFF 2004a); Tahitian lime	Intercepted in Australia on starfruit in air baggage; adults intercepted on fresh cut orchid flowers and fresh cut foliage in air cargo; adult and nymph intercepted on dragon fruit On <i>Zingiber officinale</i> from Indonesia to the USA; <i>Malus pumila</i> from Pakistan to India; <i>Croton</i> sp. Orchidaceae, <i>Gossypium hirsutum</i> from the Philippines to the USA; on <i>Hoya</i> sp. from Thailand to the USA (Williams 2004)	No	Yes (Bhat et al. 2003; Hughes & Lister 1953; Kirkpatrick 1950; Posnette 1950; Posnette & Strickland 1948)

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		<i>virgata</i> from Central, South and North America may be unreliable due to confusion of this species with <i>F. dasylirii</i> (Kaydan & Gullan 2012)		from New Caledonia (Biosecurity Australia 2006c); and mangoes from India (Biosecurity Australia 2008a)			
<i>Formicococcus celtis</i> (Strickland) [As <i>Pseudococcus celtis</i> in (Attafuah, Blencowe & Brunt 1963)]	1, 2	West Africa (Attafuah, Blencowe & Brunt 1963; García Morales et al. 2018)	No record found (García Morales et al. 2018)	On <i>Celtis</i> (García Morales et al. 2018) and cocoa (Attafuah, Blencowe & Brunt 1963)	–	Yes	Yes (Attafuah, Blencowe & Brunt 1963)
<i>Formicococcus latens</i> Williams	4	India (Williams 2004)	No record found (García Morales et al. 2018)	On roots of mulberry (<i>Morus</i> sp.) and on roots of orange (<i>Citrus sinensis</i>) (Williams 2004)	–	Yes	No
<i>Formicococcus matileae</i> Williams	1	Myanmar and Cambodia (Williams 2004)	No record found (García Morales et al. 2018)	On <i>Garcinia mangostana</i> and <i>Manilkara zapota</i> (García Morales et al. 2018; Williams 2004)	On <i>Garcinia mangostana</i> from Myanmar (Burma) to India (Williams 2004)	Yes	No
<i>Formicococcus njalensis</i> (Laing) [as <i>Planococcoides</i> in CPC, as <i>Planococcoides njalensis</i> in (AFFA 2002; Bigger 1981)]	2, 4, 5	Africa (Bigger 1981; Brunt & Kenten 1962; Campbell 1983; Ezzat & McConnell 1956; García Morales et al. 2018; Posnette & Strickland 1948)	No record found (García Morales et al. 2018)	On a wide range of host plants, including pineapple, acacia, cocoa, coffee and pepper (Campbell 1983; García Morales et al. 2018; Posnette & Strickland 1948) Assessed as on pathway for pineapples – generic (AFFA 2002)	Intercepted in the USA from Africa, commonly collected on cocoa (Miller et al. 2014a)	Yes	Yes (Posnette 1950; Posnette & Strickland 1948)
<i>Formicococcus polysperes</i> Williams	1	South Asia (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On a number of host plants, including coconut, black	On roots of <i>Zingiber officinale</i> and root of <i>Zingiber</i> sp. from the Philippines to the USA and on	Yes	No

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				pepper and ginger (García Morales et al. 2018)	<i>Cocos nucifera</i> from the Philippines to Japan; on <i>Zingiber officinale</i> from Thailand to the USA; on <i>Lansium domesticum</i> from Vietnam to the USA (Miller et al. 2014a; Williams 2004)		
<i>Formicococcus robustus</i> (Ezzat & McConnell)	1, 4, 5	Asia (Ezzat & McConnell 1956; García Morales et al. 2018; Moghaddam 2006)	No record found (García Morales et al. 2018)	On a range of host plants, including mango, acacia, coffee and cucurbita (Ezzat & McConnell 1956; García Morales et al. 2018)	Commonly intercepted on mango (Miller et al. 2014a); on <i>Mangifera indica</i> from India to the USA (Ezzat & McConnell 1956); on <i>Annona squamosa</i> from Pakistan to the USA (Rung et al. 2006; Williams 2004)	Yes	No
<i>Helicococcus bohemicus</i> Šulc	2, 4	Europe and Asia (China and Mongolia) (García Morales et al. 2018; Sforza, Boudon-Padieu & Greif 2003; Zorloni et al. 2006)	No record found (García Morales et al. 2018)	It is frequently found in vineyards affected by leafroll disease (Sforza, Boudon-Padieu & Greif 2003; Zorloni et al. 2006)	–	Yes	Yes (Sforza, Boudon-Padieu & Greif 2003; Zorloni et al. 2006)
<i>Helicococcus osborni</i> (Sanders)	5	North America, Egypt and Sweden (Ezzat 1960; García Morales et al. 2018; Miller 2005)	No record found (García Morales et al. 2018)	On a range of host plants, including maples, vaccinium berries and prunus (García Morales et al. 2018)	–	Yes	No
<i>Hordeolicoccus heterotrichus</i> Williams	1, 5	South Asia (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On mangosteen, rambutan and a few other plant species (García Morales et al. 2018) Assessed as on pathway for mangosteen from Indonesia (DAFF 2012b)	On <i>Nephelium lappaceum</i> from Cambodia, Vietnam, Singapore; <i>Garcinia mangostana</i> from Thailand and on an unknown host from Indonesia to the USA (Miller et al. 2014a; Williams 2004)	Yes	No
<i>Hordeolicoccus invocatus</i> Williams	1	The Philippines (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On rambutan (García Morales et al. 2018; Williams 2004)	On <i>Nephelium lappaceum</i> from the Philippines and Thailand to the USA (Miller et al. 2014a; Williams 2004)	Yes	No

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<i>Hordeolicoccus nephelii</i> (Takahashi)	1	Southeast Asia (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On a small number of host plants including durian, mangosteen and rambutan (García Morales et al. 2018; Williams 2004)	On <i>Nephelium lappaceum</i> from Malaysia, <i>N. lappaceum</i> and <i>N. mutabile</i> from the Philippines; on <i>Garcinia mangostana</i> from Singapore; on <i>Durio</i> sp., <i>D. ziberthinus</i> and <i>Garcinia</i> sp. from Thailand; on <i>Artocarpus heterophyllus</i> and <i>N. lappaceum</i> from Vietnam to the USA (Miller et al. 2014a; Williams 2004)	Yes	No
<i>Humococcus resinophilus</i> (Green)	4	India (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On <i>Pinus</i> (Williams 2004)	–	Yes	No
<i>Hypogeococcus boharti</i> Miller	1	Central and South America (García Morales et al. 2018; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On leaves of a small number of host plants including coffee, citrus and orchids (García Morales et al. 2018; Williams & Granara de Willink 1992)	On orchids from Mexico, Panama, Belize, Costa Rica, Guatemala, Honduras and Peru to the USA (Miller et al. 2014a)	Yes	No
<i>Hypogeococcus gilli</i> Miller	1	Costa Rica (García Morales et al. 2018; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On orchid (García Morales et al. 2018; Williams & Granara de Willink 1992)	On orchids from Costa Rica to the USA (Miller et al. 2014a)	Yes	No
<i>Hypogeococcus othnius</i> Miller & McKenzie	1	Central and South America (García Morales et al. 2018; Williams 1973; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On orchids (García Morales et al. 2018); on Orchidaceae, Bromeliaceae, <i>Brassia</i> sp., <i>Cattleya</i> sp. and <i>Maxillaria</i> sp. (Williams & Granara de Willink 1992)	On orchids and bromeliads from Costa Rica, Ecuador, Guatemala, Mexico, Nicaragua, Panama and Venezuela to the USA (Miller et al. 2014a)	Yes	No
<i>Hypogeococcus pungens</i> Granara de Willink	1	Europe, South America and USA (Florida and Hawaii) (García Morales et al. 2018; Matile-Ferrero & Étienne 2006;	No record found (García Morales et al. 2018)	On roots and aerial parts of many cut-flower plants (García Morales et al. 2018) On <i>Alternanthera</i> , <i>Cereus</i> , <i>Cleistocactus</i> , <i>Portulaca</i> , <i>Eriocereus</i> (Matile-Ferrero &	On cactus (primarily on roots) from Germany, Peru and Puerto Rico to the USA (Miller et al. 2014a)	Yes	No

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<i>Hypogeococcus spinosus</i> Ferris	1	Williams & Granara de Willink 1992) Americas and Japan (García Morales et al. 2018; Kiritani & Morimoto 2004; Miller 2005; Williams 1973; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	Étienne 2006; Williams & Granara de Willink 1992) Mainly on cactus (García Morales et al. 2018); also on <i>Alternanthera pungens</i> and <i>Portulaca</i> sp. (Williams & Granara de Willink 1992)	On cactus from Argentina, Mexico and Switzerland to the USA (Miller et al. 2014a)	Yes	No
<i>Kiritshenkella sacchari</i> (Green)	4, 5	Asia (García Morales et al. 2018; Williams 1970) and Cuba (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	Under the leaf sheaths and on the nodes, underground stems and roots, mainly on species of Poaceae including bamboo, sugarcane and <i>sorghum</i> (García Morales et al. 2018; Williams 2004)	–	Yes	No
<i>Lankacoccus ornatus</i> (Green)	4	Southern Asia (García Morales et al. 2018; Suresh & Mohanasundaram 1996; Williams 2004)	No record found (García Morales et al. 2018)	On <i>Jasminum</i> , <i>Camellia</i> and <i>Thea</i> (García Morales et al. 2018; Suresh & Mohanasundaram 1996; Williams 2004)	–	Yes	No
<i>Lantanacoccus sauroides</i> Williams & Granara de Willink	1	Haiti, Jamaica and Martinique (García Morales et al. 2018; Matile-Ferrero & Étienne 2006; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	Only reported on <i>Lantana</i> species (García Morales et al. 2018; Matile-Ferrero & Étienne 2006; Williams & Granara de Willink 1992)	In galls of <i>Lantana</i> sp. from Jamaica to the USA (Williams & Granara de Willink 1992)	Yes	No
<i>Leptococcus metroxyli</i> Reyne	5	Papua New Guinea and Indonesia (García Morales et al. 2018; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On coconut and other palm and pineapple (García Morales et al. 2018)	–	Yes	No

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<i>Maconellicoccus hirsutus</i> (Green)	1, 4, 5	Worldwide (Abd-Rabou, Ahmed & Badary 2012; García Morales et al. 2018; Mani 1989; Mani & Thontadarya 1987; Matile-Ferrero & Étienne 2006; Miller, Miller & Watson 2002; Moghaddam 2006; Suresh & Mohanasundaram 1996; Watson & Kubiriba 2005; Williams 1970, 1996a)	Yes, NT, Qld, SA, WA (Baker & Huynh 2000; Brookes 1964; García Morales et al. 2018; Williams 1996a)	On twigs, stems and leaves of numerous host plants including grapevine, hibiscus, sugarcane, peanut, citrus and cucurbita (Baker & Huynh 2000; García Morales et al. 2018; Suresh & Mohanasundaram 1996; Williams 1970, 1996a). In India, it is a severe pest on fibre crops such as jute, mesta, roselle, and grapevines (Mani 1989) Assessed as on pathway for citrus from Egypt (Biosecurity Australia 2002a)	Adult, nymph and egg intercepted in Australia on betel fruit; on fresh custard apple From India on <i>Annona</i> sp. to England; on <i>Annona reticulata</i> , <i>A. sp.</i> , <i>A. squamosa</i> and <i>Psidium guajava</i> to the USA; from Indonesia on <i>Hibiscus manihot</i> (now <i>Abelmoschus manihot</i>) and <i>Nephelium lappaceum</i> to the USA; on <i>Punica granatum</i> from Pakistan to India; from the Philippines on <i>Lansium domesticum</i> , <i>Lansium sp.</i> , <i>Annona muricata</i> , <i>A. squamosa</i> , <i>Dendrobium dearsi</i> , <i>Psidium sp.</i> and <i>Nephelium lappaceum</i> to the USA; on <i>Annona</i> sp. from Singapore to the USA; on <i>Annona</i> sp. from Thailand to England; on <i>Litchi chinensis</i> , <i>Durio sp.</i> , <i>D. zibethnus</i> , <i>Nephelium lappaceum</i> , <i>Nephelium sp.</i> , <i>Annona cherimoya</i> , <i>A. reticulata</i> and <i>Psidium guajava</i> from Thailand to the USA; on <i>Annona squamosa</i> , <i>Averrhoa carambola</i> from Vietnam to the USA (Miller et al. 2014a; Williams 2004); on <i>Areca</i> and <i>Ficus</i> from China to South Korea (Ji, Wu & Suh 2010)	No	No
<i>Maconellicoccus multipori</i> (Takahashi)	1, 5	East Asia (García Morales et al. 2018; Williams 1996a, 2004)	No record found (García Morales et al. 2018)	On many host plants, including cacao, black pepper, carabola (García Morales et al. 2018). <i>Piper betle</i> , <i>Crypteronia</i>	On <i>Alectryon</i> sp. and <i>Garcinia</i> sp. from Malaysia to the USA; on <i>Averrhoa carrabola</i> from Malaysia to England; on <i>Piper nigrum</i> , <i>Durio sp.</i> and <i>Nephelium</i>	Yes	No

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				<i>griffithii</i> , <i>Neonauclea</i> and <i>Daemonorops</i> (Williams 2004)	<i>lappaceum</i> from Thailand to the USA (Miller et al. 2014a; Williams 2004); intercepted from Cambodia, India, the Philippines, Singapore and Vietnam to the USA (Miller et al. 2014a)		
<i>Maconellicoccus ramchensis</i> Williams	1	Nepal (Williams 1996a) and Thailand (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On fruit of <i>Durio</i> sp. (Rung et al. 2006; Williams 2004)	On fruit of <i>Durio</i> sp. from Thailand to the USA (Miller et al. 2014a; Williams 2004)	Yes	No
<i>Maculicoccus malaitensis</i> (Cockerell)	4	Pacific Islands and Papua New Guinea (García Morales et al. 2018; Williams 1960)	No record found (García Morales et al. 2018)	On several host plants including coconut, cacao and citrus (Williams 1960; Williams & Watson 1988b)	–	Yes	No
<i>Neotrionymus monstatus</i> Borchsenius	1	Europe and north Asia (García Morales et al. 2018; Kaydan & Kozár 2010)	No record found (García Morales et al. 2018)	On some species of Poaceae (García Morales et al. 2018; Kaydan & Kozár 2010)	On <i>Arundo</i> from China to South Korea (Ji, Wu & Suh 2010)	Yes	No
<i>Nipaecoccus aurilanatus</i> (Maskell)	5	Australia, NZ and USA (Brown & Eads 1967; García Morales et al. 2018; Miller, Miller & Watson 2002; Williams 1985a)	Yes, NSW, Qld, SA, Vic, WA (Williams 1985a)	On small branches and young stems, only reported on <i>Agathis</i> and <i>Araucaria</i> of Araucariaceae (Brown & Eads 1967; García Morales et al. 2018)	–	No	No
<i>Nipaecoccus filamentosus</i> (Cockerell) [As <i>Pseudococcus filamentosus</i> in (Moghaddam 2006)]	1, 5	Iran and Central America (García Morales et al. 2018; Moghaddam 2006; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On coffee, ficus and <i>Bucida buceras</i> (García Morales et al. 2018) Assessed on pathway for Tahitian lime from New Caledonia (Biosecurity Australia 2006c)	On <i>Bucida</i> from Puerto Rico to the USA (Rung et al. 2006)	Yes	No

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
<i>Nipaecoccus gilli</i> Williams & Granara de Willink	1	Mexico (García Morales et al. 2018; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On <i>Dieffenbachia</i> , <i>Acacia</i> and <i>Manilkara zapota</i> (García Morales et al. 2018; Williams & Granara de Willink 1992)	On <i>Dieffenbachia</i> from Mexico to the USA (Rung et al. 2006)	Yes	No
<i>Nipaecoccus nipae</i> (Maskell)	1, 4, 5	Europe, Central and South America, Hawaii, Fiji, Asia, Africa (South Africa, Tanzania, Zanzibar, Zimbabwe and Madagascar) (García Morales et al. 2018; Kondo 2001; Lit, Caasi-Lit & Larona 2006; Miller 2005; Sagarra, Vincent & Stewart 2001; Watson & Kubiriba 2005)	No record found (García Morales et al. 2018)	On foliage of numerous host plants including cacao, guava, coconut and avocado (García Morales et al. 2018; Kondo 2001; Matile-Ferrero & Étienne 2006). <i>N. nipae</i> is a pest of economically important crops in the Philippines, including coconuts and several ornamental palms (Lit, Caasi-Lit & Larona 2006) Assessed as on pathway for bananas from the Philippines (Biosecurity Australia 2008b)	Intercepted in Australia on citrus leaves in air baggage Intercepted from nearly any warm part of the world to the USA (Miller et al. 2014a); adult females intercepted on coconut and banana from the Philippines to Japan (Tokihiro 2006)	Yes	No
<i>Nipaecoccus viridis</i> (Newstead)	1, 4, 5	Worldwide (Ben-Dov 1985; Franco et al. 2004; García Morales et al. 2018; Mani & Thontadarya 1987; Moghaddam 2006; Suresh & Mohanasundaram 1996)	Yes, NT, Qld, WA (Baker & Huynh 2000; García Morales et al. 2018)	On roots, twigs, branches, shoots, leaves, flower buds and fruit of numerous host plants including citrus, tea, banana, carambola, mango and grapevine (Baker & Huynh 2000; García Morales et al. 2018; Kondo & Kawai 1995; Mani & Thontadarya 1987; Suresh & Mohanasundaram 1996) Assessed as on pathway for citrus from Egypt (Biosecurity Australia 2002a)	Intercepted in Australia on <i>Citrus tangerina</i> fruit in sea cargo; eggs, nymphs and adults intercepted on fresh pomelos and also seeds, fruits and spores for sowing from air and sea cargos; adult, nymph and egg intercepted on piper betel fruit; on fresh citrus leaves On an undetermined plant from Bangladesh, on <i>Punica granatum</i> from India, on <i>Nephelium lappaceum</i> from Malaysia, on <i>Eugenia</i> sp. from the Philippines, on <i>Citrus</i> sp. and <i>C. aurantifolia</i> from Thailand and on <i>Musa</i> sp. from Vietnam to the USA (Williams 2004)	No	No

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<i>Oracella acuta</i> (Lobdell)	4	USA and China (García Morales et al. 2018; Miller 2005; Sun et al. 1996)	No record found (García Morales et al. 2018)	On bark, twigs and at base of needles of <i>Pinus</i> species (García Morales et al. 2018; Sun et al. 1996)	–	Yes	No
<i>Palmicultor browni</i> (Williams)	1	Australasian (García Morales et al. 2018), USA (FL) (Miller 2005; Williams & Butcher 1987)	Yes, Qld (García Morales et al. 2018; Williams 1985a)	On a few species of palm trees (Williams 1985a) including coconut (García Morales et al. 2018)	On palms from Tahiti to the USA (Miller et al. 2014a); intercepted from Australia, the Bahamas, Colombia and Puerto Rico to the USA (Miller et al. 2014a)	No	No
<i>Palmicultor palmarum</i> (Ehrhorn)	1, 4	Pacific Islands, North and Central America, Asia and Canary Islands (Beardsley 1966; García Morales et al. 2018; Lit, Caasi-Lit & Larona 2006; Miller 2005; Williams 2004; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	Mainly on palm hosts, including coconut (García Morales et al. 2018; Lit, Caasi-Lit & Larona 2006; Matile-Ferrero & Étienne 2006)	Adults intercepted in Australia on coconuts in sea cargo Commonly intercepted on coconuts and occasionally on other palms in the USA (Miller et al. 2014a); intercepted from India to the USA (no plant species specified); from Indonesia to Australia and France (no plant species specified); on <i>Phyllostachys</i> sp. and four other occasions from the Philippines to Japan and to the USA; on <i>Licula</i> sp. from Singapore; on <i>Cocos nucifera</i> from Vietnam to the USA (Williams 2004)	Yes	No
<i>Paracoccus burnerae</i> (Brain)	1, 2, 4	Africa, India and Iran (de Lotto 1967; Ezzat & McConnell 1956; García Morales et al. 2018; Watson & Kubiriba 2005; Williams 2004)	No record found (García Morales et al. 2018)	On a wide range of host plants, including citrus, coffee, banana and guava (García Morales et al. 2018; Watson & Kubiriba 2005), <i>Passiflora edulis</i> and <i>Beaumontia grandiflora</i> (Ezzat & McConnell 1956)	On <i>Polypodium</i> from Madagascar to the USA (Miller et al. 2014a); intercepted from China, India, South Africa, Sri Lanka, Thailand and Vietnam to the USA (Miller et al. 2014a)	Yes	Yes (Muturi et al. 2013)

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<i>Paracoccus circuliprivis</i> Ezzat & McConnell	1	Mexico (Ezzat & McConnell 1956; García Morales et al. 2018; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On <i>Thompsonella minutiflora</i> (Ezzat & McConnell 1956; García Morales et al. 2018; Williams & Granara de Willink 1992)	On <i>Thompsonella minutiflora</i> from Mexico to the USA (Ezzat & McConnell 1956; Miller et al. 2014a)	Yes	No
<i>Paracoccus ferrisi</i> Ezzat & McConnell	1	Central America (Ezzat & McConnell 1956; García Morales et al. 2018; Rung et al. 2006; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On a number of host plants including pomegranate, coriander and capsicum (García Morales et al. 2018; Williams & Granara de Willink 1992)	On <i>Gardenia</i> sp. from Mexico to the USA (Williams & Granara de Willink 1992); on <i>Capsicum</i> , <i>Catalpa</i> , <i>Coriandrum</i> , <i>Crataegus</i> , <i>Cydonia</i> , <i>Diospyros</i> , <i>Fernaldia</i> , <i>Gardenia</i> , <i>Lantana</i> , <i>Malus</i> and <i>Punica</i> from Mexico, El Salvador, Guatemala and Costa Rica to the USA (Ezzat & McConnell 1956; Miller et al. 2014a)	Yes	No
<i>Paracoccus glaucus</i> (Maskell)	5	New Zealand (Cox 1987; Henderson, Sultan & Robertson 2010)	No record found (García Morales et al. 2018)	On the pygmy mistletoe genus <i>Korthalsella</i> (Henderson, Sultan & Robertson 2010). Also on fern, club moss and grapevine (Cox 1987)	–	Yes	No
<i>Paracoccus hamoni</i> Williams & Granara de Willink	1	Mexico (García Morales et al. 2018; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On cactus (García Morales et al. 2018; Williams & Granara de Willink 1992)	On <i>Backebergia</i> (= <i>Cephalocereus</i>) <i>chrysomelius</i> from Mexico to Florida (Miller et al. 2014a; Williams & Granara de Willink 1992)	Yes	No
<i>Paracoccus herreni</i> Williams & Granara de Willink	1	Central and South America (García Morales et al. 2018; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On <i>cassava</i> , <i>lantana</i> and <i>Acalypha</i> (García Morales et al. 2018; Williams & Granara de Willink 1992)	Most commonly intercepted on <i>Fernaldia</i> from El Salvador, <i>Punica</i> from Mexico, <i>Protea</i> from Colombia and Costa Rica to the USA (Miller et al. 2014a)	Yes	No
<i>Paracoccus interceptus</i> Lit	1, 5	Benin (DOA South Africa) and South Asia	No record found (García Morales et al. 2018)	On a wide range of host plants, including many tropical fruit (García Morales et al. 2018)	Adult intercepted in Australia on mangosteen; on adults	Yes	No

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		(Gavrilov 2013; Williams 2004)		and ornamentals (Orchidaceae, Hoya) (Williams 2004) Assessed as on pathway for mangosteen from Indonesia (DAFF 2012b) and lychees from Vietnam (DAFF 2013c)	intercepted on fresh cut roses in air cargo Commonly intercepted in the USA on a wide diversity of hosts, particularly tropical trees (Miller et al. 2014a); on <i>Dendrobium</i> sp. and <i>Saccholabium blumei</i> from India to the USA; on <i>Nephelium lappaceum</i> from Indonesia to the USA; on <i>Lansium domesticum</i> from Malaysia to the USA; on <i>Citrus aurantifolia</i> , <i>L. domesticum</i> , <i>Psidium guajava</i> , <i>Annona chermola</i> , <i>Platonia insignis</i> , <i>Euphria longan</i> , <i>Melicoccus bijugatus</i> , <i>Garcinia</i> from the Philippines to the USA; on <i>Garcinia mangostana</i> and <i>N. lappaceum</i> from Thailand to England; on <i>Litchi sinensis</i> , <i>Nephelium</i> sp., <i>G. mangostana</i> , <i>Hoya pachyclada</i> , <i>Spondias delcie</i> , <i>L. domesticum</i> and <i>Durio</i> from Thailand to the USA; on <i>N. lappaceum</i> and <i>G. mangostana</i> from Vietnam to the USA (Williams 2004)		
<i>Paracoccus invectus</i> Williams	1	India and Thailand (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On orchids of two species - <i>Dendrobium parishii</i> and <i>Coeogyne stricta</i> (García Morales et al. 2018; Williams 2004)	On leaf of orchid from Thailand to the USA; on <i>Dendrobium parishii</i> and <i>Coeogyne stricta</i> from India to the USA (Miller et al. 2014a; Williams 2004)	Yes	No
<i>Paracoccus lycopersici</i> Ezzat & McConnell	1	Mexico and Chile (Ezzat & McConnell 1956; Williams &	No record found (García Morales et al. 2018)	On tomato (Ezzat & McConnell 1956); also on Asteraceae, <i>Encelia</i> sp., <i>Penstemon</i> sp.	On <i>Lycopersicon</i> from Mexico to the USA (Ezzat & McConnell 1956; Miller et al. 2014a)	Yes	No

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<i>Paracoccus marginatus</i> Williams & Granara de Willink	1, 3, 5	Granara de Willink 1992) Africa, Pacific, Americas, South Asia (Cham et al. 2011; Chen, Wong & Wu 2011; Galanihe et al. 2010; García Morales et al. 2018; Heu, Fukada & Conant 2007; Mani et al. 2013; Miller, Miller & Watson 2002; Miller, Williams & Hamon 1999; Muniappan et al. 2008; Saengyot & Burikam 2011)	No record found (García Morales et al. 2018)	(Williams & Granara de Willink 1992) On veins of older leaves, all parts of young leaves, flowers, and fruit from numerous host plants including citrus, coconut, hibiscus, papaya, plumeria, pomegranate, mango, cassava, eggplant and tomato (Cham et al. 2011; García Morales et al. 2018; Miller, Williams & Hamon 1999; Muniappan et al. 2008; Saengyot & Burikam 2011) Assessed as on pathway for pineapples – generic (AFFA 2002) Identified as high priority pest for papaya and coffee industries by Plant Health Australia	Commonly intercepted in the USA on papaya and hibiscus but not limited to these hosts; most frequently intercepted from Mexico but also reported from Central and South America and the Caribbean Islands (Miller et al. 2014a)	Yes	No
<i>Paracoccus mexicanus</i> Ezzat & McConnell	1	Mexico (Ezzat & McConnell 1956; García Morales et al. 2018; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On <i>Sedum</i> (Ezzat & McConnell 1956) and <i>Acacia</i> (García Morales et al. 2018; Williams & Granara de Willink 1992)	On <i>Sedum</i> (Ezzat & McConnell 1956) and <i>Acacia</i> from Mexico to the USA (Miller et al. 2014a)	Yes	No
<i>Paracoccus solani</i> Ezzat & McConnell	1	North and Central America (Ezzat & McConnell 1956; García Morales et al. 2018; Williams & Granara de Willink 1992)	Yes, Qld (García Morales et al. 2018; Williams 1985a)	On many host plants including agave plant, eggplant, <i>Erigeron</i> and <i>Canadensis</i> (Ezzat & McConnell 1956; García Morales et al. 2018). Reported on <i>Parthenium hysterophorus</i> in Qld (Williams 1985a)	Adults and nymphs intercepted in Australia on orchids On <i>Erigeron canadensis</i> from Mexico to the USA (Ezzat & McConnell 1956; Miller et al. 2014a); intercepted from Chile, Cuba, Ecuador, Jamaica and Mexico to the USA (Miller et al.	No	No

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<i>Paraputo aracearum</i> Williams	1, 5	Fiji (García Morales et al. 2018; Williams 2005)	No record found (García Morales et al. 2018)	On corm of taro (García Morales et al. 2018; Williams 2005) Assessed as on pathway for taro corms from all countries (Biosecurity Australia 2011e)	2014a); commonly intercepted on Lamiaceae and <i>Leucaena</i> (Miller et al. 2014a) Adult and immature intercepted in Australia on taro	Yes	No
<i>Paraputo banzigeri</i> Williams	4	Thailand (Williams 2004)	No record found (García Morales et al. 2018)	On roots of longan (Williams 2004)	–	Yes	No
<i>Paraputo carnosae</i> (Takahashi)	1	Malaysia (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On <i>Lecanopteris carnososa</i> (Polypodiaceae) (García Morales et al. 2018; Williams 2004)	On a fern from Malaysia to the USA (Miller et al. 2014a; Williams 2004)	Yes	No
<i>Paraputo corbetti</i> (Takahashi)	1	Indonesia and Malaysia (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On mango (García Morales et al. 2018; Williams 2004)	On <i>Mangifera indica</i> from Indonesia to the USA; on root of <i>M. indica</i> from Indonesia to Guam (Williams 2004)	Yes	No
<i>Paraputo guatemalensis</i> (Ferris) [as <i>Cataenococcus guatemalensis</i> in (Williams & Granara de Willink 1992)]	1	Central and South America (García Morales et al. 2018; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On many species of orchids (García Morales et al. 2018; Williams & Granara de Willink 1992)	Commonly intercepted on orchids from Mexico, and Central and South America to the USA (Miller et al. 2014a)	Yes	No
<i>Paraputo ingrandi</i> (Balachowsky) [as <i>Cataenococcus ingrandi</i> in (Williams & Granara de Willink 1992)]	1	Central and South America (García Morales et al. 2018; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On twelve species of host plants in ten families including banana, persimmon (García Morales et al. 2018), <i>Tabebuia pentaphylla</i> , <i>Cordia</i> , <i>Cereus</i> , <i>Capparis</i> and <i>Ficus</i> (Williams & Granara de Willink 1992)	On several hosts from Mexico, Guatemala and Colombia to the USA (Miller et al. 2014a)	Yes	No

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<i>Paraputo kukumi</i> Williams	1	Solomon Islands (García Morales et al. 2018; Williams 1960, 2005)	No record found (García Morales et al. 2018)	On aerial roots of coconut (García Morales et al. 2018; Williams 1960, 2005)	Adult intercepted in Australia on <i>Cytisus</i> in sea cargo; on taro in air cargo	Yes	No
<i>Paraputo larai</i> (Williams) [as <i>Cataenococcus larai</i> in (Williams & Granara de Willink 1992)]	1	Central and South Americas (García Morales et al. 2018; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On banana and <i>Nolina recurvata</i> (García Morales et al. 2018; Williams & Granara de Willink 1992)	On <i>Cecropia</i> from Costa Rica and Colombia to the USA (Miller et al. 2014a)	Yes	No
<i>Paraputo leverii</i> (Green)	1, 4, 5	South Asia and Pacific Islands (Beardsley 1966; García Morales et al. 2018; Williams 1960, 2005)	No record found (García Morales et al. 2018)	On roots of many host plants including mango, coconut, figs, coffee, taro and grapevines (García Morales et al. 2018; Williams 2005) Assessed on pathway for taro corms from all countries (Biosecurity Australia 2011e)	Intercepted in Australia on taro in air cargo On <i>Calocasia</i> from Fiji to the USA (Miller et al. 2014a)	Yes	No
<i>Paraputo odontomachi</i> (Takahashi)	1, 5	Southeast Asia (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On several host plants, including mangosteen and <i>Elaeocarpus petiolatus</i> (García Morales et al. 2018; Williams 2004) Assessed as on pathway for mangosteen from Indonesia (DAFF 2012b)	On <i>Garcinia mangostana</i> from India, Indonesia, Malaysia, the Philippines, Singapore and Vietnam to the USA (Miller et al. 2014a; Williams 2004)	Yes	No
<i>Paraputo olivaceus</i> (Cockerell) [as <i>Cataenococcus olivaceus</i> in (Williams & Granara de Willink 1992)]	1	North, Central and South America (García Morales et al. 2018; Miller 2005; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On a number of host plants in ten families including yucca, ficus, <i>Platanus</i> and Cactaceae (García Morales et al. 2018; Williams & Granara de Willink 1992)	On several hosts from Mexico and Central America to the USA (Miller et al. 2014a)	Yes	No

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<i>Paraputo pandanicola</i> Williams	1	Indonesia (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On fruit of <i>Pandanus</i> sp. (García Morales et al. 2018; Williams 2004)	On fruits of <i>Pandanus</i> sp. from Indonesia to Hawaii (Miller et al. 2014a; Williams 2004)	Yes	No
<i>Paraputo theaecola</i> (Green in Green & Mann)	1, 4	India (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On roots of tea plants and <i>Taraktogenos kurzii</i> (García Morales et al. 2018); also on <i>Zantesdechia</i> (Williams 2004)	On <i>Cucurma amada</i> , <i>Hedychium</i> and tubers of <i>Zantesdechia</i> from India to the USA (Miller et al. 2014a; Williams 2004); on <i>Camellia sinensis</i> from India to the Netherlands (Williams 2004)	Yes	No
<i>Pelionella cycliger</i> (Leonardi)	5	Africa and Europe (García Morales et al. 2018; Mansour et al. 2011; Sánchez-García & Ben-Dov 2010)	No record found (García Morales et al. 2018)	On <i>Olea europaea</i> (Mansour et al. 2011; Sánchez-García & Ben-Dov 2010) and <i>Cynodon dactylon</i> (García Morales et al. 2018)	–	Yes	No
<i>Phenacoccus aceris</i> (Signoret)	2, 5	North America, Europe, South Korea and China (García Morales et al. 2018; Kaydan et al. 2004; Malumphy & Ostrauskas 2008; Malumphy, Ostrauskas & Pye 2008; Park et al. 2010)	No record found (García Morales et al. 2018)	On numerous host plants including kiwifruit, apple, persimmon, oaks, fig, stone fruit and grapevine (García Morales et al. 2018; Malumphy, Ostrauskas & Pye 2008; Park et al. 2010) Assessed as on pathway for Korean pear from South Korea (AQIS 1999b); apples from China (Biosecurity Australia 2010a); stone fruit from the USA (Biosecurity Australia 2010b).	–	Yes	Yes (Le Maguet et al. 2012; Raine, McMullen & Forbes 1986; Sforza, Boudon-Padieu & Greif 2003)
<i>Phenacoccus avenae</i> Borchsenius	1, 4	Europe (García Morales et al. 2018; Kaydan & Kozár 2010; Williams 1985b, 1989b)	No record found (García Morales et al. 2018)	On a wide range of host plants including plants from families Gramineae, Amaryllidaceae, Iridaceae and Liliaceae; also on poa grasses, oats and cut flower hosts (García Morales et	On bulbs from Turkey to the USA (Miller et al. 2014a)	Yes	No

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<i>Phenacoccus azaleae</i> (Kuwana)	1, 4	North Asia (Ezzat & McConnell 1956; Fox-Wilson 1939; García Morales et al. 2018; Williams 1985b)	No record found (García Morales et al. 2018)	al. 2018; Kaydan & Kozár 2010; Williams 1985b) On a small number of host plants including <i>Azalea</i> , <i>Viburnum</i> , <i>Fatsia</i> and apple (Ezzat & McConnell 1956; Fox-Wilson 1939; García Morales et al. 2018)	On <i>Azalea</i> and <i>Fatsia</i> sp. from Japan to the USA (Ezzat & McConnell 1956; Miller et al. 2014a)	Yes	No
<i>Phenacoccus franseriae</i> Ferris	1	Mexico (García Morales et al. 2018; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)S	On <i>Ambrosia</i> , <i>Eupatorium</i> , <i>Hymenoclea monogyra</i> , <i>Cnidoscolus angustidens</i> and <i>Kallstroemia</i> (Williams & Granara de Willink 1992)	On herbs from Mexico to the USA (Miller et al. 2014a); intercepted from Canada, Costa Rica and Ecuador to the USA (Miller et al. 2014a)	Yes	No
<i>Phenacoccus gossypii</i> Townsend & Cockerell	1	Americas and Southern Europe (García Morales et al. 2018; Miller 2005; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On many host plants including capsicum, eggplant and lantana (García Morales et al. 2018); on <i>Gossypium</i> sp. and <i>Borrchia arborescens</i> (Williams & Granara de Willink 1992)	Although <i>P. gossypii</i> has been identified hundreds of times from quarantine interceptions, these determinations are mostly misidentifications of <i>P. madeirensis</i> (Miller et al. 2014a)	Yes	No
<i>Phenacoccus graminicola</i> Leonardi [as <i>Phenacoccus graminosus</i> in (McKenzie 1967)]	5	South Africa, Australasia, Europe, North and South America (Cox 1987; García Morales et al. 2018; McKenzie 1967; Miller, Miller & Watson 2002)	Yes, Qld, SA, Vic, WA (García Morales et al. 2018; Williams 1985a) Not under official control	On many host plants including clover, pear, apple and peach (García Morales et al. 2018). In New Zealand it is often found under the bark of fruit trees and under the calyces of fruit (Cox 1987). <i>P. graminicola</i> is known to damage the heads of barley in Australia (Williams 1985a)	On <i>Feijoa</i> from New Zealand to the USA (Miller et al. 2014a)	No	No
<i>Phenacoccus hargreavesi</i> (Laing)	2, 5	Africa (Bigger 1981; Campbell 1983; García Morales et al. 2018; Williams 1970)	No record found (García Morales et al. 2018)	On many host plants including pineapple, fig, sugarcane, cocoa, coffee and woody trees (García Morales et al. 2018; Williams 1970)	-	Yes	Yes (Attafuah, Blencowe & Brunt 1963; Bigger 1981)

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
<i>Phenacoccus madeirensis</i> (Green)	1, 4, 5	Africa, South Asia, Pacific Islands, Americas and Europe (Culik, Ventura & dos S. Martins 2009; García Morales et al. 2018; Miller 2005; Williams 2004; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	Assessed as on pathway for pineapple generic (AFFA 2002) On hundreds of host plants including bushes, fruit trees, vegetable plants and ornamentals (García Morales et al. 2018; Matile-Ferrero & Étienne 2006; Williams 2004; Williams & Granara de Willink 1992)	Adult intercepted in Australia on fresh <i>Chrysanthemum</i> and <i>Hypericum</i> for cut-flowers in air cargo <i>P. madeirensis</i> has been intercepted in the USA hundreds of times but most of the interceptions were misidentified as <i>P. gossypii</i> (Rung et al. 2006); found in nearly all warm areas of the world but has limited distribution in the Australasian and Oriental regions (Miller et al. 2014a); on <i>Rumex</i> sp. and <i>Helichrysum</i> sp. from the Philippines to the USA; on <i>Nepheium lappaceum</i> from Vietnam to the USA (Williams 2004); on <i>Ocimum</i> from China to South Korea (Ji, Wu & Suh 2010)	Yes	No
<i>Phenacoccus manihoti</i> Matile-Ferrero	1	South America, Africa and South Asia (Cham et al. 2011; García Morales et al. 2018; Le Rü & Mitsipa 2000; Norgaard 1988; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On a number of host plants, but only cassava is known to experience significant damage from this insect (García Morales et al. 2018; Norgaard 1988; Williams & Granara de Willink 1992)	On <i>Manihot</i> from Central Africa and South America to the USA (Miller et al. 2014a)	Yes	No
<i>Phenacoccus parvus</i> Morrison	1, 4	Africa, Pacific Islands, Americas, Asia and Europe (García Morales et al. 2018;	Yes, Qld, WA (Campbell 1990; García Morales et al. 2018;	On numerous host plants including banana, tomato, capsicum, grapes, eggplant, <i>Lantana</i> , <i>Amaranthus</i> and	Intercepted in the USA (Miller et al. 2014a); on <i>Oncidium</i> sp. from	No	No

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		Miller 2005; Watson & Kubiriba 2005; Williams 2004; Williams & Granara de Willink 1992)	Government of Western Australia 2015)	<i>Chrysanthemum</i> (García Morales et al. 2018; Matile-Ferrero & Étienne 2006; Pacheco da Silva et al. 2014; Williams 2004; Williams & Granara de Willink 1992)	Thailand to the USA (Williams 2004)		
<i>Phenacoccus pergandei</i> Cockerell	1, 5	China and Japan (García Morales et al. 2018; Kuwayama & Hori 1930; Ueno 1971)	No record found (García Morales et al. 2018)	On a number of host plants including persimmon (Ueno 1971), fig and prunus (García Morales et al. 2018), apple, pear, cherry, <i>Lonicera</i> and <i>Hydrangea</i> (Kuwayama & Hori 1930) Assessed as on pathway for Fuji apples from Japan (AQIS 1998a); persimmon from Japan and Korea (DAFF 2004c)	On <i>Diospyros</i> , <i>Magnolia</i> , <i>Malus</i> , <i>Prunus</i> , <i>Punica</i> , and <i>Rhododendron</i> from Japan and Korea to the USA (Miller et al. 2014a)	Yes	No
<i>Phenacoccus saccharifolii</i> (Green)	4	India, Nepal (Williams 1970) and Pakistan (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On sugar cane leaves (Williams 1970, 2004), also reported on <i>Sorghum halepense</i> (García Morales et al. 2018)	–	Yes	No
<i>Phenacoccus solani</i> Ferris	1, 4, 5	Africa, Pacific Islands, Americas, Asia and Europe (Beardsley 1966; Cham et al. 2011; García Morales et al. 2018; Miller 2005; Moghaddam 2006; Walton & Pringle 2004a; Williams 2004; Williams & Granara de Willink 1992)	Yes, WA (García Morales et al. 2018); Vic. (Department of Economic Development, Jobs, Transport and Resources 2017, pers. comm.)	On lower leaves and roots, on numerous host plants including potato, tobacco, citrus, capsicum (García Morales et al. 2018), papaya (Cham et al. 2011), eggplant (Matile-Ferrero & Étienne 2006) and ornamental plants (Moghaddam 2006; Trencheva et al. 2010). Also present on weeds in vineyards (Walton & Pringle 2004a)	Adults intercepted in Australia on citrus leaves; on Orchidaceae and <i>Plumeria</i> for nursery stock in air cargo Adult females intercepted on cut flowers of <i>Ornithogalum</i> sp. from Israel and Australia [note <i>P. solani</i> is not reported in Australia] and young plant of <i>Tacitus</i> sp. from Korea (Tokihito 2006); adult and nymph intercepted on orchid and <i>Plumeria</i> for nursery stock	No	No

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
<i>Phenacoccus solenopsis</i> Tinsley	1, 4, 6	Africa, Americas, Asia, Europe, Australia and Papua New Guinea (Abbas et al. 2010; García Morales et al. 2018; Hodgson et al. 2008; Miller 2005; Negrare et al. 2011; Williams & Granara de Willink 1992)	Yes, Qld (Charleston et al. 2010; García Morales et al. 2018); Vic. (Department of Economic Development, Jobs, Transport and Resources 2017, pers. comm.); Declared pest, prohibited by WA (Government of Western Australia 2018)	Usually occurs above ground, but sometimes on roots. Numerous host plants including mango, <i>Eucalyptus</i> (García Morales et al. 2018), <i>Hibiscus</i> (Gavrilov 2013; Matile-Ferrero & Étienne 2006; Trencheva et al. 2010), eggplant, atriplex, cotton (Hodgson et al. 2008), potato, tomato, tobacco, pumpkin (Abbas et al. 2010) and grapes (Pacheco da Silva et al. 2014)	On <i>Dendrobium</i> sp., <i>Zephyranthes</i> sp. and <i>Curcuma</i> sp. from Thailand to the USA; on unidentified plant, Cactaceae and Orchidaceae from Vietnam to the USA (Williams 2004); on numerous hosts from the Bahamas, China, Dominican Republic, Israel, Japan, Malaysia, Mexico, Panama, South Africa, Thailand and Vietnam to the USA (Miller et al. 2014a) Adult and nymph intercepted in Australia on <i>Sansevieria</i> spp. and <i>Plumeria</i> for nursery stock On <i>Sida</i> from Cuba, <i>Euphorbia</i> from Dominican Republic, <i>Cucurbita</i> from Ecuador and many hosts from Mexico to the USA (Rung et al. 2006); on <i>Echeveria</i> and <i>Ficus</i> from China to South Korea (Ji, Wu & Suh 2010)	Yes (WA)	No
<i>Planococcus angkorensis</i> (Takahashi)	1	Asia (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On many host plants including fig, lychee, guava, pomegranate, jam and coffee (García Morales et al. 2018; Williams 2004)	On many tropical plants from China, India, Indonesia, Japan, Malaysia, the Philippines, Taiwan, Thailand and Vietnam to the USA (Miller et al. 2014a); on roots of <i>Dioscorea</i> sp. from	Yes	No

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
<i>Planococcus citri</i> (Risso)	1, 2, 4, 5	Africa, Pacific islands, Americas, Asia and Europe (Ezzat & McConnell 1956; García Morales et al. 2018; Mani & Thontadarya 1987; Suresh & Mohanasundaram 1996; Wakgarl & Giliomee 2003; Williams 1982)	Yes, ACT, NSW, NT, Qld, SA, Tas, WA (García Morales et al. 2018)	On numerous host plants including many outdoor crops in tropics and subtropics and in greenhouses in temperate regions. Host plants include many citrus species (Wakgarl & Giliomee 2003), pineapple, apple, banana, melon, grapes, asparagus, coconut, strawberry, guava, pear, eggplant, pumpkin, yam, sweet potato, avocado, rose, impatiens, bougainvillea, cactus, ficus and cacao (Ezzat & McConnell 1956; Mani & Thontadarya 1987) Assessed as on pathway for citrus from Egypt (Biosecurity Australia 2002a)	India to the USA; on <i>Punica granatum</i> from Thailand to Hawaii (Williams 2004) Adult and nymph intercepted in Australia on mangosteen, lime, grapefruit, orange, citrus medica (etrog) and cycad; on cacti (<i>Gymnocalycium</i> and <i>Notocactus</i>) for nursery stock; <i>Notocactus</i> for tissue culture; on roses for cut-flowers; immature intercepted on pomegranate in air Intercepted at US ports of entry from nearly every area of the world since it occurs outdoors in warm areas, in greenhouses and indoor landscapes in cooler areas (Miller et al. 2014a); on <i>Carmona</i> , <i>Codiaeum</i> , <i>Ficus</i> , <i>Philodendron</i> and <i>Schefflera</i> from China to South Korea (Ji, Wu & Suh 2010)	No	Yes (Lheureux et al. 2007)
<i>Planococcus dendrobii</i> Ezzat & McConnell	1	South Asia (Cox 1989; García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On a few species of orchids (Cox 1989; García Morales et al. 2018; Williams 2004)	On Orchidaceae from Bhutan to U.K., on <i>Dendrobium transparens</i> , <i>D. moschatum</i> , on stem of <i>Dendrobium</i> sp. and orchid from India to the USA; on orchid leaves from Singapore to Hawaii; on <i>Dendrobium</i> sp. from Thailand to the USA (Williams 2004); on <i>Cypripedium</i> , <i>Dendrobium</i> , <i>Phalaenopsis</i> , <i>Saccolobium</i> and <i>Vanda</i> from India, the Philippines, Singapore	Yes	No

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<i>Planococcus dioscoreae</i> Williams	4	Papua New Guinea and Solomon Islands (Cox 1989; Williams 1982; Williams & Watson 1988b)	No record found (García Morales et al. 2018)	On roots of host plants (García Morales et al. 2018) including yams (Cox 1989) and <i>Xanthosoma sagittifolium</i> (Williams & Watson 1988b)	– and Thailand to the USA (Rung et al. 2006)	Yes	No
<i>Planococcus ficus</i> (Signoret)	1, 2, 3, 5	Europe (Greece, Italy, Portugal, Spain, Turkey, France), North, Central and South America, Africa, Maritius and Asia (Ezzat & McConnell 1956; García Morales et al. 2018; Godfrey et al. 2003; Hassan, Radwan & El-Sahn 2012; Kaydan & Kozár 2010; Miller, Miller & Watson 2002; Walton & Pringle 2004a)	No record found (García Morales et al. 2018)	On many host plants, including mango, bamboo, citrus, melon, avocado, grape, figs, pomegranate, cacao, walnut, <i>Dahlia</i> sp. (Ezzat & McConnell 1956; García Morales et al. 2018; Walton & Pringle 2004a, b) Identified as high priority pest for viticulture industry by Plant Health Australia	Adult, nymph and egg intercepted in Australia on pomegranate in air cargo On <i>Vitis vinifera</i> , <i>Malus pumila</i> , <i>Salix</i> sp., <i>S. acmophila</i> from Pakistan to India (Williams 2004); on <i>Annona</i> , <i>Diospyros</i> , <i>Ficus</i> , <i>Psidium</i> , <i>Punica</i> , <i>Rosa</i> , <i>Theobroma</i> , <i>Vitis</i> and <i>Zingiber</i> from Chile, Afghanistan, Azores, Dominican Republic, Ethiopia, Germany, Great Britain, Iran, Greece, Haiti, Israel, Italy, Jordan, Mexico, Lebanon, Pakistan, Netherlands, Oman, Portugal, South Africa, Syria and Turkey to the USA (Miller et al. 2014a)	Yes	Yes (Douglas & Krüger 2008; Mahfoudhi, Digiario & Dhouibi 2009; Martelli 1997b; Meyer et al. 2008; Rosciglione et al. 1983; Tsai et al. 2008; Tsai et al. 2010)
<i>Planococcus halli</i> Ezzat & McConnell	1	Africa, Central and South America and Italy (García Morales et al. 2018; Matile-Ferrero & Étienne 2006), British West Indies (Ezzat & McConnell 1956; Sagarra, Vincent & Stewart 2001)	No record found (García Morales et al. 2018)	On citrus, coffee, sugarcane and <i>Dioscorea</i> (Ezzat & McConnell 1956; García Morales et al. 2018; Matile-Ferrero & Étienne 2006)	Commonly on <i>Dioscorea</i> (yams), but also on <i>Epipremnum</i> , <i>Manihot</i> and <i>Melicoccus</i> from Brazil, Cameroon, Cuba, Gabon, Ghana, Haiti, Jamaica, Liberia, Nigeria, Panama, South Africa, Trinidad and Tobago to the USA (Miller et al. 2014a)	Yes	No

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<i>Planococcus hosnyi</i> (Ezzat & McConnell)	1	Southern Africa (Cox 1989; Ezzat & McConnell 1956; García Morales et al. 2018)	No record found (García Morales et al. 2018)	On <i>Aerangis</i> (Orchidaceae) (Cox 1989; Ezzat & McConnell 1956; García Morales et al. 2018)	On orchids from South Africa to the USA (Miller et al. 2014a)	Yes	No
<i>Planococcus hospitus</i> De Lotto	1	Uganda (Cox 1989; García Morales et al. 2018)	No record found (García Morales et al. 2018)	On tubers of <i>Eulophia</i> (García Morales et al. 2018) and other orchids (Cox 1989)	On <i>Cyrtorchis</i> from Uganda to the USA (Miller et al. 2014a)	Yes	No
<i>Planococcus japonicus</i> Cox	1	USA, Japan and South Asia (García Morales et al. 2018; Miller, Miller & Watson 2002; Williams 2004)	No record found (García Morales et al. 2018)	On many host plants including apple, pear, tea (García Morales et al. 2018; Williams 2004), also trees including <i>Loquat</i> (Cox 1989)	On <i>Lansium</i> sp., <i>L. domesticum</i> from the Philippines to the USA (Williams 2004); on <i>Carpinus</i> , <i>Fatsia</i> , <i>Lansium</i> , <i>Malus</i> , <i>Rhododendron</i> and <i>Vitis</i> from Japan and the Philippines to the USA (Miller et al. 2014a)	Yes	No
<i>Planococcus kenyae</i> (Le Pelley)	1, 2, 4	Africa and Indonesia (Attafuah, Blencowe & Brunt 1963; Cox 1989; Ezzat & McConnell 1956; García Morales et al. 2018)	No record found (García Morales et al. 2018)	On many host plants including coffee, cacao, yam, citrus and sugarcane (Cox 1989; Ezzat & McConnell 1956; García Morales et al. 2018)	On <i>Ficus</i> and <i>Cola</i> from Nigeria and Sierra Leone to the USA (Miller et al. 2014a)	Yes	Yes (Attafuah, Blencowe & Brunt 1963)
<i>Planococcus kraunhiae</i> (Kuwana)	1, 5	USA, Jamaica and Asia (Ezzat & McConnell 1956; Ueno 1971) (García Morales et al. 2018; Park et al. 2010; Shiraiwa 1935; Williams 2004)	No record found (García Morales et al. 2018)	In crevices of twig, leaves of many host plants, including persimmon (Park et al. 2010; Ueno 1971), citrus, pear, coffee, fig, olive, grape (Ezzat & McConnell 1956; García Morales et al. 2018; Shiraiwa 1935) Assessed as on pathway for Korean pear from South Korea (AQIS 1999b); persimmon from Japan, Korea and Israel (DAFF 2004c); mandarins from Japan (Biosecurity Australia	Adult, nymph and egg intercepted in Australia on persimmon On <i>Diospyros kuki</i> from the Philippines to the USA (Williams 2004); mostly on citrus and <i>Diospyros</i> from Japan, but also recorded from China, Korea and the Philippines to the USA (Miller et al. 2014a)	Yes	No

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<i>Planococcus lilacinus</i> (Cockerell)	1, 4, 5	Africa, Asia Central and Central and South Americas, the Philippines and Papua New Guinea (Ezzat & McConnell 1956) (García Morales et al. 2018; Gavrilov 2013; Reddy, Bhat & Naidu 1997; Suresh & Mohanasundaram 1996; Williams 1982, 2004)	Yes, Torres Strait, under official control (QDAF 2018a)	2009); table grapes from China (Biosecurity Australia 2011a); table grapes from South Korea (Biosecurity Australia 2011c) On numerous host plants including mango, coffee, mangosteen, citrus, lychee, grapevine, apple, grapefruit, cacao, pomegranate, yam and soya bean (Ezzat & McConnell 1956; García Morales et al. 2018; Kondo & Kawai 1995; Reddy, Bhat & Naidu 1997; Suresh & Mohanasundaram 1996) Assessed as on pathway for mangoes from the Philippines (AQIS 1999c); durian from Thailand (AQIS 1999a); mangoes from Taiwan (Biosecurity Australia 2006d); mangoes from India (Biosecurity Australia 2008a); mandarins from Japan (Biosecurity Australia 2009); mangosteen from Indonesia (DAFF 2012b); lychees from Taiwan and Vietnam (DAFF 2013c)	Intercepted in Australia on <i>Anthurium</i> cut-flowers and nursery stock in air cargo; on lychee fruit in air baggage; on bonsai trees in air cargo; adult and nymph on <i>Ochna</i> spp. for nursery stock; on longan, rambutan and mangosteen On <i>Annona</i> sp. and <i>Theobroma cacao</i> from Indonesia to England; on <i>Pandanus</i> sp., <i>Lansium domesticum</i> , <i>Citrus maxima</i> , <i>C. sinensis</i> , <i>C. reticulata</i> , <i>Gardenia jasminoides</i> , <i>Quisqualis indica</i> , <i>Engenia</i> sp., <i>Vanda sanderiana</i> , <i>Dendrobium cruminatum</i> and <i>D. deareii</i> from the Philippines to the USA; on <i>Codiaeum</i> sp. from Sri Lanka to England; on <i>Nephelium lappaceum</i> and <i>Dimocarpus longan</i> , from Thailand to England; on <i>Garcinia mangostana</i> and <i>Durio zibethnus</i> from Thailand to the USA; on <i>Litchi</i> sp. from Vietnam to Australia; on <i>G. mangostana</i> and <i>N. lappaceum</i> from Vietnam to the USA (Williams 2004); intercepted in the USA from nearly any warm area of the world (Miller et al. 2014a); on <i>Dimocarpus</i> , <i>Ficus</i> and	Yes	No

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<i>Planococcus litchi</i> Cox	1, 5	Asia (Cox 1989; García Morales et al. 2018)	No record found (García Morales et al. 2018)	On lychees, longan, rambutan, sugar apple and <i>loquat</i> (Cox 1989; García Morales et al. 2018) Assessed as on pathway for lychees from China and Thailand (DAFF 2004a); lychees from Vietnam (DAFF 2013c)	<i>Philodendron</i> from China to South Korea (Ji, Wu & Suh 2010) On <i>Litchi sinensis</i> and <i>Nephelium lappaceum</i> from the Philippines to the USA; on lychees from Thailand to England; on <i>Eriobotrya japonica</i> and <i>Litchi</i> sp. from Thailand to the USA; on <i>Nephelium lappaceum</i> , <i>Dimocarpus longan</i> and <i>Annona squamosa</i> from Vietnam to the USA (Williams 2004); on <i>Dimocarpus</i> , <i>Eriobotrya</i> , <i>Garcinia</i> , <i>Litchi</i> and <i>Nephelium</i> from China, Hong Kong, Japan, the Philippines, Thailand and Vietnam to the USA (Miller et al. 2014a)	Yes	No
<i>Planococcus mali</i> Ezzat & McConnell	1, 5, 6	Australia and New Zealand (Charles 1993; Cox 1989; Ezzat & McConnell 1956; García Morales et al. 2018)	Yes, NSW, Tas (Cox 1989; García Morales et al. 2018) Declared pest, prohibited by WA (Government of Western Australia 2018)	On a number of host plants including <i>Acacia</i> , apple, pear, <i>Olearia chathamica</i> , blackcurrant and citrus (Charles 1993; Cox 1989; García Morales et al. 2018). <i>P. mali</i> is a pest of blackcurrants in NZ (Cox 1989) Assessed as on pathway for apples from NZ (Biosecurity Australia 2006a, 2011d)	On <i>Malus</i> and <i>Olearia</i> from New Zealand to the USA (Ezzat & McConnell 1956; Miller et al. 2014a)	Yes (WA)	No
<i>Planococcus minor</i> (Maskell) [as <i>P. pacificus</i> in (Williams & Butcher 1987; Williams & Watson 1988b)]	1, 2, 4, 5, 6	Africa, the Philippines, Australasian region, Asia and South America (García Morales et al. 2018; Lit, Caasi-Lit & Calilung 1998; Matile-	Yes, NSW, NT, Qld, SA (García Morales et al. 2018) Declared pest, prohibited by	On numerous host plants including cocoa, citrus, capsicum (García Morales et al. 2018), coffee (Reddy, Bhat & Naidu 1997), eggplant (Lit, Caasi-Lit & Calilung 1998),	Adult and egg intercepted in Australia on longan; on <i>Anthurium</i> cut-flower and foliage of <i>Dieffenbachia</i> by cruise vessel; on fruit of lime, rambutan, <i>Anthurium</i> cut-flowers and foliage of <i>Cronton</i> in	Yes (WA)	Yes (Sousa et al. 2010; Sousa, Pantoja & Boari 2011)

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		Ferrero & Étienne 2006; Reddy, Bhat & Naidu 1997), Pacific Islands (Cox 1989; Williams 1982; Williams & Butcher 1987)	WA (Government of Western Australia 2018)	pineapple (Culik, Ventura & dos S. Martins 2009) Assessed as on pathway for durian from Thailand (AQIS 1999a); bananas from the Philippines (Biosecurity Australia 2008b); mangosteen from Indonesia (DAFF 2012b); pineapples from Malaysia (DAFF 2012a); lychees from Taiwan and Vietnam (DAFF 2013c); fresh island cabbage leaves from the Pacific (DAFF 2013b)	air cargo; on durian for budwood and guava fruit in air baggage; adult intercepted on <i>Gymnocalycium</i> , <i>Hylocereus</i> , <i>Jatropha</i> , <i>Curcuma</i> and <i>Codiaeum</i> for nursery stock; on bare rooted plant, piper betel (mustard) fruit, mangosteen, banana and fresh orange; on grapefruit in air and sea cargo; on fresh herb/curry leaves On <i>Zingiber</i> sp. from Malaysia to Australia; on foliage from Singapore to Australia (Williams 2004) On orchid from Burma to the USA; on <i>Cydonia oblonga</i> from India to the USA; on <i>Piper nigrum</i> from Indonesia to the USA; on <i>Averrhoa carambola</i> from Malaysia to England; on Orchidaceae from the Philippines to the USA; on <i>Musa</i> sp. from the Philippines to Japan; on aquatic plants and <i>Ficus</i> sp. from Singapore to England; on <i>Durio</i> sp. and <i>Nephelium lappaceum</i> from Thailand to England (Williams 2004); intercepted in the USA from many parts of the world, particularly the Pacific, Caribbean and southern Asia (Miller et al. 2014a)		

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
<i>Planococcus orchidi</i> Cox	1	Liberia (Cox 1989; García Morales et al. 2018)	No record found (García Morales et al. 2018)	On Orchidaceae (Cox 1989; García Morales et al. 2018)	On orchids from Liberia to the USA (Miller et al. 2014a)	Yes	No
<i>Planococcus philippinensis</i> Ezzat & McConnell	1	The Philippines (Cox 1989; Ezzat & McConnell 1956; García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On a number of species of Orchidaceae (Cox 1989; Ezzat & McConnell 1956; García Morales et al. 2018; Williams 2004)	On <i>Vanda merrillii</i> , <i>V. sanderiana</i> (Ezzat & McConnell 1956), orchid, <i>Phalaenopsis aphrodite</i> , <i>P. grandiflora</i> , <i>Aerides</i> sp., <i>A. lawrenciae</i> , <i>Cymbidium findlaysonianum</i> , <i>Eria brachystachia</i> and <i>Spathoglottis</i> from the Philippines to the USA (Williams 2004); on <i>Aerides</i> , <i>Cymbidium</i> , <i>Dendrobium</i> , <i>Eria</i> , <i>Phalaenopsis</i> , <i>Spathoglottis</i> and <i>Vanda</i> from the Philippines to the USA (Miller et al. 2014a)	Yes	No
<i>Pseudococcus agavis</i> MacGregor	1	Mexico (García Morales et al. 2018; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On <i>Agave americana</i> and <i>A. mexicana</i> (García Morales et al. 2018; Williams & Granara de Willink 1992)	On <i>Agave</i> from Mexico to the USA (Miller et al. 2014a)	Yes	No
<i>Pseudococcus apomicrocirculus</i> Gimpel & Miller	1	Mexico and Guatemala (García Morales et al. 2018)	No record found (García Morales et al. 2018)	On several species of orchids (García Morales et al. 2018)	On orchids from Mexico to the USA (Miller et al. 2014a)	Yes	No
<i>Pseudococcus apoplanus</i> Williams	1	India (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On <i>Cypripedium</i> and <i>Vanda</i> of Orchidaceae (García Morales et al. 2018; Williams 2004)	On Orchidaceae, <i>Cypripedium</i> sp., <i>Vanda</i> sp. from India to the USA (Williams 2004); on orchids from India to the USA (Miller et al. 2014a)	Yes	No
<i>Pseudococcus aurantiacus</i> Williams	1, 5	Southeast Asia (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On many host plants, including <i>carambola</i> , mangosteen, rambutan (García Morales et al. 2018)	On <i>Lansium domesticum</i> from Malaysia to the USA; on <i>Averrhoa carambola</i> from Malaysia to New Zealand; on pepper vine from Malaysia to the USA; on <i>Garcinia mangostana</i> from Thailand to New Zealand;	Yes	No

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				Assessed as on pathway for mangosteen from Indonesia (DAFF 2012b)	on fruit of <i>Nephelium lappaceum</i> and <i>Garcina mangostana</i> from Thailand to the USA; on <i>Schefflera</i> sp. from Vietnam to Russia; on <i>Averrhoa carambola</i> from Vietnam to Hawaii (Williams 2004); on many hosts, mostly tropical fruit, from Burma, Cambodia, Indonesia, Thailand, the Philippines and Vietnam to the USA (Miller et al. 2014a)		
<i>Pseudococcus baliteus</i> Lit	1, 5	Southeast Asia (Lit & Calilung 1994; Williams 2004)	No record found (García Morales et al. 2018)	On young aerial roots of many host plants, including, mangosteen, lychee, longan and durian (García Morales et al. 2018; Williams 2004) Assessed as on pathway for mangosteen from Indonesia (DAFF 2012b)	Adult intercepted in Australia on fresh lychee fruit in air cargo On <i>Garcina mangostana</i> from Burma to India; on <i>Garcina mangostana</i> from Cambodia to the USA; on fruit of <i>Litchi chinensis</i> from Indonesia to the USA; on <i>Garcina mangostana</i> , <i>Citrus sinensis</i> and <i>Lansium domesticum</i> from the Philippines to the USA; on <i>Litchi chinensis</i> from Singapore to the USA; on <i>Garcina mangostana</i> from Thailand to India; on <i>G. mangostana</i> , <i>G. sp.</i> , <i>Durio zibethinus</i> , <i>D. sp.</i> , <i>Nephelium lappaceum</i> , <i>Lansium domesticum</i> , <i>Litchi chinensis</i> and <i>Dimocarpus longan</i> from Thailand to the USA; on <i>Garcina mangostana</i> , <i>G. sp.</i> , <i>N. lappaceum</i> , <i>N. sp.</i> , <i>Syzygium sp.</i> , <i>Dracaena sp.</i> , <i>Pouteria sp.</i> from Vietnam to the USA (Williams 2004); primarily on tropical	Yes	No

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
<i>Pseudococcus calceolariae</i> (Lidgett)	1, 4, 5, 6	Worldwide (Bigger 1981; Campbell 1983; Charles 1993; Charles et al. 2010; Clearwater 2001; García Morales et al. 2018; Malumphy, Ostrauskas & Pye 2008; Seljak 2010; Wakgarl & Giliomee 2003)	Yes, ACT, NSW, Qld, SA, Tas, Vic (Baker & Huynh 2000; García Morales et al. 2018; Williams 1985a) Declared pest, prohibited by WA (Government of Western Australia 2018)	On numerous host plants including crops such as apple, pear, citrus, persimmon and grapes (Charles 1993; Charles et al. 2010; Wakgarl & Giliomee 2003) Assessed as on pathway for table grapes from California (AQIS 2000); orange from Italy (Biosecurity Australia 2005a); table grapes from Chile (Biosecurity Australia 2005b); stone fruit from NZ to WA (Biosecurity Australia 2006b); apples from NZ (Biosecurity Australia 2006a); apples from China (Biosecurity Australia 2010a); stone fruit from the USA (Biosecurity Australia 2010b); apples from NZ (Biosecurity Australia 2011d)	fruit from Cambodia, Indonesia, Thailand, the Philippines, Vietnam and Singapore to the USA (Miller et al. 2014a) Adult intercepted in Australia on kiwifruit in sea cargo; on peach and feijoa in air cargo; immature on citrus and adult on apricot; adult on fresh persimmon fruit; on lemon in sea cargo Intercepted in the USA from nearly any warm area of the world (Miller et al. 2014a); adult females intercepted on <i>Rhododendron</i> sp. (green house) from Colombia to Japan (Tokihiro 2006)	Yes (WA)	No
<i>Pseudococcus comstocki</i> (Kuwana)	1, 2, 4, 5	Africa, Pacific Islands, Americas, Asia and Europe (Agnello et al. 1992; Ervin, Moffitt & Meyerdirk 1983; García Morales et al. 2018; Kaydan & Kozár 2010; Meyerdirk, Newell & Warkentin 1981; Miller 2005; Park et al. 2010;	No record found (García Morales et al. 2018)	On numerous host plants, including fruit trees such as banana, rambutan, apple, pear, peach, lemon, plum and pomegranate (Agnello et al. 1992; Ervin, Moffitt & Meyerdirk 1983; García Morales et al. 2018; Meyerdirk, Newell & Warkentin 1981). It is also a serious problem in numerous ornamental plants	Adult intercepted in Australia on apples; on bromeliads and <i>Caladium</i> for nursery stock; adult and immature on pomegranate in air cargo On fruit of <i>Nephelium lappaceum</i> from Malaysia to the USA (Williams 2004); primarily on fruit trees and ornamental shrubs from Britain, Canada, China, Former Soviet Union,	Yes	Yes (Kirkpatrick 1953; Martelli, Saldarelli & Minafra 2011; Nakaune et al. 2008; Su 1999)

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		Pellizzari et al. 2012; Shiraiwa 1935)		(Ervin, Moffitt & Meyerdirk 1983) Assessed as on pathway for Fuji apples from Japan (AQIS 1998a); ya pear from China (AQIS 1998b); Korean pear from South Korea (AQIS 1999b); Asian pear from China (Biosecurity Australia 2003); mandarins from Japan (Biosecurity Australia 2009); apples from China (Biosecurity Australia 2010a); stone fruit from the USA (Biosecurity Australia 2010b); table grapes from China (Biosecurity Australia 2011a); table grapes from South Korea (Biosecurity Australia 2011c)	France, Japan, Hong Kong, Korea and Mexico to the USA (Miller et al. 2014a)		
<i>Pseudococcus concavocerarii</i> James	1, 2	Africa (Attafuah, Blencowe & Brunt 1963; Bigger 1981; García Morales et al. 2018)	No record found (García Morales et al. 2018)	On a number of host plants in different families including coffee and cacao (Bigger 1981; García Morales et al. 2018)	On <i>Euphorbia</i> from Somalia to the USA (Miller et al. 2014a)	Yes	Yes (Attafuah, Blencowe & Brunt 1963)
<i>Pseudococcus cryptus</i> (Hempel) [as <i>P. citriculus</i> in (Williams & Watson 1988b)], as <i>P. spathoglottidis</i> in (Lit & Calilung 1994)]	1, 4, 5	Africa, Pacific Islands, South America and Asia (Blumberg, Ben-Dov & Mendel 1999; García Morales et al. 2018; Itioka & Inoue 1996; Lit & Calilung 1994; Matile-Ferrero & Étienne 2006); also in Spain (Sánchez-García & Ben-Dov 2010)	Yes, North Qld (QDAF 2018b) Declared pest, prohibited by WA (Government of Western Australia 2018)	On numerous host plants including citrus, coffee, lychee, rambutan and orchids (Blumberg, Ben-Dov & Mendel 1999; García Morales et al. 2018; Itioka & Inoue 1996) Identified as high priority pest for coffee industry by Plant Health Australia Assessed as on pathway for mangosteen from Thailand (DAFF 2004b); persimmon	Intercepted in Australia on mangosteen in air baggage; adult and nymph on plum; on fresh citrus leaves On <i>Cocos nucifera</i> from Cambodia to the USA; on <i>Punica granatum</i> and <i>Arecaceae</i> from India to the USA; on <i>Aglaonema</i> sp., <i>Citrus limon</i> , <i>Garcinia</i> sp., <i>Mangifera indica</i> from Indonesia to the USA; on <i>Citrus</i> sp. from Laos to the USA; on <i>Nephelium</i>	Yes (WA)	No

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
				from Japan and Israel (DAFF 2004c); mangoes from Taiwan (Biosecurity Australia 2006d); mandarins from Japan (Biosecurity Australia 2009); mangosteen from Indonesia (DAFF 2012b); lychees from Taiwan and Vietnam (DAFF 2013c)	<i>lappaceum</i> from Malaysia to the USA; on <i>Aglaonema</i> sp., Orchidaceae, <i>Paphiopedalum</i> sp., <i>Phalaenopsis amabilis</i> , <i>Lansium domesticum</i> , <i>Moringa oleifera</i> , <i>Spathoglottis</i> sp., <i>Croton</i> sp., <i>M. indica</i> , <i>Eugenia malaccensis</i> , <i>Areca</i> sp. and <i>Citrus</i> sp. from the Philippines to the USA; on <i>Ananas sativa</i> from Singapore to India; on <i>Arecaceae</i> , <i>Cyrtostachys renda</i> , <i>N. lappaceum</i> , <i>N. sp.</i> , <i>Litchi chinensis</i> and <i>Artocarpus</i> sp. from Singapore to the USA; on <i>Garcinia mangostana</i> , <i>Arecaeace</i> , <i>Orchidaceae</i> , <i>Paphiopedalum bellatulum</i> , <i>Pandanus</i> sp., <i>M. indica</i> , <i>Areca catechu</i> , <i>Citrus maxima</i> , <i>C. spp.</i> , <i>Paphiopedilum</i> sp., orchid leaf, <i>Cocos nucifera</i> and <i>Tamarindus indica</i> from Thailand to the USA; on <i>Arecaeaceae</i> , <i>Areca catechu</i> from Vietnam to the USA (Williams 2004); on many hosts and the most common is citrus from Brazil, China, El Salvador, Hong Kong, India, Indonesia, Israel, Japan, Java, Laos, Lebanon, Malaysia, Paraguay, Singapore, the Philippines, Sri Lanka, Sumatra, Taiwan, Thailand, Vietnam, Western Samoa and Yugoslavia to the USA (Miller et al. 2014a); on		

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<i>Pseudococcus dendrobiorum</i> Williams	1, 4	Asia and Australasian regions (Chen et al. 2015; García Morales et al. 2018; Williams 1985a, 2004)	Yes, NT, Qld (García Morales et al. 2018; Williams 1985a)	On many species of Orchidaceae (Chen et al. 2015; García Morales et al. 2018; Williams 1985a)	<p><i>Ficus</i> from China to South Korea (Ji, Wu & Suh 2010)</p> <p>On orchid, <i>Cymbidium</i> sp., <i>Dendrobium bigibbum</i>, <i>D. johsonae</i>, <i>D. phalaenopsis</i>, <i>D. phalaenopsis</i> var <i>compactum</i>, <i>D. sp.</i> and <i>D. discolour</i> leaves from Australia to the USA; on roots of <i>D. canaliculatum</i> and orchid from Queensland to New Zealand; on Orchidaceae from Indonesia to the USA (Williams 1985a); on <i>D. sp.</i> from Papua New Guinea to Hawaii and on <i>Ascoglossum calopterum</i> from Papua New Guinea to England (Williams 1985a; Williams & Watson 1988b); on Orchidaceae from India and Sri Lanka to the USA; on Orchidaceae and <i>Dendrobium</i> sp. from Indonesia to the USA; on <i>Pomotocalpa spicatum</i> and orchid from Malaysia to the USA; on Orchidaceae, <i>Dendrobium</i> sp., orchids and <i>Phalaenopsis sanderiana</i> from the Philippines to the USA; on Orchidaceae, orchids, <i>Dendrobium</i> sp. and <i>Pholidota orriculata</i> from Thailand to the USA (Williams 2004); on orchids from Australia, India, Indonesia, Malaysia, the Philippines, Sri Lanka, Taiwan and Thailand to the USA (Miller et al. 2014a)</p>	No	No

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<i>Pseudococcus donrileyi</i> Gimpel & Miller	1	Mexico and USA (García Morales et al. 2018; Miller 2005)	No record found (García Morales et al. 2018)	On species of <i>Citrus</i> and <i>Pithocellobium flexicaule</i> (García Morales et al. 2018)	On <i>Citrus</i> from Mexico and on <i>Melicoccus</i> from Puerto Rico to the USA (Miller et al. 2014a)	Yes	No
<i>Pseudococcus elisae</i> Borchsenius	1, 2, 4	Central and South America, Hawaii and the Pacific Islands (Beardsley 1986; Culik, Martins & Gullan 2006; Duarte & Albuquerque 2005; García Morales et al. 2018; Gimpel & Miller 1996; Lit & Calilung 1994; Miller, Miller & Watson 2002)	No record found (García Morales et al. 2018)	On many host plants including banana, citrus, mango, red ginger (<i>Alpinia purpurata</i>), <i>Aglaonema</i> , <i>Acacia</i> , tomato and coffee (Beardsley 1986; Culik, Martins & Gullan 2006; García Morales et al. 2018; Gimpel & Miller 1996)	Primarily on banana and occasionally on a number of other hosts from the South America to the USA (Miller et al. 2014a); adult females intercepted on lemon and orange from Chile, banana from Hawaii, and lime from Mexico to Japan (Tokihito 2006)	Yes	Yes (Armijos 2004; Culik, Martins & Gullan 2006; Duarte & Albuquerque 2005)
<i>Pseudococcus gilbertensis</i> (Beardsley)	1	South Asia and Pacific Islands (Beardsley 1966; García Morales et al. 2018)	No record found (García Morales et al. 2018)	On many host plants in many families including mango, citrus and ficus (García Morales et al. 2018)	On fruit of <i>Mangifera indica</i> , on leaf of <i>Fabaceae</i> , on stem of <i>Fortunella japonica</i> , leaf of <i>Chrysophyllum cainito</i> from the Philippines to the USA (under the synonym of <i>P. apodemus</i>) (Miller et al. 2014a; Williams 2004); on <i>Dracaena</i> from Guam and on citrus from the Philippines to the USA (Miller et al. 2014a)	Yes	No
<i>Pseudococcus importatus</i> McKenzie	1	Madagascar, South Africa, Americas, the Philippines and UK (García Morales et al. 2018; Miller 2005; Williams 2004; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On leaves of a large number of species of Orchidaceae (García Morales et al. 2018; Williams & Granara de Willink 1992); also on <i>Melicoccus bijugatus</i> (Williams 2004)	It has been reported that this species was intercepted in the USA on orchids from Brazil, Britain, Canada, Colombia, Costa Rica, Guatemala, Jamaica, Madagascar, Mexico, Panama, Paraguay, Peru, the Philippines, South Africa, Trinidad and Venezuela to the USA (Miller et al. 2014a); on stems of	Yes	No

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<i>Pseudococcus jackbeardsleyi</i> Gimpel & Miller	1, 2, 4, 5	Africa, Pacific Islands, Americas, South and South East Asia (García Morales et al. 2018; Gavrilo 2013; Gimpel & Miller 1996; Mani et al. 2013; Matile-Ferrero & Étienne 2006; Miller 2005; N'Guessan et al. 2014; Williams 2004)	Yes, Torres Strait and Cape York Peninsula, under official control (QDAF 2018c)	On numerous host plants, including banana, citrus, lychee, rambutan, maize, tomato, pepper, mango (García Morales et al. 2018; Gimpel & Miller 1996; Williams 2004), papaya (Mani et al. 2013), cocoa (N'Guessan et al. 2014), pineapple (Culik, Ventura & dos S. Martins 2009) and ornamental <i>Croton</i> sp. (Gavrilo 2013) Assessed as on pathway for pineapples – generic (AFFA 2002); mangoes from Taiwan (Biosecurity Australia 2006d); bananas from the Philippines (Biosecurity Australia 2008b); pineapples from Malaysia (DAFF 2012a); lychees from Taiwan and Vietnam (DAFF 2013c)	<i>Melicoccus bijugatus</i> from the Philippines to the USA (Williams 2004); Adult and nymph intercepted in Australia on <i>Plumeria</i> , <i>Aglaonema</i> and <i>Ficus benjamina</i> for nursery stock On <i>Musa</i> sp. from Mexico to the USA; on <i>Moringa oleifera</i> from the Philippines to Hawaii; on <i>Nephelium lappaceum</i> from Thailand to England; on Cactaceae, <i>Paphiopedilum</i> sp., <i>Dendrobium</i> sp. and <i>Zingiber officinale</i> from Thailand to the USA; on <i>Euphorbia</i> sp. and <i>Annona squamosa</i> from Vietnam to the USA (Williams 2004); on a wide diversity of hosts from annuals such as peppers, eggplant and tomatoes to many tropical fruit trees, and tropical shrubs and ornamentals from all over the world (Miller et al. 2014a) Adult females intercepted on cut leaves of <i>Codiaeum</i> sp. and <i>Dracaena</i> sp. from Sri Lanka to Japan (Tokihito 2006)	Yes	No
<i>Pseudococcus landoi</i> (Balachowsky & Mesnil)	1, 4	Central and South America (García Morales et al. 2018; Gimpel & Miller 1996)	No record found (García Morales et al. 2018)	On many host plants including banana, coffee, cacao and cassava (García Morales et al. 2018)	Primarily on banana and occasionally on a few other hosts from South and Central Americas to the USA (Miller et al. 2014a)	Yes	No

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<i>Pseudococcus longispinus</i> (Targioni Tozzetti)	1, 2, 4, 5	Worldwide (Charles 1982, 1993; Charles et al. 2010; Lit & Calilung 1994; Rohrbach et al. 1988; Suresh & Mohanasundaram 1996; Swirski et al. 1980; Wakgarl & Giliomee 2003; Walton & Pringle 2004a; Williams 1970)	Yes, ACT, NSW, Qld, SA, Tas, Vic, WA (Baker & Huynh 2000; Barrass, Jerie & Ward 1994; Brookes 1957; Furness 1977; García Morales et al. 2018; Williams 1985a)	On numerous host plants including fruit trees and other crops (García Morales et al. 2018); on cotton (Swirski et al. 1980) and grapevines (Charles 1982; Clearwater 2001; Walton & Pringle 2004a); on pineapple (Culik, Ventura & dos S. Martins 2009; Rohrbach et al. 1988), apple, pear, persimmon (Charles 1993), citrus (Baker & Huynh 2000; Wakgarl & Giliomee 2003) and ornamentals (Malumphy, Ostrauskas & Pye 2008) Assessed as on pathway for table grapes from California (AQIS 2000)	Intercepted in Australia on bamboo cane, banana foliage, piper betel (mustard) fruit and mangosteen in air baggage; on blueberry, gooseberry, plum, persimmon, guava, avocado, apple, lychee and orange; on orchid and fern for cut-flowers in air cargo; on foliage of <i>Chamaedorea</i> , <i>Cordyline</i> and <i>Dracaena</i> by cruise vessel; on orange, lemon, kiwifruit, pomegranate and pear in sea cargo; adult and nymph intercepted on lemon and kiwifruit in sea cargo; on cut-flowers, persimmon, <i>Dracaena</i> and <i>Tillandsia</i> for nursery stock and fresh feijoa fruit in air cargo; adult intercepted on <i>Clivia</i> spp. for nursery stock; adult and nymph intercepted on Orchidaceae for nursery stock in air cargo On <i>Pandanus</i> sp. from Malaysia to Hawaii; on <i>Vanda suaya</i> from the Philippines to Hawaii; on <i>Dracaena</i> sp. from Sri Lanka to England; on <i>Garcinia mangostanan</i> , <i>G. sp.</i> and <i>Citrus maxima</i> from Thailand to the USA; on <i>Nephelium lappaceum</i> from Vietnam to the USA (Williams 2004); intercepted in the USA from nearly any area of the world since it occurs outdoors in warm areas, in	No	Yes (Douglas & Krüger 2008; Golino, Sim & Rowani 1995; Golino et al. 2002; Gollifer et al. 1977; Hu et al. 2009; La Notte et al. 1997; Martelli 2010; N'Guessan et al. 2014; Tsai et al. 2010)

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<i>Pseudococcus maritimus</i> (Ehrhorn)	1, 2, 3, 5	Americas, Indonesia and Europe (García Morales et al. 2018; Geiger & Daane 2001; Madsen & McNelly 1960; Miller, Miller & Watson 2002; Pacheco da Silva et al. 2014; Wallingford et al. 2015; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	Hosts include <i>Alfalfa</i> , <i>Medicago</i> , <i>cassava</i> (Williams & Granara de Willink 1992), eggplant (Matile-Ferrero & Étienne 2006) and grapevine (Wallingford et al. 2015). Identified as high priority pest for viticulture industry by Plant Health Australia. It is also a pest of pears and apricots (Madsen & McNelly 1960) Assessed as on pathway for table grapes from California (AQIS 2000); table grapes from Chile (Biosecurity Australia 2005b); stone fruit from the USA (Biosecurity Australia 2010b); table grapes from China (Biosecurity Australia 2011a)	greenhouses and indoor landscapes in cooler areas (Miller et al. 2014a); on <i>Alocasia</i> , <i>Dracaena</i> , <i>Ficus</i> , <i>Philodendron</i> , <i>Polyscias</i> and <i>Rohdea</i> from China to South Korea (Ji, Wu & Suh 2010) Adult intercepted in Australia on fresh pomegranate fruit in air cargo This species has rarely been intercepted in the USA and the species was often cited in earlier literature as occurring worldwide, but these were usually misidentifications of other species in the <i>Pseudococcus maritimus</i> complex (Rung et al. 2006)	Yes	Yes (Golino et al. 2002; Mekuria et al. 2013)
<i>Pseudococcus microcircularis</i> McKenzie	1	Americas, Europe (García Morales et al. 2018; Miller 2005; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On a large number of species of Orchidaceae (García Morales et al. 2018; Williams & Granara de Willink 1992)	On orchids from Antigua, Barbados, Belgium, Belize, Brazil, Britain, British West Indies, Colombia, Costa Rica, Cuba, Haiti, Dominican Republic, Guatemala, Panama, Honduras, Jamaica, Mexico, Trinidad and Venezuela to the USA (Miller et al. 2014a)	Yes	No

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<i>Pseudococcus nakaharai</i> Gimpel & Miller	1	Americas and Japan (García Morales et al. 2018; Miller 2005)	No record found (García Morales et al. 2018)	On a large number of species, mainly the cactus family Cactaceae (García Morales et al. 2018)	Intercepted in the USA from Mexico, Peru and Guatemala; most commonly intercepted on cactus (Miller et al. 2014a)	Yes	No
<i>Pseudococcus neomaritimus</i> Beardsley	1	Pacific Islands (Beardsley 1966; García Morales et al. 2018)	No record found (García Morales et al. 2018)	On a number of host plants in a variety of families, such as Apocynaceae, Fabaceae and Malvaceae (García Morales et al. 2018). Also <i>Acalypha</i> and <i>Blechnum</i> (Beardsley 1966)	On <i>Citrus</i> , <i>Psidium</i> and <i>Punica</i> from Mexico to the USA (Miller et al. 2014a; Rung et al. 2006)	Yes	No
<i>Pseudococcus neomicrocirculus</i> Gimpel & Miller	1	Central and South America (García Morales et al. 2018; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On a few species of Orchidaceae (García Morales et al. 2018; Williams & Granara de Willink 1992)	On orchids from Costa Rica, Guatemala and Venezuela to the USA (Miller et al. 2014a)	Yes	No
<i>Pseudococcus odermatti</i> Miller & Williams	1	North (Florida, Hawaii) and Central America and Asia (García Morales et al. 2018; Miller 2005; Miller & Williams 1997)	No record found (García Morales et al. 2018)	On a number of host plants, including <i>Aglaonema</i> , <i>Annona</i> , <i>Citrus</i> , <i>Fatsia</i> and other ornamental hosts (García Morales et al. 2018; Miller & Williams 1997)	Adult females intercepted on orange from Chile to Japan (Tokihiko 2006) Intercepted in the USA primarily on <i>Aglaonema</i> and <i>Citrus</i> (Miller et al. 2014a; Miller & Williams 1997) and occasionally on a few other hosts including on <i>Aglaonema</i> , <i>Annona</i> , <i>Citrus</i> , <i>Diospyros</i> , <i>Hibiscus</i> , <i>Fatsia</i> , <i>Melicoccus</i> , <i>Pittosporum</i> and <i>Pyracantha</i> from Bahamas, Belize, China, Costa Rica, Hong Kong, India, Japan and Puerto Rico to the USA (Miller et al. 2014a)	Yes	No
<i>Pseudococcus orchidicola</i> Takahashi	1, 5	Pacific Islands (Beardsley 1966; García Morales et al. 2018)	No record found (García Morales et al. 2018)	On many host plants including banana, black pepper, <i>Pandanus</i> , taro and orchid	On <i>Alocasia</i> , <i>Dendrobium</i> and <i>Pandanus</i> from Kwajalein, Marshall, Samoa and Tonga to the USA (Miller et al. 2014a)	Yes	No

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
<i>Pseudococcus philippinus</i> Williams	1	The Philippines and China (García Morales et al. 2018; Trencheva et al. 2010; Williams 2004)	No record found (García Morales et al. 2018)	(Beardsley 1966; García Morales et al. 2018) On a few host plants including mangosteen and <i>Lansium</i> (García Morales et al. 2018; Williams 2004); also on ornamentals (<i>Dracaena</i>) (Trencheva et al. 2010)	On <i>Lansium domesticum</i> , <i>L. sp.</i> , <i>Garcinia mangostana</i> , fruit of <i>Melicoccus bijugatus</i> and <i>Nephelium</i> sp. from the Philippines to the USA (Rung et al. 2006; Williams 2004)	Yes	No
<i>Pseudococcus saccharicola</i> Takahashi	4	South and Southeast Asia (Williams 1970), and Caribbean (García Morales et al. 2018; Lit & Calilung 1994)	Yes, WA (García Morales et al. 2018; Government of Western Australia 2015)	On lower surface of leaves and on roots of Poaceae including sugarcane and rice (García Morales et al. 2018; Williams 1970, 2004)	–	No	No
<i>Pseudococcus sociabilis</i> Hambleton	1	South America (García Morales et al. 2018; Pacheco da Silva et al. 2014; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On a few host plants including coffee, grapes, <i>Mimosa</i> and <i>Hedera</i> (García Morales et al. 2018; Pacheco da Silva et al. 2014; Williams & Granara de Willink 1992)	On <i>Annona</i> , <i>Cattleya</i> , <i>Carica</i> , <i>Hedera</i> , <i>Hippeastrum</i> , <i>Dahlia</i> , <i>Oncidium</i> , <i>Solanum</i> and <i>Zygopetalum</i> from Brazil to the USA (Miller et al. 2014a)	Yes	No
<i>Pseudococcus solenedyos</i> Gimpel & Miller	1	Mexico (García Morales et al. 2018; Gimpel & Miller 1996)	No record found (García Morales et al. 2018)	On tropical fruits including mango, guava and pomegranate (García Morales et al. 2018; Gimpel & Miller 1996)	On <i>Citrus</i> , <i>Mangifera</i> , <i>Psidium</i> , <i>Punica</i> , <i>Spondias</i> and <i>Tamarindus</i> from Mexico to the USA (Rung et al. 2006)	Yes	No
<i>Pseudococcus solomonensis</i> Williams	1, 2	Pacific Islands (Beardsley 1966; García Morales et al. 2018; Macanawai et al. 2005; Williams 1960)	No record found (García Morales et al. 2018)	Host plants include cacao (Williams 1960), coffee, ficus (García Morales et al. 2018) and taro (Macanawai et al. 2005)	Adult intercepted in Australia on fresh taro in air cargo On <i>Musa</i> and <i>Piper</i> from Micronesia and Palau to the USA (Miller et al. 2014a)	Yes	Yes (Macanawai et al. 2005)
<i>Pseudococcus viburni</i> (Signoret) [as <i>Ps. affinis</i> in (Williams & Granara	1, 2, 4, 5	Worldwide (Charles 1993; Clearwater 2001; García Morales et al. 2018; Malumphy,	Yes, NSW, NT, Qld, SA, Vic, WA (Baker & Huynh 2000; Brookes	On all parts of numerous host plants including major horticultural crops such as mango, lychee, kiwifruit, citrus,	Adult intercepted in Australia on capsicum and orange; on foliage of <i>Aglaonema</i> by cruise vessel; on peach fruit and orchid	No	Yes (Garau et al. 1995; Golino et al. 2002)

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
de Willink 1992); as <i>P. malacearum</i> in (Brookes 1957)]		Ostrauskas & Pye 2008; Miller 2005; Moghaddam 2006; Walker et al. 1998; Walton & Pringle 2004a)	1957; García Morales et al. 2018; Government of Western Australia 2015; Williams 1985a)	passion fruit, apple, pear and grapevine (Charles 1993; García Morales et al. 2018; Williams 1985a); also on ornamentals (Malumphy, Ostrauskas & Pye 2008; Moghaddam 2006). In Australia it is widely known as a root species, damaging lawns and tubers and corms in storage (Williams 1985a) Assessed as on pathway for table grapes from California (AQIS 2000)	cut-flower in air cargo; on <i>Vitis</i> for nursery stock in air On <i>Mangifera indica</i> from the Philippines to the USA (Williams 2004); intercepted in the USA often on cactus but also other hosts plants from nearly any area of the world since it occurs outdoors in warm areas, in greenhouses and indoor landscapes in cooler areas (Rung et al. 2006); on <i>Punica</i> from China to South Korea (Ji, Wu & Suh 2010)		
<i>Rastrococcus iceryoides</i> (Green)	1, 4, 5	Africa and Asia (García Morales et al. 2018; Kondo & Kawai 1995; Suresh & Mohanasundaram 1996; Watson & Kubiriba 2005; Williams 1989a, 2004)	No record found (García Morales et al. 2018)	On numerous host plants, including mango, citrus grapevine, cacao, guava and cotton (García Morales et al. 2018; Kondo & Kawai 1995; Suresh & Mohanasundaram 1996; Williams 2004) Assessed as on pathway for mangoes from India (Biosecurity Australia 2008a)	Adult intercepted in Australia on fresh herb/curry leaves On aquatic plants from Singapore to England; on <i>Codiaeum</i> sp. and <i>Citrus</i> sp. from Sri Lanka to the USA (Williams 2004); on <i>Codiaeum</i> and <i>Murraya</i> from India, Malaysia, and Sri Lanka to the USA (Miller et al. 2014a)	Yes	No
<i>Rastrococcus invadens</i> Williams	1, 2, 4, 5	Southeast and South Asia, and Africa (Agoukéné & Fischer 1993; Boavida & Neuenschwander 1995b; García Morales et al. 2018; Moore & Cross 1993; Williams 1986a, 2004)	No record found (García Morales et al. 2018)	On leaves and on numerous host plants including citrus, mango and banana (Boavida & Neuenschwander 1995a; García Morales et al. 2018; Kondo & Kawai 1995; Moore & Cross 1993; Williams 1986a) Assessed as on pathway for mangoes from India (Biosecurity Australia 2008a);	On <i>Mangifera indica</i> and <i>Psidium</i> sp. from the Philippines to the USA; on <i>Strongylodon</i> sp. from Thailand to the USA; on <i>Caladium bicolor</i> from Vietnam to the USA (Williams 2004); on <i>Caladium</i> , <i>Cola</i> and <i>Strongylodon</i> from Nigeria, the Philippines, Thailand and Vietnam to the USA (Miller et al. 2014a); intercepted from	Yes	No

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
<i>Rastrococcus jabadiu</i> Williams	1	South Asia (García Morales et al. 2018; Williams 1989a, 2004)	No record found (García Morales et al. 2018)	mangoes from Pakistan (Biosecurity Australia 2011b) On rambutan, ficus and a few other host plants (García Morales et al. 2018; Williams 2004)	Bangladesh, India and Indonesia to the USA (Miller et al. 2014a) On <i>Nephelium lappaceum</i> from Indonesia and Thailand, <i>Stephanotis granatus</i> from the Philippines and <i>Ficus</i> sp. from Singapore to the USA (Williams 2004); on <i>Ficus</i> , <i>Nephelium</i> , <i>Stephanotis</i> and <i>Stropanthus</i> from Indonesia, the Philippines, Singapore and Thailand to the USA (Miller et al. 2014a)	Yes	No
<i>Rastrococcus mangiferae</i> (Green)	5	Asia (García Morales et al. 2018; Kondo & Kawai 1995; Suresh & Mohanasundaram 1996; Williams 1989a)	No record found (García Morales et al. 2018)	On mango (Kondo & Kawai 1995), citrus and <i>Eugenia hemisphaerica</i> (García Morales et al. 2018); also on ornamentals like <i>Plumeria alba</i> (Suresh & Mohanasundaram 1996)	–	Yes	No
<i>Rastrococcus spinosus</i> (Robinson)	1, 4	South and Southeast Asia (García Morales et al. 2018; Williams 1989a, 2004)	No record found (García Morales et al. 2018)	On many host plants, including mango, coconut, guava, cacao, citrus and guanabana (García Morales et al. 2018; Williams 1989a, 2004) Identified as high priority pest for coffee industry by Plant Health Australia Assessed on pathway for mangoes from Taiwan (Biosecurity Australia 2006d); mangoes from India (Biosecurity Australia 2008a); mangoes from Pakistan (Biosecurity Australia 2011b);	On Araceae and <i>Lansium domesticum</i> from the Philippines to the USA; on <i>Tabernaemontana</i> sp. from Singapore to the USA (Miller et al. 2014a; Williams 2004); intercepted from Cambodia and Laos to the USA (Miller et al. 2014a)	Yes	No

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
<i>Rastrococcus tropiciasiaticus</i> Williams	1	South Asia (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	mangosteen from Indonesia (DAFF 2012b) On citrus, mango, ficus, rambutan and neem (García Morales et al. 2018; Williams 2004)	On <i>Mangifera indica</i> from the Philippines to the USA; on <i>Nephelium lappaceum</i> from Vietnam to the USA (Rung et al. 2006; Williams 2004)	Yes	No
<i>Saccharicoccus sacchari</i> (Cockerell)	1, 2, 4, 5	Worldwide (García Morales et al. 2018; Miller 2005; Sagarra, Vincent & Stewart 2001; Suresh & Mohanasundaram 1996; Watson & Kubiriba 2005; Williams 1970)	Yes, Qld, WA (García Morales et al. 2018; Government of Western Australia 2015)	On many species of Poaceae including sugarcane, rice, <i>Sorghum</i> and lemon grass (García Morales et al. 2018; Matile-Ferrero & Étienne 2006; Suresh & Mohanasundaram 1996; Watson & Kubiriba 2005; Williams 1970)	Intercepted in Australia on fresh sugarcane in air cargo; adult and immature intercepted on <i>Sacchuram</i> for nursery stock Intercepted in the USA from warm areas of the world (Miller et al. 2014a)	No	Yes (Kubiriba et al. 2001; Lockhart, Autrey & Comstock 1992)
<i>Spilococcus mamillariae</i> (Bouché)	1	Australia, Brazil and Europe (García Morales et al. 2018)	Yes, NSW, SA, Tas (García Morales et al. 2018)	Polyphagous, host plants including large number of species of Cactaceae.	Adult intercepted in Australia on a unknown live plant Most commonly intercepted on cactus; on <i>Mammillaria</i> from Canada to the USA; on cactus, <i>Cereus</i> and <i>Echinocactus</i> from Germany to the USA; on Cactaceae from Japan to the USA; on <i>Aporocactus</i> , <i>Corypantha</i> , <i>Echinocactus</i> , <i>Ferrocactus</i> , <i>Mammillaria</i> , <i>Sedum</i> , <i>Stenocactus</i> , <i>Strombocactus</i> and <i>Wilcoxia</i> from Mexico to the USA; on cactus from The Netherlands, Switzerland and Spain to the USA; other distribution records include several countries worldwide (Miller et al. 2014a)	No	No

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
<i>Stricklandina williamsi</i> (Matile-Ferrero & Le Ruyet)	1	Ivory Coast (García Morales et al. 2018) and Thailand (Williams 2004)	No record found (García Morales et al. 2018)	On <i>Garcinia mangostana</i> and <i>Diospyros soubreana</i> (García Morales et al. 2018; Williams 2004)	On <i>Garcinia mangostana</i> from Thailand to France (Williams 2004)	Yes	No
<i>Synacanthococcus bispinosus</i> Morrison	1	Malaysia and the Philippines (García Morales et al. 2018; Morrison 1920; Williams 2004)	No record found (García Morales et al. 2018)	On <i>Bixa</i> and <i>Ficus</i> (García Morales et al. 2018; Williams 2004)	On leaf of unknown plant from the Philippines and <i>Bixa</i> sp. from Malaysia to the USA (Williams 2004)	Yes	No
<i>Trabutina serpentina</i> (Green)	4	Palearctic Asia and Pakistan (García Morales et al. 2018; Moghaddam 2006; Williams 2004)	No record found (García Morales et al. 2018)	On several species of <i>Tamarix</i> (García Morales et al. 2018; Moghaddam 2006; Williams 2004)	–	Yes	No
<i>Trionymus bambusae</i> (Green)	1	East and South Asia (García Morales et al. 2018; Li, Tsai & Wu 2014), (Williams 2004) Europe (Netherlands and Belgium) (Jansen 2009)	No record found (García Morales et al. 2018)	On bamboo (García Morales et al. 2018; Li, Tsai & Wu 2014). In the Netherlands and Belgium, in greenhouses and outdoors, on <i>Semiarundinaria fastuosa</i> , <i>Pseudosasa japonica</i> and <i>Fargesia</i> sp. (Jansen 2009)	On bamboo from India to the USA (Williams 2004)	Yes	No
<i>Trionymus internodii</i> (Hall)	5	Egypt (Williams 1970) and Israel (García Morales et al. 2018)	No record found (García Morales et al. 2018)	On leaf sheaths, stems, crowns and roots, mainly on species of Poaceae, including maize and sugarcane (García Morales et al. 2018; Williams 1970)	–	Yes	No
<i>Trionymus townesi</i> Beardsley	4	South Asia and Pacific Islands (Beardsley 1966; García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On a number of species of Poaceae, including rice sugarcane, <i>Sorghum</i> and hilo grass (Beardsley 1966; Williams 2004)	–	Yes	No
<i>Tympanococcus gardeniae</i> Williams	1	The Philippines (García Morales et al. 2018; Williams 2004)	No record found (García Morales et al. 2018)	On <i>Gardenia</i> sp. (García Morales et al. 2018; Williams 2004)	On <i>Gardenia</i> sp. from the Philippines to Hawaii (Williams 2004)	Yes	No

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
<i>Vryburgia amaryllidis</i> (Bouché) [as <i>Vryburgia lounsburyi</i> in (Cox 1987; Williams 1985a)]	1	Africa, Australasia, USA, Asia and Europe (Cox 1987; García Morales et al. 2018; Longo 2012; Miller, Miller & Watson 2002)	Yes, Qld, SA, WA (García Morales et al. 2018; Government of Western Australia 2015; Williams 1985a)	On Liliaceae (Longo 2012; Miller, Miller & Watson 2002) but also some plants of Amaryllidaceae, Iridaceae, Agavaceae and Poaceae (Williams 1985a)	Adult intercepted in Australia on <i>Hippeastrum</i> by passenger and for nursery stock Commonly intercepted on succulents from Europe; on <i>Amaryllis</i> , <i>Crassula</i> , <i>Cyranthus</i> , <i>Haemanthus</i> , <i>Haworthia</i> and <i>Trichocaulon</i> from Britain, Germany and the Netherlands to the USA (Miller et al. 2014a)	No	No
<i>Vryburgia succulentarum</i> Williams	1	Australia (Ben-Dov 1994; García Morales et al. 2018; Williams 1985a), South Africa (Miller et al. 2014a)	Yes, SA, Tas (Ben-Dov 1994; García Morales et al. 2018; Williams 1985a)	On Aizoaceae (<i>Carpobrotus aequilaterus</i>), Cactaceae (<i>Echinopsis chamaecereus</i>) and Crassulaceae (<i>Crassula</i> and <i>Sedum</i>) (Ben-Dov 1994; García Morales et al. 2018; Williams 1985a)	Adult intercepted in Australia on <i>Notocactus</i> for nursery stock On <i>Echeveria</i> (Crassulaceae) from Australia and South Africa to the USA (Miller et al. 2014a)	No	No
<i>Vryburgia trionymoides</i> (De Lotto) [as <i>Phenacoccus trionymoides</i> in (de Lotto 1961)]	1	Kenya and USA (de Lotto 1961; García Morales et al. 2018; Miller, Miller & Watson 2002)	No record found (García Morales et al. 2018)	Common on succulent plants of Crassulaceae (García Morales et al. 2018). Hosts also include <i>Caralluma</i> (Miller, Miller & Watson 2002), <i>Senecio</i> and some Liliaceae (Stocks 2013)	On <i>Euphorbia</i> from South Africa to the USA (Miller et al. 2014a)	Yes	No
<i>Vryburgia viator</i> (De Lotto) [as <i>Trionymus viator</i> in (de Lotto 1961)]	1	Kenya and South Africa (de Lotto 1961; García Morales et al. 2018; Rung et al. 2006)	No record found (García Morales et al. 2018)	On <i>Pyrus malus</i> (de Lotto 1961; García Morales et al. 2018)	On <i>Brachystelma</i> from South Africa to the USA (Rung et al. 2006); on <i>Leucodendron</i> from the Netherlands and Zimbabwe to the USA (Miller et al. 2014a); also intercepted from Ghana and South Africa (Miller et al. 2014a)	Yes	No

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
PUTOIDAE							
<i>Puto barberi</i> (Cockerell)	4	Central and South America (García Morales et al. 2018; Kondo 2001; Matile-Ferrero & Étienne 2006; Villegas-García & Benavides-Machado 2011; Williams & Granara de Willink 1992; Willimas et al. 2011); Canary Islands (Gran Canaria, Tenerife) (Gavrilov-Zimin & Danzig 2015; Malumphy 2010).	No record found (García Morales et al. 2018)	On a large number of host plants including avocado, cacao, cocoa, citrus, cassava, guava and lantana (García Morales et al. 2018; Matile-Ferrero & Étienne 2006; Williams & Granara de Willink 1992). It is a significant pest in regions of Colombia where coffee is produced (Villegas-García & Benavides-Machado 2011). It was introduced accidentally into Gran Canaria (Canary Islands), where it now occurs on ornamental plants (Malumphy 2010).	Intercepted frequently on many host plants, including <i>Annona</i> , <i>Anthurium</i> , <i>Coccoloba</i> , <i>Bougainvillea</i> , <i>Cestrum</i> , <i>Chenopodium</i> , <i>Croton</i> and <i>Melicoccus</i> , from the Central and South America to the USA (Miller et al. 2014a)	Yes	No
RHIZOECIDAE							
<i>Geococcus coffeae</i> Green	1, 4, 6	Africa, Pacific Islands, Americas, Asia and Europe (Williams 2004; Williams & Butcher 1987; Williams & Granara de Willink 1992) (García Morales et al. 2018; Matile-Ferrero & Étienne 2006)	Yes, NT (García Morales et al. 2018; Williams 1985a) Declared pest, prohibited by WA (Government of Western Australia 2018)	On roots of a very large number of host plants (García Morales et al. 2018; Williams & Watson 1988b) including coffee, grapes, citrus, banana, eggplant, yam and ornamentals (Kuitert & Dekle 1966; Matile-Ferrero & Étienne 2006; Williams 2004; Williams & Granara de Willink 1992)	Adult intercepted in Australia on taro	Yes (WA)	No
<i>Geococcus johorensis</i> Williams	4	Malaysia (García Morales et al. 2018; Williams 1968, 2004)	No record found (García Morales et al. 2018)	On roots of the Araceae, oil palm and Poaceae <i>Paspalum conjugatum</i> (García Morales et al. 2018; Williams 2004)	–	Yes	No

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
<i>Rhizoecus americanus</i> (Hambleton)	1, 4, 5	Americas, Africa (Reunion), Europe (Sicily) and Asia (Thailand) (García Morales et al. 2018; Matile-Ferrero & Étienne 2006; Williams 2004; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On roots of several host plants including lettuce, yams, banana, coffee, tomato and several ornamentals (García Morales et al. 2018; Matile-Ferrero & Étienne 2006; Williams 2004; Williams & Granara de Willink 1992)	Adult, nymph and egg intercepted in Australia on live plants	Yes	No
<i>Rhizoecus dianthi</i> (Green)	4	Europe, North America, Australasia (García Morales et al. 2018)	Yes, Vic. (García Morales et al. 2018; Williams 1985a)	Polyphagous, feeding on hosts in 20 genera of 15 families, including greenhouse plants (García Morales et al. 2018)	–	No	No
<i>Rhizoecus falcifer</i> (Kunckel d'Herculais)	5, 6	Europe, Africa, Australasia, North and Central America (Cox 1987; Danzig & Gavrilov 2009; García Morales et al. 2018; Trencheva & Tomov 2014; Williams & Granara de Willink 1992)	Yes, SA, NSW, Qld (Brookes 1964; Williams 1985a) Declared pest, prohibited by WA (Government of Western Australia 2018)	On the roots of numerous hosts including Poaceae, <i>Salvia</i> , <i>Petunia</i> , <i>Schotia</i> , parsnip, coffee, tomato, potato, cacao, grapes and ornamentals (Bournier 1977; Brookes 1964; García Morales et al. 2018; Williams 1985a; Williams & Granara de Willink 1992)	–	Yes (WA)	No
<i>Ripersiella hibisci</i> (Kawai & Takagi) [as <i>Rhizoecus hibisci</i> in Crop Protection Compendium and some other literature (Williams 1996b; Williams & Granara de Willink 1992)]	4	North and Central America, Asia (China, Taiwan, Hong-Kong, Japan) and Europe (Italy) (García Morales et al. 2018; Mazzeo et al. 2014; Williams 1996b; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	On roots of several hosts including plants from Bromeliaceae (Williams & Granara de Willink 1992), Amaryllidaceae, Apocynaceae, Araceae, Arecaceae, Geraniaceae, Commelinaceae, Poaceae and Malvaceae (García Morales et al. 2018; Williams 1996b). It has been also reported in Italy on	–	Yes	No

Mealybug	Criteria for inclusion (Table 2.1)	Global Distribution	Present within Australia	Host plants, plant parts affected and/or previous pathway assessment	Interception events for Australia (Appendix D) and other countries	Considered further as quarantine pest	Considered further as virus vector
<i>Ripersiella kondonis</i> (Kuwana) [as <i>Rhizoecus kondonis</i> in (DAFF 2013a, d) (Huang, Qiu & Jiang 1983; Williams & Granara de Willink 1992) and (Huang 1987)]	5	North and Central America, and Asia (China, Japan) (García Morales et al. 2018; Huang, Qiu & Jiang 1983; Williams & Granara de Willink 1992)	No record found (García Morales et al. 2018)	ornamentals (Mazzeo et al. 2014) On the roots of several host plants including citrus, coffee, alfalfa and several ornamentals (García Morales et al. 2018; Huang 1987; Huang, Qiu & Jiang 1983)	–	Yes	No

10 Appendix C: Summary of previous mealybug pest risk assessments

Table 10.1 Summary of previous mealybug pest risk assessments

Species	Policy (commodity and origin)	Likelihood of						Consequences	URE
		Importation	Distribution	Entry	Establishment	Spread	EES		
<i>Crisicoccus matsumotoi</i>	Table grapes (Japan) 2014	H	M	M	H	H	M	L	L
<i>Dysmicoccus grassii</i>	Pineapples (all countries) 2002	H	M	M	H	H	M	L	L
	Pineapples (Malaysia) 2012	H	M	M	H	H	M	L	L
<i>Dysmicoccus lepelleyi</i>	Mangosteen (Indonesia) 2012	H	M	M	H	H	M	L	L
	Lychees (Taiwan and Vietnam) 2013	H	M	M	H	H	M	L	L
<i>Dysmicoccus neobrevipes</i>	Pineapples (all countries) 2002	H	M	M	H	H	M	L	L
	Mangosteen (Thailand) 2004	H	M	M	H	H	M	L	L
	Bananas (Philippines) 2008	H	H	H	H	H	H	L	L
	Pineapples (Malaysia) 2012	H	M	M	H	H	M	L	L
	Mangos (Indonesia, Thailand and Vietnam) 2015	H	M	M	H	H	M	L	L
<i>Dysmicoccus</i> sp.	Salacca (Indonesia) 2014	M	M	L	H	H	L	L	VL
<i>Exallomochlus hispidus</i>	Mangosteens (Indonesia) 2012	H	M	M	H	H	M	L	L
<i>Ferrisia malvastra</i> (WA)	Mangoes (India) 2008	H	M	M	H	H	M	L	L
<i>Ferrisia virgata</i> (WA)	Longan and lychees (China and Thailand) 2004	H	M	M	H	H	M	L	L
	Tahitian Limes (New Caledonia) 2006	H	M	M	H	H	M	L	L
	Mangoes (India) 2008	H	M	M	H	H	M	L	L
<i>Hordeolicoccus heterotrichus</i>	Mangosteens (Indonesia) 2012	H	M	M	H	H	M	L	L
<i>Nipaecoccus filamentosus</i>	Tahitian Limes (New Caledonia) 2006	H	M	M	H	H	M	L	L
<i>Nipaecoccus nipae</i>	Bananas (Philippines) 2008	H	H	H	H	H	H	L	L

Species	Policy (commodity and origin)	Likelihood of						Consequences	URE
		Importation	Distribution	Entry	Establishment	Spread	EES		
<i>Paracoccus interceptus</i>	Mangosteen (Indonesia) 2012	H	M	M	H	H	M	L	L
	Lychees (Taiwan and Vietnam) 2013	H	M	M	H	H	M	L	L
<i>Paracoccus marginatus</i>	Pineapples (all countries) 2002	H	M	M	H	H	M	L	L
	Fresh Mango (Indonesia, Thailand and Vietnam) 2015	H	M	M	H	H	M	L	L
<i>Paraputo aracearum</i>	Fresh taro corms (all countries) 2011	M	M	L	M	H	L	L	VL
<i>Paraputo leverii</i>	Fresh taro corms (all countries) 2011	M	M	L	M	H	L	L	VL
<i>Paraputo odontomachi</i>	Mangosteen (Indonesia) 2012	H	M	M	H	H	M	L	L
<i>Phenacoccus aceris</i>	Apples (China) 2010	H	M	M	H	H	M	L	L
	Stone fruit (USA) 2010	H	M	M	H	H	M	L	L
<i>Phenacoccus hargreavesi</i>	Pineapples (all countries) 2002	H	M	M	H	H	M	L	L
<i>Planococcus kraunhiae</i>	Unshu mandarins (Japan) 2009	H	M	M	H	H	M	L	L
	Table grapes (China) 2011	H	M	M	H	H	M	L	L
	Table grapes (South Korea) 2011	H	M	M	H	H	M	L	L
	Table grapes (California to WA) 2013	L	M	L	H	H	L	L	VL
	Table grapes (Japan) 2014	H	M	M	H	H	M	L	L
<i>Planococcus lilacinus</i>	Mangoes (Taiwan) 2006	H	M	M	H	H	M	L	L
	Mangoes (India) 2008	H	M	M	H	H	M	L	L
	Mangosteen (Indonesia) 2012	H	M	M	H	H	M	L	L
	Lychees (Taiwan and Vietnam) 2013	H	M	M	H	H	M	L	L
	Unshu mandarins (Japan) 2009	H	M	M	H	H	M	L	L
	Table grapes (Japan) 2014	H	M	M	H	H	M	L	L
	Fresh Mango (Indonesia, Thailand and Vietnam) 2015	H	M	M	H	H	M	L	L

Species	Policy (commodity and origin)	Likelihood of						Consequences	URE
		Importation	Distribution	Entry	Establishment	Spread	EES		
<i>Planococcus litchi</i>	Longan and Lychees (China and Thailand) 2004	H	M	M	H	H	M	L	L
	Lychees (Taiwan and Vietnam) 2013	H	M	M	H	H	M	L	L
<i>Planococcus mali</i>	Apples (New Zealand) 2006	H	M	M	H	H	M	L	L
<i>Planococcus minor</i> (WA)	Bananas (Philippines) 2008	H	H	H	H	H	H	L	L
	Mangosteen (Indonesia) 2012	H	M	M	H	H	M	L	L
	Lychees (Taiwan and Vietnam) 2013	H	M	M	H	H	M	L	L
	Pineapples (Malaysia) 2012	H	M	M	H	H	M	L	L
	Mangoes (Indonesia, Thailand and Vietnam) 2015	H	M	M	H	H	M	L	L
	Fresh island cabbage (Pacific) 2013	H	M	M	H	H	M	L	L
<i>Planococcus</i> sp.	Salacca (Indonesia) 2014	M	M	L	H	H	L	L	VL
<i>Planococcoides njalensis</i>	Pineapples (all countries) 2002	H	M	M	H	H	M	L	L
<i>Pseudococcus aurantiacus</i>	Mangosteen (Indonesia) 2012	H	M	M	H	H	M	L	L
<i>Pseudococcus baliteus</i>	Mangosteen (Indonesia) 2012	H	M	M	H	H	M	L	L
<i>Pseudococcus calceolariae</i> (WA)	Sweet oranges (Italy) 2005	H	M	M	H	H	M	L	L
	Stone fruit (New Zealand into WA) 2006	H	M	M	H	H	M	L	L
	Table grapes (Chile) 2005	H	M	M	H	H	M	L	L
	Apples (New Zealand) 2006	H	M	M	H	H	M	L	L
	Stone fruit (USA) 2010	H	M	M	H	H	M	L	L
	Apples (China) 2010	M	M	L	H	H	L	L	VL
	Table grapes (California to WA) 2013	L	M	L	H	H	L	L	VL
<i>Pseudococcus comstocki</i>	Unshu mandarins (Japan) 2009	H	M	M	H	H	M	L	L
	Table grapes (South Korea) 2011	H	M	M	H	H	M	L	L
	Apples (China) 2010	H	M	M	H	H	M	L	L

Species	Policy (commodity and origin)	Likelihood of					Consequences	URE
		Importation	Distribution	Entry	Establishment	Spread	EES	
<i>Pseudococcus cryptus</i>	Stone fruit (USA) 2010	H	M	M	H	H	M	L
	Table grapes (China) 2011	H	M	M	H	H	M	L
	Lily cut-flowers (Taiwan) 2013	H	M	M	H	H	M	L
	Table grapes (Japan) 2014	H	M	M	H	H	M	L
	Nectarines (China) 2016	H	M	M	H	H	M	L
	Mangoes (Taiwan) 2006	H	M	M	H	H	M	L
	Unshu mandarins (Japan) 2009	H	M	M	H	H	M	L
	Mangosteen (Indonesia) 2012	H	M	M	H	H	M	L
	Lychees (Taiwan and Vietnam) 2013	H	M	M	H	H	M	L
	Mangosteen (Thailand) 2004	H	M	M	H	H	M	L
<i>Pseudococcus jackbeardsleyi</i>	Sweet Oranges (Italy) 2005	H	M	M	H	H	M	L
	Fresh Mango (Indonesia, Thailand and Vietnam) 2015	H	M	M	H	H	M	L
	Pineapples (all countries) 2002	H	M	M	H	H	M	L
	Mangoes (Taiwan) 2006	H	M	M	H	H	M	L
	Bananas (Philippines) 2008	H	H	H	H	H	H	L
	Pineapples (Malaysia) 2012	H	M	M	H	H	M	L
<i>Pseudococcus maritimus</i>	Lychees (Taiwan and Vietnam) 2013	H	M	M	H	H	M	L
	Fresh Mango (Indonesia, Thailand and Vietnam) 2015	H	M	M	H	H	M	L
	Table grapes (Chile) 2005	H	M	M	H	H	M	L
<i>Pseudococcus sp.</i>	Stone fruit (USA) 2010	H	M	M	H	H	M	L
	Table grapes (China) 2011	H	M	M	H	H	M	L
<i>Pseudococcus sp.</i>	Salacca (Indonesia) 2014	M	M	L	H	H	L	VL
<i>Rastrococcus iceryoides</i>	Mangoes (India) 2008	H	M	M	H	H	M	L

Species	Policy (commodity and origin)	Likelihood of						Consequences	URE
		Importation	Distribution	Entry	Establishment	Spread	EES		
	Fresh Mango (Indonesia, Thailand and Vietnam) 2015	H	M	M	H	H	M	L	L
<i>Rastrococcus invadens</i>	Mangoes (India) 2008	H	M	M	H	H	M	L	L
	Mangoes (Pakistan) 2011	H	M	M	H	H	M	L	L
	Fresh Mango (Indonesia, Thailand and Vietnam) 2015	H	M	M	H	H	M	L	L
<i>Rastrococcus spinosus</i>	Mangoes (India) 2008	H	M	M	H	H	M	L	L
	Mangoes (Pakistan) 2011	H	M	M	H	H	M	L	L
	Mangosteen (Indonesia) 2012	H	M	M	H	H	M	L	L
	Mangoes (Taiwan) 2006	H	M	m	H	H	M	L	L
	Fresh Mango (Indonesia, Thailand and Vietnam) 2015	H	M	M	H	H	M	L	L
<i>Rastrococcus rubellus</i>	Fresh Mango (Indonesia, Thailand and Vietnam) 2015	H	M	M	H	H	M	L	L

11 Appendix D: Mealybug interceptions by Australia (1986–2015)

There have been 3,101 mealybug interception events recorded on the plant import pathway by Australia in the last 30 years (1986–2015). Almost all the intercepted mealybugs belong to the family Pseudococcidae (99.87 per cent). There are only four interception events for the family Rhizoecidae and no interceptions for the family Putoidae.

The majority (65.3 per cent) of the intercepted mealybugs have only been identified to family level. Only 24.7 per cent have been identified to genera, and only 10 per cent to species level.

A total of 22 genera of mealybugs have been identified and the most frequently intercepted genera, in descending order, were *Paraputo*, *Pseudococcus*, and *Planococcus*, followed by *Crisicoccus*, *Phenacoccus*, *Dysmicoccus*, *Nipaecoccus*, *Ferrisia* and *Paracoccus*. Note that species of *Paraputo* were mainly intercepted on taro from the Pacific countries.

A total of 40 species have been identified; the most frequently intercepted identified species, in descending order, were *Pseudococcus longispinus*, *Planococcus citri* and *Planococcus minor*, followed by *Pseudococcus calceolariae*, *Pseudococcus viburni* and *Pseudococcus jackbeardsleyi*.

The quarantine status and/or status as a virus vector for these 40 species are presented in Table 11.1. Twenty of these species are quarantine pests for Australia and six are regional pests for Western Australia. Thirteen species in total are virus vectors.

Table 11.1 Australian mealybug interceptions (1986–2015)

Family	Genus	Species	Interception events (a)	Quarantine pest?	Virus vector?
Pseudococcidae	<i>Antonina</i>	<i>graminis</i>	2	No	No
Pseudococcidae	<i>Crisicoccus</i>	<i>theobromae</i>	6	Yes	No
Pseudococcidae	<i>Crisicoccus</i>	spp.	24		
Pseudococcidae	<i>Dysmicoccus</i>	<i>boninsis</i>	1	Yes (WA)	Yes
Pseudococcidae	<i>Dysmicoccus</i>	<i>brevipes</i>	2	No	Yes
Pseudococcidae	<i>Dysmicoccus</i>	<i>lepelleyi</i>	2	Yes	No
Pseudococcidae	<i>Dysmicoccus</i>	<i>neobrevipes</i>	3	Yes	Yes
Pseudococcidae	<i>Dysmicoccus</i>	spp.	3		
Pseudococcidae	<i>Dysmicoccus</i>	spp.	5		
Pseudococcidae	<i>Exallomochlus</i>	<i>hispidus</i>	1	Yes	No
Pseudococcidae	<i>Ferrisia</i>	<i>virgata</i>	6	No	Yes
Pseudococcidae	<i>Ferrisia</i>	spp.	5		
Pseudococcidae	<i>Formicococcus</i>	sp.	1		
Pseudococcidae	<i>Maconellicoccus</i>	<i>hirsutus</i>	4	No	No
Pseudococcidae	<i>Maconellicoccus</i>	sp.	1		
Pseudococcidae	<i>Nipaecoccus</i>	<i>nipae</i>	3	Yes	No
Pseudococcidae	<i>Nipaecoccus</i>	sp.	1		
Pseudococcidae	<i>Nipaecoccus</i>	<i>viridis</i>	7	No	No
Pseudococcidae	<i>Nipaecoccus</i>	spp.	2		
Pseudococcidae	<i>Palmicultor</i>	<i>palmarum</i>	2	Yes	No

Family	Genus	Species	Interception events (a)	Quarantine pest?	Virus vector?
Pseudococcidae	<i>Paracoccus</i>	<i>interceptus</i>	2	Yes	No
Pseudococcidae	<i>Paracoccus</i>	sp.	1		
Pseudococcidae	<i>Paracoccus</i>	spp.	7		
Pseudococcidae	<i>Paraputo</i>	<i>aracearum</i>	6	Yes	No
Pseudococcidae	<i>Paraputo</i>	<i>kukumi</i>	5	Yes	No
Pseudococcidae	<i>Paraputo</i>	<i>odontomachi</i>	1	Yes	No
Pseudococcidae	<i>Paraputo</i> [b]	spp.	296		
Pseudococcidae	<i>Phenacoccus</i>	<i>madeirensis</i>	6	Yes	No
Pseudococcidae	<i>Phenacoccus</i>	<i>solani</i>	3		
Pseudococcidae	<i>Phenacoccus</i>	<i>solenopsis</i>	3	Yes (WA)	No
Pseudococcidae	<i>Phenacoccus</i>	spp.	4		
Pseudococcidae	<i>Planococcus</i>	<i>citri</i>	50	No	Yes
Pseudococcidae	<i>Planococcus</i>	<i>ficus</i>	8	Yes	Yes
Pseudococcidae	<i>Planococcus</i>	<i>kraunhiae</i>	1	Yes	No
Pseudococcidae	<i>Planococcus</i>	<i>lilacinus</i>	5	Yes	No
Pseudococcidae	<i>Planococcus</i>	<i>minor</i>	44	Yes (WA)	Yes
Pseudococcidae	<i>Planococcus</i>	spp.	8		
Pseudococcidae	<i>Planococcus</i>	spp.	18		
Pseudococcidae	<i>Pseudococcus</i>	<i>baliteus</i>	5	Yes	No
Pseudococcidae	<i>Pseudococcus</i>	<i>calceolariae</i>	11	Yes (WA)	No
Pseudococcidae	<i>Pseudococcus</i>	<i>comstocki</i>	5	Yes	Yes
Pseudococcidae	<i>Pseudococcus</i>	<i>cryptus</i>	2	Yes (WA)	No
Pseudococcidae	<i>Pseudococcus</i>	<i>jackbeardsleyi</i>	8	Yes	No
Pseudococcidae	<i>Pseudococcus</i>	<i>longispinus</i>	83	No	Yes
Pseudococcidae	<i>Pseudococcus</i>	<i>maritimus</i>	2	Yes	Yes
Pseudococcidae	<i>Pseudococcus</i>	<i>solomonensis</i>	1	Yes	Yes
Pseudococcidae	<i>Pseudococcus</i>	spp.	22		
Pseudococcidae	<i>Pseudococcus</i>	<i>viburni</i>	11	No	Yes
Pseudococcidae	<i>Pseudococcus</i>	spp.	53		
Pseudococcidae	<i>Rastrococcus</i>	<i>iceryoides</i>	1	Yes	No
Pseudococcidae	<i>Rastrococcus</i>	spp.	2		
Pseudococcidae	<i>Saccharicoccus</i>	<i>sacchari</i>	2	No	Yes
Pseudococcidae	<i>Spilococcus</i>	<i>mammillariae</i>	1	No	No
Pseudococcidae	<i>Vryburgia</i>	<i>amaryllidis</i>	1	No	No
Pseudococcidae	<i>Vryburgia</i>	<i>succulentarum</i>	1	No	No
Pseudococcidae	Unidentified	Unidentified	2,337		
Rhizoecidae	<i>Geococcus</i>	<i>coffae</i>	1	Yes (WA)	
Rhizoecidae	<i>Geococcus</i>	spp.	2		
Rhizoecidae	<i>Rhizoecus</i>	<i>americanus</i>	1	Yes	No
2 families	22 identified genera	40 identified species	3,101		

a: Each interception event is based on the presence of at least a single mealybug taxon on a consignment. The number of mealybugs present per event is not generally recorded, and multiple mealybug taxa can infest the same commodity.

b: the 142 interception events previously recorded as *Criniticoccus* were proved to be the misidentification of *Paraputo* (M. Gorton, 2016, pers. comm.).

12 Appendix E: Substantiation of the viruses reported to be transmitted by mealybugs

Table 12.1 Viruses reported to be transmitted by mealybugs

Virus species	Acronym	Taxonomic origin	ICTV status	Virus/vector link substantiated	Included in pest categorisation	Notes
Banana streak virus	BSV	Original	Revoked	N/A	No	Invalid species
<i>Banana streak GF virus</i>	BSGFV	Revision	Recognised	Yes	Yes	–
<i>Banana streak MY virus</i>	BSMYV	Revision	Recognised	Yes	Yes	–
<i>Banana streak OL virus</i>	BSOLV	Revision	Recognised	Yes	Yes	–
<i>Banana streak VN virus</i>	BSVNV	New species	Recognised	Yes	Yes	–
<i>Banana streak IM virus</i>	BSIMV	New species	Recognised	No	No	Unknown vector
<i>Banana streak UA virus</i>	BSUAV	New species	Recognised	No	No	Unknown vector
<i>Banana streak UI virus</i>	BSUIV	New species	Recognised	No	No	Unknown vector
<i>Banana streak UL virus</i>	BSULV	New species	Recognised	No	No	Unknown vector
<i>Banana streak UM virus</i>	BSUMV	New species	Recognised	No	No	Unknown vector
<i>Cacao swollen shoot virus</i>	CSSV	Original	Recognised	Yes	Yes	–
<i>Cacao swollen shoot CD virus</i>	CSSCDV	New species	Recognised	No	No	Unknown vector
<i>Cacao swollen shoot Togo A virus</i>	CSSTAV	New species	Recognised	No	No	Unknown vector
<i>Citrus yellow mosaic virus</i>	CiYMV	New species	Recognised	Yes	Yes	–
<i>Canna yellow mottle virus</i>	CaYMV	New species	Recognised	No	No	Unknown vector
<i>Commelina yellow mottle virus</i>	ComYMV	New species	Recognised	Yes	Yes	–
<i>Dioscorea bacilliform virus</i>	DBV	Original	Revoked	N/A	No	Invalid species (became DBALV)
<i>Dioscorea bacilliform AL virus</i>	DBALV	Revision	Recognised	Yes	Yes	–
<i>Dioscorea bacilliform SN virus</i>	DBSNV	New species	Recognised	No	No	Unknown vector
<i>Kalanchoe top-spotting virus</i>	KTSV	New species	Recognised	Yes	Yes	–
<i>Pineapple bacilliform virus</i>	PBV	Original	Revoked	N/A	No	Invalid species

Virus species	Acronym	Taxonomic origin	ICTV status	Virus/vector link substantiated	Included in pest categorisation	Notes
<i>Pineapple bacilliform comosus virus</i>	PBCoV	New species/Revision	Recognised	Yes	Yes	–
<i>Pineapple bacilliform erectifolius virus</i>	PBErV	New species/Revision	Recognised	Yes	Yes	–
<i>Piper yellow mottle virus</i>	PYMoV	New species	Recognised	Yes	Yes	–
<i>Schefflera ringspot virus</i>	SRV	New species	Recognised	Yes	Yes	–
Sugarcane bacilliform virus	SCBV	Original	Revoked	N/A	No	Invalid species
<i>Sugarcane bacilliform IM virus</i>	SCBIMV	Revision	Recognised	Yes	Yes	Indirect (via original)
<i>Sugarcane bacilliform MO virus</i>	SCBMOV	Revision	Recognised	Yes	Yes	Indirect (via original)
<i>Sugarcane bacilliform Guadeloupe A virus</i>	SCBGAV	New species	Recognised	No	No	Unknown vector
<i>Sugarcane bacilliform Guadeloupe D virus</i>	SCBGDV	New species	Recognised	No	No	Unknown vector
<i>Taro bacilliform virus</i>	TaBV	New species	Recognised	Yes	Yes	–
<i>Grapevine virus A</i>	GVA	New species	Recognised	Yes	Yes	–
<i>Grapevine virus B</i>	GVB	New species	Recognised	Yes	Yes	–
<i>Grapevine virus E</i>	GVE	New species	Recognised	Yes	Yes	–
<i>Grapevine leafroll-associated virus 1</i>	GLRaV-1	New species	Recognised	Yes	Yes	–
<i>Grapevine leafroll-associated virus 2</i>	GLRaV-2	New species	Recognised	No	No	There is a report of the mealybugs <i>Pseudococcus viburni</i> (syn. <i>P. affinis</i>) and <i>P. longispinus</i> transmitting GLRaV-2 (Golino, Sim & Rowani 1995; Martelli 1997a). However, more recent papers state that the vector of GLRaV-2 is unknown, including a paper from Martelli (Martelli et al. 2002).
<i>Grapevine leafroll-associated virus 3</i>	GLRaV-3	New species	Recognised	Yes	Yes	–
<i>Grapevine leafroll-associated virus 4</i>	GLRaV-4	Revision	Recognised	Yes	Yes	GLRaV-5, GLRaV-6, GLRaV-9, GLRaV-Pr, GLRaV-De and GLRaV-Car are

Virus species	Acronym	Taxonomic origin	ICTV status	Virus/vector link substantiated	Included in pest categorisation	Notes
						synonyms of GLRaV-4 (Martelli et al. 2012)
<i>Little cherry virus 2</i>	LChV-2	New species	Recognised	Yes	Yes	–
<i>Pineapple mealybug wilt-associated virus 1</i>	PMWaV-1	New species	Recognised	Yes	Yes	–
<i>Pineapple mealybug wilt-associated virus 2</i>	PMWaV-2	New species	Recognised	Yes	Yes	–
<i>Pineapple mealybug wilt-associated virus 3</i>	PMWaV-3	New species	Recognised	Yes	Yes	–
<i>Citrus tristeza virus</i>	CTV	New species	Recognised	No	No	There is a single report of the mealybug <i>Ferrisia virgata</i> transmitting experimentally the causative agent of 'tristeza' disease, reported as lime dieback (Hughes & Lister 1953). This report is considered unsubstantiated for two reasons. Firstly, it pre-dates the period before CTV was characterised, and precise identification of the organism reported as responsible for the disease cannot be confirmed. Secondly, CTV is one of the most extensively studied plant viruses, yet there have been no subsequent reports of any mealybug species transmitting CTV.

Table 12.2 Mealybugs reported to transmit viruses

Mealybug vector	Mealybug interception events (a)	Mealybug is a quarantine pest	Mealybug transmits a quarantine virus	Viruses transmitted (b)		Virus/vector link substantiated	Reference
				Quarantine pest	Non-quarantine pest		
<i>Dysmicoccus boninsis</i>	1	Yes (WA)	Yes	–	SCBIMV	Indirectly (via original SCBV)	(Lockhart, Autrey & Comstock 1992)
				SCBMOV	–	Indirectly (via original SCBV)	(Lockhart, Autrey & Comstock 1992)
<i>Dysmicoccus brevipes</i>	2	No	Yes	CSSV	–	Proven	(Posnette 1950)
				–	BSGFV	Indirectly (via original BSV)	(Kubiriba et al. 2001; Su 1999)
				–	BSMYV	Indirectly (via original BSV)	(Kubiriba et al. 2001; Su 1999)
				–	BSOLV	Yes	(Meyer et al. 2008)
				–	PBCoV	Yes	(Gambley et al. 2008a)
				–	PBErV	Yes	(Gambley et al. 2008a)
				–	PMWaV-1	Yes	(Gambley et al. 2008b)
				–	PMWaV-2	Yes	(Gambley et al. 2008b; Sether & Hu 2002)
				–	PMWaV-3	Yes	(Gambley et al. 2008b)
<i>Dysmicoccus neobrevipes</i>	3	Yes	No	–	PBCoV	Yes	(Sether et al. 2012)
				–	PMWaV-1	Yes	(Carter 1963; Sether, Ullman & Hu 1998)
				–	PMWaV-2	Yes	(Sether & Hu 2002)
				–	PMWaV-3	Yes	(Sether & Hu 2002)
<i>Dysmicoccus</i> sp. nr. <i>texensis</i>	–	Yes	No	–	BSGFV	Indirectly (via original BSV)	[as <i>Dysmicoccus</i> sp. nr. <i>bispinosus</i>] (Armijos 2004)
				–	BSMYV	Indirectly (via original BSV)	[as <i>Dysmicoccus</i> sp. nr. <i>bispinosus</i>] (Armijos 2004)
				–	BSOLV	Indirectly (via original BSV)	[as <i>Dysmicoccus</i> sp. nr. <i>bispinosus</i>] (Armijos 2004)
<i>Ferrisia gilli</i>	–	Yes	No	–	GLRaV-3	Yes	(Wistrom et al. 2016)
				–	GLRaV-4	Yes	(Wistrom et al. 2016)

Mealybug vector	Mealybug interception events (a)	Mealybug is a quarantine pest	Mealybug transmits a quarantine virus	Viruses transmitted (b)		Virus/vector link substantiated	Reference
				Quarantine pest	Non-quarantine pest		
<i>Ferrisia virgata</i>	6	No	Yes	CSSV	–	Yes	(Kirkpatrick 1950; Posnette 1950; Posnette & Strickland 1948)
				PYMoV	–	Yes	(Bhat et al. 2003)
<i>Formicococcus celtis</i>	–	Yes	Yes	CSSV	–	Yes	(Attafuah, Blencowe & Brunt 1963)
<i>Formicococcus njalensis</i>	–	Yes	Yes	CSSV	–	Yes	(Posnette 1950; Posnette & Strickland 1948)
<i>Heliococcus bohemicus</i>	–	Yes	No	–	GLRaV-1	Yes	(Sforza, Boudon-Padieu & Greif 2003)
				–	GLRaV-3	Yes	(Sforza, Boudon-Padieu & Greif 2003; Zorloni et al. 2006)
				–	GVA	Yes	(Zorloni et al. 2006)
<i>Paracoccus burnerae</i>	–	Yes	No	–	BSGFV	Indirectly (via original BSV)	(Muturi et al. 2013)
				–	BSMYV	Indirectly (via original BSV)	(Muturi et al. 2013)
				–	BSOLV	Indirectly (via original BSV)	(Muturi et al. 2013)
<i>Phenacoccus aceris</i>	–	Yes	No	–	LChV-2	Yes	(Raine, McMullen & Forbes 1986)
				–	GLRaV-1	Yes	(Sforza, Boudon-Padieu & Greif 2003)
				–	GVA	Yes	(Le Maguet et al. 2012)
				–	GLRaV-3	Yes	(Sforza, Boudon-Padieu & Greif 2003)
				GVB	–	Yes	(Le Maguet et al. 2012)
<i>Phenacoccus hargreavesi</i>	–	Yes	Yes	CSSV	–	Yes	(Attafuah, Blencowe & Brunt 1963; Bigger 1981)
<i>Planococcus citri</i>	50	No	Yes	–	BSGFV	Yes	(Meyer et al. 2008)
				–	BSMYV	Yes	(Geering et al. 2005).
				–	BSOLV	Yes	(Meyer et al. 2008)
				BSVNV	–	Yes	(Lheureux et al. 2007)

Mealybug vector	Mealybug interception events (a)	Mealybug is a quarantine pest	Mealybug transmits a quarantine virus	Viruses transmitted (b)		Virus/vector link substantiated	Reference
				Quarantine pest	Non-quarantine pest		
<i>Planococcus ficus</i>	8	Yes	Yes	CSSV	–	Yes	(Kirkpatrick 1950; Posnette 1950; Posnette & Strickland 1948)
				CiYMV	–	Yes	(Ahlawat et al. 1999; Reddy & Ahlawat 1997)
				ComYMV	–	Yes	(Ayala-Navarrete 1993; Lockhart & Khaless 1988)
				DBALV	–	Yes	(Odu et al. 2006; Phillips et al. 1999)
				KTSV	–	Yes	(Brunt et al. 1996)
				PYMoV	–	Yes	(de Silva, Jones & Shaw 2002; Lockhart et al. 1997a)
				SCBMOV	–	Indirectly (via original SCBV)	(Lockhart, Ireys & Comstock 1995)
				–	PBCoV	Yes	(Gambley et al. 2008a)
				–	GLRaV-3	Yes	(Cabaleiro & Segura 1997a; Golino et al. 2002)
				–	SCBIMV	Indirectly (via original SCBV)	(Lockhart, Ireys & Comstock 1995)
				–	SRV	Yes	(Lockhart & Olszewski 1996)
				–	TaBV	Yes	(Gollifer et al. 1977)
				–	BSGFV	Yes	(Meyer et al. 2008)
				–	BSOLV	Yes	(Meyer et al. 2008)
				–	GLRaV-1	Yes	(Tsai et al. 2010)
<i>Planococcus kenya</i>	–	Yes	Yes	–	GLRaV-3	Yes	(Douglas & Krüger 2008; Mahfoudhi, Digiario & Dhouibi 2009; Tsai et al. 2008; Tsai et al. 2010)
				–	GLRaV-4	Yes	(Mahfoudhi, Digiario & Dhouibi 2009; Tsai et al. 2010)
				–	GVA	Yes	(Rosciglione et al. 1983; Tsai et al. 2010)
				GVB	–	Yes	(Martelli 1997b)
<i>Planococcus kenya</i>	–	Yes	Yes	CCSV	–	Yes	(Attafuah, Blencowe & Brunt 1963)

Mealybug vector	Mealybug interception events (a)	Mealybug is a quarantine pest	Mealybug transmits a quarantine virus	Viruses transmitted (b)		Virus/vector link substantiated	Reference
				Quarantine pest	Non-quarantine pest		
<i>Planococcus minor</i>	44	Yes (WA)	Yes	PYMoV	–	Yes	(Sousa et al. 2010; Sousa, Pantoja & Boari 2011)
<i>Pseudococcus comstocki</i>	5	Yes	Yes	–	GVE	Yes	(Nakaune et al. 2008)
				–	BSGFV	Indirectly (via original BSV)	(Su 1999)
				–	BSMYV	Indirectly (via original BSV)	(Su 1999)
				–	BSOLV	Indirectly (via original BSV)	(Su 1999)
				–	GLRaV-3	Yes	(Martelli, Saldarelli & Minafra 2011)
<i>Pseudococcus concavocerarii</i>	–	Yes	Yes	CSSV	–	Yes	(Attafuah, Blencowe & Brunt 1963)
<i>Pseudococcus elisae</i>	–	Yes	Yes	PYMoV	–	Yes	(Culik, Martins & Gullan 2006; Duarte & Albuquerque 2005)
				–	BSGFV	Indirectly (via original BSV)	(Armijos 2004)
				–	BSMYV	Indirectly (via original BSV)	(Armijos 2004)
				–	BSOLV	Indirectly (via original BSV)	(Armijos 2004)
<i>Pseudococcus longispinus</i>	83	No	Yes	CSSV	–	Yes	(N'Guessan et al. 2014)
				GVB	–	Yes	(Martelli 2010)
				–	GLRaV-3	Yes	(Douglas & Krüger 2008; Golino et al. 2002)
				–	GLRaV-4	Yes	(Golino et al. 2002; Tsai et al. 2010)
				–	GVA	Yes	(La Notte et al. 1997)
				–	PMWaV-2	Yes	(Hu et al. 2009)
				–	TaBV	Yes	(Gollifer et al. 1977)
<i>Pseudococcus maritimus</i>	2	Yes	No	–	LChV-2	Yes	(Mekuria et al. 2013)
				–	GLRaV-3	Yes	(Golino et al. 2002)

Mealybug vector	Mealybug interception events (a)	Mealybug is a quarantine pest	Mealybug transmits a quarantine virus	Viruses transmitted (b)		Virus/vector link substantiated	Reference
				Quarantine pest	Non-quarantine pest		
<i>Pseudococcus solomonensis</i>	1	Yes	No	–	TaBV	Yes	(Macanawai et al. 2005)
<i>Pseudococcus viburni</i>	11	No	Yes	GVB	–	Yes	[as <i>Ps. affinis</i>] (Garau et al. 1995)
				–	GVA	Yes	[as <i>Ps. affinis</i>] (Garau et al. 1995)
				–	GLRaV-3	Yes	(Golino et al. 2002), [as <i>Ps. affinis</i>] (Martelli, Saldarelli & Minafra 2011)
<i>Saccharicoccus sacchari</i>	2	No	Yes	–	BSGFV	Indirectly (via original BSV)	(Kubiriba et al. 2001)
				–	BSMYV	Indirectly (via original BSV)	(Kubiriba et al. 2001)
				–	BSOLV	Indirectly (via original BSV)	(Kubiriba et al. 2001)
				–	SCBIMV	Indirectly (via original SCBV)	(Lockhart, Autrey & Comstock 1992)
				SCBMOV	–	Indirectly (via original SCBV)	(Lockhart, Autrey & Comstock 1992)

a. An interception event can refer to a single or multiple mealybug species being present, and the number of mealybugs present is not usually recorded. The interception events are from 1986-2015 (Appendix D). **b.** Acronyms: *Banana streak GF virus* (BSGFV), *Banana streak MY virus* (BSMYV), *Banana streak OL virus* (BSOLV), *Banana streak VN virus* (BSNVN), *Cacao swollen shoot virus* (CSSV), *Citrus yellow mosaic virus* (CiYMV), *Commelina yellow mottle virus* (CoYMV), *Dioscorea bacilliform AL virus* (DBALV), *Grapevine leafroll-associated virus 1* (GLRaV-1), *Grapevine leafroll-associated virus 3* (GLRaV-3), *Grapevine leafroll-associated virus 4* (GLRaV-4), *Grapevine virus A* (GVA), *Grapevine virus B* (GVB), *Grapevine virus E* (GVE), *Kalanchoe top-spotting virus* (KTSV), *Little cherry virus-2* (LChV-2), *Pineapple bacilliform comosus virus* (PBCoV), *Pineapple bacilliform erectifolius virus* (PBErV), *Pineapple mealybug wilt-associated virus 2* (PMWaV-2), *Pineapple mealybug wilt-associated virus 3* (PMWaV-3), *Pineapple mealybug wilt-associated virus 1* (PMWaV-1), *Piper yellow mottle virus* (PYMoV), *Schefflera ringspot virus* (SRV), *Sugarcane bacilliform IM virus* (SCBIMV), *Sugarcane bacilliform MO virus* (SCBMOV) and *Taro bacilliform virus* (TaBV).

13 Appendix F: Pest categorisation of viruses transmitted by mealybugs

Notes on Table 13.1

Viral species named 'banana streak virus' and 'sugarcane bacilliform virus' were previously recognised. However, these names are no longer valid due to advances in virus research and taxonomy.

Banana streak virus (BSV):

- Banana streak virus (BSV) was first recognised as a virus species in 1991 (Francki et al. 1991).
- There are many references reporting mealybugs as vectors of BSV, including *Planococcus citri* (Lockhart 1995), *Saccharicoccus sacchari* (Kubiriba et al. 2001), *Dysmicoccus brevipes* (Kubiriba et al. 2001; Su 1999), *Planococcus ficus* (Meyer et al. 2008), *Pseudococcus comstocki* (Su 1999), *Pseudococcus elisae* (Armijos 2004), *Paracoccus burnerae* (Muturi et al. 2013), *Dysmicoccus* sp. nr. *texensis* [as *Dysmicoccus* sp. nr. *bispinosus*] (Armijos 2004).
- In the last 10 years, taxonomic reassessment of BSV resulted in the splitting of this virus into three species, and as a result 'banana streak virus' became an invalid species and the name was abandoned (Fauquet et al. 2005).
- To ensure that all mealybugs reported as transmitting the original 'banana streak virus' were considered during pest categorisation, known mealybug vectors were assigned to each of the three species into which it was split, namely *Banana streak GF virus*, *Banana streak MY virus* and *Banana streak OL virus*.

Sugarcane bacilliform virus (SCBV):

- Sugarcane bacilliform virus (SCBV) was first recognised in 1991 (Francki et al. 1991).
- There are many references reporting mealybugs as vectors of SCBV, including *Saccharicoccus sacchari* (Lockhart, Autrey & Comstock 1992), *Dysmicoccus boninsis* (Lockhart, Autrey & Comstock 1992) and *Planococcus citri* (Lockhart, Ireys & Comstock 1995).
- In the last 10 years, taxonomic reassessment of SCBV resulted in the splitting of this virus into two species, and as a result 'sugarcane bacilliform virus' became an invalid species, and the name was abandoned (Fauquet et al. 2005).
- To ensure that all mealybugs reported as transmitting the original 'sugarcane bacilliform virus', were considered during pest categorisation, known mealybug vectors were assigned to each of the two species into which it was split, namely *Sugarcane bacilliform IM virus* and *Sugarcane bacilliform MO virus*.

Nomenclature convention directs that scientific names of viruses that are officially recognized by the ICTV as species should be italicized, whereas those not yet recognized should not be italicized. Therefore, synonyms and former names of viruses are not italicized throughout this document.

Host plants listed in the pest categorisation table demonstrate potential economic consequences, but lists do not represent a comprehensive listing of all natural host plants of each virus, which are extensive for some species.

Table 13.1 Pest categorisation of viruses transmitted by mealybugs

Virus [Family: genus]	Acronym	Transmitted by	Present within Australia	Virus has potential for establishment and spread	Virus has potential for economic consequence to Australia	Natural hosts include	Consider further
BADNAVIRUS							
<i>Banana streak GF virus</i> [Caulimoviridae: Badnavirus] (Syn. Banana streak Goldfinger virus)	BSGFV	<i>Planococcus citri</i> , <i>Planococcus ficus</i> (Meyer et al. 2008). Former BSV was also reported to be transmitted by <i>Saccharicoccus sacchari</i> (Kubiriba et al. 2001), <i>Dysmicoccus brevipes</i> (Kubiriba et al. 2001; Su 1999); <i>Pseudococcus</i> <i>comstocki</i> (Su 1999), <i>Pseudococcus elisae</i> (Armijos 2004), <i>Dysmicoccus</i> sp. nr. <i>texensis</i> [as <i>Dysmicoccus</i> sp. nr. <i>bispinosus</i> (Armijos 2004)]	Yes. (Geering, Parry & Thomas 2011; Geering et al. 2000; Lockhart & Jones 2000)	Further assessment is not required	–	–	No
<i>Banana streak MY virus</i> [Caulimoviridae: Badnavirus] (Syn. Banana streak Mysore virus)	BSMYV	<i>Planococcus citri</i> (Geering et al. 2005). Former BSV was also reported to be transmitted by <i>Saccharicoccus sacchari</i> (Kubiriba et al. 2001), <i>Dysmicoccus brevipes</i> (Kubiriba et al. 2001; Su 1999); <i>Pseudococcus</i> <i>comstocki</i> (Su 1999), <i>Pseudococcus elisae</i> (Armijos 2004), <i>Dysmicoccus</i> sp. nr. <i>texensis</i> [as <i>Dysmicoccus</i> sp. nr. <i>bispinosus</i> (Armijos 2004)]	Yes. (Geering et al. 2000; Lockhart & Jones 2000)	Further assessment is not required	–	–	No
<i>Banana streak OL virus</i>	BSOLV	<i>Dysmicoccus brevipes</i> , <i>Planococcus citri</i> ,	Yes. (Geering, Parry & Thomas 2011;	Further assessment is not required	–	–	No

Virus [Family: genus]	Acronym	Transmitted by	Present within Australia	Virus has potential for establishment and spread	Virus has potential for economic consequence to Australia	Natural hosts include	Consider further
[Caulimoviridae: Badnavirus]		<i>Planococcus ficus</i> (Meyer et al. 2008). Former BSV was also reported to be transmitted by: <i>Saccharicoccus sacchari</i> (Kubiriba et al. 2001), <i>Pseudococcus comstocki</i> (Su 1999), <i>Pseudococcus elisae</i> (Armijos 2004), <i>Dysmicoccus</i> sp. nr. <i>texensis</i> [as <i>Dysmicoccus</i> sp. nr. <i>bispinosus</i> (Armijos 2004)].	Geering et al. 2000; Lockhart & Jones 2000)				
<i>Banana streak VN virus</i> [Caulimoviridae: Badnavirus] (Syn. Banana streak Acuminata Vietnam virus)	BSVNV	<i>Planococcus citri</i> (Lheureux et al. 2007).	No records found	Yes. The data for BSVNV are inconclusive, but closely related banana streak viruses have been reported within Australia (Geering et al. 2000; Lockhart & Jones 2000). It is likely that BSVNV also has the potential to establish and spread within Australia. The mealybug that transmits BSVNV is present in Australia. Closely related banana streak viruses are transmitted by vegetative propagation, either by tissue culture or the production of suckers, and through seed (Lockhart 1995). BSVNV would also be likely to spread by similar means.	Yes. The data for BSVNV are inconclusive, other than that it infects banana, but closely related banana streak viruses are important pathogen of bananas and plantains globally and also infect sugarcane and arrowroot (Reichel et al. 1997). Banana streak disease was first reported in Australia in 1992 and subsequently infected a range of varieties of bananas in Queensland and New South Wales (Daniells, Geering & Thomas 1998). There is potential for economic consequences to Australia from this virus.	Banana	Yes

Virus [Family: genus]	Acronym	Transmitted by	Present within Australia	Virus has potential for establishment and spread	Virus has potential for economic consequence to Australia	Natural hosts include	Consider further
<i>Cacao swollen shoot virus</i> [Caulimoviridae: Badnavirus]	CSSV	<i>Formicococcus njalensis</i> (Posnette 1950; Posnette & Strickland 1948), <i>Planococcus citri</i> (Kirkpatrick 1950; Posnette 1950; Posnette & Strickland 1948), <i>Ferrisia virgata</i> (Kirkpatrick 1950; Posnette 1950; Posnette & Strickland 1948), <i>Pseudococcus longispinus</i> (N'Guessan et al. 2014), <i>Planococcus kenya</i> (Attafuah, Blencowe & Brunt 1963), <i>Pseudococcus concavocerarii</i> (Attafuah, Blencowe & Brunt 1963), <i>Phenacoccus hargreavesi</i> (Attafuah, Blencowe & Brunt 1963; Bigger 1981), <i>Formicococcus celtis</i> (Attafuah, Blencowe & Brunt 1963), <i>Dysmicoccus brevipes</i> (Posnette 1950).	No records found	Yes. CSSV species is known to affect cacao, cola, ceiba and adansonia (Domfeh et al. 2011; Posnette 1950), and some of these hosts are present within Australia. CSSV has been recorded within Africa (Ghana, Nigeria, Sierra Leone, Togo, Ivory Coast and Ceylon) (Muller & Sackey 2004; N'Guessan et al. 2014; Oro et al. 2012). Australia has similar climatic conditions to these areas. Some of the mealybugs that transmit CSSV are present in Australia.	Yes. CSSV causes serious crop losses in all the main cocoa producing countries of West Africa (Domfeh et al. 2011). It is reported that CSSV causes symptoms including red vein banding, chlorotic vein flecking and smaller abnormally shaped pods with green mottling (Hughes & Ollennu 1994). There is potential for economic consequences to Australia from this virus.	Cacao, cola, ceiba and adansonia	Yes
<i>Citrus yellow mosaic virus</i> [Caulimoviridae: Badnavirus] (syn. Citrus yellow mosaic badnavirus; Citrus mosaic virus, CiMV)	CiYMV	<i>Planococcus citri</i> (Ahlawat et al. 1999; Reddy & Ahlawat 1997).	No records found	Yes. CiYMV affects orange, pumelo, lime, lemon and grapefruit (Ahlawat et al. 1996b; Borah et al. 2013) which are present in Australia. The virus is present in India (Ahlawat et al. 1996a; Borah et al. 2009; Ghosh et al. 2014; Johnson et al. 2012) and Australia has similar climatic conditions. In addition, its vector <i>P. citri</i> is present in Australia.	Yes. CiYMV is a major factor in citrus decline and can lead to total failure of production by causing plant premature death (Borah et al. 2013). Disease symptoms include yellow mosaic of the leaves and yellow flecking along the veins, reduction in fruit production, and fruit with less juice and ascorbic acid content (Ahlawat et	Sweet and sour orange, pumelo, lime, lemon, grapefruit	Yes

Virus [Family: genus]	Acronym	Transmitted by	Present within Australia	Virus has potential for establishment and spread	Virus has potential for economic consequence to Australia	Natural hosts include	Consider further
				CiYMV can also be spread via infected rootstocks (Borah et al. 2013), grafting and dodder (Ahlawat et al. 1996a).	al. 1996a; Huang & Hartung 2001). CiYMV is included in the EPPO A1 list of pests recommended for regulation as quarantine pests (EPPO 2015). There is potential for economic consequences to Australia from this virus.		
<i>Commelina yellow mottle virus</i> [Caulimoviridae: Badnavirus]	ComYMV	<i>Planococcus citri</i> (Lockhart & Khaless 1988)	No records found	Yes. ComYMV affects <i>Commelina</i> (Ayala-Navarrete 1993; Lockhart & Khaless 1988). <i>C. diffusa</i> is an Australian native plant (Bostock & Holland 2007). ComYMV has been recorded in the Caribbean (CABI & EPPO 2008; Lockhart 1990; Migliori & Lastra 1978) and Australia has similar climatic conditions. In addition, its vector <i>P. citri</i> is present in Australia. This virus is also spread via vegetative propagation and seed (Ayala-Navarrete 1993; Lockhart & Khaless 1988).	Yes. ComYMV infection is associated with vein yellowing and mottling in leaves, and reduction in leaf size and plant vigour (Ayala-Navarrete 1993; Qu et al. 1991). <i>Commelina diffusa</i> is a native plant, not commonly grown as an ornamental.	<i>Commelina diffusa</i>	Yes
<i>Dioscorea bacilliform AL virus</i> [Caulimoviridae: Badnavirus]	DBALV	<i>Planococcus citri</i> (Odu et al. 2006; Phillips et al. 1999)	No records found	Yes. DBALV affects yam (Kenyon, Lebas & Seal 2008; Phillips et al. 1999) which is present in Australia. DBALV is present in Central and	Yes. DBALV symptoms include leaf distortion and veinal chlorosis and necrosis (Phillips et al. 1999). There is potential for economic	<i>Dioscorea alata</i>	Yes

Virus [Family: genus]	Acronym	Transmitted by	Present within Australia	Virus has potential for establishment and spread	Virus has potential for economic consequence to Australia	Natural hosts include	Consider further
(syn. <i>Dioscorea bacilliform virus</i> , DBV)				South America (Barbados, Guyana, Brazil, Puerto Rico), Asia (Japan), South Pacific Islands and West Africa (Briddon et al. 1999; Davis & Ruabete 2010; Eni et al. 2008; Guimaraes et al. 2015; Kenyon, Lebas & Seal 2008; Odu et al. 2006; Phillips et al. 1999; Seal et al. 2014) and Australia has similar climatic conditions. In addition, its vector <i>P. citri</i> is present in Australia. This virus is also spread via vegetative propagation (Kenyon, Lebas & Seal 2008).	consequences to Australia from this virus.		
<i>Kalanchoe top-spotting virus</i> [Caulimoviridae: Badnavirus]	KTSV	<i>Planococcus citri</i> (Brunt et al. 1996)	No records found	Yes. KTSV affects <i>Kalanchoe blossfeldiana</i> (Lockhart & Ferji 1988; Yang et al. 2005) which is present in Australia. KTSV is present in North America and Europe (Netherlands, UK) (Lockhart & Ferji 1988; Yang et al. 2005) and Australia has similar climatic conditions. In addition, its vector <i>P. citri</i> is present in Australia. KTSV is also spread in vegetative propagation (Yang et al. 2005), and by	Yes. KTSV affects commercial cultivars of <i>Kalanchoe blossfeldiana</i> , causing yellow spotting of leaves (Lockhart & Ferji 1988; Yang et al. 2005). There is potential for economic consequences to Australia from this virus.	<i>Kalanchoe blossfeldiana</i>	Yes

Virus [Family: genus]	Acronym	Transmitted by	Present within Australia	Virus has potential for establishment and spread	Virus has potential for economic consequence to Australia	Natural hosts include	Consider further
				grafting, seed, and pollen (Hearon & Locke 1984).			
<i>Pineapple bacilliform comosus virus</i> [Caulimoviridae: Badnavirus]	PBCoV	<i>Dysmicoccus neobrevipes</i> (Sether et al. 2012), <i>Dysmicoccus brevipes</i> (Gambley et al. 2008a), <i>Planococcus citri</i> (Gambley et al. 2008a)	Yes (Gambley et al. 2008a)	Further assessment is not required.	–	–	No
<i>Pineapple bacilliform erectifolius virus</i> [Caulimoviridae: Badnavirus]	PBErV	<i>Dysmicoccus brevipes</i> (Gambley et al. 2008a)	Yes (Gambley et al. 2008a)	Further assessment is not required.	–	–	No
<i>Piper yellow mottle virus</i> [Caulimoviridae: Badnavirus]	PYMoV	<i>Planococcus citri</i> (de Silva, Jones & Shaw 2002; Lockhart et al. 1997a), <i>Ferrisia virgata</i> (Bhat et al. 2003), <i>Pseudococcus elisae</i> (Culik, Martins & Gullan 2006; Duarte & Albuquerque 2005), <i>Planococcus minor</i> (Sousa et al. 2010; Sousa, Pantoja & Boari 2011)	No records found	Yes. PYMoV affects <i>Piper</i> (Lockhart et al. 1997a) which is present in Australia. PYMoV is present in Asia and Brazil (de Oliveira et al. 2010; Deeshma & Bhat 2015; Duarte & Albuquerque 2005; Hany et al. 2013; Lockhart et al. 1997a; Siju, Bhat & Hareesh 2008) and Australia has similar climatic conditions. Its vectors, <i>Planococcus citri</i> , <i>P. minor</i> and <i>Ferrisia virgata</i> are present in Australia. The virus is also transmitted through vegetative means and seeds (Deeshma & Bhat 2015).	Yes. PYMoV causes decline in black pepper production in many areas of Southeast Asia. Disease symptoms include chlorotic mottling, vein- clearing, interveinal chlorosis, reduction in leaf size, puckering of leaves and reduced fruit set (Lockhart et al. 1997a). There is potential for economic consequences to Australia from this virus.	Black and long pepper, betel vine	Yes

Virus [Family: genus]	Acronym	Transmitted by	Present within Australia	Virus has potential for establishment and spread	Virus has potential for economic consequence to Australia	Natural hosts include	Consider further
<i>Schefflera ringspot virus</i> [Caulimoviridae: Badnavirus]	SRV	<i>Planococcus citri</i> (Lockhart & Olszewski 1996)	Yes (Lockhart & Olszewski 1996)	Further assessment is not required.	–	–	No
<i>Sugarcane bacilliform IM virus</i> [Caulimoviridae: Badnavirus] (syn. Sugarcane bacilliform virus - Ireng Maleng, SCBV-IM)	SCBIMV	Former SCBV was reported to be transmitted by <i>Saccharicoccus sacchari</i> (Lockhart, Autrey & Comstock 1992), <i>Dysmicoccus boninsis</i> (Lockhart, Autrey & Comstock 1992), <i>Planococcus citri</i> (Lockhart, Ireyt & Comstock 1995)	Yes (Geijskes et al. 2002)	Further assessment is not required.	–	–	No
<i>Sugarcane bacilliform MO virus</i> [Caulimoviridae: Badnavirus] (syn. Sugarcane bacilliform virus, Sugarcane bacilliform Mor virus, Sugarcane bacilliform Morocco virus, SCBMV)	SCBMOV	Former SCBV was reported to be transmitted by: <i>Saccharicoccus sacchari</i> (Lockhart, Autrey & Comstock 1992), <i>Dysmicoccus boninsis</i> (Lockhart, Autrey & Comstock 1992), <i>Planococcus citri</i> (Lockhart, Ireyt & Comstock 1995)	No records found	Yes. The data for SCBMOV is inconclusive, but the former species SCBV was known to affect sugarcane (Bouhida, Lockhart & Olszewski 1993; Lockhart & Autrey 1988) which is present within Australia. The mealybugs that transmit SCBV are present in Australia. SCBV was also reported to be transmitted by vegetative propagation (Lockhart, Ireyt & Comstock 1995). It is likely that this would apply to SBMOV.	Yes. SCBV caused significant yield reduction of sugarcane production in some varieties, and infection can be asymptomatic or symptomatic with flecks or freckles on the leaves (Lockhart & Autrey 1988). There is potential for economic consequences to Australia from this virus.	Sugarcane	Yes
<i>Taro bacilliform virus</i> [Caulimoviridae: Badnavirus] (syn. Taro badnavirus)	TaBV	<i>Pseudococcus longispinus</i> (Gollifer et al. 1977), <i>Planococcus citri</i> (Gollifer et al. 1977), <i>Pseudococcus</i>	Yes (Carmichael et al. 2008; Midmore et al. 2006)	Further assessment is not required.	–	–	No

Virus [Family: genus]	Acronym	Transmitted by	Present within Australia	Virus has potential for establishment and spread	Virus has potential for economic consequence to Australia	Natural hosts include	Consider further
		<i>solomonensis</i> (Macanawai et al. 2005)					
VITIVIRUS							
<i>Grapevine virus A</i> [Betaflexiviridae: Vitivirus]	GVA	<i>Phenacoccus aceris</i> (Le Maguet et al. 2012) <i>Pseudococcus viburni</i> [as <i>Ps affinis</i>] (Garau et al. 1995), <i>Planococcus ficus</i> (Rosciglione et al. 1983; Tsai et al. 2010), <i>Pseudococcus longispinus</i> (La Notte et al. 1997), <i>Heliococcus bohemicus</i> (Zorloni et al. 2006)	Yes (Goszczynski & Habili 2012; Habili & Symons 2000)	Further assessment is not required.	–	–	No
<i>Grapevine virus B</i> [Betaflexiviridae: Vitivirus]	GVB	<i>Phenacoccus aceris</i> (Le Maguet et al. 2012), <i>Planococcus ficus</i> (Martelli 1997b), <i>Pseudococcus longispinus</i> (Martelli 2010), <i>Pseudococcus viburni</i> [as <i>Ps affinis</i>] (Garau et al. 1995)	Yes (Habili & Symons 2000), but strains associated with grapevine ‘corky bark’ disease are not known to occur in Australia (Agriculture Victoria 2016; DAFF 2013d)	Yes. GVB affects grapevine and other strains have already been recorded in Australia (Habili & Symons 2000). Grapevine is present in Australia. Its vectors <i>Pseudococcus longispinus</i> and <i>P. viburni</i> , are already present in Australia. In addition, GVB is spread via infected grapevine germplasm (Leo et al. 2014).	Yes. GVB is associated with ‘corky bark’ disease but some infected grapevine hosts can be symptomless (Habili & Symons 2000). GVB has been reported in Australia but strains associated with grapevine ‘corky bark’ are not known to occur and therefore have potential for economic consequences in parts of Australia (DAFF 2013d).	Grapevine	Yes ‘corky bark’ strains
<i>Grapevine virus E</i> [Betaflexiviridae: Vitivirus]	GVE	<i>Pseudococcus comstocki</i> (Nakaune et al. 2008)	No records found	Yes. GVE affects grapevine (Nakaune et al. 2008) which is present in Australia. GVE is present in Africa, Asia (Japan, China) and North America (Alabi et al. 2013; Fan et	No. GVE has been listed as a quarantine pest for Australia (DAFF 2013d). However, no significant evidence of disease or economic loss is associated with GVE	Grapevine	No

Virus [Family: genus]	Acronym	Transmitted by	Present within Australia	Virus has potential for establishment and spread	Virus has potential for economic consequence to Australia	Natural hosts include	Consider further
AMPELOVIRUS				al. 2015; Nakaune et al. 2008) and Australia has similar climatic conditions.	infection (Alabi et al. 2013; Constable & Rodoni 2011; Nakaune et al. 2008). Therefore, GVE cannot meet the definition of a quarantine pest, and there is no technical justification to continue its regulation.		
<i>Grapevine leafroll-associated virus 1</i> [Closteroviridae: Ampelovirus]	GLRaV-1	<i>Planococcus ficus</i> (Tsai et al. 2010), <i>Phenacoccus aceris</i> (Sforza, Boudon-Padieu & Greif 2003), <i>Heliococcus bohemicus</i> (Sforza, Boudon-Padieu & Greif 2003)	Yes (DAWA 2006) (Habili et al. 1998)	Further assessment is not required.	–	–	No
<i>Grapevine leafroll-associated virus 3</i> [Closteroviridae: Ampelovirus]	GLRaV-3	<i>Ferrisia gilli</i> (Wistrom et al. 2016), <i>Planococcus citri</i> (Cabaleiro & Segura 1997a; Golino et al. 2002), <i>Planococcus ficus</i> (Douglas & Krüger 2008; Mahfoudhi, Digiario & Dhouibi 2009; Tsai et al. 2008; Tsai et al. 2010), <i>Pseudococcus longispinus</i> (Douglas & Krüger 2008; Golino et al. 2002), <i>Pseudococcus calceolariae</i> (Petersen & Charles 1997), <i>Pseudococcus viburni</i> (Golino et al. 2002) [as <i>Ps affinis</i>] (Martelli, Saldarelli & Minafra 2011), <i>Pseudococcus maritimus</i> (Golino et al. 2002), <i>Pseudococcus comstocki</i>	Yes (Habili, Cameron & Randles 2009; Habili et al. 1998; Habili et al. 1995; Habili & Nutter 1997; Habili & Symons 2000)	Further assessment is not required.	–	–	No

Virus [Family: genus]	Acronym	Transmitted by	Present within Australia	Virus has potential for establishment and spread	Virus has potential for economic consequence to Australia	Natural hosts include	Consider further
		(Martelli, Saldarelli & Minafra 2011), <i>Heliococcus bohemicus</i> (Sforza, Boudon-Padieu & Greif 2003; Zorloni et al. 2006), <i>Phenacoccus aceris</i> (Sforza, Boudon-Padieu & Greif 2003)					
<i>Grapevine leafroll-associated virus 4</i> [Closteroviridae: Ampelovirus] (Syn: GLRaV-5, GLRaV-6, GLRaV-9, GLRaV-Pr, GLRaV-De and GLRaV-Car)	GLRaV-4	<i>Ferrisia gilli</i> (Wistrom et al. 2016), <i>Planococcus ficus</i> (Mahfoudhi, Digiario & Dhouibi 2009; Tsai et al. 2010), <i>Pseudococcus longispinus</i> (Golino et al. 2002; Tsai et al. 2010)	Yes (Habibi et al. 1998; Habili & Randles 2008)	Further assessment is not required.	–	–	No
<i>Little cherry virus 2</i> [Closteroviridae: Ampelovirus]	LChV-2	<i>Phenacoccus aceris</i> (Raine, McMullen & Forbes 1986), <i>Pseudococcus maritimus</i> (Mekuria et al. 2013)	Yes. First reported in 2013 (but present for up to 35 years) (IPPC 2015). Declared as a prohibited organism for WA (Government of Western Australia 2018). No diagnostic test is currently imposed on cherry propagative material imported from other states into WA (Government of Western Australia 2014). This	Further assessment is not required.	–	–	No

Virus [Family: genus]	Acronym	Transmitted by	Present within Australia	Virus has potential for establishment and spread	Virus has potential for economic consequence to Australia	Natural hosts include	Consider further
			propagative plant material is likely to be asymptomatic for LChY-2 (MAL 2007). The regulatory status of LChV-2 will be confirmed with WA prior to finalisation.				
<i>Pineapple mealybug wilt-associated virus 1</i> [Closteroviridae: Ampelovirus]	PMWaV-1	<i>Dysmicoccus brevipes</i> (Gambley et al. 2008b; Sether, Ullman & Hu 1998), <i>Dysmicoccus neobrevipes</i> (Carter 1963; Sether, Ullman & Hu 1998)	Yes (Gambley et al. 2008b)	Further assessment is not required.	–	–	No
<i>Pineapple mealybug wilt-associated virus 2</i> [Closteroviridae: Ampelovirus]	PMWaV-2	<i>Dysmicoccus brevipes</i> (Gambley et al. 2008b; Sether & Hu 2002), <i>Dysmicoccus neobrevipes</i> (Sether & Hu 2002), <i>Pseudococcus</i> sp. (Subere 2009), <i>Pseudococcus longispinus</i> (Hu et al. 2009)	Yes (Gambley et al. 2008b)	Further assessment is not required.	–	–	No
<i>Pineapple mealybug wilt-associated virus 3</i> [Closteroviridae: Ampelovirus]	PMWaV-3	<i>Dysmicoccus brevipes</i> (Gambley et al. 2008b), <i>Dysmicoccus neobrevipes</i> (Sether et al. 2005)	Yes (Gambley et al. 2008b)	Further assessment is not required.	–	–	No

14 Appendix G: Distribution of quarantine viruses and the mealybugs that transmit them

Notes on Table 14.1

This table indicates the known distribution of the quarantine viruses transmitted by mealybugs, and those mealybug species (as of August 2017).

Acronyms: *Banana streak VN virus* (BSVNV), *Cacao swollen shoot virus* (CSSV), *Citrus yellow mosaic virus* (CiYMV), *Commelina yellow mottle virus* (ComYMV), *Dioscorea bacilliform AL virus* (DBALV), *Kalanchoe top-spotting virus* (KTSV), *Piper yellow mottle virus* (PYMoV), *Sugarcane bacilliform MO virus* (SCBMOV) and *Grapevine virus B* (GBV) 'corky bark' strains.

The original Sugarcane bacilliform virus (SCBV) is no longer accepted as a species by the ICTV (ICTV 2017). SCBV was split into SCBIMV and SCBMOV (as Sugarcane bacilliform MO virus) in 2005 (Fauquet et al. 2005). In this assessment the mealybugs that transmit 'sugarcane bacilliform virus' have been associated with both species into which it was split.

Presence of a virus and/or the mealybug(s) that transmit them in a given region is indicated by a 'Y'. Where both are co-located in a region, both virus and vector will have a 'Y'. Where no report of presence exists for a region, this is indicated by a '-'.

If distribution is limited, the specific country (or countries) are given (BR, Brazil; CN, China; CU, Cuba; GP, Guadeloupe; HI, Hawaii; ID, Indonesia; IN, India; IL, Israel; JP, Japan; MA, Morocco; VC, Saint Vincent and the Grenadines; VN, Vietnam). South and Southwest (S. & SW) Asia includes India and countries to the West. East and Southeast (E. & SE) Asia includes countries to the East of India. South America is considered to include Central America and the Caribbean, and North America is considered to include Mexico.

Table 14.1 Distribution of quarantine viruses and the mealybugs that transmit them

Virus/vector(s)	Virus/vector reference	Geographic Current distribution reference							
		Africa	S. & SW Asia	E. & SE Asia	Australasia	Europe	N. America	S. America	
BSVNV	(Lheureux et al. 2007)	-	-	VN, CN	-	-	-	CU	(Bhat, Hohn & Selvarajan 2016; Javier Higginson et al. 2014; Lheureux et al. 2007)
<i>Planococcus citri</i>	(Lheureux et al. 2007)	Y	Y	Y	Y	Y	Y	Y	(Ezzat & McConnell 1956; García Morales et al. 2018; Mani & Thontadarya 1987; Suresh & Mohanasundaram 1996; Wakgarl & Giliomee 2003; Williams 1982)
CSSV	(Posnette & Strickland 1948)	Y	-	-	-	-	-	-	(Muller & Sackey 2004; N'Guessan et al. 2014; Oro et al. 2012)
<i>Formicococcus njalensis</i>	(Posnette 1950; Posnette & Strickland 1948)	Y	-	-	-	-	-	-	(Bigger 1981; Brunt & Kenten 1962; Campbell 1983; Ezzat & McConnell 1956; García Morales et al. 2018; Posnette & Strickland 1948)
<i>Planococcus citri</i>	(Kirkpatrick 1950; Posnette 1950; Posnette & Strickland 1948)	Y	Y	Y	Y	Y	Y	Y	(Ezzat & McConnell 1956; García Morales et al. 2018; Mani & Thontadarya 1987; Suresh & Mohanasundaram 1996; Wakgarl & Giliomee 2003; Williams 1982)
<i>Ferrisia virgata</i>	(Kirkpatrick 1950; Posnette 1950; Posnette & Strickland 1948)	Y	Y	Y	Y	Y	Y	Y	(Abul-Nasir, Swailem & Dawood 1975; Brunt & Kenten 1962; Culik, Martins & Gullan 2006; García Morales et al. 2018; Gavrilov 2013; Hassan, Radwan & El-Sahn 2012; Lit, Caasi-Lit & Calilung 1998; Posnette & Strickland 1948; Suresh & Mohanasundaram 1996; Watson & Kubiriba 2005; Williams 1960)
<i>Pseudococcus longispinus</i>	(N'Guessan et al. 2014)	Y	Y	Y	Y	Y	Y	Y	(Charles 1982, 1993; Charles et al. 2010; Lit & Calilung 1994; Rohrbach et al. 1988; Suresh & Mohanasundaram 1996; Swirski et al. 1980; Wakgarl & Giliomee 2003; Walton & Pringle 2004a; Williams 1970)
<i>Planococcus kenya</i>	(Attafuah, Blencowe & Brunt 1963)	Y	-	ID	-	-	-	-	(Attafuah, Blencowe & Brunt 1963; Cox 1989; Ezzat & McConnell 1956; García Morales et al. 2018)
<i>Pseudococcus concavocerarii</i>	(Attafuah, Blencowe & Brunt 1963)	Y	-	-	-	-	-	-	(Attafuah, Blencowe & Brunt 1963; Bigger 1981; García Morales et al. 2018)

Virus/vector(s)	Virus/vector reference	Africa	S. & SW Asia	E. & SE Asia	Australasia	Europe	N. America	S. America	Geographic Current distribution reference
<i>Phenacoccus hargreavesi</i>	(Attafuah, Blencowe & Brunt 1963; Bigger 1981)	Y	-	-	-	-	-	-	(Bigger 1981; Campbell 1983; García Morales et al. 2018; Williams 1970)
<i>Formicococcus celtis</i>	(Attafuah, Blencowe & Brunt 1963)	Y	-	-	-	-	-	-	(Attafuah, Blencowe & Brunt 1963; García Morales et al. 2018)
<i>Dysmicoccus brevipes</i>	(Posnette 1950)	Y	Y	Y	Y	Y	Y	Y	(Beardsley 1959, 1993; Carter 1942; García Morales et al. 2018; Granara de Willink 2009; Ito 1938; Mani & Thontadarya 1987; Miller 2005; Watson & Kubiriba 2005; Williams & Granara de Willink 1992)
CiYMV	(Ahlawat et al. 1996a)	-	IN	-	-	-	-	-	(Ahlawat et al. 1996a; Borah et al. 2009; Ghosh et al. 2014; Johnson et al. 2012)
<i>Planococcus citri</i>	(Ahlawat et al. 1999; Reddy & Ahlawat 1997)	Y	Y	Y	Y	Y	Y	Y	(Ezzat & McConnell 1956; García Morales et al. 2018; Mani & Thontadarya 1987; Suresh & Mohanasundaram 1996; Wakgarl & Giliomee 2003; Williams 1982)
ComYMV	(Lockhart & Khaless 1988)	-	-	-	-	-	-	GP, VC	(CABI & EPPO 2008; Lockhart 1990; Migliori & Lastra 1978)
<i>Planococcus citri</i>	(Ayala-Navarrete 1993; Lockhart & Khaless 1988)	Y	Y	Y	Y	Y	Y	Y	(Ezzat & McConnell 1956; García Morales et al. 2018; Mani & Thontadarya 1987; Suresh & Mohanasundaram 1996; Wakgarl & Giliomee 2003; Williams 1982)
DBALV	(Phillips et al. 1999)	Y	-	JP	Y	-	-	Y	(Briddon et al. 1999; Davis & Ruabete 2010; Eni et al. 2008; Guimaraes et al. 2015; Kenyon, Lebas & Seal 2008; Odu et al. 2006; Phillips et al. 1999; Seal et al. 2014)
<i>Planococcus citri</i>	Odu et al. 2006; Phillips et al. 1999)	Y	Y	Y	Y	Y	Y	Y	(Ezzat & McConnell 1956; García Morales et al. 2018; Mani & Thontadarya 1987; Suresh & Mohanasundaram 1996; Wakgarl & Giliomee 2003; Williams 1982)
KTSV	(Lockhart & Ferji 1988)	-	-	-	-	Y	Y	-	(Lockhart & Ferji 1988; Yang et al. 2005)

Virus/vector(s)	Virus/vector reference	Africa	S. & SW Asia	E. & SE Asia	Australasia	Europe	N. America	S. America	Geographic Current distribution reference
<i>Planococcus citri</i>	(Brunt et al. 1996)	Y	Y	Y	Y	Y	Y	Y	(Ezzat & McConnell 1956; García Morales et al. 2018; Mani & Thontadarya 1987; Suresh & Mohanasundaram 1996; Wakgarl & Giliomee 2003; Williams 1982)
PYMoV	(Lockhart et al. 1997a)	–	IN	Y	–	–	–	BR	(de Oliveira et al. 2010; Deeshma & Bhat 2015; Duarte & Albuquerque 2005; Hany et al. 2013; Lockhart et al. 1997a; Siju, Bhat & Hareesh 2008)
<i>Planococcus citri</i>	(de Silva, Jones & Shaw 2002; Lockhart et al. 1997a)	Y	Y	Y	Y	Y	Y	Y	(Ezzat & McConnell 1956; García Morales et al. 2018; Mani & Thontadarya 1987; Suresh & Mohanasundaram 1996; Wakgarl & Giliomee 2003; Williams 1982)
<i>Ferrisia virgata</i>	(Bhat et al. 2003)	Y	Y	Y	Y	Y	Y	Y	(Abul-Nasir, Swailem & Dawood 1975; Brunt & Kenten 1962; Culik, Martins & Gullan 2006; García Morales et al. 2018; Gavrilov 2013; Hassan, Radwan & El-Sahn 2012; Lit, Caasi-Lit & Calilung 1998; Posnette & Strickland 1948; Suresh & Mohanasundaram 1996; Watson & Kubiriba 2005; Williams 1960)
<i>Pseudococcus elisae</i>	(Culik, Martins & Gullan 2006; Duarte & Albuquerque 2005)	–	–	–	Y	–	HI	Y	(Beardsley 1986; Culik, Martins & Gullan 2006; Duarte & Albuquerque 2005; García Morales et al. 2018; Gimpel & Miller 1996; Lit & Calilung 1994; Miller, Miller & Watson 2002)
<i>Planococcus minor</i>	(Sousa et al. 2010; Sousa, Pantoja & Boari 2011)	Y	–	Y	Y	–	–	Y	(García Morales et al. 2018; Lit, Caasi-Lit & Calilung 1998; Matile-Ferrero & Étienne 2006; Reddy, Bhat & Naidu 1997), Pacific Islands (Cox 1989; Williams 1982; Williams & Butcher 1987)
SCBMOV	(Lockhart & Autrey 1988)	MA	IN	CN	–	–	–	CU, GU	(Alexander & Viswanathan 1995; Autrey et al. 1992; Bhat, Hohn & Selvarajan 2016; Karuppaiah, Viswanathan & Kumar 2013; Lockhart & Autrey 1988)
<i>Saccharicoccus sacchari</i>	Lockhart, Autrey & Comstock 1992)	Y	Y	Y	Y	Y	Y	Y	(García Morales et al. 2018; Miller 2005; Sagarra, Vincent & Stewart 2001; Suresh & Mohanasundaram 1996; Watson & Kubiriba 2005; Williams 1970)
<i>Dysmicoccus boninsis</i>	(Lockhart, Autrey & Comstock 1992)	Y	Y	Y	Y	Y	Y	Y	(García Morales et al. 2018; Granara de Willink 2009; Matile-Ferrero & Étienne 2006; Miller 2005;

Virus/vector(s)	Virus/vector reference	Africa	S. & SW Asia	E. & SE Asia	Australasia	Europe	N. America	S. America	Geographic Current distribution reference
<i>Planococcus citri</i>	(Lockhart, Ireys & Comstock 1995)	Y	Y	Y	Y	Y	Y	Y	Moghaddam 2006; Williams 2004; Williams & Granara de Willink 1992) (Ezzat & McConnell 1956; García Morales et al. 2018; Mani & Thontadarya 1987; Suresh & Mohanasundaram 1996; Wakgarl & Giliomee 2003; Williams 1982)
GVB 'corky bark' strains	(Habibi & Symons 2000)	Y	IL	JP	–	Y	Y	Y	(Boscia et al. 1993; Garau et al. 1993; Lima 2009; Monette & James 1991; Namba et al. 1991; Tanne, Ben-Dov & Raccach 1989; Teliz et al. 1980)
<i>Phenacoccus aceris</i>	(Le Maguet et al. 2012)	–	–	Y	–	Y	Y	–	(García Morales et al. 2018; Kaydan et al. 2004; Malumphy & Ostrauskas 2008; Malumphy, Ostrauskas & Pye 2008; Park et al. 2010)
<i>Planococcus ficus</i>	(Martelli 1997b)	Y	Y	Y	–	Y	Y	Y	(Ezzat & McConnell 1956; García Morales et al. 2018; Godfrey et al. 2003; Hassan, Radwan & El-Sahn 2012; Kaydan & Kozár 2010; Miller, Miller & Watson 2002; Walton & Pringle 2004a)
<i>Pseudococcus longispinus</i>	(Martelli 2010)	Y	Y	Y	Y	Y	Y	Y	(Charles 1982, 1993; Charles et al. 2010; Lit & Calilung 1994; Rohrbach et al. 1988; Suresh & Mohanasundaram 1996; Swirski et al. 1980; Wakgarl & Giliomee 2003; Walton & Pringle 2004a; Williams 1970)
<i>Pseudococcus viburni</i> [as <i>Ps affinis</i>]	(Garau et al. 1995)	Y	Y	Y	Y	Y	Y	Y	(Charles 1993; Clearwater 2001; García Morales et al. 2018; Malumphy, Ostrauskas & Pye 2008; Miller 2005; Moghaddam 2006; Walker et al. 1998; Walton & Pringle 2004a)

Glossary

Term or abbreviation	Definition
Appropriate level of protection (ALOP)	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). The <i>Biosecurity Act 2015</i> defines the ALOP for Australia as a high level of sanitary and phytosanitary protection aimed at reducing biosecurity risks to very low, but not to zero.
Area	An officially defined country, part of a country or all or parts of several countries (FAO 2017b).
Arthropod	The largest phylum of animals, including the insects, arachnids and crustaceans.
Australian territory	Australian territory as referenced in the <i>Biosecurity Act 2015</i> refers to Australia, Christmas Island and Cocos (Keeling) Islands.
Biosecurity	The prevention of the entry, establishment or spread of unwanted pests and infectious disease agents to protect human, animal or plant health or life, and the environment.
Biosecurity risk	The <i>Biosecurity Act 2015</i> refers to biosecurity risk as the likelihood of a disease or pest entering, establishing or spreading in Australian territory, and the potential for the disease or pest causing harm to human, animal or plant health, the environment, economic or community activities.
Biosecurity import risk analysis (BIRA)	The <i>Biosecurity Act 2015</i> defines a BIRA as an evaluation of the level of biosecurity risk associated with particular goods, or a particular class of goods, that may be imported, or proposed to be imported, into Australian territory, including, if necessary, the identification of conditions that must be met to manage the level of biosecurity risk associated with the goods, or the class of goods, to a level that achieves the ALOP for Australia. The risk analysis process is regulated under legislation.
Commodity	A type of plant, plant product, or other article being moved for trade or other purpose (FAO 2017b).
Embryogenesis	The formation and development of an embryo.
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 2017b).
Establishment (of a pest)	Perpetuation, for the foreseeable future, of a pest within an area after entry (FAO 2017b).
Goods	The <i>Biosecurity Act 2015</i> defines goods as an animal, a plant (whether moveable or not), a sample or specimen of a disease agent, a pest, mail or any other article, substance or thing (including, but not limited to, any kind of moveable property).
Haplodiploidy	A sex-determination system in which males develop from unfertilized eggs and are haploid, and females develop from fertilized eggs and are diploid.
Import risk analysis	An administrative process through which quarantine policy is developed or reviewed, incorporating risk assessment, risk management and risk communication.
Infection	The internal 'endophytic' colonisation of a plant, or plant organ, and is generally associated with the development of disease symptoms as the integrity of cells and/or biological processes are disrupted.
Infestation (of a commodity)	Presence in a commodity of a living pest of the plant or plant product concerned. Infestation includes infection (FAO 2017b).
Inspection	Official visual examination of plants, plant products or other regulated articles to determine if pests are present or to determine compliance with phytosanitary regulations (FAO 2017b).
Instar	An instar is a developmental stage of arthropods, such as insects, between each moult (ecdysis), until sexual maturity is reached. Arthropods must shed the exoskeleton in order to grow or assume a new form.

Intended use	Declared purpose for which plants, plant products, or other regulated articles are imported, produced or used (FAO 2017b).
Interception (of a pest)	The detection of a pest during inspection or testing of an imported consignment (FAO 2017b).
International Plant Protection Convention (IPPC)	The IPPC is an international plant health agreement, established in 1952, that aims to protect cultivated and wild plants by preventing the introduction and spread of pests. The IPPC provides an international framework for plant protection that includes developing International Standards for Phytosanitary Measures (ISPMs) for safeguarding plant resources.
International Standard for Phytosanitary Measures (ISPM)	An international standard adopted by the Conference of the Food and Agriculture Organization, the Interim Commission on Phytosanitary Measures or the Commission on Phytosanitary Measures, established under the IPPC (FAO 2017b).
Introduction (of a pest)	The entry of a pest resulting in its establishment (FAO 2017b).
Non-regulated risk analysis	Refers to the process for conducting a risk analysis that is not regulated under legislation (Biosecurity import risk analysis guidelines 2016).
Nymph	The immature form of some insect species that undergoes incomplete metamorphosis. It is not to be confused with larva, as its overall form is already that of the adult.
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 2017b).
Open reading frames	In molecular genetics, an open reading frame (ORF) is the part of a reading frame that has the potential to be translated. An ORF is a continuous stretch of codons that do not contain a stop codon (usually UAA, UAG or UGA).
Pathogen	A biological agent that can cause disease to its host.
Pathway	Any means that allows the entry or spread of a pest (FAO 2017b).
Parthenogenesis	Reproduction from an ovum without fertilization, especially as a normal process in some invertebrates and lower plants.
Pest	Any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products (FAO 2017b).
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 2017b).
Pest risk analysis (PRA)	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 2017b).
Pest risk assessment (for quarantine pests)	Evaluation of the probability of the introduction and spread of a pest and of the magnitude of the associated potential economic consequences (FAO 2017b).
Pest risk assessment (for regulated non-quarantine pests)	Evaluation of the probability that a pest in plants for planting affects the intended use of those plants with an economically unacceptable impact (FAO 2017b).
Pest risk management (for quarantine pests)	Evaluation and selection of options to reduce the risk of introduction and spread of a pest (FAO 2017b).
Pest risk management (for regulated non-quarantine pests)	Evaluation and selection of options to reduce the risk that a pest in plants for planting causes an economically unacceptable impact on the intended use of those plants (FAO 2017b).
Pest status (in an area)	Presence or absence, at the present time, of a pest in an area, including where appropriate its distribution, as officially determined using expert judgement on the basis of current and historical pest records and other information (FAO 2017b).
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 2017b).

PRA area	Area in relation to which a pest risk analysis is conducted (FAO 2017b).
Pupa	An inactive life stage that only occurs in insects that undergo complete metamorphosis, for example butterflies and moths (Lepidoptera), beetles (Coleoptera) and bees, wasps and ants (Hymenoptera).
Quarantine	Official confinement of regulated articles for observation and research or for further inspection, testing or treatment (FAO 2017b).
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 2017b).
Regulated pest	A quarantine pest or a regulated non-quarantine pest (FAO 2017b).
Restricted risk	Risk estimate with phytosanitary measure(s) applied.
Risk analysis	Refers to the technical or scientific process for assessing the level of biosecurity risk associated with the goods, or the class of goods, and if necessary, the identification of conditions that must be met to manage the level of biosecurity risk associated with the goods, or class of goods to a level that achieves the ALOP for Australia.
Risk management measure	Conditions that must be met to manage the level of biosecurity risk associated with the goods or the class of goods, to a level that achieves the ALOP for Australia. In this risk analysis, the term 'risk management measure' and 'phytosanitary measure' may be used interchangeably.
Spread (of a pest)	Expansion of the geographical distribution of a pest within an area (FAO 2017b).
SPS Agreement	WTO Agreement on the Application of Sanitary and Phytosanitary Measures.
Stakeholders	Government agencies, individuals, community or industry groups or organizations, whether in Australia or overseas, including the proponent/applicant for a specific proposal, who have an interest in the policy issues.
Surveillance	An official process which collects and records data on pest occurrence or absence by surveying, monitoring or other procedures (FAO 2017b).
The department	The Department of Agriculture and Water Resources.
Thelytokous	A type of parthenogenesis in which females are produced from unfertilized eggs.
Treatment	Official procedure for the killing, inactivation or removal of pests, or for rendering pests infertile or for devitalisation (FAO 2017b).
Unrestricted risk	Unrestricted risk estimates apply in the absence of risk mitigation measures.
Vector	An organism that does not cause disease itself, but which causes infection by conveying pathogens from one host to another.
Viruliferous	An organism that contains, produces, or conveys an agent of infection, principally a virus.
Zygote	The cell formed by the union of the nuclei of two reproductive cells (gametes), especially a fertilized egg cell.

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