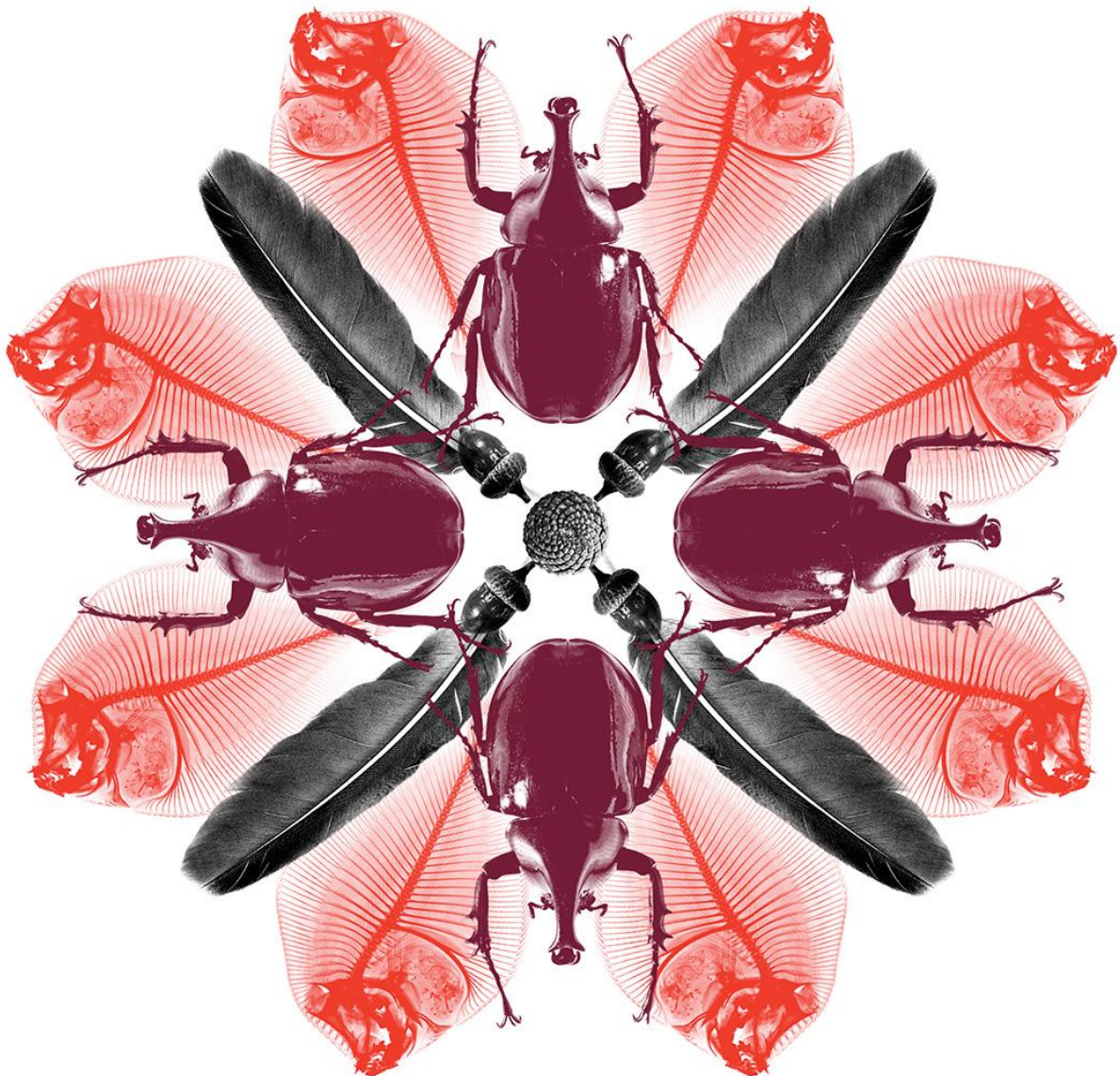




Australian Government
Department of Agriculture
and Water Resources

Final group pest risk analysis for thrips and orthotospoviruses on fresh fruit, vegetable, cut-flower and foliage imports

November 2017



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Cataloguing data

Australian Government Department of Agriculture and Water Resources 2017, *Final group pest risk analysis for thrips and orthotospoviruses on fresh fruit, vegetable, cut-flower and foliage imports*, Department of Agriculture and Water Resources, Canberra.

This publication is available at agriculture.gov.au.

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Acronyms and abbreviations

Term or abbreviation	Definition
ACT	Australian Capital Territory
ALOP	Appropriate level of protection
BA	Biosecurity Advice
BICON	Biosecurity Import Conditions System for Australia
BIRA	Biosecurity Import Risk Analysis
FAO	Food and Agriculture Organization of the United Nations
GVP	Gross value of production
IPM	Integrated pest management
IPPC	International Plant Protection Convention
ISPM	International Standard for Phytosanitary Measures
NSW	New South Wales
NPPO	National Plant Protection Organisation
NT	Northern Territory
PRA	Pest risk analysis
Qld	Queensland
SA	South Australia
SPS Agreement	WTO Agreement on the Application of Sanitary and Phytosanitary Measures
Tas.	Tasmania
The department	The Australian Government Department of Agriculture and Water Resources
URE	Unrestricted risk estimate
Vic.	Victoria
WA	Western Australia
WTO	World Trade Organization

Summary

The Australian Government 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 groups 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 2016b). 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. Each Group PRA 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 first Group PRA to be finalised—further group PRAs are underway. This Group PRA considers the biosecurity risk posed by all members of the insect order Thysanoptera (commonly referred to as thrips) and all members of the virus genus *Orthotospovirus* (formerly tospovirus) that are (or are likely to be) associated with fresh fruit, vegetables, cut-flowers or foliage imported into Australia as commercial consignments. It also assesses the emerging risks posed by orthotospoviruses, which are transmitted by some thrips.

The genus tospovirus has recently undergone taxonomic revision by the International Committee on Taxonomy of Viruses (ICTV 2017) being renamed *Orthotospovirus* and assigned to the new family *Tospoviridae* and new order *Bunyavirales*. This revision will be applied in this report to all 30 species formerly described as tospoviruses, as appropriate.

Thrips and the orthotospoviruses they transmit can cause considerable economic consequences across a wide range of fruit, vegetable, legume and ornamental crops by reducing yield, quality and marketability. Orthotospoviruses are a significant emerging risk to Australia with many recent reports of new species with rapidly expanding host plant ranges, geographic distributions and thrips vectors.

This Group PRA identifies and analyses the key quarantine pests of biosecurity importance to Australia in these two groups of organisms. It is built on a foundation of 18 years of PRAs undertaken by the department—all of which were subjected to robust scientific analyses and

extensive processes of stakeholder consultation. These pest risk assessments showed marked consistency in the level of biosecurity risk posed by thrips relative to the appropriate level of protection (ALOP) for Australia. They also indicated that certain thrips 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 26 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, or by Australian industry, or those identified by states and territories as regional pests for Australia.

This report does not address the risk posed by thrips and orthospoviruses on nursery-stock imports, which are another significant commercial pathway for the possible introduction of these pests. These will be considered in a separate review. The department will consult with stakeholders if any changes are made to existing nursery-stock import conditions.

The order Thysanoptera comprises more than 6,000 described thrips species within nine families. This Group PRA identified the thrips families that are not likely to be associated with fresh fruit, vegetable, cut-flower and foliage imports, or have no potential for economic consequences for Australia and cannot meet the definition of a quarantine pest. As a result, only the phytophagous (plant-feeding) members of the Thripidae and phytophagous members of the Phlaeothripidae were identified as potential quarantine pests for Australia. These phytophagous thrips are the focus of this Group PRA.

Selection criteria were used to identify thrips species within the identified phytophagous Thripidae and the phytophagous Phlaeothripidae with potential biosecurity importance for Australia. Within this group, 79 thrips species were confirmed as quarantine pests for Australia. The final Group PRA also identified 27 orthospoviruses that are quarantine pests for Australia.

These thrips and orthospovirus quarantine pests were all estimated to have an 'indicative' unrestricted risk estimate of 'Low', which does not achieve the ALOP for Australia. These risk estimates are 'indicative' because the likelihood of entry for quarantine pests can be influenced by a range of factors relating to specific trade pathways.

Fourteen thrips species are known to naturally transmit orthospoviruses. Eleven of these are already regarded as quarantine pests for Australia. The remaining three are present in Australia and not under official control. This Group PRA recommends that the regulatory status of these three thrips species—*Frankliniella schultzei*, *Scirtothrips dorsalis* and *Thrips tabaci*—be changed from non-regulated to regulated because these thrips can carry and transmit quarantine orthospoviruses. This change is not expected to significantly affect trade.

Initial evaluation of six viruses other than orthospoviruses that are transmitted by thrips was also undertaken in this group PRA. The department will undertake further separate analysis for *Maize chlorotic mottle virus* and has sought further information on viruses of potential regional concern to Western Australia (*Sowbane mosaic virus*, *Tobacco streak virus* and *Strawberry necrotic shock virus*). The thrips vector of *Pelargonium flower break virus* is regulated, which also mitigates the risk from this virus. *Prunus necrotic ringspot virus* is not a quarantine pest.

Phytosanitary measures are identified in this final report for use in specific cases where measures are required. These measures are consistent with long-standing established policy for quarantine thrips and also mitigate the risk posed by the quarantine orthospoviruses they transmit.

Imported commodities will be regulated if they are infested with quarantine pest thrips or regulated thrips that transmit quarantine orthospoviruses to reduce the risk of establishment of these organisms in Australia. Regulation will be in accordance with the final Group PRA and any other relevant commodity-based PRAs.

The final Group PRA identifies measures for quarantine and regulated thrips 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.

Where measures are required, they will include:

- freedom from quarantine and regulated thrips and
- verification, such as inspection, to provide assurance that Australia's import conditions have been met and appropriate level of protection achieved.

Imported goods that are frequently found to be infested with thrips may be subject to mandatory treatment.

Written submissions on the draft report were received from five stakeholders. The final report takes into account stakeholder comments on the draft report. The department has made a number of changes to this Group PRA following consideration of these comments, and additional review of the literature. These changes include:

- Explaining further the basis for assessing phytophagous thrips as a group, including that they 'share common biological characteristics', a term used in the International Standards for Phytosanitary Measures
- Renaming and revising Chapter 2 to add additional text on thrips biology
- Adding additional evidence to support the removal of *Capsicum chlorosis virus-Phalaenopsis* strain as a quarantine pest for Australia
- Revising the likelihood of spread for orthospoviruses from Moderate to High
- Rewording text to provide more clarity for reasoning and conclusions.

Responses to key issues raised by stakeholders are presented in Appendix I.

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 2016b). The 'PRA area', the area in relation to which the PRA is conducted (FAO 2016b), is defined for this report as Australia. A pest is '*Any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products*' (FAO 2016b). 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 2016b).

Scope

This PRA considers all members of the insect order Thysanoptera (commonly referred to as thrips) and all members of the genus *Orthotospovirus* (formerly tospovirus) that are (or are likely to be) associated with fresh fruit, vegetables and cut-flowers or foliage imported into Australia as commercial consignments from any country. This will be referred to as the plant import pathway in this report.

The genus tospovirus has been renamed *Orthotospovirus* (ICTV 2017). There are 30 described species that were formerly named as tospoviruses. Eleven of these are officially recognised by the ICTV and are renamed within this report as orthotospoviruses—for example, *Tomato spotted wilt orthotospovirus*. The remainder retain their original names—such as *Capsicum chlorosis virus*. However, the scope of this report is inclusive of all 30 species. Specific details about this taxonomic revision are provided in Chapters 4.2 and 4.5. As a result of this taxonomic revision, scientific studies on tospoviruses are considered to refer to orthotospoviruses.

Out of scope

A risk analysis of the other viruses transmitted by thrips is beyond the scope of this group PRA. However, an initial evaluation was made to determine if additional work may be required, which would be undertaken as a separate process.

This report does not address the risk posed by thrips and orthotospoviruses on nursery-stock imports which are another significant commercial pathway for the possible introduction of these pests. These will be considered in a separate review. This approach is adopted because the nursery-stock pathway has a significantly different risk profile, as discussed within Appendix H. The department will consult with stakeholders if any changes are made to existing nursery-stock import conditions.

1.2 Introducing 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 groups of pests across numerous plant import pathways. This process applies the significant body of scientific knowledge available to the department

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 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.

Phytophagous thrips of biosecurity concern share common biological characteristics including plant-feeding behaviour, relatively small size and cryptic habits, high levels of natural or human-assisted mobility, lack of an obligate diapause life stage, high fecundity, and a predisposition to parthenogenesis in some species.

The Group PRA approach is built on the foundation of 18 (or more) years of PRAs undertaken by the department—all of which were subjected to robust scientific analysis and extensive processes of stakeholder consultation. For many common groups of pests, these pest risk assessments show marked consistencies in the levels 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 this Group PRA are validated with available scientific evidence including 26 years (or more) of interception data collected at Australia’s borders, similar records available from other countries, and extensive literature review. This Group PRA includes significant pests that have been recognised internationally, or by Australian industry, or those identified as regional pests for Australia in consultation with the states and territories.

Consistent with international standards and requirements

The Group PRA approach 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 2016e) and the SPS Agreement (WTO 1995).

Defined scope

Each Group PRA has clearly defined scope in relation to the pests being assessed 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 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. Each Group PRA 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 activities, 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 first Group PRA. It considers the biosecurity risk posed by all members of the insect order Thysanoptera (commonly referred to as thrips) and all members of the virus genus *Orthotospovirus* that are (or are likely to be) associated with fresh fruit, vegetables, cut-flowers or foliage imported into Australia as commercial consignments. It also assesses the emerging risks posed by orthotospoviruses, which are transmitted by some thrips. Further group PRAs are in preparation.

Thrips and the orthotospoviruses they transmit can cause considerable economic consequences across a wide range of fruit, vegetable, legume and ornamental crops by reducing yield, quality and marketability. Orthotospoviruses are a significant emerging risk to Australia with many recent reports of new species with rapidly expanding host ranges and geographic distributions.

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 thrips species associated with plant import pathway show a marked consistency in the estimated levels of biosecurity risk relative to the appropriate level of protection (ALOP) for Australia. This Group PRA is built on this foundation.

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 very few exceptions.

Identification of key pests

The purpose of this Group PRA was to focus on and identify those pests that are of biosecurity significance to Australia. Most thrips species described in the literature are not of biosecurity concern. A scoping assessment was undertaken to eliminate from further consideration thrips families (or sub-groups within these families) that are not phytophagous. This is because they are unlikely to have the potential to (i) be on the plant import pathway and/or (ii) cause economic (including environmental) consequences.

The phytophagous pest groups that remained after this elimination process have the potential to be quarantine pests for Australia and as a result required further consideration in pest categorisation.

Pest categorisation was included for both thrips and orthospoviruses.

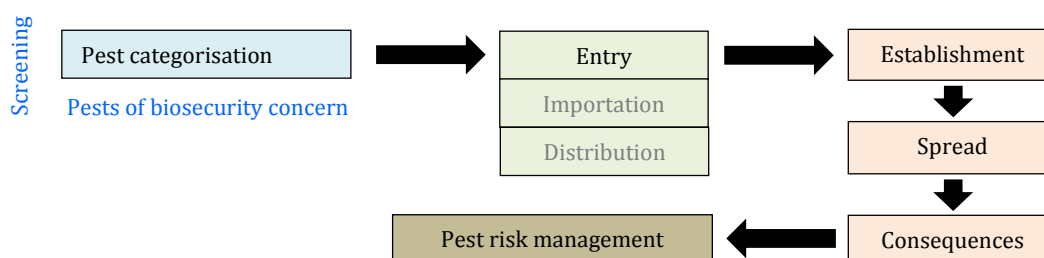
For thrips, selection criteria were then used to identify which phytophagous species to categorise in detail.

For orthospoviruses, pest categorisation was undertaken for all known (or likely) species that are transmitted by thrips.

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 in this 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 assessment of the likelihood of entry provided by 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 at or beyond its point of entry.

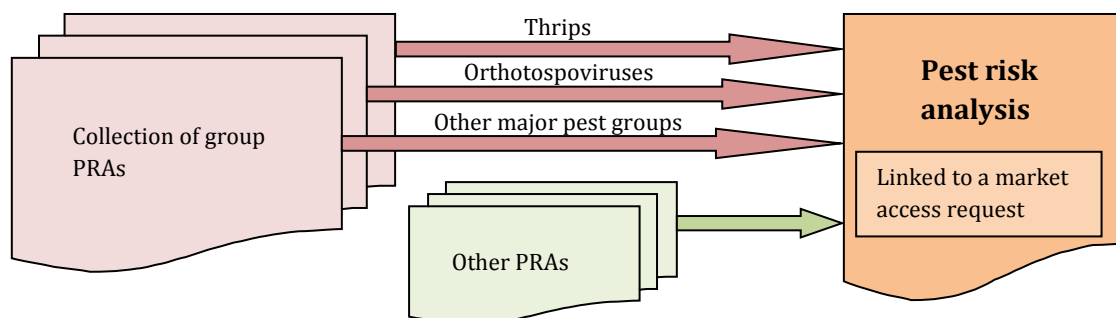
An 'indicative' unrestricted risk was estimated by combining the assessed likelihoods of entry (indicative), establishment and spread with the estimate of consequence.

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

1.4 Future Group PRAs

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 relevant pre-existing Group PRAs to review 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 Australian Government 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 the *Biosecurity Import Risk Analysis Guidelines 2016* located on the [Australian Government Department of Agriculture and Water Resources](#) website.

2 Scoping assessment for thrips

2.1 Introduction

The order Thysanoptera comprises more than 6,000 described thrips species (ThripsWiki 2017), which represent a diverse range of feeding strategies—herbivores, fungivores and predators.

This scoping assessment for thrips is required to review this diversity and eliminate from further consideration thrips families (or sub-groups within these families) that are not phytophagous and therefore unlikely to have the potential to (i) be on the plant import pathway and/or (ii) cause economic (including environmental) consequences. It also takes into account Australian and international interception records for thrips on the plant import pathway, and other relevant information.

The pest groups that remained after this elimination process have the potential to be quarantine pests for Australia and as a result required further consideration in pest categorisation.

2.2 Biology and taxonomy

Thrips are small, slender insects that are a few millimetres long. Adults of most species have band-like, delicately fringed wings with long cilia, from which the name Thysanoptera is derived (Lewis 1997c).

Reproduction of most thrips species requires mating. However, females are able to lay both fertilised and unfertilised eggs, with fertilised eggs producing females and unfertilised eggs producing males (Moritz 1997). Sexual and asexual populations can also exist for some species, such as *Thrips tabaci* (Moritz 1997). Additionally, some species only reproduce parthenogenetically.

Thrips lay between 30 and 300 eggs depending on the species and quality of food available (Lewis 1997c). Their life cycle usually takes between 10 and 30 days depending largely on temperature. A maximum of 12 to 15 generations per year is feasible under optimal conditions, but this reduces considerably to one or two generations in cooler regions. Thrips can overwinter as larvae in soil or as adults among dead plant litter, tree bark or crop debris (Lewis 1997c).

The order Thysanoptera is divided into two sub-orders, the Terebrantia and Tubulifera.

Species in the Terebrantia have a saw-like ovipositor, their eggs are inserted singly into plant tissue, and their life cycle consists of an egg, two active feeding nymphal (larval) instars, two relatively inactive non-feeding pupal instars (prepupa and pupa) and an adult. Members of the Tubulifera have no ovipositor but have a tube-shaped apical abdominal segment; their eggs are laid on the surface of plant tissues, and their life cycle has an additional pupal instar (Lewis 1997c).

The Terebrantia comprises eight families of about 2,500 species, with Thripidae being the largest family in this sub-order. The number of species in each family is given in parentheses within Table 2.1 (ThripsWiki 2017). Note that the Stenurothripidae includes 18 species, only six of which are living members (extant), and often referred to as the Adiheterothripidae (ThripsWiki 2017). The Tubulifera comprise a single family, the Phlaeothripidae, which is the largest in the Thysanoptera, with more than 3,600 described species (ThripsWiki 2017), split into two sub-families, the Idolothropinae and Phlaeothripinae.

Table 2.1 Taxonomy of the order Thysanoptera

Order	Thysanoptera	
Sub-order	Terebrantia	Tubulifera
Family and sub-family, if applicable	Aeolothripidae (208) Fauriellidae (5) Heterothripidae (89) Melanthripidae (67) Merothripidae (15) Stenurothripidae (6) Thripidae (2111)—sub-families Dendrothripinae, Panchaetothripinae, Sericothripinae and Thripinae Uzelothripidae (1)	Phlaeothripidae (3666)—sub-families Idolothripinae and Phlaeothripinae —

The current taxonomy of Thysanoptera is mainly based on morphological characteristics. However, some current morphological species are actually complexes of cryptic species (Kadirvel et al. 2013). For example, *Frankliniella occidentalis* was reported to contain a complex of two cryptic species based on nuclear and mitochondrial barcoding (Rugman-Jones, Hoddle & Stouthamer 2010). Similarly, a *Scirtothrips dorsalis* species complex was reported to comprise nine cryptic species within two morphologically distinguishable species, using histogram analysis of DNA barcodes, Bayesian phylogenetics, and the multi-species coalescent parameters (Dickey et al. 2015). Phylogenetic analysis of the mitochondrial cytochrome oxidase I gene also implied that there may be two major groups of *T. palmi*—one associated with populations from India and the second associated with populations from Japan, Thailand, Dominican Republic, China, and UK (Rebijith et al. 2011).

Future taxonomic studies, including the use of molecular analyses, are likely to generate more information on these cryptic species complexes, and identify additional possible species complexes.

2.3 Scoping assessment of thrips families

Aeolothripidae

This family contains 204 species in 23 genera distributed worldwide (Mound & Marullo 1998; Mound, Paris & Fisher 2009; ThripsWiki 2017). Aeolothripidae demonstrate a wide range of feeding behaviours. Most members of the genera *Aeolothrips* (98 species), *Desmothrips* (about 20 species) and *Erythrothrips* (12 species), which together comprise more than 60 per cent of species in the family, live in flowers, feed on plant tissues and are also facultative predators; a few are obligate predators of small arthropods (Kirk 1997b; Mound & Marullo 1998; Mound & Reynaud 2005; ThripsWiki 2017). In contrast, members of the genera *Cycadothrips* (3 species) and *Dactuliothrips* (9 species) all appear to be phytophagous, breeding in male cycad cones and *Yucca* flowers, respectively (Mound, Paris & Fisher 2009).

Members of the genera *Frankliniothrips* (16 species) and *Mymarothrips* (3 species) are probably obligate predators of small arthropods (Mound & Marullo 1998; Mound & Reynaud 2005; ThripsWiki 2017), and those of the genus *Stomatothrips* (8 species) are also probably all predatory (ThripsWiki 2017). *Frankliniothrips* species have been used as biological control agents (BCAs) (Mound & Reynaud 2005) and further species may exist within the family with potential as BCAs. Predatory aeolothripids typically feed on mites (Acari) but sometimes also on

thrips and other arthropods; often little host specificity is shown (Kirk 1997b; Mound, Paris & Fisher 2009; Mound & Reynaud 2005).

Aeolothripidae are not regarded as plant pests of economic consequence (Mound 1997) and they are rarely intercepted on the plant import pathway by Australia (Appendices C and D). Over a 26 year period only five species have been intercepted by Australia: three in interception group D (Appendix D; yearly average range 0.1 to less than 0.5; *Aeolothrips collaris*, *Aeolothrips fasciatus* and *Franklinothrips megalops*) and two in interception group E (Appendix D; yearly average less than 0.1; *Desmothrips australis* and *Franklinothrips vespiformis*). Excluding the species of the genus *Melanthrips*, now placed in a separate family Melanthripidae (ThripsWiki 2017), the United States has also reported infrequent interceptions of 12 identified species of Aeolothripidae at its ports of entry over the period 1983 to 1999 from Europe, the Mediterranean and Africa (Nickle 2003). Japan has also reported the interception of nine species of Aeolothripidae, although their interception frequency was not reported (Hayase 1991; Masumoto, Oda & Hayase 1999, 2003; Oda & Hayase 1994).

The rare interceptions of Aeolothripidae that do occur are considered to be contaminating pests ('contaminants') on the plant import pathway. The risks posed by contaminants on the plant import pathway are addressed by existing standard operational procedures (Appendix G). The risks posed by contaminating Aeolothripidae species that are current or potential BCAs are also addressed by existing requirements for BCAs (Appendix G). For these reasons, the family Aeolothripidae is excluded from further consideration in this PRA.

Fauriellidae

This family contains five species (Mound, Paris & Fisher 2009; ThripsWiki 2017). Their biology is uncertain, but one species was collected on flowers of *Garrya vealchii* (Garryaceae), another was described from a species of Asteraceae and two others are possibly associated with *Artemisia* (also Asteraceae) (Mound, Paris & Fisher 2009). Cut-flowers from these plant families are not currently imported into Australia, with the exception of tarragon (*Artemisia dracunculus*). However, tarragon is not a recorded host of Fauriellidae species.

There is no available evidence indicating that the Fauriellidae are plant pests of economic consequence. They have not been intercepted on the plant import pathway by Australia over a 26 year period (Appendices C and D). The United States has not reported any interceptions at its ports of entry over the period 1983 to 1999 from Europe, the Mediterranean or Africa (Nickle 2003) and neither has Japan (Hayase 1991; Masumoto, Oda & Hayase 1999, 2003; Masumoto et al. 2005; Oda & Hayase 1994). Consequently, the family Fauriellidae is excluded from further consideration in this PRA.

Heterothripidae

This family contains 89 species in four genera, and all but three species feed and breed in flowers, usually in the plant family Malpighiaceae (ThripsWiki 2017). Adult Heterothripidae have also been found on the flowers of Asteraceae, Fabaceae, Caesalpiniaceae, Mimosaceae and Cactaceae, but their juvenile developmental stages have not been recorded on flowers of these plant families (Retana-Salazar 2009), which implies they are only used as an adult food source. Larvae and adults of *Heterothrips lopezae* have been recorded from the flowers of apple guava (*Psidium guajaba*), but there is no available evidence of them being pests of economic consequence, or being associated with apple guava fruit (Retana-Salazar 2009). The three species in the genus *Aulacothrips* (*Aulacothrips amazonicus*, *A. dictyotus* and *A. minor*) are ectoparasites of plant-feeding Hemiptera in the Aetalionidae, Cicadellidae and Membracidae families (Cavalleri, Kaminski & Mendonca 2010; Cavalleri, Kaminski & Mendonça 2012).

There is no available evidence indicating that the Heterothripidae are plant pests of economic consequence (Mound 1997). They have not been intercepted on the plant import pathway by Australia over a 26 year period (Appendices C and D). The United States has not reported any interceptions at its ports of entry over the period 1983 to 1999 from Europe, the Mediterranean or Africa (Nickle 2003) and neither has Japan (Hayase 1991; Masumoto, Oda & Hayase 1999, 2003; 2005; Oda & Hayase 1994). They are considered unlikely to be present on the plant import pathway except as occasional contaminants. The risks posed by contaminants on the plant import pathway are addressed by existing standard operational procedures (Appendix G). For these reasons, the family Heterothripidae is excluded from further consideration in this PRA.

Melanthripidae

This family, previously considered a subfamily of the Aeolothripidae, contains 67 species in four genera that all seem to be phytophagous, feeding on and breeding within flowers, and probably pupating at soil level within a silken cocoon (Mound, Paris & Fisher 2009; ThripsWiki 2017). Many species seem likely to be both host specific and have one generation per year (univoltine) but there are few studies on their biology and life history (Mound, Paris & Fisher 2009).

There is no available evidence indicating that the Melanthripidae are plant pests of economic consequence. They have not been intercepted on the plant import pathway by Australia over a 26 year period (Appendices C and D). The United States has reported infrequent interceptions of three identified species in the genus *Melanthrips* at their ports of entry over the period 1983 to 1999 from Europe, the Mediterranean and Africa (Nickle 2003). Japan has also reported interception of two species of Melanthripidae although the frequency of these interceptions was not reported (Hayase 1991; Masumoto et al. 2005). Melanthripidae are considered unlikely to be present on the plant import pathway except as occasional contaminants. The risks posed by contaminants on the plant import pathway are addressed by existing standard operational procedures (Appendix G). For these reasons, the family Melanthripidae is excluded from further consideration in this PRA.

Merothripidae

This family contains 15 species in three genera that feed on fungi on dead twigs, branches or leaf material (Mound, Paris & Fisher 2009).

There is no available evidence indicating that Merothripidae are plant pests of economic consequence. They are rarely intercepted by Australia (Appendices C and D); over a 26 year period only two species have been intercepted at ports of entry by Australia, both within interception group E (Appendix D; yearly average less than 0.1; *Merothrips brunneus* and *Merothrips floridensis*). The United States has not reported any interceptions at its ports of entry over the period 1983 to 1999 from Europe, the Mediterranean or Africa (Nickle 2003). Japan has reported interception of one species of Merothripidae (*Merothrips brunneus* Ward), although the frequency of this interception was not reported (Masumoto et al. 2005). Merothripidae are considered unlikely to be present on the plant import pathway except as occasional contaminants. The risks posed by contaminants on the plant import pathway are addressed by existing standard operational procedures (Appendix G). For these reasons, the family Merothripidae is excluded from further consideration in this PRA.

Phlaeothripidae

The Phlaeothripidae comprises the suborder Tubulifera and is the largest family in the order Thysanoptera with 3,664 described species in two subfamilies, the Idolothripinae (83 genera and 737 species) and the Phlaeothripinae (374 genera and 2,927 species) (ThripsWiki 2017).

Many species are not known to be pests of economic consequence, but some are regarded as pests (Lewis 1997c; Mound & Morris 2007). The Phlaeothripidae comprise about nine per cent of all Thysanoptera interceptions across the plant import pathway. Some species in the subfamily Phlaeothripinae are plant feeders with potential to be pests of economic consequence.

The family Phlaeothripidae is further discussed in three separate groups based on their feeding behaviours, which are fungivorous, predatory or phytophagous.

Fungivorous Phlaeothripidae: About 60 per cent of Phlaeothripidae species feed on fungi. This group includes all the subfamily Idolothripinae, and, in the subfamily Phlaeothripinae, species in the large genera *Hoplandrothrips* (105 species), *Holothrips* (125 species) and *Hoplothrips* (130 species) (Mound, Paris & Fisher 2009; Mound & Tree 2012).

Fungivorous Phlaeothripidae are infrequently intercepted by Australia. Over a 26 year period six species were intercepted by Australia on the plant import pathway (Appendices C and D): one in interception group C (Appendix D; yearly average range 0.5 to 5; *Hoplandrothrips flavipes*), two in interception group D (Appendix D; yearly average range 0.1 to less than 0.5; *Nesothrips laventris* and *Nesothrips propinquus*) and three in interception group E (Appendix D; yearly average less than 0.1; *Ecacanthothrips tibialis*, *Hoplothrips kea* and *Priesneriella citricauda*). Only one of these species is not already present in Australia (*Hoplothrips kea*). The United States has also reported infrequent interceptions of two species of fungivorous Phlaeothripidae (*Bolothrips cingulatus* and *Elaphrothrips* sp.) at its ports of entry over the reported period 1983 to 1999 from Europe, the Mediterranean and Africa (Nickle 2003). Japan has also reported the interception of 13 species of fungivorous Phlaeothripidae (all in the subfamily Idolothripinae), although their interception frequency was not reported (Hayase 1991; Masumoto, Oda & Hayase 1999, 2003; Masumoto et al. 2005; Oda & Hayase 1994).

There are no reports of these species being pests of economic consequence (Mound 1997; Ullman, Sherwood & Geric-Stare 1997) and there is no available evidence to demonstrate that exotic fungivorous Phlaeothripidae have caused damage to the environment. They are only likely to be present on the plant import pathways as infrequent contaminants. The risks posed by contaminants on the plant import pathway are addressed by existing standard operational procedures (Appendix G). For these reasons, fungivorous species of Phlaeothripidae are excluded from further consideration in this PRA.

Predatory Phlaeothripidae: All species in the genera *Leptothrips* and *Podothrips* are assumed to be predators and two species of *Karnyothrips* and one species of *Aleurodothrips* (*A. fasciapennis*) are known to be predatory on scale insects (Mound 2005d; Mound & Minaei 2007).

Predatory Phlaeothripidae are rarely intercepted by Australia (Appendices C and D). Over a 26 year period six species have been intercepted: four in interception group D (Appendix D; yearly average range 0.1 to less than 0.5; *Aleurodothrips fasciapennis*, *Karnyothrips flavipes*, *Leptothrips mali* and *Podothrips semiflavus*) and two in interception group E (Appendix D; yearly average less than 0.1; *Haplothrips collyerae* and *Podothrips lucasseni*). Only two of these are not already present in Australia (*Leptothrips mali* and *Podothrips semiflavus*). The United States has also reported infrequent interceptions of five species of predatory Phlaeothripidae at its ports of entry over the reported period 1983 to 1999 from Europe, the Mediterranean and Africa (Nickle 2003). Japan has also reported the interception of eight species of predatory Phlaeothripidae, although their interception frequency was not reported (Hayase 1991; Masumoto, Oda & Hayase 1999, 2003; 2005; Oda & Hayase 1994).

Intercepted predatory Phlaeothripidae are considered to be contaminants on the plant import pathway. The risks posed by contaminants on the plant import pathway are addressed by existing standard operational procedures (Appendix G).

It is recognised that some predatory species may have current or potential use as BCAs and that these may possibly also be present on plant import pathway as contaminants. These risks are also addressed by existing requirements for BCAs (Appendix G). For these reasons, predatory species of Phlaeothripidae are excluded from further consideration in this PRA.

Phytophagous Phlaeothripidae: Plant feeding Phlaeothripidae are all in the subfamily Phlaeothripinae. Thrips from the genus *Haplothrips* feed mainly on pollen, while those from the large genus *Liothrips* feed mainly on leaves (Mound 1997; Mound, Paris & Fisher 2009). About 300 thrips species are able to form galls on their host plants and most of these species are found within the *Liothrips* genus (Crespi, Carmean & Chapman 1997).

Haplothrips live mainly in flowers of Compositae and Graminae, and are generally not considered to be important pests. However, some are known to live on weeds associated with crops (Mound 1997). Examples of plant pest *Haplothrips* species that are absent from Australia include *H. aculeatus*, *H. chinensis*, *H. tritici* and *H. ganglbaueri* (ThripsWiki 2017), with the former three species reported as being abundant on cereal crops (Mound 1997).

Leaf-feeding *Liothrips* can be serious pests, but generally are associated with a single plant host species (Mound 2005d). Particular species of *Liothrips* are known to damage several horticulturally important crops including pepper vines (*L. piperinus*, *L. karynyi*), wasabi (*L. wasabiae*) and greenhouse grown *Liliacaea* (*L. vaneckei*, present in Australia) (Mound 1997; Mound & Morris 2007). Species in the closely related genus *Pseudophilothrips* (previously classified as *Liothrips*) are reported to damage avocado trees (*Pseudophilothrips persea* and *P. avocadis*) and *Paullinia cupana* trees in Brazil (*P. adisi*) (Mound & Morris 2007; Mound, Wheeler & Williams 2010). Mound (2010) identified *L. karynyi* and *P. adisi* as particularly significant pests.

Other Phlaeothripidae species are known to damage persimmon (*Ponticulothrips diospyrosi*) and form galls on *Ficus* (*Gynaikothrips ficorum*, present in Australia, and *G. uzeli*) (Held et al. 2005; Mound 1997; Mound & Morris 2007).

Over a 26 year period, Australia has intercepted nine species of plant feeding Phlaeothripidae on the plant import pathway (Appendices C and D). *Haplothrips gowdeyii* was the most frequently intercepted (group B in Appendix D; yearly average between 10 and 50) comprising about 75 per cent of all Phlaeothripidae interceptions identified to species level. Two species were in interception group C (Appendix D; yearly average range 0.5 to 5; *Haplothrips ganglbaueri* and *Hoplandrothrips flavipes*). Of the remaining six species, four were in interception group D (Appendix D; yearly average range 0.1 to less than 0.5; *Gynaikothrips ficorum*, *Haplothrips aculeatus*, *Haplothrips leucanthemi* and *Haplothrips robustus*) and two were in interception group E (Appendix D; yearly average less than 0.1; *Plicothrips apicalis* (*syn. Haplothrips apicalis*) and *Haplothrips ceylonicus*). Only four of these are not already present in Australia (*Haplothrips ganglbaueri*, *Haplothrips aculeatus*, *Plicothrips apicalis* and *Haplothrips ceylonicus*). The United States has also reported infrequent interceptions of at least 16 species of phytophagous Phlaeothripidae, mainly *Haplothrips*, at its ports of entry over the reported period 1983 to 1999 from Europe, the Mediterranean and Africa (Nickle 2003). Japan has also reported the interception of 24 species of phytophagous Phlaeothripidae, although their interception frequency was not reported (Hayase 1991; Masumoto, Oda & Hayase 1999, 2003; 2005; Oda & Hayase 1994).

It is recognised that some plant feeding species, particularly those targeting single host species that are regarded as weeds (e.g. *Liothrips* species), may have current or potential use as BCAs, and that these may possibly be present on the plant import pathway as contaminants. These risks are addressed by existing requirements for BCAs (Appendix G). For these reasons, potential BCA species for weeds are excluded from further consideration in this PRA, even though they are also plant feeders.

Only phytophagous species of Phlaeothripidae with potential economic consequences are considered further in this PRA (Table 2.2). These include species in the genera *Haplothrips*, *Liothrips*, *Pseudophilothrips* and *Gynaikothrips*.

Stenurothripidae

This family contains 12 fossil and six extant (present-day) species (ThripsWiki 2017). Extant species are often placed in a separate family, Adiheterothripidae; they breed on dead twigs, presumably feeding on fungal hyphae (Mound, Paris & Fisher 2009). The six extant species are described in three genera, four in *Holarthrothrips*, and one each in *Heratythrips* and *Oligothrips* (ThripsWiki 2017). Species of *Holarthrothrips* have been reported to occur from India to the Mediterranean area including the Canary Islands, whereas *Heratythrips* and *Oligothrips* are known only from western North America (Mound, Paris & Fisher 2009; ThripsWiki 2017).

There is no available evidence indicating that the Stenurothripidae are plant pests of economic consequence, and they have not been intercepted on the plant import pathway by Australia over a 26 year period (Appendices C and D). The United States has not reported any interceptions at its ports of entry over the period 1983 to 1999 from Europe, the Mediterranean or Africa (Nickle 2003) and neither has Japan (Hayase 1991; Masumoto, Oda & Hayase 1999, 2003; 2005; Oda & Hayase 1994). For these reasons, the family Stenurothripidae is excluded from further consideration in this PRA.

Thripidae

This family contains about one third (2079) of all thrips species within four subfamilies: Thripinae, Panchaetothripinae, Dendrothripinae and Sericothripinae (Mound, Paris & Fisher 2009; ThripsWiki 2017). Most Thripidae feed on flowers or leaves, with members of the two largest genera *Thrips* (275 spp.) and *Frankliniella* (175 spp.) able to exploit both (Mound 1997). These two genera contain most of the significant pest taxa within the Thysanoptera (Mound 1997). Leaf-feeding behaviour is observed across a range of Thripidae genera (Mound 1997). Many Thripidae feed only on grasses, with *Chirothrips* and *Limothrips* species feeding mainly on florets and *Aptinothrips* and *Stechaetothrips* species feeding mainly on leaves (Mound 1997). A small number of Thripidae, such as species of the genus *Scolothrips*, are obligate predators of mites (Mound & Tree 2012).

There is a large body of scientific evidence indicating that many members of the Thripidae are plant pests of economic consequence, and Australia has intercepted them in large numbers on the plant import pathway (Appendices C and D). The United States has reported the interception of 102 species in 38 genera of Thripidae at its ports of entry over the period 1983 to 1999 from Europe, the Mediterranean and Africa (Nickle 2003). Japan has also reported the interception of at least 138 species in 59 genera of Thripidae, although their interception frequency was not reported (Hayase 1991; Masumoto, Oda & Hayase 1999, 2003; 2005; Oda & Hayase 1994). For these reasons, the family Thripidae (excluding the predatory species) is considered further in this PRA.

Uzelothripidae

This family contains one living species, *Uzelothrips scabrosus*, which is a detritivore thought to feed on fungal hyphae growing on dead plant material (Mound, Paris & Fisher 2009). *Uzelothrips scabrosus* originates from Brazil, and has been recorded in Singapore and Australia. The Australian record consists of four females collected over a range of six kilometres in Brisbane Forest Park under the bark of *Eucalyptus major* trees (Tree 2009).

There is no evidence indicating that *Uzelothrips scabrosus* is a plant pest of economic consequence either in Australia or elsewhere. It has not been intercepted on the plant import pathway by Australia over a 26 year period (Appendices C and D). The United States has not reported any interceptions of Uzelothripidae at its ports of entry over the period 1983 to 1999 from Europe, the Mediterranean and Africa (Nickle 2003) and neither has Japan (Hayase 1991; Masumoto 2010; Masumoto, Oda & Hayase 1999, 2003; 2005; Oda & Hayase 1994). For these reasons, the family Uzelothripidae is excluded from further consideration in this PRA.

2.4 Conclusion

The outcome of the scoping assessment, based on the information presented, is summarised in Table 2.2.

The Aeolothripidae, Fauriellidae, Heterothripidae, Melanthripidae, Merothripidae, fungivorous and predatory Phlaeothripidae, Stenurothripidae, obligate predatory Thripidae and Uzelothripidae are excluded from further consideration in this Group PRA.

These families are not considered likely to be associated with the plant import pathway, except occasionally as contaminants, and/or to have no potential economic consequences for Australia. The risks posed by contaminants on the plant import pathway are addressed by existing standard operational procedures, and the risks posed by potential BCAs are also addressed by existing requirements. Consequently, only the phytophagous Thripidae and the phytophagous Phlaeothripidae are considered further in this Group PRA.

Table 2.2 Outcome of the scoping assessment for thrips

Family	Potential to be on the plant import pathway	Potential for economic consequences	Australia interception data 1986-2006 (a)	US and Japanese interception data (b)	Consider further in pest categorisation
Aeolothripidae	No, only as rare contaminants	No	Interception groups D (3 species) and E (2 species)	12 species by US and 9 species by Japan	No
Fauriellidae	No	No	None	None	No
Heterothripidae	No	No	None	None	No
Melanthripidae	No	No	None	3 species by US and 2 species by Japan	No
Merothripidae	No, only as rare contaminants	No	Interception group E (2 species)	1 species by Japan	No
Phlaeothripidae					
Fungivorous	No, only as rare contaminants	No	Interception groups D (2 species) and E (2 species)	2 species by US and 13 species by Japan	No
Predatory	No, only as rare contaminants	No	Interception groups D (4 species) and E (2 species)	5 species by US and 8 species by Japan	No
Phytophagous	Yes	Yes	Interception groups B (1 species), C (4 species), D (5 species) and E (2 species)	16 species by US and 24 species by Japan	Yes
Stenurothripidae	No	No	None	None	No
Thripidae					
Obligate Predatory	No, only as rare contaminants	No	Interception groups D (1 species) and E (1 species)	1 species by US and 1 species by Japan	No
Phytophagous	Yes	Yes	Interception groups A (2 species), B (4 species), C (17 species), D (18 species) and E (47 species)	102 species by US and 138 species by Japan	Yes
Uzelothripidae	No	No	None	None	No

a. Data presented in Appendices C and D. **b.** US data (Nickle 2003), and Japan data (Hayase 1991; Masumoto, Oda & Hayase 2003; 2005; Oda & Hayase 1994).

3 Pest categorisation of phytophagous thrips

3.1 Introduction

In the preceding chapter, the phytophagous Thripidae and phytophagous Phlaeothripidae (excluding those species that are used as BCAs for weeds) were identified as containing species that have potential to be on the plant import pathway, and to cause damage to plants (Table 2.2). This chapter considers the phytophagous species within these two families and categorises them in accordance with ISPM 2: Framework for Pest Risk Analysis and ISPM 11: *Pest Risk Analysis for Quarantine Pests* (FAO 2016e).

The phytophagous Thripidae and phytophagous Phlaeothripidae (hereafter referred to as phytophagous thrips, or pest thrips) collectively contain thousands of species, but it is not practical or necessary to categorise them all. Instead, selection criteria (Table 3.1) were used to identify pest thrips species for inclusion in the pest categorisation of thrips (Table 3.2), with inclusion dependent on meeting one or more of these criteria.

Table 3.1 Criteria for inclusion of thrips species in pest categorisation

Criterion	Description
1	Species is known to have a history of being among the more frequently intercepted thrips at Australian ports of entry (averaging more than 0.5 interception events per year over a 26 year period; Appendix C and D)
2	Species is known to transmit an orthospovirus (Chapter 4)
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 (2014a)
5	Species is identified as a plant pest in the scoping assessment for thrips
6	Species has previously been considered by Australia at the species level in pest categorisation in published final risk analyses, regardless of whether it was absent or present in Australia and whether or not it was found to be associated with the specific commodity at the time, excluding species in families that were excluded within scoping assessment for thrips
7	Species is under official control as a regional pest within Australia

Based on the selection criteria, 112 thrips species (Table 3.2) were included for pest categorisation as representative members of the phytophagous thrips. This process produced a list of species likely to be important from a biosecurity perspective and associated with the plant import pathway. Any future pest categorisation of additional species that meet one or more of the selection criteria will be considered on a case-by-case basis.

3.2 Pest categorisation

The process for pest categorisation is described in Appendix A. The pest categorisation process considers the:

- identity of 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.

These components of pest categorisation of phytophagous thrips are presented in Table 3.2, except for the potential for establishment and spread and potential for economic and environmental consequences in the PRA area that are presented in Chapters 3.3 and 3.4, respectively. This approach is consistent with the ISPM 11 categorisation guidelines (FAO 2016e).

3.3 Potential for establishment and spread

Establishment is defined as the ‘perpetuation for the foreseeable future, of a pest within an area after entry’ (FAO 2016b), and spread is defined as ‘the expansion of the geographical distribution of a pest within an area’ (FAO 2016b).

Pest thrips are considered to have the potential to establish and spread in Australia because they share common biological characteristics that enable them to adapt to a new region, the climatic conditions in Australia are suitable, and host plants are widely available.

Share common biological characteristics

Thrips species that have successfully established in new regions share common biological characteristics including plant-feeding behaviour, relatively small size and cryptic habits, high levels of natural or human-assisted mobility, lack of an obligate diapause life stage, high fecundity, and a predisposition to parthenogenesis in some species. For example, species in the genera *Frankliniella*, *Scirtothrips*, and *Thrips*, which share these characteristics, have established and spread in many regions of the world after their introduction (Morse & Hoddle 2006). These characteristics can be extrapolated to other members of the phytophagous thrips.

Climatic conditions

Many pest thrips occur in the tropics and subtropics of the world (Mound 2012b), and suitable conditions for establishment and spread are available in Australia, which has tropical, subtropical, temperate, and cool temperate climatic regions (Bureau of Meteorology 2013). In addition, Australia produces many crops, such as tomatoes, capsicum, cucumber and eggplant under protected conditions (Ausveg 2014b), which can assist the establishment and spread of pest thrips.

Hosts plants

Many crops, including a range of fruit, vegetables, cut-flowers and foliage that are hosts of thrips are grown in Australian field and greenhouse environments. These hosts are widespread in all states and territories. In addition, Australia also has an extensive diversity of native vegetation, which may serve as hosts for exotic thrips species, as many species are capable of feeding on a wide range of unrelated host plants (Mound 1997, 2005d).

Examples of thrips that have established and spread within Australia

At least 60 thrips species have successfully established in Australia following their introduction. These include common grass-living Thripidae of Europe, such as species of *Aptinothrips*, *Chirothrips* and *Limothrips*, and leaf-feeding tropical species such as *Chaetanaphothrips*, *Heliiothrips*, *Hercinothrips*, *Parthenothrips*, *Selenothrips*, *Scirtothrips* and *Thrips* (Mound & Tree 2012). Many of these species probably established years ago, but relatively recent introductions have included *Frankliniella occidentalis*, *Liothrips vaneeckei* and *Thrips palmi*.

Summary

All pest thrips are considered to have the potential to establish and spread in the PRA area because they occur in regions with similar climatic conditions and agricultural production systems to Australia. Establishment and spread are also facilitated because pest thrips share common biological characteristics, including small size, polyphagous feeding behaviours and adaptive reproductive strategies. This assessment is consistent with the outcomes of all previous pest categorisations undertaken by Australia, in which every included species has been assessed as having potential for establishment and spread in Australia, when the species was also found to be on the plant import pathway.

3.4 Potential for economic consequences

Thrips have potential to become key economic pests because they feed on the cellular contents of leaves, petals, fruit and seeds, and on pollen grains (Kirk 1997b). This feeding damages plant cells, resulting in tissue death or deformation (Kirk 1997b). This can cause considerable crop loss, as summarised by Lewis (1997c). For example, when thrips feed on horticultural crops, the resultant damage is likely to affect yields and marketability, with direct effects due to damage to fruit intended for sale, and indirect effects through stress caused by damage elsewhere on the hosts (Lewis 1997c).

It should be noted that even plant-feeding thrips that have not been reported as important pests in their native regions have the potential to become serious pests when they are introduced into new regions. This phenomenon has been observed for other groups of arthropods such as mites and mealybugs as well as for thrips. For example, *Scirtothrips perseae* was first discovered in California in June 1996, damaging fruit and foliage of avocado (Hoddle, Nakahara & Phillips 2002) and spread quickly. By May 1998, this pest infested 80 per cent of California avocado acreage, and by 2002, 95 per cent of fruit-bearing acreage (Hoddle, Nakahara & Phillips 2002). Heavily infested orchards experienced 50 to 80 per cent crop damage in 1997 and crop losses in 1998 were estimated at US\$7.6 to 13.4 million from the combined effects of losses in quality and increased production costs associated with the pest management (Hoddle, Nakahara & Phillips 2002). However, this species does not appear to be a serious pest of avocado in its presumed native Mexico and Central America, where exploration of potential classical biological control agents had been attempted (Hoddle, Nakahara & Phillips 2002).

In a comprehensive review of thrips biology, Mound (2005d) emphasised the unpredictability and opportunism characteristic of this group of insects. As an example, it was noted that thrips can be very opportunistic in exploring available resources. Some monophagous species have exhibited remarkable host shifts, becoming pests on plants unrelated to their natural hosts (Marullo 2009; Mound 1997). For example, *Apterothrips apteris* is restricted to *Erigeron* in California but became a minor pest of *Medicago* and *Allium* in Australia. *Neohydatothrips gracilicornis* is generally considered host specific to *Vicia* species (Fabaceae) in northern Europe, but damages the foliage of Pinaceae and Betulaceae in Spain and Southern Italy (Marullo 2009; Mound 2005d). *Drepanothrips reuteri* Uzel is largely specific to *Quercus* in Europe, but became a well known pest of grapevines in other parts of the world. The highly polyphagous species, *Heliothrips haemorrhoidalis* (Bouchè) can produce large populations on many unrelated plants including *Camellia*, *Citrus*, *Pinus* and *Dicksonia* (Marullo 2009).

Summary

Pest thrips are considered to have the potential to cause economic (including environmental) consequences in Australia, even when they are not reported as economic pests in their native regions. This assessment is consistent with the outcomes of previous pest categorisations

undertaken by Australia. All but one species were previously assessed as having the potential to cause economic consequences in Australia, whenever the species was found to be on the plant import pathway, and to also have the potential for establishment and spread. Many of the 112 thrips species that have been specifically categorised in this report (Table 3.2) have also been reported as plant pests elsewhere.

3.5 Pest categorisation table

The pest categorisation for phytophagous thrips is presented in Table 3.2, and the outcomes of the categorisation process are summarised in Table 3.3.

Notes on Table 3.2

To assist with the interpretation of this pest categorisation, these notes and comments are provided.

The identity of the pest (Column 1), the criteria for its inclusion (Column 2 from Table 3.1), and the absence or presence and regulatory status in the PRA area (Column 4) are provided for each species in the categorisation table.

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. Instead, these were presented for all the pest thrips as a group in Sections 3.3 and 3.4, respectively. The determination of the quarantine pest status for each species (Column 7) took account of information in Sections 3.3 and 3.4.

The categorisation also includes, for each species, general world distribution (Column 3); plant parts affected, host plants/or previous pathway assessment by Australia (Column 5); interception data from Australia and overseas, mainly USA and Japan (Column 6), and whether or not the pest is a potential orthospovirus vector (Column 8).

In Column 6, each interception event is based on the presence of at least a single thrips individual in a consignment. The number of thrips present per event is not generally recorded, and multiple thrips individuals can infest the same commodity. Interception events are averaged over 26 years (1986–2012) and expressed as a range and grouped within five cohorts A to E:

- A = greater than 250 events per year
- B = 10 to 50 events per year
- C = 0.5 to 5 events per year
- D = 0.1 to less than 0.5 events per year
- E = less than 0.1 events per year.

The interception data are non-continuous because, for example, there are no yearly average interception events between 51 and 249 for any thrips species (Appendix D).

Table 3.2 Pest categorisation of phytophagous thrips

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthotospovirus vector
THRIPIDAE							
<i>Anaphothrips obscurus</i> (Müller) Grass thrips	6	Worldwide in temperate areas (CABI 2013a; Mound & Tree 2012)	Yes, Southern Australia (Mound & Tree 2012)	Leaves, commonly in leaf axils of grasses (Mound & Tree 2012), and seedling cereals and young grasses (CABI 2013a)	Interception group D; on <i>Asparagus</i> spears. Fourteen interceptions from Europe and/or Africa from 1983-1999 and also intercepted from Europe and Africa from 1994-1999 at US ports (Nickle 2003). Intercepted on asparagus from New Zealand, <i>Cichorium intybus</i> from USA, strawberry from Korea and cut-flowers of <i>Dianthus</i> sp. from China to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003; 2005)	No	No
<i>Anaphothrips sudanensis</i> Trybom	1, 6	Worldwide in tropical and subtropical areas (CABI 2013a; Mound & Tree 2012)	Yes, widespread (Mound & Tree 2012)	Leaves of grasses and cereal crops (CABI 2013a; Mound & Tree 2012)	Interception group C; from a variety of pathways. One interception from Mediterranean or Africa from 1983-1999 and also being intercepted from Europe and Africa from 1994-1999 at US ports (Nickle 2003). Intercepted on <i>Allium fistulosum</i> from China, <i>Asparagus officinalis</i> from Thailand and cut-flowers from Zimbabwe to Japan (Masumoto, Oda & Hayase 2003; 2005)	No	No
<i>Arorathrips mexicanus</i> (Crawford)	1	Widespread throughout the world in tropics and subtropics (Hoddle, Mound & Paris 2012)	Yes, Qld, NSW and NT (Mound 2012a)	Leaves of citrus (Childers & Nakahara 2006) and also within individual florets of various Poaceae (Hoddle, Mound & Paris 2012)	Interception group C; from rose cut-flowers and vegetables. Intercepted on <i>Asparagus officinalis</i> from Thailand and New Zealand and <i>Chrysanthemum morifolium</i> from South Africa to Japan (Masumoto, Oda & Hayase 2003; 2005)	No	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthospovirus vector
<i>Asprothrips seminigricornis</i> (Girault)	7	Australia, Marquesas Islands, central and north America (Mound & Tree 2012)	Yes, Eastern Australia (Mound & Tree 2012) Declared pest, prohibited by WA (Government of Western Australia 2016)	On leaves, probably polyphagous, adults have been found on leaves of <i>Gardenia</i> , <i>Citrus</i> and <i>Ricinus</i> (Mound & Tree 2012)	None	Yes (WA)	No
<i>Caliothrips fasciatus</i> (Pergande) Californian bean thrips	1, 3, 6	Western USA and parts of Mexico, and apparently also in China (Hoddle, Mound & Paris 2012; 2006; Mound & Tree 2012)	No record found (Hoddle, Stosic & Mound 2006; Mound & Tree 2012)	Foliage of beans; also overwinters inside the navel of 'navel' orange (Hoddle, Stosic & Mound 2006) Identified as high priority pest for citrus industry by Plant Health Australia	Interception group B; from Citrus fruit pathways. Intercepted on asparagus and citrus from Mexico and USA to Japan (Hayase 1991)	Yes	No
<i>Caliothrips impurus</i> (Priesner) African cotton thrips	6	Africa and India (ThripsWiki 2017)	No record found (Mound 2005c; Mound & Tree 2012)	Leaves of cotton and other fibres and grasses (Mound 2005c; ThripsWiki 2017)	None	Yes	No
<i>Caliothrips indicus</i> Bagnall Groundnut thrips	6	India (ThripsWiki 2017)	No record found (Mound 2012a; Mound & Tree 2012)	Leaves, polyphagous (Butani 1993)	Intercepted on <i>Anethum glaveolens</i> from Thailand to Japan (Masumoto, Oda & Hayase 2003)	Yes	No
<i>Caliothrips phaseoli</i> (Hood) American bean thrips	4	North and South America (Hoddle, Mound & Paris 2012)	No record found (Mound & Tree 2012)	Leaves of particularly Fabaceae (Hoddle, Mound & Paris 2012), including common bean, lentil, maize and soybean (CABI 2013a)	Interception group D; from <i>Citrus</i> fruit and <i>Asparagus</i> spears. Intercepted on <i>Asparagus officinalis</i> from Peru to Japan (Oda & Hayase 1994)	Yes	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthospovirus vector
<i>Caliothrips striatopterus</i> (Kobus) Mangosteen thrips	6	Java, Philippines, Solomon Islands and Australia (Mound 2012a; Mound & Tree 2012)	Yes, QLD, NSW, NT, WA (Mound & Tree 2012)	Leaves of various Poaceae, including sugar cane and <i>Zea mays</i> (Mound & Tree 2012), also on mangosteen (Pableo & Velasco 1994)	None	No	No
<i>Ceratothripoides claratris</i> (Shumsher)	2	Asia from India to Thailand (Hoddle, Mound & Paris 2012)	No record found (Mound & Tree 2012)	Flowers, young fruit and leaves of tomato plants (Hoddle, Mound & Paris 2012)	None	Yes	Yes (Premachandra et al. 2005a)
<i>Chaetanaphothrips leeuweni</i> (Karny)	7	West Indies, India, Indonesia, Guam, Australia (Mound & Tree 2012)	Yes, NT (Mound & Tree 2012). Declared Pest, prohibited by WA (Government of Western Australia 2016)	On leaves of <i>Musa</i> spp. (Mound & Tree 2012)	None	Yes (WA)	No
<i>Chaetanaphothrips orchidii</i> (Moulton) Anthurium thrips	4, 6, 7	Widespread in tropical and subtropical countries in North, Central and South America, Africa, Europe, Asia and Australasia and also in green house in temperate areas (CABI 2013a; Mound & Tree 2012)	Yes, Qld, NSW, SA (Mound & Tree 2012). Declared Pest, prohibited by WA (Government of Western Australia 2016)	Concealed within unopened leaves and flowers throughout most of its life cycle; polyphagous (CABI 2013a). Assessed as on pathway for Unshu mandarins from Japan (Biosecurity Australia 2009b)	Interception group D; from cut-flowers. Intercepted on <i>Anthurium</i> sp. from Hawaii to Japan (Oda & Hayase 1994)	Yes (WA)	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthospovirus vector
<i>Chaetanaphothrips signipennis</i> (Bagnall)	4, 6, 7	Australasia, Asia and North, Central and South America (CABI 2013a)	Yes, NT, QLD, NSW (Mound & Tree 2012). Declared Pest, prohibited by WA (Government of Western Australia 2016)	Foliage and fruits of host plants, including <i>Anthurium</i> and <i>Musa</i> (CABI 2013a). Assessed as on pathway for bananas from the Philippines (Biosecurity Australia 2008b)	Intercepted on cut-flowers of <i>Anthurium</i> sp. from Philippines to Japan (Masumoto et al. 2005)	Yes (WA)	No
<i>Chirothrips manicatus</i> (Haliday)	6	Widespread in temperate regions (Mound & Tree 2012)	Yes, NSW, TAS, SA, WA (Mound & Tree 2012)	Within individual florets of Poaceae and some Cyperaceae (Hoddle, Mound & Paris 2012; Mound & Tree 2012)	Interception group E; from kiwifruit and cut-flowers. Six interceptions from Europe from 1983-1999 and also being intercepted from Europe and Africa from 1994-1999 at US ports (Nickle 2003). Intercepted on asparagus from Australia and New Zealand, and <i>Ranunculus</i> sp. from New Zealand to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)	No	No
<i>Chirothrips molestus</i> Priesner	6	Widely spread in Eurasia (ThripsWiki 2017)	No record found (Mound & Tree 2012)	Flowers of wheat and barley (Minaei & Mound 2010)	None	Yes	No
<i>Danothrips trifasciatus</i> Sakimura	7	Hawaii, Florida and Caribbean, Sumatra, Australia (Mound & Tree 2012)	Yes, Qld (Mound & Tree 2012) Declared Pest, prohibited by WA (Government of Western Australia 2016)	Feeding on leaves and young fruit, host plants including <i>Anthurium</i> sp (Araceae), <i>Citrus paradisi</i> (Rutaceae), <i>Musa</i> sp (Musaceae) (Mound & Tree 2012)	None	Yes (WA)	No
<i>Dendrothrips minowai</i> Priesner Minowai thrips	6	Taiwan, Mainland China and Japan (Wang 2013)	No record found (Mound & Tree 2012)	On <i>Camellia sinensis</i> , <i>Cocculus trilobus</i> and <i>Diospyros kaki</i> (Chen	None	Yes	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthospovirus vector
				1979; ThripsWiki 2017; Wang 2013)			
<i>Dendrothrips saltator</i> Uzel	6	Europe (ThripsWiki 2017)	No record found (Mound & Tree 2012)	On <i>Peucedanum officinale</i> (ThripsWiki 2017)	Two interceptions from Europe at US ports from 1983-1999 (Nickle 2003)	Yes	No
<i>Dichromothrips corbetti</i> (Priesner)	6	Widespread around the world (Mound & Tree 2012)	Yes, NT, QLD (Mound & Tree 2012)	Leaves and flowers of <i>Vanda</i> and other Orchidaceae (Hoddle, Mound & Paris 2012; Mound & Tree 2012)	Interception group D; from cut orchid flowers. One interception possibly from Europe at US ports from 1983-1999 (Nickle 2003). Intercepted on <i>Aranda</i> sp., <i>Cattleya</i> sp., <i>Dendrobium</i> sp. and/or <i>Vanda</i> sp. from Singapore, Thailand and Hawaii to Japan (Hayase 1991)	No	No
<i>Dictyothrips betae</i> Uzel	2, 6	Palaeartic Europe (Riley et al. 2011b)	No record found (Mound & Tree 2012)	On sugar beet (Riley et al. 2011b); collected by beating many plants at roadsides, in public and private gardens and in waste places (Vierbergen 2013)	None	Yes	Yes (Ciuffo et al. 2010)
<i>Drepanothrips reuteri</i> Uzel	6	Widespread in Europe, also California, Illinois and Chile (Hoddle, Mound & Paris 2012)	No record found (Mound & Tree 2012)	Leaves of <i>Vitis vinifera</i> , <i>Quercus robur</i> , <i>Betula</i> and <i>Corylus</i> (Hoddle, Mound & Paris 2012). Assessed as on pathway for table grapes from Chile (Biosecurity Australia 2005b)	Four interceptions from Europe at US ports from 1983-1999 (Nickle 2003)	Yes	No
<i>Echinothrips americanus</i> Morgan Poinsettia thrips	3, 7	North and Central America, Europe and	Yes, Qld (Plant Health Australia 2001). Declared Pest, prohibited by WA	Mainly foliage, and flowers when population levels increase; polyphagous on numerous plants, including species traded	One interception from Europe at US ports from 1983-1999 (Nickle 2003). Intercepted on <i>Capsicum annum</i> from Netherland and <i>Echinodorus</i> sp.	Yes (WA)	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthospovirus vector
		Asia (CABI 2013a)	(Government of Western Australia 2016)	as nursery-stock (PaDIL 2010b) Identified as high priority pest for nursery and garden industry by Plant Health Australia	from Singapore to Japan (Masumoto, Oda & Hayase 2003; 2005)		
<i>Elixothrips brevisetis</i> (Bagnall) Banana rind thrips	6, 7	Seychelles and Rodrigues Islands, Taiwan, Philippines, Pacific Islands, Australia (Mau & Martin Kessing 1993; Mound & Tree 2012)	Yes, NT, QLD (Mound & Tree 2012). Declared Pest, prohibited by WA (Government of Western Australia 2016)	Leaves, flowers or stems of many hosts including banana and papaya (Mau & Martin Kessing 1993) Assessed as on pathway for bananas from the Philippines (Biosecurity Australia 2008b)	Interception group E; from cut orchid flowers.	Yes (WA)	No
<i>Ernothrips lobatus</i> (Bagnall)	6	Asia (Masumoto & Okajima 2002)	No record found (Mound & Tree 2012)	Flowers and leaves of many plants (Masumoto & Okajima 2002)	None	Yes	No
<i>Frankliniella australis</i> Morgan	6	Chile, Argentina and Brazil (Cavalleri & Mound 2012; ThripsWiki 2017)	No record found (Mound & Tree 2012)	Flowers of <i>Cestrum parqui</i> (Cavalleri & Mound 2012). Assessed as on pathway for table grapes from Chile (Biosecurity Australia 2005b)	Intercepted on <i>Rubus</i> sp. from Chile to Japan (Masumoto, Oda & Hayase 2003)	Yes	No
<i>Frankliniella bispinosa</i> (Morgan) Florida flower thrips	2, 3, 6	South eastern USA, Bermuda and the Bahamas (Hoddle, Mound & Paris 2012)	No record found (Mound & Tree 2012)	Flowers and young fruit of <i>Citrus</i> and other various plant species (Hoddle, Mound & Paris 2012) Identified as high priority pest for citrus	None	Yes	Yes (Avila et al. 2006)

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthospovirus vector
				industry by Plant Health Australia			
<i>Frankliniella cephalica</i> (Crawford)	2	Bermuda and Trinidad, Mexico and Colombia, Japan (Okinawa) and Taiwan (Hoddle, Mound & Paris 2012; Riley et al. 2011b)	No record found (Mound & Tree 2012)	Flowers of <i>Mangifera</i> , <i>Ligustrum</i> and <i>Bidens pilosa</i> (Hoddle, Mound & Paris 2012)	Intercepted on seedlings of <i>Chrysanthemum morifolium</i> from Costa Rica to Japan (Masumoto et al. 2005)	Yes	Yes (Ohnishi, Katsuzaki & Tsuda 2006)
<i>Frankliniella fusca</i> (Hinds) Tobacco thrips	2, 6	Central and North America (CABI 2013a; Hoddle, Mound & Paris 2012; Nakao et al. 2011), Japan	No record found (Mound & Tree 2012)	Flowers and leaves, polyphagous, hosts including <i>Capsicum</i> and <i>Solanum</i> (CABI 2013a)	Interception group E; from fig fruit. Seven interceptions from Europe at US ports from 1983-1999 (Nickle 2003)	Yes	Yes (Mound 2002)
<i>Frankliniella gemina</i> Bagnall	2, 6	South America (Riley et al. 2011b; ThripsWiki 2017)	No record found (Mound & Tree 2012)	Flower of various plants, including <i>Persea</i> , <i>Lycopersicon</i> and <i>Lactuca</i> (Riley et al. 2011b)	None	Yes	Yes (de Borbon, Gracia & De Santis 1999)
<i>Frankliniella intonsa</i> (Trybom)	1, 2, 3, 6	Europe, Asia and Pacific North America (CABI 2013a; Hoddle, Mound & Paris 2012)	No record found (Mound & Tree 2012)	Flowers, buds and fruit; polyphagous; hosts including <i>Asparagus</i> , <i>Capsicum</i> , <i>Fragaria</i> , <i>Gossypium</i> , <i>Prunus</i> and <i>Rosa</i> (CABI 2013a). Assessed as on pathways for <i>Citrus</i> fruit from Japan (Biosecurity Australia 2009b),	Interception group C; from cut-flowers, <i>Asparagus</i> spears, <i>Capsicum</i> fruit and <i>Actinidia</i> fruit. 94 interceptions from Europe and/or Mediterranean from 1983-1999 and 15 interceptions from Europe and Africa from 1994-1999 at US ports (Nickle 2003). Intercepted on many plants from Asia, North America and	Yes	Yes (Wijkamp et al. 1995)

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthotospovirus vector
				<i>Capsicum</i> fruit from South Korea (Biosecurity Australia 2009a), stone fruit from USA. (Biosecurity Australia 2010a), and <i>Phalaenopsis</i> orchids from Taiwan (Biosecurity Australia 2010b) Identified as high priority pest for tomato and cut-flower industries by Plant Health Australia	Italy to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)		
<i>Frankliniella minuta</i> (Moulton) Minute flower thrips	6	North, Central and South America and Hawaii (Hoddle, Mound & Paris 2012)	No record found (Mound & Tree 2012)	Flowers of usually Asteraceae (Hoddle, Mound & Paris 2012)	Intercepted on <i>Craspedia</i> sp. and <i>Limonium</i> sp. from USA to Japan (Hayase 1991)	Yes	No
<i>Frankliniella occidentalis</i> Pergande Western flower thrips	1, 2, 4, 6, 7	Cosmopolitan (CABI 2013a; Riley et al. 2011b)	Yes, all states except the NT (Mound & Tree 2012). Host plants regulated by NT (DPIF 2013). Unwanted quarantine pest for Tas, which is not officially regulated	Flowers, buds, leaves and fruit of numerous host plants (CABI 2013a). Assessed as on pathways for truss tomatoes from the Netherland (DAFF 2003); table grapes from Chile (Biosecurity Australia 2005b), from China (Biosecurity Australia 2011a) and from South Korea (Biosecurity Australia	Interception group A; from numerous pathways including cut-flowers, garlic bulbs, <i>Asparagus</i> spears and snow peas. 448 interceptions from Europe, Mediterranean and/or Africa from 1983-1999 and 59 interceptions from Europe and Africa from 1994-1999 at US ports (Nickle 2003). Intercepted on numerous plants mainly from USA but also from Europe, Asia and South America to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)	Yes (NT)	Yes (Wijkamp et al. 1995)

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthotospovirus vector
			(DPIPWE Tasmania 2015) Vic prohibiting the import of any nursery plants, cut-flowers, leafy vegetables, potato tubers, <i>Rubus</i> spp. or strawberry plants into the Toolangi Plant Protection District unless the import conditions of entry are satisfied (DPI Victoria 2013)	2011c); stone fruit from NZ (Biosecurity Australia 2006a) and from USA (Biosecurity Australia 2010a); capsicum from South Korea (Biosecurity Australia 2009a); and citrus from Italy (Biosecurity Australia 2005a) and from Japan (Biosecurity Australia 2009b)			
<i>Frankliniella schultzei</i> (Trybom) Cotton thrips	1, 2, 4, 6	Pantropical (CABI 2013a; Mound & Tree 2012)	Yes, widespread (Mound & Tree 2012)	Flowers, leaves and fruit, polyphagous (CABI 2013b)	Interception group B; from cut-flowers, <i>Asparagus</i> spears and sugar snap peas. 55 interceptions from Europe, Mediterranean and/or Africa from 1983-1999 and 7 interceptions from Europe and Africa from 1994-1999 at US ports (Nickle 2003). Intercepted on many plants from Asia, Africa, Australia and Hawaii to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)	No	Yes (Nagata et al. 2004; Wijkamp et al. 1995)
<i>Frankliniella tritici</i> (Fitch) Eastern flower thrips	3, 6	North America (Hoddle, Mound & Paris 2012)	No record found (Mound & Tree 2012)	Flowers and possibly leaves of a wide range of flowering plants (Hoddle, Mound & Paris 2012) Assessed as on pathway for stone fruit from the	Interception group E; from <i>Asparagus</i> spears. Three interceptions from Europe, Mediterranean and/or Africa at US ports from 1983-1999 (Nickle 2003). Intercepted on <i>Vaccinium</i> sp. from USA to Japan (Masumoto, Oda & Hayase 2003)	Yes	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthospovirus vector
				USA (Biosecurity Australia 2010a). Identified as high priority pest for cut-flower industry by Plant Health Australia			
<i>Frankliniella williamsi</i> Hood Corn thrips	1, 7	Widespread in tropical and subtropical countries (Hoddle, Mound & Paris 2012)	Yes, QLD, VIC, TAS (Mound & Tree 2012). Declared Pest, prohibited by WA (Government of Western Australia 2016)	Leaves and leaf axils of <i>Zea mays</i> and probably other Poaceae including <i>Saccharum</i> (Mound & Tree 2012)	Interception group C; from <i>Asparagus</i> spears, <i>Citrus</i> fruit and cut-flowers. Intercepted on <i>Asparagus officinalis</i> from Mexico, <i>Coriandrum sativa</i> from Thailand, and <i>Zea mays</i> from Australia and USA to Japan (Masumoto, Oda & Hayase 2003)	Yes (WA)	No, but it is a vector of <i>Maize chlorotic mottle virus</i> (considered further in Appendix F)
<i>Frankliniella zucchini</i> Nakahara & Monterio	2	South America (Riley et al. 2011b)	No record found (Mound & Tree 2012)	Flowers and foliage of Cucurbit crops (Riley et al. 2011b)	None	Yes	Yes (Nakahara & Monteiro 1999)
<i>Fulmekiola serrata</i> (Kobus) Sugarcane thrips	4	Asia, Africa, and Central and northern South America (Sugar Research Australia 2013; ThripsWiki 2017)	No record found (Mound & Tree 2012)	Leaves of mainly sugarcane (Sugar Research Australia 2013)	None	Yes	No
<i>Heliothrips haemorrhoidalis</i> (Bouche) Black tea thrips	1, 4	Widespread in the tropics and subtropics; also in greenhouses of temperate areas (CABI 2013a)	Yes, all states (Mound & Tree 2012)	Leaves and fruit, highly polyphagous (CABI 2013a)	Interception group C; from a range of fruit, vegetable and cut-flower pathways. Five interceptions from Europe, Mediterranean and/or Africa at US ports from 1983-1999 (Nickle 2003). Intercepted on <i>Anigozanthos</i> sp. from USA, <i>Erica</i> sp. from Australia, <i>Citrus aurantiifolia</i> from Mexico, <i>Viburnum</i> sp. from Italy	No	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthospovirus vector
					and <i>Vaccinium</i> sp. and kiwifruit from New Zealand to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003; Masumoto et al. 2005)		
<i>Heliothrips sylvanus</i> Faure	6	South Africa (ThripsWiki 2017)	No record found (Mound & Tree 2012)	Leaves of grapevines (Schwartz 1989)	None	Yes	No
<i>Hercinothrips femoralis</i> Reuter Banded greenhouse thrips	4, 6	Pantropical; also in greenhouses in temperate areas (Mound & Tree 2012)	Yes, WA (CABI 2013a; Mound 2012a)	Leaves; polyphagous (Hoddle, Mound & Paris 2012)	Interception group E; from stone fruit	No	No
<i>Holopothrips ananasi</i> Da Costa Lima	6	South America (ThripsWiki 2017)	No record found (Mound & Tree 2012)	Potentially on flowers, fruit and leaves of pineapples (Plant Health Australia 2008)	None	Yes	No
<i>Kenyattathrips katarinae</i> Mound	1	Kenya (ThripsWiki 2017)	No record found (Mound 2009; Mound & Tree 2012)	Leaves of <i>Catha edulis</i> (khat) (ThripsWiki 2017)	Interception group C; from <i>Catha</i> leaves	Yes	No
<i>Limothrips cerealium</i> (Haliday) Corn thrips	4, 6	Worldwide in temperate areas (Mound & Tree 2012)	Yes, Tas, SA, ACT, NSW and WA (Mound & Tree 2012)	Leaves of grasses and cereal crops (Mound & Tree 2012)	Interception group D; from cut-flowers, <i>Asparagus</i> spears, kiwifruit and fresh berries. Eighteen interceptions from Europe, Mediterranean and/or Africa from 1983-1999 and five interceptions from Europe and Africa from 1994-1999 at US ports (Nickle 2003). Intercepted on a number of plants from Europe, USA, Australia and New Zealand, South Africa and Chile to	No	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthospovirus vector
					Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)		
<i>Limothrips denticornis</i> (Haliday) Barley thrips	4, 7	Europe, North America, and Australia (Mound & Tree 2012)	Yes, SA (Mound & Tree 2012). Declared Pest, prohibited by WA (Government of Western Australia 2016)	Leaves of cereal crops and <i>Brassica</i> (CABI 2013a)	Nine interceptions from Europe from 1983-1999 and two interceptions from Europe and Africa from 1994-1999 at US ports (Nickle 2003). Intercepted on <i>Abies</i> sp. from Denmark to Japan (Hayase 1991)	Yes (WA)	No
<i>Megalurothrips distalis</i> (Karny)	6, 7	Asia and Australia (CABI 2013a; ThripsWiki 2017)	No, record for Australia such as in (CABI 2013a) is likely based on misidentification of a SA specimen (pers com L Mound 2015)	Flowers and occasionally leaves of many host plants (CABI 2013a)	Intercepted on <i>Cymbidium</i> sp. from New Zealand to Japan (Hayase 1991). Intercepted on <i>Capsicum annum</i> from Korea to Japan (Masumoto, Oda & Hayase 2003)	Yes	No
<i>Megalurothrips sjostedti</i> (Trybom) Bean flower thrips	1, 4	Sub-Saharan Africa and Saudi Arabia (CABI 2013a)	No record found (Mound & Tree 2012)	Flowers of legumes, alternative hosts in Mimosaceae and Caesalpiniaceae (CABI 2013a)	Interception group C; from cut-flowers, Alliaceae bulbs and snow peas. Five interceptions from Africa at US ports from 1983-1999 (Nickle 2003). Intercepted on <i>Anigozanthos</i> sp. from Zimbabwe to Japan (Masumoto, Oda & Hayase 2003)	Yes	No
<i>Megalurothrips typicus</i> Bagnall [syn: <i>Taeniothrips varicornis</i> Moulton]	6	South-east Asia and Australia (Mound & Tree 2012)	Yes, WA, NT (Mound & Tree 2012)	Flowers of Fabaceae such as crops <i>Glycine</i> (Mound & Tree 2012)	None	No	No
<i>Megalurothrips usitatus</i> (Bagnall) Bean flower thrips	4, 6	Australasia and Asia (CABI 2013a)	Yes, WA, NT, QLD, NSW (Mound & Tree 2012)	Flowers of various Fabaceae (Mound & Tree 2012)	Intercepted on <i>Limonium</i> sp., <i>Oncidium</i> sp., <i>Phalaenopsis</i> sp. and <i>Pisum sativum</i> from Taiwan to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)	No	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthospovirus vector
<i>Microcephalothrips abdominalis</i> (Crawford) Sunflower thrips	6	Tropical and subtropical around the world (Mound & Tree 2012)	Yes, NT, QLD, VIC, TAS, WA (Government of Western Australia 2016; Mound & Tree 2012)	Flower of various Asteraceae (Mound & Tree 2012)	Interception group D; from cut-flowers and persimmon fruit. Five interceptions from Africa at US ports from 1983-1999 (Nickle 2003). Intercepted on <i>Chrysanthemum</i> sp. from Taiwan, <i>Dianthus</i> sp. from Kenya, <i>Gomphrena</i> sp. from Hawaii and <i>Oncidium</i> sp. from Thailand to Japan (Hayase 1991)	No	No
<i>Neohydatothrips gracilicornis</i> (Williams)	6	England and Japan (ThripsWiki 2017)	No record found (Mound & Tree 2012)	On clover and meadow grasses (ThripsWiki 2017)	Interception group E; on kiwifruit. Intercepted on leaves of <i>Viburnum</i> sp. from Italy to Japan (Masumoto et al. 2005)	Yes	No
<i>Neohydatothrips samayunkur</i> Kudo	1	North and central Americas, Africa, Asia and Australia (Mound & Tree 2012)	Yes, Eastern Australia (Mound & Tree 2012)	Leaves and in flowers of Tagetes species (Asteraceae) (Mound & Tree 2012)	Interception group C; from cut-flowers. Thirteen interceptions from Mediterranean and/or Africa from 1983-1999 and two interceptions from Europe and Africa from 1994-1999 at US ports (Nickle 2003)	No	No
<i>Neohydatothrips variabilis</i> (Beach) Soybean thrips	2	North America (Hoddle, Mound & Paris 2012)	No record found (Mound & Tree 2012)	Leaves of legumes, including soybeans (Mound & Tree 2012), tomato production, including occasionally on flowers (Nault et al. 2003), reported associated with peach orchards in Georgia, USA (Yonce et al. 1990).	None	Yes	No
<i>Pezothrips kellyanus</i> Bagnall	6	Europe, New Caledonia and Australia	Yes, ACT, NSW, Qld, SA and WA (Mound & Tree 2012)	Scented flowers and immature fruit of various unrelated plants with scented and	None	No	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthospovirus vector
		(Mound & Tree 2012)		white flowers, hosts including citrus (Mound & Tree 2012)			
<i>Pseudodendrothrips mori</i> (Niwa) Mulberry thrips	4, 6	Western Europe, North and South America, Asia and Australia (Hoddle, Mound & Paris 2012)	Yes (Mound & Tree 2012)	Leaves of <i>Morus</i> and <i>Ficus</i> spp. (Moraceae) (Hoddle, Mound & Paris 2012; Mound & Tree 2012). Assessed as on pathway for persimmons from South Korea (DAFF 2004c)	Interception group E; from fresh fig fruit	No	No
<i>Retithrips syriacus</i> (Mayet) Black vine thrips	6	Africa, India, Brazil and Florida (Hoddle, Mound & Paris 2012)	No record found (Mound & Tree 2012)	Leaves, usually older leaves of many host plants, including <i>Rosa</i> , <i>Vitis</i> and <i>Eucalyptus</i> (Hoddle, Mound & Paris 2012). Assessed as on pathway for persimmons from Japan, South Korea and Israel (DAFF 2004c)	Two interceptions from Mediterranean and/or Africa at US ports from 1983-1999 (Nickle 2003)	Yes	No
<i>Rhipiphorotherips cruentatus</i> Hood Grapevine thrips	4, 6	India, Sri Lanka, Pakistan and Afghanistan (Hoddle, Mound & Paris 2012)	No record found (Mound & Tree 2012)	Leaves, usually older leaves of Grapes, roses, <i>Anacardium occidentale</i> , <i>Juglans</i> , <i>Syzygium</i> , <i>Terminalia</i> , <i>Ricinus</i> (Hoddle, Mound & Paris 2012). Assessed as on pathways for mangoes from Taiwan (Biosecurity Australia 2006b), from India (Biosecurity Australia 2008a) and from Pakistan (Biosecurity	None	Yes	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthospovirus vector
				Australia 2011b) and table grapes from China (Biosecurity Australia 2011a)			
<i>Rubiothrips vitis</i> (Priesner) European grape thrips	6	Israel and Romania (ThripsWiki 2017)	No record found (Mound & Tree 2012)	Shoots, buds, leaves and fruit of grape (Vasiliu-Oromulu, Barbuceanu & Ion 2009)	None	Yes	No
<i>Scirtothrips albomaculatus</i> Bianchi	7	New Caledonia, Australia (Mound & Tree 2012)	Yes, NSW, SA and Qld (Mound & Tree 2012). Declared pest, prohibited by WA (Government of Western Australia 2016)	Feeding and breeding on leaves of <i>Dodonaea viscosa</i> (Sapindaceae), adults collected from many plants, including <i>Citrus</i> , <i>Rosa</i> and <i>Acacia</i> (Mound & Tree 2012)	None	Yes (WA)	No
<i>Scirtothrips aurantii</i> Faure South African citrus thrips	3, 7	Africa, Australia (Mound & Tree 2012)	Yes, Qld, NSW (Mound & Tree 2012). Declared pest, prohibited by WA (Government of Western Australia 2016).	Young leaves and fruits, highly polyphagous, including <i>Bryophyllum delagoense</i> in Australia (Mound & Tree 2012) Identified as high priority pest for citrus industry by Plant Health Australia as the species in Australia has not switched to citrus in the field to date. As of 2015, this species is not known to be a pest of citrus in Australia (Garms, Mound & Schellhorn 2013; Rafter,	Interception group D; from cut-flowers and snow peas. Five interceptions from Africa at US ports from 1983-1999 (Nickle 2003)	Yes (WA)	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthotospovirus vector
				Hereward & Walter 2013)			
<i>Scirtothrips citri</i> (Moulton) California citrus thrips	4, 6	North and Central America (Hoddle, Mound & Paris 2012)	No record found (Mound & Tree 2012)	Young tissues of leaves and fruits; pupating on trees or in soil, primarily on <i>Citrus</i> , and also <i>Rhusa</i> (Anacardiaceae) (Hoddle, Mound & Paris 2012)	None	Yes	No
<i>Scirtothrips dorsalis</i> Hood Chilli thrips	1, 2, 4, 6	Widespread across Asia, between Pakistan, Japan and Australia; introduced to Israel and the Caribbean area (Hoddle, Mound & Paris 2012; Riley et al. 2011b)	Yes, widespread across northern Australia (Mound & Tree 2012)	Young leaves and sometimes flowers, highly polyphagous (Hoddle, Mound & Paris 2012)	Interception group B; from numerous pathways, including cut-flowers, <i>Actinidia</i> , <i>Citrus</i> fruit, <i>Asparagus</i> spears. Three interceptions from Africa at US ports from 1983-1999 (Nickle 2003). Intercepted on <i>Acacia jarnesian</i> , <i>Asparagus</i> and <i>Oncidium</i> from Philippines and/or Thailand to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)	No	Yes (Chen & Chiu 1996; Chu et al. 2001)
<i>Scirtothrips mangiferae</i> Priesner	6	North Africa and Middle East (Mound & Stiller 2011)	No record found (Mound & Tree 2012)	Young leaves of mango (Mound & Stiller 2011)	None	Yes	No
<i>Scirtothrips oligochaetus</i> Karny Mangosteen thrips	6	India and central Africa, Barbados (Mound & Stiller 2011)	No record found (Mound & Tree 2012)	Flowers and shoots of pomegranate, cotton, <i>Pisum</i> , <i>Prosopis</i> , <i>Gossypium</i> , <i>Punica</i> , <i>Solanum</i> and <i>Arachis</i> (Mound & Palmer 1981); foliage and immature fruit of	None	Yes	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthospovirus vector
				mangosteen (DAFF 2004b)			
<i>Scirtothrips perseae</i> Nakahara Avocado thrips	3, 4	Southern California, Mexico, Guatemala (Hoddle, Mound & Paris 2012; Mound & Palmer 1981; PaDIL 2010a)	No record found (Mound & Tree 2012)	Leaves and fruit of <i>Persea americana</i> , adults collected on eleven other plants in California (PaDIL 2010a) Identified as high priority pest for avocado industry by Plant Health Australia	None	Yes	No
<i>Selenothrips rubrocinctus</i> (Giard) Red banded thrips	1, 4, 6	Pantropical and subtropical (Denmark & Wolfenbarger 1999; Mound & Tree 2012)	Yes, Qld, NT (Mound 2012a)	Leaves and pods; highly polyphagous (CABI 2013a)	Interception group C; from mangosteen fruit. One interception from Europe, Mediterranean or Africa at US ports from 1983-1999 (Nickle 2003). Intercepted on <i>Garcinia mangostana</i> from Colombia, <i>Gomphrena</i> sp. from Hawaii and <i>Litchi chinensis</i> from Mexico to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)	No	No
<i>Sigmothrips aotearoana</i> Ward	6	New Zealand (ThripsWiki 2017)	No record found (Mound & Tree 2012)	Leaf litter of forests (Mound & Walker 1982)	None	Yes	No
<i>Stenchaetothrips biformis</i> (Bagnall) Oriental rice thrips	4	Europe, South America, Asia and Australia (Mound & Tree 2012)	Yes, Qld, NSW (Mound & Tree 2012)	Young leaves, particularly seedling rice plants, but probably other Poaceae including sugarcane (Mound & Tree 2012)	Interception group E; from fresh baby corn. Intercepted on <i>Asparagus officinalis</i> from Philippines and <i>Dendrobium</i> sp. from Thailand to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)	No	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthospovirus vector
<i>Stenchaetothrips fuscus</i> (Moulton)	6	China and Philippines (Mirab-balou et al. 2011)	No record found (Mound & Tree 2012)	On longan, not assessed as on fruit (DAFF 2004a)	None	Yes	No
<i>Taeniothrips inconsequens</i> (Uzel) Pear thrips	4, 6	Widespread across the Northern Hemisphere, from Sweden to Japan and Korea; and presumably introduced to North America (Hoddle, Mound & Paris 2012)	No record found (Mound & Tree 2012)	Leaves and flowers, polyphagous, economic hosts including <i>Acer</i> , <i>Malus</i> , <i>Prunus</i> and <i>Pyrus</i> (Agnello 1999; Hoddle, Mound & Paris 2012). Assessed as on pathway for stone fruit from USA (Biosecurity Australia 2010a)	Three interceptions from Europe from 1983-1999 and also being intercepted from Europe and Africa from 1994-1999 at US ports (Nickle 2003).	Yes	No
<i>Tenothrips frici</i> (Uzel) Dandelion thrips	6	Southern Europe, South Africa, North America, Western USA, Pakistan, Oceania (Mound & Tree 2012)	Yes, all states except the NT (Mound & Tree 2012)	Flower of Asteraceae, particularly weedy species (Hoddle, Mound & Paris 2012; Mound & Tree 2012), and <i>Luffa cylindrical</i> (Cucurbitaceae) (Mirab-balou & Tong 2013)	Interception group D; from kiwifruit, blueberries, <i>Citrus</i> fruit, cut <i>Lavendula</i> flowers, and <i>Asparagus</i> spears Four interceptions from Mediterranean at US ports from 1983-1999 (Nickle 2003)	No	No
<i>Thrips alni</i> Uzel	6	Europe and Japan (Masumoto & Okajima 2013; ThripsWiki 2017)	No record found (Mound & Tree 2012)	Leaves and flowers of Betulaceae, Fabaceae, Polygonaceae and Ranunculaceae (Masumoto & Okajima 2013)	None	Yes	No
<i>Thrips angusticeps</i> Uzel	4	South and southwest Asia, Africa and	No record found (Mound & Tree 2012)	Seedling and young plants, leaves, flowers, stems and fruit; highly	Interception group E; from cut <i>Dianthus</i> flowers. 24 interceptions from Europe, Mediterranean and/or	Yes	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthospovirus vector
Field thrips		Europe (CABI 2013a)		polyphagous (CABI 2013a)	Africa at US ports from 1983-1999 (Nickle 2003). Intercepted on a number of plants from Italy and France to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)		
<i>Thrips australis</i> (Bagnall) Gum tree thrips	6	Widespread around the world (Mound & Tree 2012)	Yes, all states (Mound & Masumoto 2005; Mound & Tree 2012)	Flowers of <i>Eucalyptus</i> and <i>Melaleuca</i> (Mound & Tree 2012)	Interception group D; from <i>Citrus</i> fruit, table grapes, broccoli and <i>Asparagus</i> spears. Ten interceptions from Europe, Mediterranean and/or Africa from 1983-1999 and two interceptions from Europe and Africa from 1994-1999 at US ports (Nickle 2003). Intercepted on a number of plants from USA, Australia, New Zealand, Italy and South Africa to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)	No	No
<i>Thrips coloratus</i> Schmutz	6	Widespread from Pakistan to Japan, Australia (Mound & Tree 2012)	Yes, Qld, NSW (Mound & Tree 2012)	Flower of many plants including <i>Citrus</i> and <i>Ficus</i> (Mound & Tree 2012)	Interception group D; from cut-flowers. Intercepted on <i>Pisum sativum</i> from Taiwan to Japan (Oda & Hayase 1994)	No	No
<i>Thrips flavus</i> Schrank European flower thrips	1, 4, 6	Widespread across Eurasia from Britain to China, Japan and Taiwan (Hoddle, Mound & Paris 2012)	No record found (Mound & Tree 2012)	Flowers and leaves; highly polyphagous (Hoddle, Mound & Paris 2012)	Interception group C; from cut-flowers and <i>Asparagus</i> spears. 28 interceptions from Europe from 1983-1999 and five interceptions from Europe and Africa from 1994-1999 at US ports (Nickle 2003). Intercepted on <i>Pisum sativum</i> from Taiwan to Japan (Oda & Hayase 1994)	Yes	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthospovirus vector
<i>Thrips florum</i> Schmutz	6	Widespread across Asia and Pacific, Florida, and the Caribbean Islands (Mound & Tree 2012)	Yes, NT, Qld (Mound & Tree 2012)	Flower, highly polyphagous (Mound & Tree 2012)	Interception group E; from various cut-flowers. Intercepted on <i>Hedychium coronarium</i> from Hawaii to Japan (Hayase 1991)	No	No
<i>Thrips fulvipes</i> Bagnall	6	England (ThripsWiki 2017) and Romania (Vasiliu-Oromulu, Barbuceanu & Ion 2009)	No record found (Mound & Tree 2012)	On buds and berries of grapevine (Vasiliu-Oromulu, Barbuceanu & Ion 2009) and <i>Mercurialis perennis</i> (Euphorbiaceae) (DBIF 2014),	Six interceptions from Europe at US ports from 1983-1999 (Nickle 2003)	Yes	No
<i>Thrips fuscipennis</i> Haliday Rose thrips	1	Europe and North America (ThripsWiki 2017)	No record found (Mound & Tree 2012)	Leaves of a wide range of flower plants, particularly Rosaceae (Alford 2007)	Interception group C; all from kiwifruit. 200 interceptions from Europe from 1983-1999 and 41 interceptions from Europe and Africa from 1994-1999 at US ports (Nickle 2003). Intercepted on <i>Eryngium</i> sp. from Netherlands, <i>Cynara scolymus</i> from France] and <i>Rubus</i> sp. from USA to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)	Yes	No
<i>Thrips hawaiiensis</i> (Morgan)	1, 4, 6	Widespread across Asia and the Pacific Islands, Southern USA, and Jamaica	Yes, NT, Qld, NSW (Mound & Tree 2012)	Flowers, highly polyphagous (Mound & Tree 2012)	Interception group C; from cut-flowers, <i>Asparagus</i> spears and baby corn. Intercepted on many plants from mainland China, Taiwan, Thailand, USA, Australia, New Zealand to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)	No	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthospovirus vector
		(Mound & Tree 2012)					
<i>Thrips imaginis</i> Bagnall Plague thrips	1, 4, 6	Oceania (Mound & Tree 2012)	Yes, all states (Mound & Houston 1987)	Flowers, polyphagous (Mound & Tree 2012)	Interception group C; from cut-flowers, <i>Asparagus</i> spears, stone tropical and kiwi fruits, and strawberries. Intercepted on many plants from Australia, New Zealand and Thailand to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)	No	No
<i>Thrips major</i> Uzel Rubus thrips	1	Europe (ThripsWiki 2017)	No record found (Mound & Tree 2012)	Flowers of many plants, especially Rosaceae (Alford 2007)	Interception group C; mainly from kiwifruit and sometimes from cut-flowers. 178 interceptions from Europe, Mediterranean and/or Africa from 1983-1999 and 32 interceptions from Europe and Africa from 1994-1999 at US ports (Nickle 2003). Intercepted on <i>Agapanthus</i> sp. and <i>Anemone</i> sp. from France, <i>Chamelaucium</i> sp. from Israel, <i>Citrus paradise</i> from USA and <i>Acacia</i> sp. from Italy to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)	Yes	No
<i>Thrips obscuratus</i> (Crawford) New Zealand flower thrips	1, 6	New Zealand (ThripsWiki 2017)	No record found (Mound & Tree 2012)	Flowers, highly polyphagous (Hoddle, Mound & Paris 2012). Assessed as on pathway for fresh cherry and stone fruit from New Zealand to Western Australia (AFFA 2003; Biosecurity Australia 2006a)	Interception group C; from cut-flowers, fruit (including stone fruits, kiwifruit and strawberries) and vegetables (including capsicum and broccoli). Intercepted on many plants from New Zealand to Japan (Hayase 1991)	Yes	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthotospovirus vector
<i>Thrips palmi</i> Karny Melon thrips	1, 2, 4, 6, 7	Widespread in tropical countries in Asia, northern Australia, and, Caribbean and southern Florida and Africa (Hoddle, Mound & Paris 2012; Mound & Tree 2012; Riley et al. 2011b)	Yes, NT, Qld (Mound & Tree 2012). Host plants regulated by NT (DPIF 2013) and SA (Government of South Australia 2015). Unwanted quarantine pest for Tas, which is not officially regulated (DPIPWE Tasmania 2015). Listed as an exotic pest under Victoria's Plant Biosecurity Act 2010 Declared pest by WA (Government of Western Australia 2016)	Flowers and leaves, polyphagous, crops including the Cucurbitaceae and Solanaceae (Mound & Tree 2012). Assessed as on pathway for capsicum from South Korea (Biosecurity Australia 2009a) and Unshu mandarin from Japan (Biosecurity Australia 2009b)	Interception group B; from cut-flowers, <i>Asparagus</i> spears, baby corn and snow peas. Eleven interceptions from Africa at US ports from 1983-1999 (Nickle 2003). Intercepted on many plants from other Asian countries, New Zealand and Hawaii to Japan (Hayase 1991)	Yes (NT, SA, Vic, WA)	Yes (Jain et al. 1998)
<i>Thrips parvispinus</i> (Karny)	1	Widespread in South East Asia, Australia and Greece (Mound & Tree 2012)	Yes, widespread across northern and western Australia (Government of Western Australia 2016; Mound & Tree 2012)	Flowers and leaves, polyphagous (Mound & Tree 2012)	Interception group C; from cut-flowers and citrus fruit. Intercepted on <i>Heliconia</i> sp. from Mauritius to Japan (Masumoto, Oda & Hayase 2003)	No	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthotospovirus vector
<i>Thrips physapus</i> Linnaeus	6	Europe (ThripsWiki 2017)	No record found (Mound 2005a)	Leaves, polyphagous, hosts including <i>Leontodon hispidus</i> (Vasiliiu-Oromulu 2000)	One interception from Europe from 1983-1999 and also being intercepted from Europe and Africa from 1994-1999 at US ports (Nickle 2003)	Yes	No
<i>Thrips pillichii</i> Priesner	6	Europe (ThripsWiki 2017)	No record found (Mound 2005a)	On a number of species of Compositae (DBIF 2014)	One interception from Europe at US ports from 1983-1999 (Nickle 2003)	Yes	No
<i>Thrips setosus</i> Moulton Japanese flower thrips	2, 6	Japan and Korea (Mound 2005a; ThripsWiki 2017), Netherlands (EPPO 2015)	No record found (Mound 2005a)	Flowers and leaves of many plants including <i>Capsicum</i> and <i>Cucumis</i> (Mound 2005a)	Interception group E; from cut-flowers and onion bulbs	Yes	Yes (Fujisawa, Tanaka & Ishii 1988; Persley, Thomas & Sharman 2006)
<i>Thrips simplex</i> (Morison) Gladiolus thrips	1, 6	Widespread around the world (Mound & Tree 2012)	Yes, local, wherever <i>Gladiolus</i> is grown (Mound & Tree 2012)	Flowers and leaves of mainly <i>Gladiolus</i> (Mound & Tree 2012)	Interception group C; from cut-flowers, snow peas and tropical fruits. 26 interceptions from Europe, Mediterranean and/or Africa from 1983-1999 and three interceptions from Europe and Africa from 1994-1999 at US ports (Nickle 2003). Intercepted on many plants from mainland China, Taiwan, Portugal, USA, Colombia, Ecuador, South Africa, Australia and New Zealand to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003).	No	No
<i>Thrips subnudula</i> (Karny)	6	India, Pakistan, Nigeria and Australia (Mound & Masumoto)	Yes, Qld (a single female was recorded near Brisbane) (Mound & Masumoto 2005) and WA	Flowers, possibly polyphagous, including <i>Parnthenium hysterophorus</i> (Mound & Masumoto 2005; Mound & Tree 2012)	None	No	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthospovirus vector
		2005; Mound & Tree 2012)	(Poole 2010) (citing an internal report)				
<i>Thrips tabaci</i> Lindemann Onion thrips, potato thrips	1, 2, 3, 4, 6	Worldwide, but rare in wet tropics (Hoddle, Mound & Paris 2012; Mound & Masumoto 2005; Mound & Tree 2012)	Yes, widespread across Australia (Mound & Tree 2012). Unwanted quarantine pest for Tas, which is not officially regulated (DPIPWE Tasmania 2015)	Flowers and leaves, polyphagous (CABI 2013a; Mound & Tree 2012) Exotic strains/biotypes of <i>Thrips tabaci</i> identified as high priority pest for onion industry by Plant Health Australia	Interception group A; on cut-flowers and foliage, <i>Asparagus</i> spears, fruit, vegetables and Alliaceae bulbs. 474 interceptions from Europe, Mediterranean and/or Africa from 1983-1999 and 81 interceptions from Europe and Africa from 1994-1999 at US ports (Nickle 2003). Intercepted on numerous plants from other Asian countries, Europe, USA, Colombia, South Africa, Australia and New Zealand to Japan (Hayase 1991)	No	Yes (Hassani-Mehraban et al. 2005)
<i>Thrips urticae</i> Fabricius	6	Japan and Europe (Masumoto & Okajima 2013)	No record found (Mound & Tree 2012)	Leaves and flowers of many host plants (Masumoto & Okajima 2013)	Three interceptions from Europe at US ports from 1983-1999 (Nickle 2003)	Yes	No
<i>Thrips validus</i> Uzel	6	Europe and USA Europe (ThripsWiki 2017)	No record found (Mound & Tree 2012)	Flowers of many herbaceous species, especially in Asteraceae (Barbuceanu & Vasiliu-Oromulu 2012)	None	Yes	No
PHLAEOTHIRIPIDAE							
<i>Gynaikothrips ficorum</i> (Marchal) Cuban laurel thrips	4, 5	Pantropical (Mound 2012a)	Yes, WA, NT, Qld, NSW (Mound 2012a)	Within rolled-leaf galls, apparently specific to <i>Ficus microcarpa</i> (Moraceae) (Hoddle, Mound & Paris 2012)	Interception group D; from cut-flowers and foliage, avocado fruit and a variety of vegetables. One interception from Africa at US ports from 1983-1999 (Nickle 2003). Intercepted on <i>Chrysanthemum</i> sp.	No	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthospovirus vector
					from Taiwan to Japan (Oda & Hayase 1994)		
<i>Haplothrips acanthoscelis</i> (Karny)	6	Europe (Karadjova & Krumov 2015; ThripsWiki 2017; Trdan 2002)	No record found (Mound 2012a)	On grass (ThripsWiki 2017), <i>Diantus barbatus</i> (Trdan 2002), <i>Lotus corniculatus</i> , <i>Onobrychis sativa</i> and <i>Zea mays</i> (Karadjova & Krumov 2015)	None	Yes	No
<i>Haplothrips aculeatus</i> (Fabricius) Grass thrips	4, 5, 6	Europe and Asia (CABI 2013a)	No record found (Mound & Tree 2012)	Leaves, polyphagous; major hosts include sugarcane, cereal crops and textile crops (CABI 2013a)	Interception group D; from kiwifruit, cut-flowers and <i>Asparagus</i> spears. Four interceptions from Europe and/or Africa at US ports from 1983-1999 (Nickle 2003). Intercepted on <i>Brassica</i> spp. and <i>Amaranthus</i> sp. from China and <i>Cynara scolymus</i> from Italy to Japan (Masumoto, Oda & Hayase 2003; Masumoto et al. 2005)	Yes	No
<i>Haplothrips chinensis</i> Priesner	3, 5, 6	North Asia (Mirab-balou et al. 2011; Wang & Hsu 1996)	No record found (Mound & Tree 2012)	Flowers of cereal grains, vegetable crops and <i>Oryza</i> (Wang & Hsu 1996; Woo 1988) Identified as high priority pest for cut-flower industry by Plant Health Australia	Intercepted on <i>Chrysanthemum</i> sp. from Taiwan to Japan (Hayase 1991)	Yes	No
<i>Haplothrips ganglbaueri</i> Schmutz	1, 5, 6	Asia, the Middle East and Egypt (Mirab-balou et al. 2011)	No record found (Mound & Tree 2012)	Florescence of cereal crops including <i>Oryza</i> , <i>Sorghum</i> and <i>Triticum</i> (Ananthkrishnan & Thangavelu 1976)	Interception group C; from cut-flowers, baby corn and <i>Asparagus</i> spears. Intercepted on <i>Asparagus officinalis</i> from Thailand to Japan (Oda & Hayase 1994)	Yes	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthotospovirus vector
<i>Haplothrips gowdeyi</i> (Franklin)	1, 6	Widespread in tropical and subtropical countries (Hoddle, Mound & Paris 2012)	Yes, WA, NT, Qld, NSW (Mound 2012a)	Flowers of a wide range of plants, possibly also a facultative predatory (Hoddle, Mound & Paris 2012)	Interception group B; from cut-flowers, <i>Asparagus</i> spears and a number of tropical fruit species. 65 interceptions from Europe, Mediterranean and/or Africa from 1983-1999 and 11 interceptions from Europe and Africa from 1994-1999 at US ports (Nickle 2003). Intercepted on <i>Anigozanthos</i> sp. from Zimbabwe, <i>Brodiaea</i> sp. <i>Leucospermum</i> sp. from South Africa and <i>Rosa</i> sp. from India to Japan (Masumoto, Oda & Hayase 2003; Oda & Hayase 1994)	No	No
<i>Haplothrips leucanthemi</i> (Schrank) [Syn: <i>Haplothrips niger</i> Osborn]	6, 7	Europe, the Middle East, North America, South America and Oceania (Hoddle, Mound & Paris 2012)	Yes, southern areas (Hoddle, Mound & Paris 2012). Declared pest, prohibited by WA (Government of Western Australia 2016)	Flowers of various Asteraceae, also <i>Trifolium</i> sp. (Fabaceae) and <i>Plantago</i> sp. (Plantaginaceae) (Hoddle, Mound & Paris 2012)	Interception group D; from cut-flowers, <i>Citrus</i> and kiwifruit	Yes (WA)	No
<i>Haplothrips nigricornis</i> Bagnall	6	South Africa (ThripsWiki 2017)	No record found (Mound & Tree 2012)	Flowers of <i>Diplopappus</i> , <i>Europs</i> , <i>Olipterus</i> and <i>Sebaea</i> (ThripsWiki 2017)	12 interceptions from Africa from 1983-1999 and 4 interceptions from Europe and Africa from 1994-1999 at US ports (Nickle 2003). Intercepted on <i>Leucospermum</i> sp. and <i>Telopea</i> sp. from South Africa to Japan (Oda & Hayase 1994)	Yes	No
<i>Haplothrips tenuipennis</i> Bagnall	6	China, India and Indonesia (Mirab-balou et al. 2011)	No record found (Mound & Tree 2012)	Flowers of host plants including rose and <i>Mangifera</i> (ThripsWiki 2017)	None	Yes	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthotospovirus vector
<i>Haplothrips tritici</i> (Kurdjumov) Wheat thrips	4, 5	Europe, Asia, and Africa (CABI 2013a; Mirab-balou et al. 2011)	No record found (Mound & Tree 2012)	Leaves and ripening seed or fruit of wheat and other host plants (CABI 2013a)	None	Yes	No
<i>Hoplandrothrips flavipes</i> Bagnall	1	Africa, Pacific, Asia, Central and South America (ThripsWiki 2017)	Yes, Qld (Mound 2012a)	Calyxes of coconut fruit and inflorescence (Sakimura 1986)	Interception group C; from cut-flowers, coconut fruit, jasmine, citrus fruit and pineapples. Two interceptions from Africa at US ports from 1983-1999 (Nickle 2003). Intercepted on <i>Cocos nucifera</i> from Thailand to Japan (Masumoto, Oda & Hayase 1999)	No	No
<i>Liothrips karnyi</i> (Bagnall) Pepper leaf gall thrips	5	Sri Lanka (ThripsWiki 2017)	No record found (Mound 2012a)	Marginal leaf galls of <i>Piper nigrum</i> (ThripsWiki 2017)	None	Yes	No
<i>Liothrips oleae</i> Costa Olive thrips	5, 6	Mediterranean Europe and the Middle East (PlantPro 2013)	No record found (Mound & Tree 2012)	Leaves, sprouts, flowers and fruit of olive trees (PlantPro 2013)	None	Yes	No
<i>Liothrips piperinus</i> Priesner	5	China and Japan (ThripsWiki 2017)	No record found (Mound 2012a)	Leaves. Hosts including <i>Castanopsis cuspidate</i> , <i>C. sieboldii</i> , <i>Elaeocarpus sylvestris</i> , <i>Piper kadzura</i> and <i>Piper</i> sp. (ThripsWiki 2017)	None	Yes	No
<i>Liothrips vaneeckei</i> Priesner Lily thrips	5, 7	Widespread (Hoddle, Mound & Paris 2012; ThripsWiki 2017)	Yes, Vic (Malipatil et al. 2002). Declared pest, prohibited by WA (Government of	Bulbs of lilies and corms of orchids (Hoddle, Mound & Paris 2012)	Intercepted on <i>Fritillaria</i> sp. from Netherlands to Japan (Hayase 1991)	Yes (WA)	No

Pest thrips	Criteria for inclusion (Table 3.1)	Distribution	Present within Australia	Plant parts affected, host plants and/or previous pathway assessment	Interception events for Australia (Appendix D), and overseas	Considered further as quarantine pest	Considered further as an orthotospovirus vector
			Western Australia (Mound 2016)				
<i>Liothrips wasabiae</i> Haga & Okajima	5	Japan (ThripsWiki 2017)	No record found (Mound 2012a)	On <i>Wasabia japonica</i> (ThripsWiki 2017)	None	Yes	No
<i>Neoheegeria mangiferae</i> Priesner This name is invalid as its identity cannot be verified and it is not included in the thrips database (ThripsWiki 2017)	6	–	–	–	–	–	–
<i>Ponticulothrips diospyrosi</i> Haga & Okajima Japanese gall thrips	5, 6	Japan (ThripsWiki 2017), Korea (Park et al. 2009)	No record found (Mound & Tree 2012)	Leaves of <i>Diospyros kaki</i> (Park et al. 2009)	None	Yes	No
<i>Pseudophilothrips avocadis</i> Hood	5	Panama and Costa Rica (Mound, Wheeler & Williams 2010)	No record found (Mound 2012a)	Leaves of <i>Persea</i> species (Hoddle, Mound & Paris 2012)	None	Yes	No
<i>Pseudophilothrips perseae</i> Watson	5	Mexico (Hoddle et al. 2002) Guatemala and Honduras (Mound, Wheeler & Williams 2010)	No record found (Mound 2012a)	Leaves and young fruit of <i>Persea americana</i> (Hoddle, Mound & Paris 2012)	None	Yes	No

3.6 Conclusion

Based on the criteria for inclusion of thrips species in the pest categorisation of phytophagous thrips (Table 3.1), 112 species from the phytophagous Thripidae (92 species) and phytophagous Phlaeothripidae (20 species) were categorised (Table 3.2).

As an outcome of pest categorisation 79 species were confirmed as quarantine pests for Australia, including eleven known to transmit orthospoviruses (Table 3.3). Three additional species, *Frankliniella schultzei*, *Scirtothrips dorsalis* and *Thrips tabaci* are not quarantine pests for Australia, but are known to transmit orthospoviruses, which have the potential to be quarantine pests for Australia. Consequently, 82 thrips species were considered further in the pest risk assessment.

Table 3.3 Outcome of the pest categorisation of phytophagous thrips

Thrips	Common name if available	Quarantine pest	Known to transmit orthospoviruses
Thripidae			
<i>Asprothrips seminigricornis</i> (Girault)	–	Yes (WA)	No
<i>Caliothrips fasciatus</i> (Pergande)	Californian bean thrips	Yes	No
<i>Caliothrips impurus</i> (Priesner)	African cotton thrips	Yes	No
<i>Caliothrips indicus</i> Bagnall	Groundnut thrips	Yes	No
<i>Caliothrips phaseoli</i> (Hood)	American bean thrips	Yes	No
<i>Ceratothripoides claratris</i> (Shumsher)	–	Yes	Yes
<i>Chaetanaphothrips leeuweni</i> (Karny)	–	Yes (WA)	No
<i>Chaetanaphothrips orchidii</i> (Moulton)	Anthurium thrips	Yes (WA)	No
<i>Chaetanaphothrips signipennis</i> (Bagnall)	–	Yes (WA)	No
<i>Chirothrips molestus</i> Priesner	–	Yes	No
<i>Danothrips trifasciatus</i> Sakimura	–	Yes (WA)	No
<i>Dendrothrips minowai</i> Priesner	Minowai thrips	Yes	No
<i>Dendrothrips saltator</i> Uzel	–	Yes	No
<i>Dictyothrips betae</i> Uzel	–	Yes	Yes
<i>Drepanothrips reuteri</i> Uzel	–	Yes	No
<i>Echinothrips americanus</i> Morgan	Poinsettia thrips	Yes (WA)	No
<i>Elixothrips brevisetis</i> (Bagnall)	Banana rind thrips	Yes (WA)	No
<i>Ernothrips lobatus</i> (Bagnall)	–	Yes	No
<i>Frankliniella australis</i> Morgan	–	Yes	No
<i>Frankliniella bispinosa</i> (Morgan)	Florida flower thrips	Yes	Yes
<i>Frankliniella cephalica</i> (Crawford)	–	Yes	Yes
<i>Frankliniella fusca</i> (Hinds)	Tobacco thrips	Yes	Yes
<i>Frankliniella gemina</i> Bagnall	–	Yes	Yes
<i>Frankliniella intonsa</i> (Trybom)	–	Yes	Yes
<i>Frankliniella minuta</i> (Moulton)	Minute flower thrips	Yes	No
<i>Frankliniella occidentalis</i> Pergande	Western flower thrips	Yes (NT)	Yes

Thrips	Common name if available	Quarantine pest	Known to transmit orthotospoviruses
<i>Frankliniella schultzei</i> (Trybom)	Cotton thrips	No	Yes
<i>Frankliniella tritici</i> (Fitch)	Eastern flower thrips	Yes	No
<i>Frankliniella williamsi</i> Hood	Corn thrips	Yes (WA)	No, but it is a vector of MCMV
<i>Frankliniella zucchini</i> Nakahara & Monterio	–	Yes	Yes
<i>Fulmekiola serrata</i> (Kobus)	Sugarcane thrips	Yes	No
<i>Heliothrips sylvanus</i> Faure	–	Yes	No
<i>Holopothrips ananasi</i> Da Costa Lima	–	Yes	No
<i>Kenyattathrips katarinae</i> Mound	–	Yes	No
<i>Limothrips denticornis</i> (Haliday)	Barley thrips	Yes (WA)	No
<i>Megalurothrips distalis</i> (Karny)	–	Yes	No
<i>Megalurothrips sjostedti</i> (Trybom)	Bean flower thrips	Yes	No
<i>Neohydatothrips gracilicornis</i> (Williams)	–	Yes	No
<i>Neohydatothrips variabilis</i> (Beach)	Soybean thrips	Yes	No
<i>Retithrips syriacus</i> (Mayet)	Black vine thrips	Yes	No
<i>Rhipiphorothrips cruentatus</i> Hood	Grapevine thrips	Yes	No
<i>Rubiothrips vitis</i> (Priesner)	European grape thrips	Yes	No
<i>Scirtothrips albomaculatus</i> Bianchi	–	Yes (WA)	No
<i>Scirtothrips aurantii</i> Faure	South African citrus thrips	Yes (WA)	No
<i>Scirtothrips citri</i> (Moulton)	California citrus thrips	Yes	No
<i>Scirtothrips dorsalis</i> Hood	Chilli thrips	No	Yes
<i>Scirtothrips mangiferae</i> Priesner	–	Yes	No
<i>Scirtothrips oligochaetus</i> Karny	Mangosteen thrips	Yes	No
<i>Scirtothrips perseae</i> Nakahara	Avocado thrips	Yes	No
<i>Sigmothrips aotearoana</i> Ward	–	Yes	No
<i>Stenchaetothrips fuscus</i> (Moulton)	–	Yes	No
<i>Taeniothrips inconsequens</i> (Uzel)	Pear thrips	Yes	No
<i>Thrips alni</i> Uzel	–	Yes	No
<i>Thrips angusticeps</i> Uzel	Field thrips	Yes	No
<i>Thrips flavus</i> Schrank	Honeysuckle thrips	Yes	No
<i>Thrips fulvipes</i> Bagnall	–	Yes	No
<i>Thrips fuscipennis</i> Haliday	Rose thrips	Yes	No
<i>Thrips major</i> Uzel	Rubus thrips	Yes	No
<i>Thrips obscuratus</i> (Crawford)	NZ flower thrips	Yes	No
<i>Thrips palmi</i> Karny	Melon thrips	Yes (NT, SA, Vic, WA)	Yes
<i>Thrips physapus</i> Linnaeus	–	Yes	No
<i>Thrips pillichii</i> Priesner	–	Yes	No

Thrips	Common name if available	Quarantine pest	Known to transmit orthospoviruses
<i>Thrips setosus</i> Moulton	Japanese flower thrips	Yes	Yes
<i>Thrips tabaci</i> Lindemann	Onion thrips	No	Yes
<i>Thrips urticae</i> Fabricius	–	Yes	No
<i>Thrips validus</i> Uzel	–	Yes	No
Phlaeothripidae			
<i>Haplothrips acanthoscelis</i> (Karny)	–	Yes	No
<i>Haplothrips aculeatus</i> (Fabricius)	Grass thrips	Yes	No
<i>Haplothrips chinensis</i> Priesner	–	Yes	No
<i>Haplothrips ganglbaueri</i> Schmutz	–	Yes	No
<i>Haplothrips leucanthemi</i> (Schrank)	–	Yes (WA)	No
<i>Haplothrips nigriconis</i> Bagnall	–	Yes	No
<i>Haplothrips tenuipennis</i> Bagnall	–	Yes	No
<i>Haplothrips tritici</i> (Kurdjumov)	Wheat thrips	Yes	No
<i>Liothrips karnyi</i> (Bagnall)	Pepper leaf gall thrips	Yes	No
<i>Liothrips oleae</i> Costa	Olive thrips	Yes	No
<i>Liothrips piperinus</i> Priesner	–	Yes	No
<i>Liothrips vaneeckei</i> Priesner	Lily thrips	Yes (WA)	No
<i>Liothrips wasabiae</i> Haga & Okajima	–	Yes	No
<i>Ponticulothrips diospyrosi</i> Haga & Okajima	Japanese gall thrips	Yes	No
<i>Pseudophilothrips avocadis</i> Hood	–	Yes	No
<i>Pseudophilothrips perseae</i> Watson	–	Yes	No

4 Pest categorisation of orthotospoviruses

4.1 Introduction

This pest categorisation builds on Chapter 3 which identified the thrips species that are quarantine pests for Australia, or are not quarantine pests but have potential to transmit orthotospoviruses that are quarantine pests for Australia, and required further risk assessment. It considers:

- all known (or likely) orthotospoviruses
- all known (or likely) Thripidae species that transmit orthotospoviruses.

Thrips species can also transmit a limited number of viruses in genera other than *Orthotospovirus*. These viruses are members of the *Ilarvirus*, *Carmovirus*, *Sobemovirus* and *Machlomovirus* (Jones 2005). These viruses are considered in Appendix F.

4.2 Biology and taxonomy

In 1930, *Tomato spotted wilt orthotospovirus* (formerly Tomato spotted wilt virus; TSWV) was shown to be the causal agent of spotted wilt disease (Samuel 1931; Samuel, Bald & Pittman 1930), a plant disease first reported in Australia in 1915 (Brittlebank 1919), although unlikely to have originated on that continent (Best 1968; Mound 2001). For many years TSWV was the sole member of the genus. Milne and Francki (1984) first proposed that TSWV be assigned to the family *Bunyaviridae*, which includes significant human and animal pathogens (Briese, Calisher & Higgs 2013).

The *Bunyaviridae* was recently revised by the International Committee on Taxonomy of Viruses (ICTV 2017). This resulted in the creation of a new order *Bunyavirales*, with eight new assigned families and one renamed, with a total of 13 assigned genera. These families and their assigned genera are: (1) *Feraviridae*: *Orthoferavirus*; (2) *Fimoviridae*: *Emaravirus*; (3) *Hantaviridae*: *Orthohantavirus*; (4) *Jonviridae*: *Orthojonvirus*; (5) *Nairoviridae*: *Orthonairovirus*; (6) *Phasmaviridae*: *Orthophasmavirus*; (7) *Phenuiviridae*: *Goukovirus*, *Phasivirus*, *Phlebovirus*, *Tenuivirus*; (8) *Tospoviridae*: *Orthotospovirus*; *Peribunyaviridae* (renamed); (9) *Herbevirus*, *Orthobunyavirus* (formerly *Bunyaviridae*). Consequently, the former genus tospovirus has been renamed *Orthotospovirus* and has been assigned to the family *Tospoviridae* within the order *Bunyavirales*. There are 30 described species formerly named as tospoviruses. Eleven of these are officially recognised by the ICTV and have been renamed as *Orthotospovirus*—for example *Tomato spotted wilt orthotospovirus*. In this report, original names are retained for the remainder as they are not yet officially recognised by the ICTV, for example, *Capsicum chlorosis virus*.

The orthotospovirus structure

The complete virus particle (virion) of *Orthotospovirus* consists of a quasi-spherical (80–120 nm diameter) phospholipid membrane envelope with a genome of three single-stranded RNA segments, denoted S (small) M (medium) and L (large). The S and M RNAs are ambisense, with both positive ‘sense’ and negative ‘anti-sense’ open reading frames (ORFs), while the L RNA is negative anti-sense (Adkins 2000; Geerts-Dimitriadou et al. 2012; Moyer 2000; Nguyen & Haenni 2003). The nine nucleotides of the 3’ end of each genomic RNA are highly conserved and of inverted complementarity to the 5’, facilitating the ‘panhandle’ secondary structure of each segment.

Positive sense RNA can be directly translated into proteins, but negative anti-sense RNA must first be transcribed. There are five open reading frames (ORFs) that encode structural (nucleocapsid N protein, precursors of the glycoproteins Gn/Gc) and non-structural (NSs, NSm, RNA-dependent RNA polymerase) proteins (Eifan et al. 2013; Moyer 2000).

The S RNA encodes in positive orientation for the NSs protein and in negative orientation for the N protein. Plant anti-viral defences include a highly conserved RNA silencing mechanism, and the NSs protein is a suppressor of this mechanism (Takeda et al. 2002). The N protein and genomic RNA form the ribonucleocapsid. The M RNA encodes in negative orientation for the precursors of the glycoproteins Gn/Gc which are embedded within the virion envelope, and in positive orientation for the non-structural protein NSm. The NSm protein is encoded by all plant-pathogenic viruses; it facilitates viral cell-to-cell movement (Lewandowski & Adkins 2005). The L RNA encodes viral RNA-dependent RNA polymerase (RdRp) which catalyses synthesis of the viral mRNA for translation by the host's system, which leads to production of new viral genomes (German, Ullman & Moyer 1992).

The fact that orthotospoviruses infect and replicate in both thrips and plants is noteworthy because it offers opportunities for complex biological interactions between virus, thrips vector and plant host.

Orthotospovirus diversity

Orthotospoviruses are considered to form at least five distinct ancestral groups (phylogenetic clades), based on alignment of protein amino acid sequences. The clades are referred to by the type species within each: *Watermelon silver mottle orthotospovirus* (Eurasian clade), *Tomato spotted wilt orthotospovirus* (American clade), *Iris yellow spot orthotospovirus* (IYSV), *Groundnut yellow spot orthotospovirus* (GYSV), and *Soybean vein necrosis virus* (SVNV) (Cheng et al. 2013; de Oliveira et al. 2011; Dong et al. 2008; Yin et al. 2014). De Oliveria et al. (2012) proposed the novel evolutionary lineage containing *Bean necrotic mosaic virus* (BeNMV) (de Oliveira et al. 2011) and SVNV (Zhou et al. 2011), and considered more species related to the SVNV group probably remain to be discovered, advising that the specificity of some molecular diagnostics tools may result in members of this group being overlooked.

Orthotospovirus species are defined primarily on a molecular basis using their N protein sequence (King et al. 2012). Those with an N protein identity of 90 per cent or greater are viewed as the same species, and if less than 80 per cent, as different species. Those with an intermediate N protein identity (80–89 per cent) are considered either different strains or different species depending on their biological properties, including host-plant range or thrips vectors. However, Hassani-Mehraban et al. (2007) and Webster et al. (2011) suggest that these criteria may require revision considering the range of genetic and biological diversity observed within the genus.

RNA viruses show high genetic variability and can evolve rapidly (Moya et al. 2000). They have a high mutation rate, partly as a result of RdRp lacking a proofreading mechanism (Crotty, Cameron & Andino 2001). This is aided by their presence in large numbers within infected hosts, their high replication rate, short generation time, and small genome size (Moya et al. 2000).

Infections of two or more orthotospoviruses have been observed within a single plant (Chiemsombat et al. 2008; Kunkalikal et al. 2011; Mullis et al. 2004; Peng et al. 2011; Webster et al. 2011). This provides opportunities for exchange of genetic material between orthotospoviruses, influencing their evolution and biology (Bag et al. 2012; Qiu et al. 1998; Webster et al. 2011). Exchange of genomic RNA segments (reassortment) between two orthotospoviruses has created progeny with stable novel phenotypes (Qiu et al. 1998). Natural

reassortment resulting in an orthotospovirus with two of its three genomic segments from one parent, *Groundnut ringspot orthotospovirus* (GRSV) and the other from *Tomato chlorotic spot orthotospovirus* (TCSV), designated L_GM_TS_G has been reported by Webster et al. (2011). Briese et al. (2013) have proposed that most, if not all, members of the former family *Bunyaviridae* may be reassortants.

Orthotospovirus isolates designated as the same species can exhibit different genetic and biological traits, including pathogenicity. Hassani-Mehraban et al. (2007) described two *Tomato yellow ring virus* isolates—one that infected tomato, the other soybean and potato. Sequence comparison of the N protein and DAS-ELISA determined these isolates as the same species. However, their experimental host-plant ranges differed—both causing systemic infection in *Nicotiana*, but one also causing localized infection in tomato. Torres et al. (2012) described *Pepper necrotic spot virus* (PNSV) isolates from pepper and tomato. In this case, the tomato isolate was unable to infect pepper, but the pepper isolate was able to infect both.

A further mechanism behind observed diversity was reported by Bag et al. (2012). Co-infection of plants with two orthotospoviruses, IYSV and TSWV, influenced disease expression by functional complementation—increased suppression of the plant's RNA silencing system occurred in the presence of NSs proteins (RNA silencing suppressors) from both viruses.

Acquisition of orthotospovirus by thrips

For a thrips vector to infect a plant it must: (i) acquire sufficient virus for its own infection; (ii) undergo an incubation—latency—period in which the virus multiplies and the thrips become viruliferous and competent to convey a virus to infect a plant; and (iii) transmit sufficient virus to infect a susceptible host plant.

Orthotospovirus perpetuation necessitates a continuous cycle from plant to thrips and back again. This is because, excluding vegetative propagation or artificial transmission, a thrips vector is essential for orthotospovirus perpetuation beyond the life-cycle of individual annual or biennial host-plants. The weight of evidence is that orthotospoviruses are not transmitted via seed (Albrechtsen 2006; Pappu et al. 1999b); although there is a single report of seed transmission for an isolate of *Soybean vein necrosis virus* under laboratory conditions, this has not yet been observed in the field (Hajimorad et al. 2015). Equally, a thrips vector can only acquire an orthotospovirus from infected plant material because transmission between individual thrips or from parent to offspring (transovarially) does not occur (Nagata et al. 1999; Van de Wetering, Goldbach & Peters 1996; Wijkamp et al. 1996). Therefore, each generation of thrips must reacquire the virus from an infected plant for its continuance in their population.

Thrips species develop from eggs through two feeding larval instars (L1 and L2), then two relatively inactive, non-feeding pupal instars (pre-pupa and pupa) before becoming adults. Thrips larval instars (L1 and L2) and adults can acquire orthotospoviruses (de Assis Filho, Deom & Sherwood 2004; Moritz, Kumm & Mound 2004; Van de Wetering, Goldbach & Peters 1996).

Only virus acquired in L1 and early L2 larvae can be successfully transmitted by subsequent stages (de Assis Filho, Deom & Sherwood 2004; Moritz, Kumm & Mound 2004; Nagata et al. 1999; Van de Wetering, Goldbach & Peters 1996). There is a temporary physical association between midgut, visceral muscles and salivary glands at L1 and early L2 stages (de Assis Filho, Deom & Sherwood 2004; Moritz, Kumm & Mound 2004; Nagata et al. 1999; Van de Wetering, Goldbach & Peters 1996). Orthotospoviruses acquired by late stage L2 instars and adults cannot be transmitted because this temporary physical association is lost in late L2 and adult stages (de Assis Filho, Deom & Sherwood 2004; Moritz, Kumm & Mound 2004; Nagata et al. 1999; Van de Wetering, Goldbach & Peters 1996). Loss of this association leads to a strong input of virus

particles into the Malpighian tubules via the haemocoel, but not into the salivary glands (de Assis Filho, Deom & Sherwood 2004; Moritz, Kumm & Mound 2004; Nagata et al. 1999; Van de Wetering, Goldbach & Peters 1996), even after prolonged feeding on virus infected plants (de Assis Filho, Deom & Sherwood 2004).

Thrips feeding behaviour includes exploratory probing to discern host from non-host plants, and feeding probes of short or longer duration (Whitfield, Ullman & German 2005). The single mandible is used to puncture the leaf epidermis, followed by insertion of a pair of maxillary stylets, salivation, and ingestion of cytoplasm from the mesophyll. The orthotospovirus is ingested during this process. Acquiring sufficient virus for infection is probably related to the length of time larvae feed on infected host plants (Rotenberg et al. 2009). However, not all thrips feeding on infected host plants become viruliferous, but those that do can remain so for life (Mautino et al. 2012; Nagata et al. 1999; Wijkamp, Goldbach & Peters 1996).

Effects of orthotospoviruses on thrips

Orthotospovirus infection is reported to influence thrips behaviour and physiology (Belluire et al. 2005; Ogada, Maiss & Poehling 2013; Shrestha et al. 2012; Stafford, Walker & Ullman 2011). Observed effects are attributed to either direct effects on a thrips from being infected, or the indirect effects on a thrips caused by their host plant being infected.

Infection of *Frankliniella occidentalis* (WFT) with TSWV triggers an immune response within the thrips including the activation of genes encoding antimicrobial peptides and those involved in pathogen recognition and signal transduction pathways (Medeiros, Resende & De Ávila 2004). Infection of *F. occidentalis* with INSV is reported to extend the period from second instar to adult, and reduce reproductive and survival rates (deAngelis, Sether & Rossignol 1993). Wijkamp et al. (1996) observed that TSWV infection of *F. occidentalis* had no significant effect on thrips reproductive physiology. Infection of *F. occidentalis* with TSWV was later reported to increase thrips longevity and reduce fecundity (Ogada, Maiss & Poehling 2013). However, TSWV infection of *F. occidentalis* was also observed to increase the frequency of non-ingestion and short-ingestion probes made by male thrips, but not to significantly influence female behaviour (Stafford, Walker & Ullman 2011).

Maris et al. (2004) observed that TSWV infection of host plants raised their attractiveness to *F. occidentalis*, and that more offspring were produced on virus infected-plants with eggs hatching earlier and larvae pupating faster. TSWV infection of host plants is considered to increase their attractiveness to *F. occidentalis* as a result of suppression of the plant's anti-herbivore defences (Abe et al. 2012; Belluire et al. 2005; Ogada, Maiss & Poehling 2013). Additionally, infection of host plants with TSWV increased ovipositing and probing rates of *Frankliniella fusca*, which was considered to be caused by the 15 fold increase in free amino acid concentration within the plant enhancing their quality as a food source for thrips (Shrestha et al. 2012). However, this study also reported that thrips development was delayed, and that fewer adults emerged.

In summary, the evidence of the precise effects of orthotospovirus infection on thrips biology and behaviour remains inconclusive, with observed inconsistencies. Some reports implying infection promotes thrips survival and/or development (Medeiros, Resende & De Ávila 2004), with others being neutral (Wijkamp et al. 1996), or reporting deleterious effects (deAngelis, Sether & Rossignol 1993). Factors including the use of different virus isolates, host plants, or experimental conditions (including temperature) may explain some apparent contradictions among published reports, as discussed by Stumpf and Kennedy (2007). Belluire et al. (2005) also concluded that mechanically induced infection, a method used in some of these studies, may not

induce the full spectrum of natural plant defence responses, which may also be a contributory factor.

Transmission of orthotospoviruses by thrips

Orthotospovirus transmission is likely to be influenced by several processes relating to thrips infection biology: virus acquisition, becoming infectious, maintaining infectivity, and transmission through feeding or probing behaviours to host plants (Srinivasan et al. 2012; Wijkamp, Goldbach & Peters 1996). The competency of thrips to transmit orthotospoviruses is reported to show inter-species (Inoue et al. 2004; Wijkamp et al. 1995) and intra-species (Chatzivassiliou, Peters & Katis 2002; Van de Wetering et al. 1999; Wijkamp et al. 1995) variations. Although most virus-vector combinations have not been tested, current understanding is that each orthotospovirus is transmitted by only a limited number of thrips species (Table 4.2 and 4.3).

Orthotospoviruses are transmitted in a persistent and propagative mode (Whitfield, Ullman & German 2005) by viruliferous L2 instars and adult thrips. This requires replication (amplification) of the ingested virus, which occurs in the mid-gut or salivary glands, as a prerequisite to becoming viruliferous (Van de Wetering, Goldbach & Peters 1996). Salivary gland infection is necessary for transmission (Nagata et al. 1999; 2002), and the viruses are transmitted to host plants via virus-laden saliva, injected during probing or feeding (Whitfield, Ullman & German 2005). The number of successive times an individual thrips can continue to transmit an orthotospovirus to a host plant is reported to have a dose dependent relationship with accumulated virus concentration (Inoue et al. 2004; Rotenberg et al. 2009).

Male and female thrips have been observed to differ in their capacity to transmit TSWV, with male *F. occidentalis* thrips being more efficient at transmitting TSWV in successive events compared to female thrips of the same cohort, even though females contained up to three times more copies of TSWV RNA per insect (Rotenberg et al. 2009). Hence, absolute virus titer may not be the only factor involved in transmission. Male *F. occidentalis* thrips infected with TSWV made three times more non-ingestion (non-feeding) probes than uninfected males (Lewandowski & Adkins 2005; Stafford, Walker & Ullman 2011). Short- and long-ingestion (feeding) probes are destructive to plant tissues, which may result in lower rates of infection. Conversely, short non-ingestion probes may be more likely to result in infection of host plants because they cause less severe tissue damage, and are feasibly less likely to inhibit initial cell-to-cell movement of orthotospoviruses from epidermal/mesophyll cells at their point entry (Lewandowski & Adkins 2005; Stafford, Walker & Ullman 2011).

It is worth noting that thrips populations can be thelytokous (consisting only of females reproducing by parthenogenesis with female offspring) or arrhenotokous (consisting of males and females reproducing sexually with diploid females produced from fertilized eggs and haploid males from unfertilized eggs). However, female only thrips populations are common, and for some species males are rare or unknown (Vasiliu-Oromulu 2001). Therefore, this would moderate any sexually dimorphic effects that result from viral infection of males.

Plant resistance to orthotospoviruses

Plants have defence mechanisms that provide an immune response against microbial infection (Chisholm et al. 2006; Jones & Dangl 2006). This includes genetic resistance through basal and R-gene mediated elements (Gururani et al. 2012). The basal defence is the first line of protection, which has both non-host (elicited by all species members) and host (often cultivar or accession) specific elements. Microbes have evolved a suite of effector proteins that suppress these defences, but plants have co-evolved a suite of receptors (R proteins) that detect these effectors

and activate counter defences (Bent & Mackey 2007; Kang, Yeam & Jahn 2005). Many plant resistance (R) genes have been used within crop improvement programs for disease management against a range of pathogens (Gururani et al. 2012). The majority of these traits are monogenic, and frequently based on dominant alleles (Kang, Yeam & Jahn 2005).

In managing the impacts of TSWV, two genes Sw-5 and Tsw have been extensively introgressed (bred) into commercial cultivars of tomato (Riley et al. 2011a) and pepper (Gunter et al. 2012), respectively. These genes elicit a hypersensitive response *in planta* and programmed localised cell death, which impedes systemic virus infection under certain conditions. The Sw-5 gene also offers some protection against other orthotospoviruses, such as TCSV and GRSV (Soler, Cebolla-Cornejo & Nuez 2003).

Isolates of TSWV can show genetic variability (Kaye et al. 2011; Tsompana et al. 2005), and resistance-breaking isolates have been reported globally overcoming the Sw-5 gene-based resistance in South Africa (Thompson & van Zijl 1996), Australia (Latham & Jones 1998), Spain (Aramburu & Marti 2003), and Italy (Ciuffo et al. 2005). This has also occurred with Tsw gene-based resistance in Brazil (Boiteux et al. 1993b), USA (Hobbs et al. 1994), Italy (Roggero, Masenga & Tavella 2002), Spain (Margaria, Ciuffo & Turina 2004), and Australia (Sharman & Persley 2006). Mechanisms causing this breakdown may include mutations in the viral NSs (Margaria et al. 2007; Tentchev et al. 2011) and NP (Lovato et al. 2008) genes for Tsw/pepper, and the NSm for Sw-5/tomato (Hoffmann, Qiu & Moyer 2001; Jahn et al. 2000; López et al. 2011). The inherent vulnerability of single-gene resistance strategies is shown by Tsw gene resistance being rapidly overcome soon after its deployment within Italy and Spain (Garcia-Arenal & McDonald 2003). Lopez et al. (2011) advised convergent evolution and positive selection as influences promoting the breakdown of TSWV Sw-5 resistance, which is consistent with the findings of Tentchev et al. (2011).

Research continues into germplasm collections and uncultivated plant species as sources of untapped broad-spectrum resistance to orthotospovirus infection for crop plant breeding strategies, and improved knowledge of the underpinning mechanisms (Dianese et al. 2011; Mandal et al. 2012; Puangmalai et al. 2013). Strategies conferring broad-spectrum resistance could include development of genetically modified crops based on methods such as enhanced RNA silencing, or disruption of the virus–vector interaction by blocking virus entry into its vector (Bucher et al. 2006; Peng et al. 2014; Whitfield & Rotenberg 2015). However, public acceptance of genetically modified organisms may be contentious, with both perceived benefits and risks associated with adoption of engineered viral resistance being factors in regulatory approval and industry adoption (Thompson & Tepfer 2010).

Summary

The genus *Orthotospovirus*, family *Tospoviridae*, comprises 11 officially recognised species and 19 proposed species. Their virion is a quasi-spherical membrane-like envelope with a viral genome of three single-stranded RNA segments, two of which are ambisense. They have five open reading frames that encode three structural and three non-structural proteins. RNA viruses show high genetic variability and are known to evolve rapidly, and *Orthotospovirus* members exhibit genetic and biological diversity. Thrips must acquire an orthotospovirus from a plant host. Viral transmission between thrips or from parent to offspring is not known to occur. Only larval thrips at L1 and rarely early stage L2 instars can become infected; they can then remain infective for life and transmit orthotospoviruses in a persistent and propagative way during feeding or probing. Orthotospovirus transmission involves complex interactions between the host plant and several processes relating to thrips infection biology—virus acquisition,

becoming infectious, and maintaining infectivity. Orthospovirus infection may influence thrips biology and behaviour, but a range of effects have been reported.

4.3 Pest categorisation

The process for pest categorisation is described in Appendix A. The pest categorisation process considers the:

- identity of 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.

These components of pest categorisation of orthospoviruses are presented in Table 4.2, except for the potential for establishment and spread in the PRA area that are presented only in Chapter 4.4. This approach is consistent with the ISPM 11 categorisation guidelines (FAO 2016e).

4.4 Potential for establishment and spread

Establishment is defined as the 'perpetuation for the foreseeable future, of a pest within an area after entry' (FAO 2016b), and spread is defined as 'the expansion of the geographical distribution of a pest within an area' (FAO 2016b).

Quarantine pest orthospoviruses have the potential to establish and spread in Australia because they have relevant biological attributes, hosts are readily available, and environmental conditions within Australia are suitable.

Orthospovirus perpetuation

As discussed in Chapter 4.2, the weight of evidence is that orthospoviruses are not transmitted via seed and excluding vegetative propagation or artificial transmission, without a thrips vector, virus perpetuation beyond the life-cycle of individual annual or biennial host-plants could not occur. Additionally, orthospovirus transmission between individual thrips or from parent to offspring does not occur, and each generation of thrips must reacquire the virus from infected plant material for its continuance in their population. As a result, the virus must cycle from plant to thrips and back again. Consequently, an ongoing thrips presence to transmit the virus is essential for orthospovirus '*perpetuation for the foreseeable future*' within the natural environment.

Thrips

As discussed in Chapter 3, thrips species, including those that transmit orthospoviruses, have the potential to spread and establish within Australia. The Australian climate is conducive to thrips survival and susceptible host plants are readily available.

Viruliferous thrips could facilitate the spread of orthospoviruses within Australia by factors that include their active aerial dispersal via flight or on wind currents, and passive dispersal as a contaminant on plant produce, vehicles or clothes.

Orthotospoviruses and their thrips vectors that are already present within Australia

Three orthotospovirus species are reported as established and widespread within Australia—TSWV (Jones 2005; Samuel, Bald & Pittman 1930), CaCV (McMichael, Persley & Thomas 2002), and IYSV (Coutts et al. 2003). Additionally, a localised *Impatiens necrotic spot orthotospovirus* (INSV) incursion occurred in 2010, but was successfully eradicated (PHA & NGIA 2011). Although the pathway(s) for the entry of these orthotospoviruses is uncertain, these examples show that the Australian environment can support orthotospovirus establishment and that host plants were and are likely to remain accessible.

Several thrips species that transmit orthotospoviruses are also present within Australia—*Frankliniella schultzei*, *F. occidentalis*, *Scirtothrips dorsalis*, *Thrips palmi* and *T. tabaci*. These species are widely distributed within Australian agricultural and horticultural production areas, domestic gardens and the natural environment where host plants susceptible to orthotospoviruses are likely to be present. The presence of these thrips may further facilitate establishment and spread of a number of orthotospoviruses. The fact that orthotospoviruses have previously established and spread within Australia may indicate that natural barriers, including deserts, arid areas, and distance between production areas within Australia are unlikely to stop the spread of orthotospoviruses within Australia following their establishment.

Global distribution of orthotospoviruses

Table 4.1 documents the date and region where orthotospovirus species were first described, which may or may not reflect their true origin, and their current known distribution. If assumed that at least some had a discrete origin, the difference between their initial and current reported distributions may indicate their potential to spread globally and to establish within new locations. It also shows that orthotospoviruses as a group are present within a broad range of regions, including those likely to have similar climatic conditions and agricultural production systems to Australia.

Based solely on the region where a species was first described, Asia and South America are possibly the regions of highest orthotospovirus diversity—Asia (15 species), South America (7 species), North America (3 species), Europe (2 species), Australasia (2 species), and Africa (1 species).

Table 4.1 First recorded appearance and current known distribution of orthotospoviruses

Date (a)	Orthotospovirus (b)	Initial region where reported	Current distribution (c, d)
1915	TSWV	Australasia (AU)	Africa, Asia, Australasia, Europe, N. America, S. America
1968	GBNV	S. and SW Asia (IN)	S. and SW Asia, E. and SE Asia
1982	WSMoV	E. and SE Asia (JP)	E. and SE Asia
1991 (80s)	INSV	N. America (US)	Africa, Asia, Australasia, Europe, N. America, S. America
1991	GYSV	S. and SW Asia (IN)	S. and SW Asia (IN), E. and SE Asia (TH)
1992	GCFSV	E. and SE Asia (TW)	E. and SE Asia (TW)
1993	GRSV	Africa (ZA)	Africa (ZA, GH), N. America (FL, NY, SC), S. America (AR, BR), Europe (FI)
1993	TCSV	S. America (BR)	N. America (FL, OH), S. America (AR, BR, DO, PR)
1996	ZLCV	S. America (BR)	S. America (BR)
1998	WBNV	S. and SW Asia (JP)	S. and SW Asia (JP, CN, TW, IN)

Date (a)	Orthotospovirus (b)	Initial region where reported	Current distribution (c, d)
1998 (92)	IYSV	Europe (NL)	Africa, Asia, Australasia, Europe, N. America, S. America
1999 (92)	CaCV	Australasia (AU)	S. and SW Asia, E. and SE Asia, Australasia, N. America (HI)
1999 (92)	MYSV	E. and SE Asia (JP)	E. and SE Asia (JP, CN, TW, TH), S. America (EC)
1999	CSNV	S. America (BR)	E. and SE Asia (JP, KR), S. and SW Asia (IR), Europe (IT), S. America (BR)
2005	CCSV	E. and SE Asia (TW)	E. and SE Asia (TW, CN)
2005	TYRV	S. and SW Asia (IR)	Africa (KE), S. and SW Asia (IR), Europe (PL)
2005	TZSV	E. and SE Asia (CN)	E. and SE Asia (CN)
2008	PolRSV	Europe (IT)	Europe
2009	MeSMV	N. America (MX)	N. America (MX)
2010	ANSV	S. America (CO)	S. America (CO)
2010	TNRV	E. and SE Asia (TH)	E. and SE Asia (TH)
2011	BeNMV	S. America (BR)	S. America (BR)
2011	L ₆ M ₇ S ₆	N. America (FL)	N. America (FL)
2011	SVNV	N. America (US)	N. America (US, CA)
2012	PNSV	S. America (PE)	S. America (PE)
2013	HCRV	E. and SE Asia (CN)	E. and SE Asia (CN)
2013	PCSV	E. and SE Asia (TW)	E. and SE Asia (TW)
2014 (07)	LNRV	E. and SE Asia (JP)	E. and SE Asia (JP)
2014	TNSaV	E. and SE Asia (CN)	E. and SE Asia (CN)
2015	MVBaV	E. and SE Asia (CN)	E. and SE Asia (CN)

a. Dates in parentheses indicate probable orthotospovirus presence in the region prior to the date of the first report. **b.** ANSV, *Alstroemeria necrotic streak virus*; BeNMV, *Bean necrotic mosaic virus*; CaCV, *Capsicum chlorosis virus*; CCSV, *Calla lily chlorotic spot virus*; CSNV, *Chrysanthemum stem necrosis virus*; GRSV, *Groundnut ringspot virus*; GBNV, *Groundnut bud necrosis orthotospovirus*; GCFSV, *Groundnut chlorotic fan-spot virus*; GRSV, *Groundnut ring spot orthotospovirus*; GYSV, *Groundnut yellow spot orthotospovirus*; HRCV, *Hippeastrum chlorotic ringspot virus*; INSV, *Impatiens necrotic spot orthotospovirus*; IYSV, *Iris yellow spot orthotospovirus*; LNRV, *Lisianthus necrotic ringspot virus*; MeSMV, *Melon severe mosaic virus*; MYSV, *Melon yellow spot virus*; MVBaV, *Mulberry vein banding associated virus*; PolRSV, *Polygonum ringspot orthotospovirus*; PCSV, *Pepper chlorotic spot virus*; PNSV, *Pepper necrotic spot virus*; L₆M₇S₆; SVNV, *Soybean vein necrosis virus*; TNRV, *Tomato necrotic ringspot virus*; TNSaV, *Tomato necrotic spot-associated virus*; TCSV, *Tomato chlorotic spot orthotospovirus*; TSWV, *Tomato spotted wilt orthotospovirus*; TYRV, *Tomato yellow ring virus*; TZSV, *Tomato zonate spot virus*; WBNV, *Watermelon bud necrosis orthotospovirus*; WSMoV, *Watermelon silver mottle orthotospovirus*; ZLCV, *Zucchini lethal chlorosis orthotospovirus*. **c.** If distribution is limited, country is given (AR, Argentina; AU, Australia; BM, Bermuda; BS, Bahamas; BR, Brazil; CA, Canada; CN, China; CO, Colombia; DO, Dominican Republic; EC, Ecuador; FI, Finland; FL, Florida; GH, Ghana; HI, Hawaii; IL, Israel; IN, India; IR, Iran; IT, Italy; JP, Japan; KE, Kenya; KR, South Korea; MX, Mexico; NL, Netherlands; NY, New York; OH, Ohio; PE, Peru; PL, Poland; PR, Puerto Rico; SC, South Carolina; TH, Thailand; TW, Taiwan; US, United States; ZA, South Africa). **d.** South and Southwest (S. and SW) Asia includes India and countries to the West. East and Southeast (E. and 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.

Summary

Orthotospoviruses as a group are widespread globally, and are present in a wide range of ecological and climatic conditions. They also infect a broad range of host plants. They have the potential to establish and spread within Australia because Australia has comparable ecological and climatic conditions to areas where orthotospoviruses currently occur, and there are susceptible host plants readily available. This conclusion is supported by the fact that three

orthotospoviruses are already established and widespread within Australia, and a number of thrips species that transmit orthotospoviruses are also present to facilitate their establishment and spread.

4.5 Potential for economic consequences

Orthotospoviruses cause substantial economic consequences across an extensive range of fruit, vegetable, legume and ornamental crops (Jones 2005; Kunkalikal et al. 2011; Mandal et al. 2012; Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006). Impacts from orthotospoviruses on host crops include yield losses and reduced commercial quality and marketability of produce. Orthotospoviruses were initially thought to infect only a narrow range of host plants. However, TSWV has been reported to infect, via natural or experimental transmission, at least 1,090 host plant species in 15 monocotyledonous and 69 dicotyledonous families (Parrella et al. 2003). However, some earlier reports may in fact be attributable to other orthotospoviruses.

A number of orthotospoviruses have existing broad and/or rapidly expanding natural host plant ranges, including *Groundnut bud necrosis orthotospovirus* (GBNV) (Reddy et al. 1992); *Impatiens necrotic spot orthotospovirus* (INSV) (Law, Speck & Moyer 1991), *Tomato chlorotic spot orthotospovirus* (TCSV) (De Avila et al. 1993), *Tomato necrotic ringspot virus* (TNRV) (Chiemsombat et al. 2010; Seepiban et al. 2011) and *Watermelon bud necrosis orthotospovirus* (WBNV) (Jain et al. 1998).

There are also several newly emergent orthotospoviruses whose full economic impact is still unfolding, including *Melon severe mosaic virus* (MeSMV) (Ciuffo et al. 2009), *Alstroemeria necrotic streak virus* (ASNV) (Hassani-Mehraban et al. 2010), *Bean necrotic mosaic virus* (BeNMV) (de Oliveira et al. 2011), *L_GM_TS_G* (Webster et al. 2011), *Soybean vein necrosis virus* (SVNV) (Zhou et al. 2011), *Pepper necrotic spot virus* (PNSV) (Torres et al. 2012); *Hippeastrum chlorotic ringspot virus* (HCRV) (Dong et al. 2013), *Pepper chlorotic spot virus* (PCSV) (Cheng et al. 2013), *Lisianthus necrotic ringspot virus* (LNRV) (Shimomoto, Kobayashi & Okuda 2014), and *Mulberry vein banding associated virus* (MVBaV) (Meng et al. 2015).

Therefore, new orthotospovirus host plants are likely to continue to emerge in crops not previously known to be susceptible. Additionally, orthotospoviruses are likely to continue to expand their geographic distribution and economic significance (Daughtrey et al. 1997; Jones 2005; Kunkalikal et al. 2011; Pappu, Jones & Jain 2009).

Additional details of the potential for economic consequences associated with each orthotospovirus are provided in Table 4.2.

Summary

Orthotospoviruses have been demonstrated to cause substantial economic impacts across an extensive range of crops. Further evidence for this is also accumulating as new hosts continue to emerge in crops not previously known to be susceptible and orthotospoviruses continue to expand their distribution and economic significance. The magnitude of economic impact of several newly emergent orthotospoviruses is likely to increase in significance.

4.6 Pest categorisation table

The pest categorisation for orthotospoviruses is presented in Table 4.2, and the outcomes of the categorisation process are summarised in Table 4.3.

Notes on Table 4.2

To assist with the interpretation of this pest categorisation, these notes and comments are provided.

Taxonomic revision: As described in Chapter 4.2, the taxonomy of *Bunyaviridae* has been revised by the International Committee on Taxonomy of Viruses (ICTV 2017). The former genus tospovirus has been renamed *Orthotospovirus* and assigned to a new family *Tospoviridae* within a new order *Bunyavirales*. As a result, the virus taxonomy has been amended in this document since the publication of the draft report as indicated:

- order and family are revised to *Bunyavirales* and *Tospoviridae*, respectively
- genus is revised to orthotospovirus when referring generically to genus
- species officially recognised by ICTV have their name ending revised from ‘virus’ to ‘orthotospovirus’, for example, ‘*Tomato spotted wilt orthotospovirus*’
- species not yet officially recognised by ICTV retain their original ‘virus’ name, for example, ‘*Capsicum chlorosis virus*’.

Orthotospovirus species: Eleven orthotospoviruses have been officially recognized as species (as of June 2017) by the ICTV. These species are *Groundnut bud necrosis orthotospovirus*, *Groundnut ringspot orthotospovirus*, *Groundnut yellow spot orthotospovirus*, *Impatiens necrotic spot orthotospovirus*, *Iris yellow spot orthotospovirus*, *Polygonum ringspot orthotospovirus*, *Tomato chlorotic spot orthotospovirus*, *Tomato spotted wilt orthotospovirus*, *Watermelon bud necrosis orthotospovirus*, *Watermelon silver mottle orthotospovirus*, and *Zucchini lethal chlorosis orthotospovirus*. Nineteen additional viruses (formerly described as tospoviruses) that are proposed and likely to be recognized by ICTV as *orthotospovirus* species, given current genetic sequence differences and published analyses, are also included within this pest categorisation.

Italicized scientific names: It is acknowledged that the scientific names of orthotospoviruses that are officially recognized by the ICTV as species should be italicized, whereas those not yet recognized should not be italicized. However, for readability and simplicity both categories are italicized throughout this document.

Potential consequences: Host plants listed in the pest categorisation table demonstrate potential consequences, and may not represent a comprehensive list of all natural host plants of each orthotospovirus, which are extensive for some species.

Geographic regions: Within this pest categorisation table, 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.

Natural and experimental hosts: A host is defined by ISPM 5 as a ‘species capable, under natural conditions, of sustaining a specific pest or other organism’ (FAO 2016b).

Orthotospoviruses can be introduced experimentally into plants, and many studies have tested the theoretical range of host plant species for a given virus. These studies can provide useful information about prospective hosts, but in most cases they do not provide comparable evidence to natural transmission because virus transmission to a theoretical host plant species may well be infeasible or improbable in nature. Reasons include that the geographical distributions or host ranges of a given orthotospovirus and the thrips species that transmit them may not overlap in nature.

Capsicum chlorosis virus: Australia has regulated a proposed strain of *Capsicum chlorosis virus* (CaCV-Ph) as a quarantine pest on *Phalaenopsis* orchids from Taiwan. This decision has been reviewed in this group PRA. In conclusion, there is no technical justification to continue its regulation. Details of this decision are provided within this pest categorisation table with additional contextual detail on CaCV provided within these notes.

Capsicum chlorosis virus was first reported infecting capsicum and tomato in Queensland during 1999 (McMichael, Persley & Thomas 2002), but may have been present from 1992 (Persley, Thomas & Sharman 2006). In Australia, CaCV infects a range of crops that include peppers, tomatoes and peanuts (Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006). Symptom expression, for example on capsicum, often includes stunting, with small, distorted fruit that develop necrotic lesions and scarring (Jones 2005). CaCV has caused significant economic impacts on tomato production in Thailand (Premachandra et al. 2005b). In India it causes production losses in tomato (Kunkalikal et al. 2007) and chilli (Krishnareddy et al. 2008). In China, CaCV is reported as infecting peanuts (Chen et al. 2007b). In Hawaii waxflower (*Hoya calycina*) is a host (Melzer et al. 2014). In Taiwan, it has been reported infecting calla lily (Chen et al. 2007a), tomato (Huang et al. 2010) and *Phalaenopsis* orchids (Zheng et al. 2008).

Although Zheng et al. (2008) reported a CaCV isolate from *Phalaenopsis* in Taiwan that shared 96.1 per cent N gene nucleotide and 97.5 per cent amino acid identity with the Australian isolate CaCV-958, they still considered this *Phalaenopsis* isolate as a distinct strain. This was mainly based on the comparison of disease expression and/or host plant range differences of CaCV-Ph, derived from mechanical inoculations, with that of Australian isolate CaCV-958 (McMichael, Persley & Thomas 2002). For example, Zheng et al. (2008) reported *Capsicum annuum* mechanically inoculated with CaCV-Ph showed necrotic ringspots and deformations on both inoculated and systemic leaves, and plants eventually wilted. However, isolate CaCV-958 caused mottling on systemic leaves of *C. annuum* and did not show any symptoms on inoculated leaves. *Lycopersicon esculentum* infected by CaCV-Ph or CaCV-958 showed necrotic spots systemically, but only CaCV-Ph caused chlorotic or necrotic spots on inoculated leaves. Therefore, host data for CaCV-Ph was based on a mechanical inoculations, and there is no published evidence of any naturally occurring differences in economic impact.

There are other isolates of CaCV present in Australia, such as CaCV-Qld3432. Widana et al. (2015) advised from sequence and phylogenetic analyses that CaCV-Ph is more closely related to the Australian isolate CaCV-Qld3432 than isolates from Thailand (CaCV-AIT) and China (CaCV-CP). They also stated that if only N protein phylogeny and sequence identity are considered the Chinese and Thai isolates appeared to be CaCV, but differences in the intergenic region (IGR) sequence identities of the M and S RNA could imply these two isolates may be distinct orthotospoviruses. Huang et al. (2017) studied the evolutionary origin of CaCV isolates through analysis of IGR sequences, concluding CaCV-Ph was derived from CaCV-Qld3432 with the deletion of 218-nt S RNA IGR sequences, and that isolates from mainland China (CaCV-Hainan) and Thailand (CaCV-NRA) were also most likely derived from CaCV-Qld3432.

Zheng et al. (2008) also reported that *T. palmi* was not capable of transmitting CaCV-Ph (based on unpublished data), whereas the authors stated that *T. palmi* was able to transmit CaCV (isolate not specified) in Australia, citing Persley, Thomas and Sharman (2006) also on the basis of their unpublished data. This comparison is across two independent unsubstantiated studies, where any variances could equally be attributed to dissimilar experimental conditions.

On the basis of the evidence, there is no data that shows significant differences in economic consequences between CaCV-Ph and Australian CaCV isolates, and CaCV-Ph is considered to be the same as CaCV-Qld3432.

Table 4.2 Pest categorisation of orthotospoviruses

Orthotospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
<i>Alstroemeria necrotic streak virus</i> [ICTV official recognition pending]	ANSV	S. America (Colombia) (Hassani-Mehraban et al. 2010)	No records found (recently described)	<i>Frankliniella occidentalis</i> (Hassani-Mehraban et al. 2010)	Yes. ANSV was described in Colombia infecting <i>Alstroemeria</i> sp. causing necrotic streaks on leaves (Hassani-Mehraban et al. 2010). Transmission by mechanical inoculation to petunia and cucumber caused localized symptoms, while pepper and tomato became systemically infected (Hassani-Mehraban et al. 2010). Natural infection of tomato and pepper has been reported in Colombia (Olaya et al. 2017). The full economic impact of ANSV is still to be determined, but there is potential for economic consequences to Australia from this virus.	<i>Alstroemeria</i> sp.	Yes
<i>Bean necrotic mosaic virus</i> [ICTV official recognition pending]	BeNMV	S. America (Michels et al.) (de Oliveira et al. 2011)	No records found (recently described)	Species unknown (de Oliveira et al. 2011; 2012)	Yes. BeNMV was described in Brazil infecting <i>Phaseolus vulgaris</i> (common bean) (de Oliveira et al. 2011), where it is a significant legume crop. The extent of BeNMV natural host plant range is unknown. Transmission by mechanical inoculation occurred with Chenopodiaceae, Cucurbitaceae, Fabaceae and Solanaceae species (de Oliveira et al. 2012). Although <i>P. vulgaris</i> exhibited systemic infection, symptoms observed in the field were not totally reproducible. <i>Datura stramonium</i> (Solanaceae) symptoms consisted of mottling, necrotic lesions, foliar deformation and stunting, while <i>Physalis pubescens</i> plants exhibited mottling and stunting. Local symptom expression occurred in Cucurbitaceae plants. This initial data may suggest a limited range of host plants, but the full economic impact of BeNMV is still to be determined, and there is potential for economic consequences to Australia from this virus.	common bean	Yes

Orthotospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
<i>Calla lily chlorotic spot virus</i> [ICTV official recognition pending]	CCSV	E. & SE Asia (Pappu, Jones & Jain 2009)	No records found (Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006)	<i>Thrips palmi</i> (Chen et al. 2005)	Yes. CCSV was isolated from <i>Zantedeschia</i> sp. (calla lilies) in Taiwan (Chen et al. 2005). Symptoms include chlorosis, yellow spots radiating from midrib toward the leaf margin. Liu et al. (2012) report CCSV naturally infecting <i>Hymenocallis littoralis</i> (spider lily) and tobacco in China. Of 35 plant species mechanically inoculated, 24 were susceptible to CCSV, including wax gourd (<i>Benincasa hispida</i>) and zucchini squash (<i>Cucurbita pepo</i>). <i>Thrips palmi</i> experimentally transmitted CCSV from wax gourd to wax gourd and zucchini squash plants (Chen et al. 2005). The full economic impact of CCSV is still to be determined, but there is potential for economic consequences to Australia from this virus.	calla lily, spider lily, tobacco	Yes
<i>Capsicum chlorosis virus</i> (syn. Gloxinia ringspot virus, Gloxinia tospovirus, Thailand tomato tospovirus, Tomato necrosis virus TD8, <i>Capsicum chlorosis virus Phalaenopsis</i> strain–CaCV-Ph) [ICTV official recognition pending]	CaCV	Asia, Australasia (Pappu, Jones & Jain 2009); N. America (Hawaii) (Melzer et al. 2014)	Yes (McMichael, Persley & Thomas 2002; Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006). Unlisted by WA (Government of Western Australia 2016) and declared list A disease by Tas. (DPIPWE Tasmania 2015). However, its vector <i>F. schultzei</i> is permitted entry by WA (Government of Western Australia 2016) and not regulated by Tas. (DPIPWE Tasmania 2015)	<i>Ceratothripoides claratris</i> (Premachandra et al. 2005a); <i>Frankliniella schultzei</i> and <i>Thrips palmi</i> (Persley, Thomas & Sharman 2006)—stated as being a vector, but on the basis of unpublished data	No. Zheng et al. (2008) considered a CaCV isolate from <i>Phalaenopsis</i> in Taiwan as a distinct strain—designated CaCV-Ph. On the basis of this initial report, Australia regulated CaCV-Ph as a quarantine pest on <i>Phalaenopsis</i> orchids from Taiwan. Later molecular data by Widana et al. (2015) and Huang et al. (2017) confirm CaCV-Ph is most likely derived from an Australian CaCV isolate. There is no data that shows significant differences in economic consequences between CaCV-Ph and Australian CaCV isolates. Therefore, CaCV-Ph cannot now meet the definition of a quarantine pest, and there is no technical justification to continue its regulation. Additional background on CaCV-Ph is provided within the notes to this table.	tomato, chilli/ sweet peppers, peanuts, calla lily, wax-flower <i>Phalaenopsis</i> spp.	No

Orthotospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
<i>Chrysanthemum stem necrosis virus</i> [ICTV official recognition pending]	CSNV	E. & SE Asia (Japan, South Korea) (Yoon, Choi & Choi 2016), S. and SW Asia (IR) (Jafarpour 2010), S. America (Michels et al.) (Pappu, Jones & Jain 2009), Europe (de Jonghe, Morio & Maes 2013)—declared eradicated from Europe (EPP0 2005), except for a recent incursion in Italy, that is under official control (EPP0 2014b)	No records found (Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006)	<i>F. occidentalis</i> (Nagata et al. 2004; Nagata & De Ávila 2000); <i>F. schultzei</i> (Nagata et al. 2004; Nagata & De Ávila 2000); <i>F. intonsa</i> Okuda et al. (2013) report a strain of <i>F. Intonsa</i> that acquired CSNV, but only as a very weak vector and under experimental conditions. This is insufficient evidence of this species being a natural vector. However, this will be kept under review.	Yes. CSNV was first described in Brazil on chrysanthemum during a survey in the mid-1990s (Nagata et al. 1994). It was designated as CSNV by Bezerra et al. (1999). CSNV symptoms on chrysanthemum include necrotic lesions surrounded by yellow areas on leaves followed by necrosis on stems, peduncles and floral receptacles (Duarte et al. 1995). CSNV also infects tomato and symptoms include stem necrosis with necrotic spots and rings on leaves (Nagata et al. 1998). CSNV infected Brazilian chrysanthemum cuttings were alleged as causing several incursions in Europe (de Jonghe, Morio & Maes 2013; Mumford et al. 2003; Ravnkar et al. 2003; Verhoeven & Roenhorst 1998). In Japan, CSNV has affected chrysanthemum (Matsuura, Kubota & Okuda 2007) and tomato (Kuwabara & Sakai 2008) production. Momonoi et al. (2011) report CSNV causing necrotic streaks on stems and necrosis on leaves of aster (<i>Callistephus chinensis</i>) and lisianthus (<i>Eustoma grandiflorum</i>) in Japan. Duarte et al. (1995) report mechanical transmission to tobacco. Takeshita et al. (2011) report mechanical transmission to capsicum, resulting in systemic infection, and to aubergine with local infection. This might suggest CSNV has a broader host range. There is potential for economic consequences to Australia from this virus.	tomato, chrysanthemum, aster, lisianthus	Yes
<i>Groundnut bud necrosis orthotospovirus</i> (syn. Groundnut bud necrosis virus, Peanut bud necrosis virus)	GBNV	Asia (Pappu, Jones & Jain 2009)	No records found (Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006)	<i>Frankliniella schultzei</i> (Meena et al. 2005); <i>Scirtothrips dorsalis</i> (German, Ullman & Moyer 1992; Meena et al.	Yes. GBNV was first recorded infecting peanuts in India (Reddy, Reddy & Appa Rao 1968), although at first thought to be a strain of TSWV (Jones 2005). By the mid-1990's, its impact on production in Asia was estimated at about US \$89 million per annum (Reddy et al. 1995), and it is a significant pest of crops such as peanut, potato, tomato and soybean in countries such as China,	potato, tomato, onion, soybean, peanut, peas, mungbeans, watermelon, jute, taro	Yes

Orthospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
				2005); <i>Thrips palmi</i> (Lakshmi et al. 1993; Reddy et al. 1992)	India, Iran, Nepal, Sri Lanka and Thailand (Pappu, Jones & Jain 2009). In India, disease incidence of up to 90 per cent was recorded on peanut production (Singh & Srivatava 1995) and up to 29 per cent for potato (Singh et al. 1997). On mungbean it caused necrosis of leaves, stems, petioles, buds, pods and growing points with disease incidence up to 70 per cent (Thien, Bhat & Jain 2003). In southern India, GBNV has been reported as being responsible for farmers abandoning watermelon production (Singh & Krishnareddy 1996). GBNV has been reported as widely distributed and having significant impacts on peanut production in Thailand (Chiemsoombat et al. 2008). GBNV was discovered in Indonesia during a survey of stunted tomato production in 2009 (Damayanti & Naidu 2009). Recently, GBNV was reported in India for the first time infecting peas (Akram & Naimuddin 2010), taro (Sivaprasad et al. 2011), jute (Sivaprasad et al. 2001) and onion (Sujitha et al. 2012), and in Bangladesh on tomato (Akhter et al. 2012). This suggests that the reported host plant range and distribution of GBNV are still expanding. There is potential for economic consequences to Australia from this orthospovirus.		
<i>Groundnut chlorotic fan-spot virus</i> (syn. Peanut chlorotic fan-spot virus) [ICTV official recognition pending]	GCFSV	E. & SE Asia (Taiwan) (Chen & Chiu 1996; Chu et al. 2001). Note Pappu et al. (2009) in error state presence in S. America and absence	No records found (Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006)	<i>Scirtothrips dorsalis</i> (Chen & Chiu 1996; Chu et al. 2001)	Yes. GCFSV was first observed during 1992 as an orthospovirus-like virus isolated from peanut in central Taiwan (Chen & Chiu 1996). The virus was named GCFSV by Elliot et al. (2000) and characterized by Chu et al. (2001). GCFSV symptoms include large chlorotic, fan-shaped spots and concentric rings on leaves that later yellow, brown and then become necrotic (Chen & Chiu 1996). In Taiwan, GCFSV disease incidence was correlated with season, with lower incidence in the warm, dry summer months (July to	peanut	Yes

Orthospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
		from Asia referencing Chen and Chiu (1996) who report GCFSV in Taiwan. Chu et al. (2001) confirm GCFSV presence in Taiwan.			September). There is potential for economic consequences to Australia from this virus.		
<i>Groundnut ringspot orthospovirus</i> (syn. Groundnut ringspot virus)	GRSV	Africa, S. America (Pappu, Jones & Jain 2009), N. America (Florida) (Webster et al. 2010), Europe (Finland) (EPPO 2015)	No records found (Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006)	<i>Frankliniella gemina</i> (de Borbon, Gracia & De Santis 1999); <i>F. intonsa</i> (Wijkamp et al. 1995); <i>F. occidentalis</i> (Nagata et al. 2004; Wijkamp et al. 1995); <i>F. schultzei</i> (de Borbón, Gracia & Piccolo 2006; Nagata et al. 2004; Wijkamp et al. 1995)	Yes. GRSV was first isolated from peanut from South Africa (De Avila et al. 1993), and has been reported infecting soybean with leaf mottle symptoms (Pietersen & Morris 2002). GRSV has been reported in Brazil infecting coriander (Lima et al. 1999), lettuce (Chaves et al. 2001) and cubiu (<i>Solanum sessiliflorum</i>) (Boari et al. 2002). The first report of GRSV infection in Argentina was on tomato (Dewey et al. 1995). It was later reported causing necrotic spots on leaves and necrotic streaks along the petioles and stems of potato plants (Granval de Millan & Piccolo 1998) and in tomato and lettuce (Gracia et al. 1999). In Argentina, GRSV is of concern in peanut production (de Breuil et al. 2007; de Breuil et al. 2008). Alexandre et al. (1999) report GRSV infection of China aster (<i>Callistephus</i> sp.), and lisianthus (<i>Eustoma grandiflorum</i>) as mixed infections with other orthospoviruses—CSNV, TCSV or TSWV. Cucumber (<i>Cucumis sativus</i>) and chilli pepper (<i>Capsicum annuum</i>) were infected in commercial glasshouse production in Brazil (Spadotti et al. 2014). GRSV was also detected in a commercial crop of potted begonia in Northern Finland but is under official control (EPPO 2015).	potato, tomato, peanut, soybean, chilli pepper, coriander, lettuce, cucumber, aster, begonia and possibly lisianthus	Yes

Orthospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
					It was also reported in Ghana infecting peanut production (EPPO 2015). There is potential for economic consequences to Australia from this orthospovirus.		
<i>Groundnut yellow spot orthospovirus</i> (syn. Groundnut yellow spot virus, Peanut yellow spot virus-[sweet pepper], Peanut yellow spot virus)	GYSV	Asia (Pappu, Jones & Jain 2009)	No records found (Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006)	<i>Scirtothrips dorsalis</i> (Gopal et al. 2010)	Yes. GYSV was described as a disease of peanut by Reddy et al. (1991) and characterized by Satyanaryana et al. (1998; 1996). Symptoms of GYSV include chlorotic, yellow leaf spots that coalesce and become necrotic. GYSV incidence of up to 90% was observed in southern India, but yield loss was not reported (Reddy et al. 1991). The natural host plant range of GYSV is currently not known, but in India GYSV is considered of less economic importance to vegetable production than other orthospoviruses because it only causes occasional impacts beyond peanut (Kunkalikal et al. 2011). The full economic impact of GYSV is still to be determined, but there is potential for economic consequences to Australia from this orthospovirus.	peanut	Yes
<i>Hippeastrum chlorotic ringspot virus</i> (syn. Spider lily necrotic spot virus) [ICTV official recognition pending]	HCRV	E. & SE Asia (China) (Dong et al. 2013)	No records found (recently described)	Species unknown (Dong et al. 2013), but <i>Taeniothrips eucharis</i> are competent to transmit HCRV experimentally, and field collected thrips tested positive for HCRV (Xu et al. 2017). This is insufficient evidence of this species being a natural vector.	Yes. HCRV was isolated from <i>Hippeastrum</i> host plants that displayed necrotic and chlorotic ringspot symptoms in China (Dong et al. 2013). From 2009 –12, a survey of 10 major parks and recreation areas in Kunming, the capital of Yunnan Province, China, indicated that almost 100 per cent of spider lily plants had symptoms of concentric ring spots and necrotic spots attributed to HCRV (Xu et al. 2013). The surveys found <i>Philodendron bipinnatifidum</i> with symptoms of vein necrosis and chlorotic lesions; <i>Hippeastrum rutilum</i> with concentric rings; and <i>Nicotiana tabacum</i> with necrotic spots. Dong et al. (2013) mechanically inoculated tomato, tobacco and capsicum plants with HRCV resulting in systemic infection. They also re-inoculated HCRV onto <i>Phalaenopsis</i> resulting in systemic	various ornamentals including <i>Hippeastrum</i> spp. and <i>Philodendron bipinnatifidum</i> , and tobacco (<i>Nicotiana tabacum</i>)	Yes

Orthotospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
				However, this will be kept under review.	infection of new growth. Xu et al. (2013) also report mechanical inoculation studies of HCRV which resulted in systemic expression on tomato (<i>Solanum lycopersicum</i>), winter squash (<i>Cucurbita moschata</i>), cucumber (<i>Cucumis sativus</i>), bean (<i>Phaseolus vulgaris</i>), cowpea (<i>Vigna unguiculata</i>), nasturtium (<i>Tropaeolum majus</i>), lilac, tasselflower (<i>Emilia sonchifolia</i>) and lettuce (<i>Lactuca sativa</i>). This may suggest a broader range of crops are at potential risk from HCRV. There is potential for economic consequences to Australia from this virus.		
<i>Impatiens necrotic spot orthotospovirus</i> (syn. <i>Impatiens necrotic spot virus</i>)	INSV	Africa, Asia, Australasia, Europe, N. America, S. America (Pappu, Jones & Jain 2009)	Not present, eradicated, following an incursion in 2010 (PHA & NGIA 2011)	<i>Frankliniella intonsa</i> (Sakurai, Inoue & Tsuda 2004); <i>F. occidentalis</i> (deAngelis, Sether & Rossignol 1993; Sakurai, Inoue & Tsuda 2004; Wijkamp et al. 1995); <i>F. fusca</i> (Naidu, Deom & Sherwood 2001)	Yes. INSV was first isolated from impatiens (Balsaminaceae) in the USA during the late 1980s as a serologically distinct member of the TSWV group. Law <i>at al.</i> (1991) proposed it as a new species. INSV has a wide host plant range. For instance, in Europe and the USA, INSV infects a range of ornamental crops ((Blockley & Mumford 2001; Daughtrey et al. 1997) as in Iran (Shahraeen, Ghotbi & Mehraban 2002) and elsewhere. Ornamental hosts include <i>Oncidium</i> orchids (Koike & Mayhew 2001), <i>Phalaenopsis</i> and <i>Dendrobium</i> orchids (Zhang, Ding & Li 2010), <i>Anthurium</i> (Ghotbi 2013; Mertelik et al. 2002), <i>Amaryllis</i> (Verhoeven & Roenhorst 1998), chrysanthemum (Verhoeven & Roenhorst 1998), <i>Alstroemeria</i> (Ghotbi 2013; Verhoeven & Roenhorst 1998), <i>Dracaena</i> (Ghotbi 2013; Ghotbi & Shahraeen 2012; Hausbeck et al. 1992), <i>Ficus</i> spp.(Ghotbi 2013; Ghotbi, Shahraeen & Winter 2005), <i>Gerbera jamesonii</i> (Elliott et al. 2009; Hausbeck et al. 1992), Kalanchoe (McDonough, Gerace & Ascerno 1999), <i>Impatiens</i> spp. (Hausbeck et al. 1992), <i>Pelargonium</i> spp. (Daughtrey 1996; Daughtrey et al. 1997; Ghotbi, Shahraeen & Winter 2005; Hausbeck et al. 1992;	potato, peanut, sweet pepper, lettuce, cucumber, tobacco, herbs, vegetables, many ornamentals, including <i>Alstroemeria</i> , <i>Phalaenopsis</i> , <i>Oncidium</i> and <i>Dendrobium</i> orchids, <i>Dracaena</i> , <i>Anthurium</i> , <i>Rosa</i> , <i>Ficus</i> , <i>Gerbera</i> , <i>Kalanchoe</i> , <i>Pelargonium</i> , <i>Impatiens</i> , <i>Schlumbergera</i> , <i>Zantedeschia</i> and several weed species	Yes

Orthotospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
					Shahraeen, Ghotbi & Mehraban 2002), <i>Oncidium</i> (Koike & Mayhew 2001), <i>Rosa spp.</i> (Ghotbi & Shahraeen 2012), <i>Schlumbergera truncata</i> (Hausbeck et al. 1992) and <i>Zantedeschia</i> (Elliott et al. 2009; Rizzo et al. 2012; Verhoeven & Roenhorst 1998). INSV also infects a range of vegetables and herbs. In the Netherlands, INSV hosts include pepino (<i>Solanum muricatum</i>), spinach and sweet pepper (Verhoeven & Roenhorst 1998). In Italy, field lettuce, glasshouse cucumber and sweet peppers have been infected (Vicchi, Fini & Cardoni 1999). In USA, INSV hosts include peanut (Pappu et al. 1999a; Wells et al. 2001), tobacco (Martínez-Ochoa et al. 2003), potato (Perry, Miller & Williams 2005); sweet pepper (Naidu, Deom & Sherwood 2005), lettuce (Koike et al. 2008) and spinach (Liu, Sears & Mou 2009). INSV was first detected in New Zealand in 2003 and again in 2006 and declared non-eradicable (Elliott et al. 2009). Recently, basil (<i>Ocimum basilicum</i>), rocket (<i>Eruca sativa</i>) and chervil (<i>Anthriscus cerefolium</i>) have been added as INSV hosts in Austria (Grausgruber-Gröger 2012). Additionally, INSV has several weed hosts (Kuo et al. 2014). This suggests that the reported host plant range and distribution of INSV are still expanding. There is potential for economic consequences to Australia from this orthotospovirus.		
<i>Iris yellow spot orthotospovirus</i> (syn. <i>Iris yellow spot virus</i>)	IYSV	Africa, Asia, Australasia, Europe, N. America, S. America (Pappu, Jones & Jain 2009)	Yes (Coutts et al. 2003; Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006). Permitted by WA (Government of Western Australia	<i>Thrips tabaci</i> (Cortes et al. 1998; Hsu et al. 2010); <i>Frankliniella fusca</i> (Mound et al. 2012)	Yes. IYSV was first isolated from iris in the Netherlands in 1992, and characterized as a distinct orthotospovirus species by Cortes et al. (1998). IYSV significantly impacts onion and ornamental production (Jones 2005; Pappu, Jones & Jain 2009). IYSV has resulted in significant impact on onion production in Spain (Córdoba-Sellés et al. 2005), Germany (Leinhos et al. 2007)	onion, garlic, leeks, cowpea, iris and several ornamentals	No

Orthospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
			2016). Declared list A disease by Tas. (DPIPWE Tasmania 2015), but its vector <i>T. tabaci</i> is an unwanted quarantine pest, which is not officially regulated by Tas. (DPIPWE Tasmania 2015)		and France (Huchette et al. 2008). In North America major losses in yield of both seed and bulb onion crops have been recorded (Gent et al. 2006; Poole et al. 2007). IYSV has also been recently recorded in Canada (Hoepting et al. 2008). In South America IYSV impacts onion production in Chile and Peru (Mullis et al. 2006; Rosales et al. 2005). In India, IYSV has been reported infecting onion (Ravi, Kitkaru & Winter 2006) and garlic (Gawande, Khar & Lawande 2010). IYSV is also present in New Zealand (Ward et al. 2008). In 2002, IYSV was first reported in Australia infecting onions and leeks, although it is believed to have been present prior to this time (Coutts et al. 2003; Jones 2005). A new orthospovirus/thrips combination could emerge that increases the economic impact of endemic orthospoviruses as was the case for the global emergence <i>F. occidentalis</i> with TSWV (2005) and INSV globally (Daughtrey et al. 1997). However, IYSV is present in Australia and not under official control, and consequently not a quarantine pest for Australia.		
<i>Lisianthus necrotic ringspot virus</i> [ICTV official recognition pending]	LNRV	E. & SE Asia (Japan) (Shimomoto, Kobayashi & Okuda 2014)	No records found (recently described)	Species unknown (Shimomoto, Kobayashi & Okuda 2014)	Yes. LNRV was reported infecting <i>Lisianthus (Eustoma grandiflorum)</i> in Japan (Shimomoto, Kobayashi & Okuda 2014). Several new orthospoviruses have become a significant threat to crops and <i>Lisianthus</i> is a major cut-flower crop in Japan. Symptoms reported included necrotic ringspots. Initial mechanical transmission studies may suggest that LNRV has a relatively narrow host range (Shimomoto, Kobayashi & Okuda 2014). However, the full economic impact of LNRV is still to be determined, but there is potential for economic consequences to Australia from this virus.	lisianthus	Yes

Orthotospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
<i>Melon severe mosaic virus</i> [ICTV official recognition pending]	MeSMV	N. America (Mexico) (Ciuffo et al. 2009)	No records found (Pappu, Jones & Jain 2009)	Species unknown, but <i>F. occidentalis</i> was present on MeSMV-infected plants (Ciuffo et al. 2009)	Yes. MeSMV was reported from Mexico (Ciuffo et al. 2009). Symptoms reported on infected melon (<i>Cucumis melo</i>) included mosaic and leaf blistering, leaf deformation, necrosis and fruit splitting. Surveys indicate that it has widespread occurrence in cucurbit crops in Mexico. MeSMV was found infecting melon, watermelon, cucumber and zucchini. Ciuffo et al. (2009) suggest that MeSMV has in recent years been emerging in cucurbits crops, especially on melon and watermelon, sometimes reducing production by up to 30 per cent. The full economic impact of MeSMV is still to be determined, but there is potential for economic consequences to Australia from this virus.	melon, watermelon, zucchini, cucumber	Yes
<i>Melon yellow spot virus</i> (syn. <i>Physalis severe mottle virus</i>) [ICTV official recognition pending]	MYSV	E. & SE Asia (Pappu, Jones & Jain 2009), S. America (Ecuador) (Quito-Avila et al. 2014)	No records found (Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006)	<i>Thrips palmi</i> (Kato, Hanada & Kameya-Iwaki 2000)	Yes. MYSV was identified as causing an outbreak of a serious disease in netted melon (<i>Cucumis melo</i>) in Japan (Kato, Hanada & Kameya-Iwaki 2000). Symptoms included leaf yellowing and necrotic spots and fruit mosaic patterning affecting quality and taste. The disease was reported as causing considerable crop losses (Kato, Hanada & Kameya-Iwaki 1999). MYSV was reported to also infect cucumber in Japan (Okuda et al. 2004). Peng et al. (2011) advise that MYSV has become a serious threat to commercial watermelon (<i>Citrullus lanatus</i>) and melon production in Taiwan. It is also reported as present in Thailand (Chatchawankanphanich 2017). There is potential for economic consequences to Australia from this virus.	melon, watermelon, cucumber	Yes
<i>Mulberry vein banding associated virus</i>	MVBaV	E. & SE Asia (China) (Meng et al. 2015)	No records found (recently described)	Species unknown (Meng et al. 2015)	Yes. Meng et al. (Meng et al. 2015) identified MVBaV as a new orthotospovirus infecting mulberry plants (<i>Morus spp.</i>) in China (Meng et al. 2015). MVBaV infected plants display typical vein banding symptoms. Also, MVBaV is considered to	Mulberry	Yes

Orthospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
[ICTV official recognition pending]					be a substantial threat to the silkworm industry in China because of the high incidence of MVBaV in Chinese mulberry orchards and the high yield loss associated with this virus (Meng et al. 2013). MVBaV has been shown to be transmitted by grafting (Meng et al. 2015) but the extent of its natural host plant range is still unknown. The full economic impact of MVBaV is still to be determined, but there is potential for economic consequences to Australia from this virus		
<i>Pepper chlorotic spot virus</i> [ICTV official recognition pending]	PCSV	E. & SE Asia (Taiwan) (Cheng et al. 2013)	No records found (recently described)	Species unknown (Cheng et al. 2013)	Yes. Cheng et al. (2013) recently characterized a disease impacting sweet pepper production in Taiwan in 2009 and 2010. They considered this to be a new orthospovirus, <i>Pepper chlorotic spot virus</i> (PCSV). The extent of PCSV natural host plant range is unknown. Mechanical transmission of PCSV occurred to a range of species (19 out of 26 tested), including sweet pepper, chilli pepper, mungbean (<i>Vigna radiata</i>) and <i>Phalaenopsis</i> orchid cultivars (Cheng et al. 2013). However, cucurbits appear not to be hosts. The full economic impact of PCSV is still to be determined, but there is potential for economic consequences to Australia from this virus.	sweet pepper	Yes
<i>Pepper necrotic spot virus</i> [ICTV official recognition pending]	PNSV	S. America (Peru) (Torres et al. 2012)	No records found (recently described)	Species unknown (Torres et al. 2012)	Yes. PNSV was recently reported infecting solanaceous crops (tomato and peppers) in Peru by Torres et al. (2012). Two isolates of the virus were identified. A pepper isolate could infect both pepper and tomato, whereas a tomato isolate did not infect pepper, nor induce systemic infection symptoms. The full economic impact of PNSV is still to be determined, but there is potential for economic consequences to Australia from this virus.	tomato, pepper	Yes

Orthospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
<i>Polygonum ringspot orthospovirus</i> (syn. <i>Polygonum ringspot virus</i>)	PolRSV	Europe (Pappu, Jones & Jain 2009)	No records found (Pappu, Jones & Jain 2009)	<i>Dictyothrips betae</i> (Ciuffo et al. 2010)	Yes. PolRSV was first isolated in Italy from wild buckwheat (<i>Polygonum convolvulus</i>) by Ciuffo et al. (2008) and <i>Dictyothrips betae</i> was identified as its vector (Ciuffo et al. 2010). This thrips is widespread across Palearctic Europe (Riley et al. 2011b) with a natural host plant range that appears restricted to the genus <i>Polygonum</i> (Ciuffo et al. 2010; Ciuffo et al. 2008). This thrips is recorded on sugar beet (Priesner 1928), but there is no contemporary evidence for sugar beet being a PolRSV host plant. Mechanical transmission studies imply PolRSV may have a wider host plant range, including solanaceous species (Ciuffo et al. 2008). PolRSV appears atypical in its natural host plant range being limited only to <i>Polygonum</i> species. Furthermore, not all thrips vectors are present within its current European distribution, and PolRSV might have more efficient vectors that could transmit it to economic crops. The full economic impact of PolRSV is still to be determined, although, current data implies a low economic consequences, uncertainty exists, and there is still potential for economic consequences to Australia from this orthospovirus.	<i>Polygonum</i> sp.	Yes
Reassortant from <i>Groundnut ringspot virus</i> and <i>Tomato chlorotic spot virus</i> (syn. L _G M _T S _G) [ICTV official recognition pending]	L _G M _T S _G	N. America (Florida) (Webster et al. 2011)	No records found (recently described)	<i>Frankliniella occidentalis</i> (Webster et al. 2011)	Yes. Webster et al. (2011) reported a virus causing severe orthospovirus infection on tomato production in Florida. Symptoms included chlorotic and necrotic areas on leaves, and necrosis of petioles and stems that were commonly more severe than TSWV. They reported the natural reassortment of genomic segments between <i>Groundnut ringspot orthospovirus</i> (GRSV) and <i>Tomato chlorotic spot orthospovirus</i> (TCSV). Neither parental genotype is known to be present in the USA, implying it was introduced in its current form.	tomato	Yes

Orthospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
					The full economic impact of L ₆ M _T S _G is still to be determined, but there is potential for economic consequences to Australia from this orthospovirus.		
<i>Soybean vein necrosis virus</i> (syn. Soybean vein necrosis-associated virus) [ICTV official recognition pending]	SVNV	N. America (Zhou et al. 2011)	No records found (recently described)	Species unknown (Zhou et al. 2011), but soybean thrips <i>Neohydatothrips variabilis</i> (syn. <i>Sericothrips variabilis</i>) are competent to transmit SVNV experimentally (Zhou & Tzanetakis 2013). There is insufficient evidence of this species being a natural vector. However, this will be kept under review.	Yes. Tzanetakis et al. (2009) first reported virus infection symptoms on soybean production in Tennessee during 2008, and Zhou et al. (2011) characterized SVNV as the causal agent. It has since rapidly spread across the USA and Ontario, Canada (NCSRP 2015) and is now present in all major soybean production areas. Symptoms include leaf intravascular chlorosis and necrosis, and in severe cases, plants die-off as the season progresses. Incidence is highly variable among fields, 10 to 80 per cent, depending on growth stage cultivar and geographic areas. The full economic impact of SVNV is still to be determined, but there is potential for economic consequences to Australia from this virus.	soybean	Yes
<i>Tomato chlorotic spot orthospovirus</i> (syn. Tomato chlorotic spot virus)	TCSV	N. America (Florida) and S. America (Brazil, Argentina, Haiti) (Adegbola et al. 2016; Londoño et al. 2012) (Pappu,	No records found (Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006)	<i>Frankliniella intonsa</i> (Wijkamp et al. 1995), <i>F. occidentalis</i> (Nagata et al. 2004; Whitfield, Ullman & German 2005), <i>F. schultzei</i> (Nagata et al.	Yes. TCSV was first described affecting tomato production in Brazil (De Avila et al. 1993). In Brazil, it has also been reported infecting sweet pepper (Boiteux et al. 1993a), lettuce (Colariccio et al. 2001b), endive (<i>Cichorium endiva</i>) (Colariccio et al. 2001a) and gilo (<i>Solanum gilo</i>) (Eiras et al. 2002; Rabelo et al. 2002). TCSV has recently been reported infecting cape gooseberry in Brazil (<i>Physalis peruviana</i>) causing stunting, mosaic, necrosis and foliar distortion (Eiras et al. 2012). In Argentina, TCSV has been reported infecting celery, lettuce, lisianthus, potato, sweet	potato, tomato, sweet pepper, celery, lettuce, peanut, endive, gilo, lisianthus, weeds, <i>Portulaca oleracea</i> , cape gooseberry	Yes

Orthospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
		Jones & Jain 2009)		2004; Wijkamp et al. 1995)	pepper, tomato, weed species including <i>Portulaca oleracea</i> (Dal Bó et al. 1999; Gracia et al. 1999; Granval de Millan & Piccolo 1998; Jones 2005). During 2012, orthospovirus like symptoms were observed on tomatoes in Florida and confirmed as the first incidence of TCSV in the USA (Londoño et al. 2012), and subsequently in Ohio (Baysal-Gurel et al. 2014). This suggests that the reported host plant range and distribution of TCSV are still expanding. There is potential for economic consequences to Australia from this orthospovirus.		
<i>Tomato necrotic ringspot virus</i> [ICTV official recognition pending]	TNRV	E. & SE Asia (Thailand) (Puangmalai et al. 2013)	No records found (recently described)	<i>Ceratothripoides claratris</i> (Seepiban et al. 2011); <i>Thrips palmi</i> (Seepiban et al. 2011)	Yes. TNRV was first reported in Thailand (Chiamsombat et al. 2010; Hassani-Mehraban et al. 2011; Seepiban et al. 2011). In 2008, tomato plants showing distinctive orthospovirus symptoms of yellowing and necrotic rings on leaves and fruits in a Chiang Mai greenhouse. The virus is now considered widely spread in Thailand and reported as causing severe yield losses in tomato and sweet pepper production (Puangmalai et al. 2013). Although the full economic impact of TNRS is still to be determined, there is potential for economic consequences to Australia from this virus.	tomato, chilli peppers	Yes
<i>Tomato necrotic spot-associated virus</i> (syn. Tomato necrotic spot virus) [ICTV official recognition pending]	TNSaV	E. & SE Asia (China) (Yin et al. 2014)	No records found (recently described)	Species unknown (Yin et al. 2014), although <i>Thrips tabaci</i> and <i>T. palmi</i> were found within tomato fields and the nearby weeds. This is insufficient evidence of this species being a	Yes. TNSaV, a putative new orthospovirus, was recently reported infecting tomato crops in Guizhou province, southwest China (Yin et al. 2014; Zheng et al. 2016). TNSaV symptoms include necrotic and concentric ringspots on fruits. Mechanical transmission studies imply TNSaV may have a wider host plant range, including solanaceous species (Yin et al. 2014). Although, the full economic impact of TNSaV is still to be determined, there is potential for	tomato	Yes

Orthospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
				natural vector. However, this will be kept under review.	economic consequences to Australia from this virus.		
<i>Tomato spotted wilt orthospovirus</i> (syn. Tomato spotted wilt virus)	TSWV	Africa, Asia, Australasia, Europe, N. America, S. America (Pappu, Jones & Jain 2009)	Yes (Latham & Jones 1997; Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006).	<i>Frankliniella bispinosa</i> (Avila et al. 2006); <i>F. cephalica</i> (Ohnishi, Katsuzaki & Tsuda 2006); <i>F. fusca</i> (Sakimura 1963); <i>F. gemina</i> (de Borbón, Gracia & Piccolo 2006); <i>F. intonsa</i> (Wijkamp et al. 1995); <i>F. occidentalis</i> (Wijkamp et al. 1995); <i>F. schultzei</i> (Wijkamp et al. 1995); <i>Thrips palmi</i> (Fujisawa, Tanaka & Ishii 1988; Persley, Thomas & Sharman 2006); <i>T. setosus</i> (Fujisawa, Tanaka & Ishii 1988; Persley, Thomas & Sharman 2006); <i>T. tabaci</i>	Yes. TSWV has significant economic impacts over a wide range of crops and is cosmopolitan in distribution (Jones 2005; Pappu, Jones & Jain 2009). Hosts include numerous <i>Solanaceae</i> , <i>Asteraceae</i> and <i>Fabaceae</i> species. TSWV infection impacts on yield and quality to varying degrees, depending on crop, timing and incidence of infection. Stunted growth is a common symptom of TSWV infection, and is usually more severe when young plants are infected. Chlorotic or necrotic rings commonly form on the leaves of many infected hosts, and fruit are often distorted with necrotic spots or ring patterns. Jones (2005) provides the historical perspective to the emergence of TSWV in Australia from 1915 onwards. TSWV impacts on crops in Australia include tomato, capsicum, lettuce, potato and several ornamental species, including aster, calendula and chrysanthemum (Jones 2005; Persley, Thomas & Sharman 2006). In managing TSWV, two genes <i>Sw-5</i> and <i>Tsw</i> have been extensively bred into commercial cultivars of tomato (Riley et al. 2011a) and pepper (Gunter et al. 2012), respectively. TSWV resistance-breaking isolates have been reported globally overcoming the <i>Sw-5</i> and <i>Tsw</i> gene-based resistance (Chapter 4.2), including within Australia (Latham & Jones 1998; Sharman & Persley 2006), and these are not under official control. Consequently, there is no scientific justification for considering individual TSWV isolates as quarantine pests for Australia.	At least 1,090 host plant species over 15 families of monocotyledonous and 69 families of dicotyledonous plants are reported (Parrella et al. 2003), although, some historic records may be attributed to other orthospoviruses	No

Orthotospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
				(Wijkamp et al. 1995)			
<i>Tomato yellow ring virus</i> (syn. Tomato fruit yellow ring virus, TFYRV). TFYRV is stated to be an isolate of TYRV (Pappu, Jones & Jain 2009) [ICTV official recognition pending]	TYRV	S. & SW Asia, Africa (Birithia, Subramanian & Villinger 2012; 2008; Golnaraghi et al. 2007a; Hassani-Mehraban et al. 2005; Pappu, Jones & Jain 2009), Europe (Poland) (Zarzynska-Nowak et al. 2016)	No records found (recently described)	<i>Thrips tabaci</i> (Golnaraghi et al. 2008)	Yes. TYRV is reported infecting many hosts including potato, tomato, soybean, peppers, ornamentals and weeds in Iran (Ghotbi & Shahraeen 2012; Ghotbi, Shahraeen & Winter 2005; 2013; Golnaraghi et al. 2008; Rasoulpour & Izadpanah 2007; Winter et al. 2006). TYRV has been reported to be transmitted through potato tubers, at low frequency (Golnaraghi et al. 2007b). Symptoms of leaf and extensive stem necrosis are frequently observed in Iranian potato fields (Golnaraghi et al. 2008). TYRV has many ornamental hosts, including alstroemeria (Beikzadeh et al. 2012), chrysanthemum (Ghotbi, Shahraeen & Winter 2005), dracaena (Ghotbi & Shahraeen 2012), rose (Ghotbi & Shahraeen 2012; Ghotbi, Shahraeen & Winter 2005) and <i>Senecio cruentus</i> (Rasoulpour & Izadpanah 2007). In a survey of Kenyan tomato production areas, frequent TYRV infection with chlorotic ring spots on fruits, stems and leaf necrosis was reported (Birithia, Subramanian & Villinger 2012). TYRV has also been recently recorded in Poland (Zarzynska-Nowak et al. 2016). This suggests that the reported host plant range and distribution of TYRV are still expanding. There is potential for economic consequences to Australia from this virus.	potato, tomato, soybean, peppers, rosemary, weeds and many ornamentals that include rose, alstroemeria, dracaena, chrysanthemum, <i>Senecio cruentus</i>	Yes
<i>Tomato zonate spot virus</i> [ICTV official recognition pending]	TZSV	E. & SE Asia (Pappu, Jones & Jain 2009)	No records found (recently described)	Species unknown (Dong et al. 2009)	Yes. TZSV was first observed infecting tomato and chilli pepper crops in China during 2005 (Dong et al. 2008), and more recently in potato (Huang, Liu & Yu 2015) and kiwifruit (Wang et al. 2016). TZSV symptoms include concentric zoned ring spots on fruits and necrotic lesions on leaves of infected plants. TZSV has been recently reported as a natural host of <i>Hymenocallis</i>	tomato, chilli peppers, potato, spinach, taro, <i>Hymenocallis littoralis</i> , <i>Iris tectorum</i> and	Yes

Orthotospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
					<i>littoralis</i> , <i>Iris tectorum</i> and <i>Phalaenopsis amabilis</i> in Kunming, China (Huang et al. 2015). The full economic impact of TZSV is still to be determined, but there is potential for economic consequences to Australia from this virus.	<i>Phalaenopsis amabilis</i>	
<i>Watermelon bud necrosis orthotospovirus</i> (syn. Watermelon bud necrosis virus)	WBNV	S. & SW Asia (Pappu, Jones & Jain 2009)	No records found (Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006)	<i>Thrips palmi</i> (Jain et al. 1998; Pappu, Jones & Jain 2009)	Yes. WBNV was first described as a distinct species by Jain et al. (1998). WBNV has caused severe yield losses of up to 100 per cent in various cucurbitaceous crops in India (Jain et al. 2007; Mandal et al. 2003; Singh & Krishnareddy 1996). Symptoms on watermelon (<i>Citrullus lanatus</i>) include leaf mottling, yellowing and necrotic streaks on veins, shortened internodes, necrosis and dieback of buds (Jain et al. 1998). WBNV has also been reported in ridge gourd (<i>Luffa acutangula</i>) (Mandal et al. 2003), cucumber (<i>Cucumis sativus</i>) and bitter melon (<i>Momordica charantia</i>) (Jain et al. 2007). WBNV has also been reported infecting tomato and chilli pepper crops in India (Kunkaliker et al. 2011). This suggests that the reported host plant range of WBNV is still expanding. There is potential for economic consequences to Australia from this orthotospovirus.	Tomato, chilli peppers, watermelon and other cucurbits	Yes
<i>Watermelon silver mottle orthotospovirus</i> (syn. Watermelon silver mottle virus)	WSMoV	E. & SE Asia (Pappu, Jones & Jain 2009)	No records found (Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006)	<i>Thrips palmi</i> (Iwaki et al. 1984)	Yes. WSMoV was first reported infecting watermelon in Japan in 1982, and initially described as a strain of TSWV (Iwaki et al. 1984), before being considered a new orthotospovirus (Yeh & Chang 1995; Yeh et al. 1997). Symptoms include silver mottle on leaves, chlorotic mottle and malformed fruit which resulted in significantly reduced fruit yield and quality (Iwaki et al. 1984). WSMoV can cause significant tip necrosis and dieback and reduced fruit set. In 1988, WSMoV infected watermelon in Taiwan, where it caused severe losses and became a constraint on watermelon and other cucurbits	watermelon and other cucurbits, and calla lily	Yes

Orthotospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
					production (Yeh & Chu 1999; Yeh et al. 1992). Losses from WSMoV were also reported in Japan (Okuda et al. 2002). In 2009 and 2010, severely stunted watermelon plants were observed in greenhouses in Guangdong province, China, with shortened internodes, and associated yield losses. This was the first report of natural infection of watermelon by WSMoV in China (Rao et al. 2001). Chen et al. (2008a) report WSMoV natural infection of <i>Zantedeschia</i> (calla lily). There is potential for economic consequences to Australia from this orthotospovirus.		
<i>Zucchini lethal chlorosis orthotospovirus</i> (syn. Zucchini lethal chlorosis virus)	ZLCV	S. America (Pappu, Jones & Jain 2009)	No records found (Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006)	<i>Frankliniella zucchini</i> (Nakahara & Monteiro 1999)	Yes. ZLCV was first reported in Brazil (Pozzer et al. 1996; Resende et al. 1996; 1997). Nagata et al. (1998) confirmed cucurbits such as zucchini and cucumber as natural hosts of ZLCV. Evidence suggests ZLCV was sporadically infecting Brazilian crops earlier than this, but it was not until 1991 that it caused significant economic consequences, although for several years the causative agent was unknown or misidentified (Nakahara & Monteiro 1999). ZLCV in Brazil has a high incidence on zucchini and intermittently infects melon, watermelon and cucumber. Symptoms include, on zucchini, severe mosaic, leaf distortion, stunting and often plant death, or on melon, ringspots on leaves and fruit, fruit malformation and stunted growth (Bezerra et al. 1999; Nakahara & Monteiro 1999). There is potential for economic consequences to Australia from this orthotospovirus.	zucchini, melon, watermelon, cucumber	Yes

Table 4.3 Outcome of pest categorisation of orthotospoviruses

Thrips	Thrips interception events (a)	Thrips is a quarantine pest	Thrips transmits a quarantine pest orthotospovirus	Orthotospoviruses transmitted	
				Quarantine pests	Non-quarantine pests
<i>Ceratothripoides claratrix</i>	None recorded	Yes	Yes	TNRV	CaCV
<i>Dictyothrips betae</i>	None recorded	Yes	Yes	PolRSV	–
<i>Frankliniella bispinosa</i>	None recorded	Yes	No	–	TSWV
<i>F. cephalica</i>	None recorded	Yes	No	–	TSWV
<i>F. fusca</i>	Interception group E	Yes	Yes	INSV	IYSV, TSWV
<i>F. gemina</i>	None recorded	Yes	Yes	GRSV	TSWV
<i>F. intonsa</i> (c)	Interception group C	Yes	Yes	GRSV, INSV, TCSV	TSWV
<i>F. occidentalis</i> (b)	Interception group A	Yes (NT)	Yes	ANSV, CSNV, GRSV, INSV, L ₆ M ₇ S ₆ , TCSV	TSWV
<i>F. schultzei</i> (d, e)	Interception group B	No	Yes	CSNV, GBNV, GRSV, TCSV	CaCV, TSWV
<i>F. zucchini</i>	None recorded	Yes	Yes	ZLCV	–
<i>Scirtothrips dorsalis</i> (d)	Interception group B	No	Yes	GBNV, GYSV, GCFSV	–
<i>Thrips palmi</i> (b, e)	Interception group B	Yes (NT, SA, Vic. WA)	Yes	CCSV, GBNV, MYSV, WBNV, WSMoV	CaCV, TSWV
<i>T. setosus</i>	Interception group E	Yes	No	–	TSWV
<i>T. tabaci</i> (d)	Interception group A	No	Yes	TYRV	IYSV, TSWV
Unidentified vector(s) (f, g, h, i)	?	?	Yes	BeNMV, HCRV, LNRV, MeSMV, PCSV, PNSV, SVNV, TNSaV, TZSV, MVBaV	–

a. An interception event can refer to one or more thrips species being present, and the number of thrips present is not usually recorded. Interception events are averaged over 26 years (1986–2012) and expressed ranges, A–E (Appendix D). Values for each range are: A = greater than 250; B = 10–50; C = 0.5–5; D = 0.1–less than 0.5; E = less than 0.1 interception events per year. **b.** Thrips species that are present in Australia, but under official control for Australian States and Territories (given in parentheses). **c.** Okuda et al. (2013) report a putative strain of *F. intonsa* that weakly acquired and transmitted CSNV under experimental conditions, but natural transmission remains unconfirmed. **d.** Thrips species that are present in Australia and not currently under official control, but identified as transmitting orthotospovirus species that are quarantine pests for Australia. **e.** Persley et al. (2006) report *F. schultzei* and *T. palmi* as transmitting CaCV, but supporting evidence remains unpublished. **f.** Ciuffo et al. (2009) reported *F. occidentalis* as a potential vector due to its presence on MeSMV-infected plants. **g.** *Neohydatothrips variabilis* (syn. *Sericothrips variabilis*) is reported as transmitting SVNV experimentally (Zhou & Tzanetakis 2013), but natural transmission remains unconfirmed. **h.** Yin et al. (2014) report *Thrips tabaci* and *T. palmi* as being present within infected tomato crops and nearby weeds, but that they actually transmit TNSaV remains unconfirmed. **i.** *Taeniothrips eucharii* are competent to transmit HCRV experimentally, and field collected thrips tested positive for HCRV (Xu et al. 2017), but natural transmission is unconfirmed. Where a vector is unidentified this is indicated by a ‘?’.

4.7 Conclusion

Pest categorisation of orthotospoviruses is presented in Table 4.2, and a summary of the quarantine status of orthotospoviruses, and the thrips species which transmit them, is given in Table 4.3.

Pest categorisation identified 30 described orthotospoviruses (with 11 formally recognised as species by the International Committee on Taxonomy of Viruses), 27 of which are quarantine pests for Australia.

The orthotospoviruses that are quarantine pests for Australia are ANSV, BeNMV, CCSV, CSNV, GBNV, GCFSV, GRSV, GYSV, HCRV, INSV, LNRV, MeSMV, MVBaV, MYSV, PCSV, PNSV, PoIRSV, L_GM_TS_G, SVN_V, TCSV, TNRV, TNSaV, TYRV, TZSV, WBNV, WSMoV and ZLCV.

Tomato spotted wilt virus (TSWV) (Jones 2005; Samuel, Bald & Pittman 1930), *Iris yellow spot virus* (IYSV) (Cortes et al. 1998) and *Capsicum chlorosis virus* (CaCV) (McMichael, Persley & Thomas 2002) are not quarantine pests for Australia because they are present and not under official control. A CaCV isolate derived from *Phalaenopsis* in Taiwan (CaCV-Ph) (Zheng et al. 2008) was formerly recognized as a distinct strain and quarantine pest for Australia. However, on the basis of current evidence, this is no longer considered to be technically justified.

Fourteen thrips species (Table 4.3) are known to naturally transmit orthotospoviruses: *Ceratothripoides claratris*, *Dictyothrips betae*, *Frankliniella bispinosa*, *F. cephalica*, *F. fusca*, *F. gemina*, *F. intonsa*, *F. occidentalis*, *F. schultzei*, *F. zucchini*, *Scirtothrips dorsalis*, *Thrips palmi*, *T. setosus* and *T. tabaci*.

Eleven of these thrips species are quarantine pests, and are presently regulated. Three of these—*F. bispinosa*, *F. cephalica* and *T. setosus*—are recorded to transmit only TSWV, which is not a quarantine pest for Australia. Eight of these thrips species—*C. claratris*, *D. betae*, *F. fusca*, *F. gemina*, *F. intonsa*, *F. occidentalis*, *F. zucchini* and *Thrips palmi*—have the potential to transmit a total of 14 orthotospoviruses that are quarantine pests for Australia: ANSV, CCSV, CSNV, GBNV, GRSV, INSV, L_GM_TS_G, MYSV, PoIRSV, TCSV, TNRV, WBNV, WSMoV and ZLCV (Table 4.3).

The additional three thrips species—*F. schultzei*, *S. dorsalis* and *T. tabaci*—which are not quarantine pests, are recommended to be regulated because they have the potential to transmit a total of seven orthotospoviruses that are quarantine pests for Australia: CSNV, GBNV, GCFSV, GRSV, GYSV, TCSV and TYRV (Table 4.3).

The thrips species that naturally transmit 10 recently described orthotospoviruses remain unidentified: BeNMV, HCRV, LNRV, MeSMV, MVBaV, PCSV, PNSV, SVN_V, TNSaV and TZSV (Table 4.3). Literature relating to these viruses remains under periodic review for reports of thrips species that transmit them, and for appropriate actions to be considered.

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

5 Pest risk assessment of thrips

5.1 Introduction

The scoping assessment for thrips (Chapter 2) identified the phytophagous thrips (Table 2.2) for further consideration in pest categorisation. Based on the criteria listed in Table 3.1, a total of 112 species were included in pest categorisation (Table 3.2), and 82 thrips species were identified as requiring further consideration as quarantine pests. However, the results of this risk assessment could apply to other phytophagous quarantine pest thrips species that have not been included in this Group PRA.

Fourteen Thripidae species were identified as capable of transmitting orthotospovirus; only three of these 14 species were identified as not being quarantine pests.

Previous pest risk assessments

This Group PRA for thrips builds on the extensive knowledge gained in previous risk assessments of thrips undertaken by Australia. To September 2017, a total of 109 Thysanoptera species (80 Thripidae, 22 Phlaeothripidae, six Aeolothripidae and one Merothripidae) had been categorised in PRAs conducted by Australia. Of these, thirteen were subsequently assessed (Appendix B).

In all instances where the unrestricted risk estimate (URE) for thrips did not achieve the appropriate level of protection (ALOP) for Australia, the URE was Low (Appendix B). On six out of 27 occasions, the URE for thrips was Very low, which achieved the ALOP for Australia.

Consistently, when the likelihood of importation for thrips was assessed as High, the URE did not achieve the ALOP for Australia; conversely, when the likelihood of importation for thrips was Low or Moderate, the URE achieved 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 host plant morphology, which influenced the likelihood of importation by reducing the likelihood of thrips being present on a given plant import pathway from a given country. In these risk assessments, the estimated likelihoods for distribution, establishment and spread were relatively consistent and did not significantly influence URE (Appendix B). Consequences were also consistently assessed as Low, although there are minor differences for the impact scores assigned to specific direct and indirect impact. Significantly, these risk assessments have undergone extensive review and consultation with stakeholders.

Interception data

Australia has a considerable trade history in commodities that comprise the plant import pathway for thrips, and more than 34,000 thrips interceptions have been recorded from these pathways since 1986 (Appendix C and D). Thrips are also routinely intercepted on international trade by other nations. This information has been considered and incorporated into this Group PRA for thrips.

Entry, establishment, spread and consequences are estimated according to the method described in Appendix A.

5.2 Likelihood (indicative) of entry

The overall likelihood (indicative) that a quarantine pest thrips will enter Australia on the plant import pathway is assessed as **Moderate**.

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 2016b).

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 shown in Appendix A.

In this Group PRA, the likelihood of entry of a thrips is assessed in an indicative manner because the assessment 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 (Appendix A). These factors were considered in this Group PRA in generic terms, based on extensive historic and contemporary analysis of the plant import pathway. Entry is also conditional on the thrips being present in the export region.

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 entry in this Group PRA is indicative only and potentially subject to revision.

Likelihood (indicative) of importation

The likelihood (indicative) that a quarantine pest thrips 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

Thripidae species can usually be found wherever there is vegetation anywhere in the world (Mound & Tree 2012). The majority of species occur in the tropics and warm temperate areas, but a few species are known from the subarctic (Greenland) and the subantarctic (Kerguelen and Macquarie Islands) (Mound & Tree 2012). More than 2,000 species of Thripidae have been described. However, the Thripidae fauna in many parts of the world are poorly known, for example, from southeast Asia (Mound & Tree 2012) and there is no doubt that more species will be discovered.

Only a limited numbers of species in Phlaeothripidae are phytophagous, as discussed in the scoping assessment for thrips and they are mainly limited to a few genera such as *Haplothrips*, *Liothrips* and *Pseudophilothrips*. Species of *Haplothrips* and *Liothrips* are found worldwide, and *Pseudophilothrips* is a Central and South American genus.

The pest thrips as a group have a wide host range that includes plants and plant commodities produced for trade including fresh fruit such as citrus, stone fruit and table grapes, vegetables including beans, capsicum and tomatoes, and cut-flowers and foliage, such as chrysanthemum and roses.

Species of Thripidae breed in different parts of plants. Many only breed on leaves, such as *Dendrothrips* and *Scirtothrips* including on old and mature leaves. Others, such as Panchaethripinae, *Anaphothrips* and *Stenchaetothrips*, reproduce on grass leaves. Some only feed in flowers, such as *Odontothrips* in Europe and *Odontothripiella* in Australia, with species of both genera often host specific and associated with Fabaceae. *Chirothrips* and related taxa breed in the flowers of grasses. Many species feed both in flowers and on leaves; some of these are major pests such as *Thrips tabaci* and *Frankliniella occidentalis* (Mound 2012b).

For Phlaeothripidae, species of *Haplothrips* mainly live in flowers, including Poaceae florets, those of *Liothrips* and *Pseudophilothrips* are leaf feeding (ThripsWiki 2017). Both leaf and flower thrips can sometimes be pests of fruit (Kirk 1997b).

Thrips are well known for seeking out narrow spaces on the plants, such as within leaf sheaths or deep within inflorescences (Kirk 1997a). This habit provides a favourable microclimate, protecting thrips from natural enemies, desiccation, solar radiation, rain or adverse temperatures. Thrips living in cereal crops show a particular tendency for small spaces, a behaviour described as thigmotaxis (Kirk 1997a). Their small size and behaviour enable pest thrips to occupy narrow crevices within or between plant parts, such as between closed petals or leaflets, in floral or leaf buds, between fronds, sheaths, or adjacent clustered fruit, between a leaf or twig and fruit surface, or at the bases of young floral ovaries (Childers 1997).

Therefore, thigmotactic adults and larvae of pest thrips of commercial crops are easily concealed under bracts, in buds, within leaf bases, or along leaf veins (Morse & Hoddle 2006). Thripidae embed their eggs into living plant tissue, making them difficult to detect by non-specialists, while the eggs of phytophagous Phlaeothripidae are laid external to their host plants (Morse & Hoddle 2006).

These characteristics make thrips highly likely to be associated with imports of fresh fruit, vegetables, cut-flowers and foliage, which typically arrive in Australia as non-refrigerated air freight; most are subject to cold storage both before and after air transportation. Refrigerated sea transport is also used for a smaller number of commodities, such as apple and citrus fruit. Thrips have variable resistance to cold temperatures. Some species, such as *Frankliniella occidentalis* and *Thrips palmi*, are able to survive at a temperature of 0 °C to 5 °C for up to 60 days (Lee, Lee & Song 2001; Tsumuki et al. 2007). In contrast, adults of *Rhipiphorothrips cruentatus* were all dead after exposure to 4 °C for five hours (Rahman & Bhardwaj 1937). There is also evidence to indicate that thrips survival under cold temperature can vary relative to season and previous conditions. For example, spring generations of *Thrips obscuratus* were found to be more cold tolerant than summer and autumn generations (McLaren, Colhoun & Butler 2010), and *F. occidentalis* survived for longer at temperatures below freezing if reared at cooler temperatures (Tsumuki et al. 2007). Cold tolerance data for thrips demonstrate that many species are capable of surviving exposure to cold storage temperatures for long enough to be viable on arrival in Australia.

Thrips interceptions (Australian data)

Over 34,000 thrips interception events have been recorded on the plant import pathway by Australia over a 26 year period (1986–2012). Table 5.1 provides a breakdown of these interception events by family. Each interception is based on presence of at least a single thrips individual on a consignment. The number of thrips present per event is not generally recorded, and multiple thrips individuals can contaminate the same commodity. Accepting that about six per cent of intercepted thrips were unassigned to family, the vast majority of identified thrips (Table 5.1) were Thripidae (84 per cent) followed by Phlaeothripidae (nine per cent). This result may be anticipated because the Thripidae are predominantly plant feeders, whereas the majority of Phlaeothripidae are fungal feeders. Therefore, Thripidae are more likely to be associated with plant commodities and intercepted on the plant import pathway of international trade.

Table 5.1 Australian thrips interceptions (1986–2012), by family

Family	Interceptions (%)	Yearly average
Aeolothripidae	19	Less than 1
Merothripidae	2	Less than 1
Phlaeothripidae	3,162 (9)	122
Thripidae	28,871 (84)	1,110
Unassigned to family	2,123 (6)	82
Total	34,199 (100)	1,315

The thrips species most frequently intercepted (average 14–267 events a year), in descending order, were *Frankliniella occidentalis*, *Thrips tabaci*, *Caliothrips fasciatus*, *T. palmi*, *F. schultzei*, *Haplothrips gowdeyi*, and *Scirtothrips dorsalis* (Appendix D). With the exception of *H. gowdeyi*, which is a member of the Phlaeothripidae, the most frequently intercepted other species all belong to the Thripidae. It is also noted that most Phlaeothripidae interceptions identified to species level were in phytophagous genera (Appendix D).

A breakdown of the most recent interception data (1999–2012), used as representative of current conditions, showed the relative proportion of interceptions at about 56 per cent for cut-flowers and foliage, 36 per cent for vegetables, and eight per cent for fruit. Differences in interception frequency between these groups may be explained by the suitability of the morphology of the commodities for thrips. Additionally, vegetables are commonly taken to include some edible inflorescences, such as asparagus spears, but to exclude vegetables that meet the botanical definition of fruit, such as capsicums; a complex breakdown was therefore considered unnecessary.

Thrips interceptions (International data)

Thrips are regularly intercepted on the plant import pathway by other nations, but only some countries publish their interception data.

The United States has published interceptions of thrips at its ports of entry from Europe, the Mediterranean and Africa for the period of 1983–99 (Nickle 2003, 2004, 2006, 2008, 2009). A total of 102 species of phytophagous Thripidae and 16 species of phytophagous Phlaeothripidae were intercepted during the period (Table 5.2) (Nickle 2003). Most frequently intercepted (average 8 to 30 events a year), in descending order, were *Thrips tabaci*, *Frankliniella occidentalis*, *T. fuscipennis*, *T. major*, *F. tenuicornis* and *Odontothrips karnyi*. It is noted that these US data were not for all plant trade during the period but only for imports from Europe, the Mediterranean and Africa. More than 91 per cent of the interceptions were Thripidae and the remainder Phlaeothripidae and Aeolothripidae, respectively (Table 5.2).

Table 5.2 United States thrips interceptions (1983–99), by family

Family	Interceptions (%)	Yearly average
Aeolothripidae	97 (4)	6
Phlaeothripidae	138 (5)	9
Thripidae	2,422 (91)	151
Total	2,657 (100)	166

Japan has reported interceptions of 138 species of Thripidae and 45 species of Phlaeothripidae (Hayase 1991; Masumoto, Oda & Hayase 1999, 2003; 2005; Oda & Hayase 1994).

There have been many examples of international trade providing opportunity for thrips to enter new regions. Morse and Hoddle (2006) summarise some of the cases including 55 thrips species entering the Netherlands from 30 countries over a 13-year period (1980–93) and 20 per cent of cuttings and 12 per cent of plants imported into Switzerland being infested with *Frankliniella occidentalis*. All known thrips species in Kiribati and 24 of 51 (47 per cent) known terebrantian thrips in New Zealand are exotic, indicating they are introduced species, including through trade.

Both the Australian and overseas interception data suggest that thrips would continue to be present on the plant import pathway in international trade as long as the trade is occurring.

Summary

Pest thrips are reported worldwide, including in the countries with which Australia trades, on a wide range of host plants, including many important agricultural and horticultural crops and plants grown for export such as fruit, vegetables and cut-flowers and foliage. They are minute, usually being only a few millimetres long. They lay small eggs on plant surfaces or within its tissues. Such factors make detection of thrips difficult during routine quality inspections for commercial commodities, which generally focus on grading produce according to size, colour and appearance. At best, removal of distorted or damaged products from the pathway may remove some, but not all, thrips from the plant import pathway. They are likely to survive transportation during international trade, evidenced by the extensive thrips interception data presented for fresh fruit, vegetables and cut-flowers and foliage.

Notwithstanding the pathway-dependent factors outlined, the indicative likelihood of importation for pest thrips arriving in Australia as a result of the import of fresh fruit, vegetables and cut-flowers and foliage is considered to be High, which is consistent with results for 11 of 13 pest thrips species in previous risk assessments conducted by Australia in 14 PRAs on 10 commodities from 11 countries (Appendix B).

Likelihood (indicative) of distribution

The likelihood (indicative) that a quarantine pest thrips 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

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

During distribution, these commodities may be kept at cool temperatures that may affect the survival of thrips. However, the perishable nature of these commodities mean transit times will be relatively short, and transit temperatures are likely to be above lethal levels for the thrips (see discussion under Likelihood of Importation). At retail outlets, these commodities may be displayed at ambient temperature that would support the survival and development of thrips.

Pest thrips may enter the environment during the process of unpacking, transportation and/or retail sale, and most importantly, from waste disposed by retailers and individual consumers. It is considered that thrips are unlikely to be successful in entering the environment through unpacking in store warehouses, during transportation in the truck or on sale in shops as these activities are generally carried out indoors where the conditions are not favourable for thrips to

find their hosts. The most likely scenario for thrips to enter the environment and find suitable hosts is through the disposal of waste.

Waste production and disposal

Viable thrips on the plant import pathway may enter the environment as a result of the end use or disposal of waste in, for example compost bins, green waste or amongst general household and commercial waste, generated through the consumption of fruit and vegetables, and discarding of used cut-flowers and foliage. Disposal of this waste will almost certainly occur at multiple locations throughout Australia, especially for commodities consumed or used by households.

As waste deteriorates quickly, eggs and nymphs may fail to develop into adults and/or they may die before being able to reach a host. Any viable thrips remaining on the waste will need to find a suitable host quickly.

The most likely way for the thrips to find a host is via flight by the adults. Depending on the stage of the thrips present on the wastes, eggs would need to hatch and develop into adults via larval and pupal stages to enable them to find a host. This is not likely to happen as they would not have enough time and available resource to complete this process. Early instar larvae would not be likely to complete this process either as alternative food sources for them to feed on are unlikely to be available. However, mature larvae may be able to shelter in soil or detritus to pupate and then emerge as adults and become airborne to search for hosts, although a period of five to 12 hours for the newly emerged adult is required for its wing muscles to function (Lewis 1997b). Deteriorating food sources from the wastes would stimulate adult thrips to search for their suitable hosts (Lewis 1997b). Starved thrips are reported to respond to stimuli associated with host plants, including plant volatiles, by moving towards its source, as shown in a laboratory study of *Frankliniella occidentalis* (Davidson, Butler & Teulon 2006).

Adult thrips would likely need to leave the waste sites to search for food. Individuals of most species can launch themselves into air from flat surfaces of the plant such as petals or leaf blades but often choose a protruding narrow edge from which to jump (Lewis 1997b). There appears to be no study on how thrips would launch themselves from the disposed wastes; presumably they need to crawl or climb to a sufficiently high level above ground to enable them to launch into flight, a condition which may or may not be available, depending on where the wastes are disposed. It should be pointed out that some wingless thrips and immature individuals have been found to be airborne (Lewis 1997b), indicating they may be able to take off, or become airborne by wind.

Once they find a launch site, the take-off of thrips flight is strongly influenced by weather, especially temperature, light and wind (Lewis 1997b). Most temperate climate originating thrips can take off at a minimum temperature of 17 °C to 21 °C, and most take-offs occur during the warmest part of the day (Lewis 1997b). Given these thresholds, climate data (Bureau of Meteorology 2011a) suggest that adult thrips would be able to take off all year round in northern Australia but only be able to take off during the summer months in southern Australia. Thrips usually take-off during the day-light, including some in the early morning. There is no evidence that thrips take off at night (Lewis 1997b). The take-off is also stimulated by wind, and different species appear to require different wind speeds, probably related to their sizes. For example, medium-sized species such as *Limothrips* require a slightly higher wind speed than the smaller sized species such as *Frankliniella* (Lewis 1997b).

Although thrips are regarded as weak flyers, their finely fringed wings enable them to remain airborne long enough for the wind to blow them to great heights and for long distances (Lewis

1991). There is abundant circumstantial evidence that, at least when they are near the level of vegetation during a long distance wind-assisted flight, there is a sufficient degree of control by thrips to allow them to choose to alight on host crops and even on individual plants (Lewis 1991). There is also evidence that thrips in flight can respond to the scent of host plants and flowers as visual and olfactory cues to recognise and land on suitable hosts (Kirk 1985).

Host exposure

Some thrips species are highly polyphagous, such as *Thrips flavus*, which has been recorded on a diversity of 52 species of host plants including many economically important species, such as stone fruit, brassica, melons, and daisy; similarly *Haplothrips tritici* has been recorded on 20 cultivated cereal and wild hosts and *Frankliniella intonsa* on 16 plants including fruit trees and vegetables (CABI 2014a). Apart from the breeding hosts, many thrips have also been collected from other plant species. For example, *Thrips flavus* was collected on a total of 310 species of plants in England and 78 species in 26 families in India (CABI 2014a). The host plants can be from a diverse range of unrelated families. Host plants such as citrus, grapevines, wheat, barley, capsicum, tomatoes, daisy and roses are available in the urban and peri-agricultural environment as home-grown food crops, ornamentals and weeds, as well as commercially-grown crops. It is likely that thrips will be able to locate and reach suitable host plants which are readily available in the environment. In addition, many thrips are ecological opportunists that would be able to find and exploit short-lived resources (Funderburk 2001; Morse & Hoddle 2006; Mound & Teulon 1995).

Summary

Pest thrips imported with fresh fruit, vegetables and cut-flowers and foliage would likely survive transportation, retail sale, and waste disposal, and be able to take off in a suitable climatic environment and land on host plants which are widely available in Australia. However, the disposed wastes would deteriorate quickly and there may be thrips mortality before they are able to reach a host. The thrips would need to launch themselves into flight from a height which may or may not be available at the waste site. These factors can limit the ability of thrips to successfully transfer to a host.

Notwithstanding the pathway-dependent factors outlined, the indicative likelihood of distribution, or specifically, the likelihood that pest thrips will be distributed in Australia as a result of the import of fresh fruit, vegetables or cut-flowers and foliage is considered to be Moderate, which is consistent with results for nine of 13 pest thrips species in previous risk assessments undertaken by Australia (Appendix B).

5.3 Likelihood of establishment

The likelihood that a quarantine pest thrips will establish within Australia following its 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 2016b).

The supporting evidence for this assessment is provided.

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

As noted under likelihood of distribution and pest categorisation (Table 3.2), pest thrips are typically polyphagous and have been reported from a wide range of host plants, which are widely available in Australia as agricultural and horticultural crops, and as garden plants and as

weeds. In addition, thrips have been shown to be opportunists that are efficient at utilising short-lived food resources, able to feed on unrelated host plants when the normal host plants are not available (Funderburk 2001; Morse & Hoddle 2006; Mound & Teulon 1995).

Suitability of the environment

Pest thrips are reported worldwide, most from the tropics and subtropics and some from temperate regions (Mound & Tree 2012). Australia's climate also includes tropical, subtropical, temperate, and cool temperate regions (Bureau of Meteorology 2011a), the same as or similar to where the pest thrips currently occur. Agricultural crops and horticultural fruit trees are grown in many parts of Australia and the ecological conditions in these areas are also similar to those of the countries or regions where the pest thrips are currently distributed. Many pest thrips occur in the tropics and subtropics of the world (Mound 2012b) and they would be active year-round in northern Australia and during the warmer months in more southern Australia, increasing the likelihood of their establishment.

Greenhouse conditions can assist thrips establishment in less suitable climates, as demonstrated with *Scirtothrips dorsalis* in the Netherlands (Plant Protection Service 2009) and *Frankliniella occidentalis* worldwide (Kirk & Terry 2003).

Reproductive strategies and potential for adaptation

Most thrips species require copulation between male and female for reproduction and females can lay fertilised and unfertilised eggs. Fertilised eggs have the full diploid number of chromosomes and produce only females, whereas unfertilised eggs are haploid and produce only males (Moritz 1997).

A few species are obligately parthenogenetic with unfertilised eggs that only develop into females, or very rarely into males. In some species such as *Apterothrips apteris*, unmated females produce both males and females (Moritz 1997). Parthenogenesis would enable viable females to overcome barriers to population establishment that might result from an inability to locate males when incipient populations are at low densities (Hoddle, Stosic & Mound 2006).

Some species have both sexual and asexual populations, such as *Frankliniella occidentalis* and *Thrips tabaci* (Cloyd 2009; Moritz 1997), which would increase their likelihood of establishment.

Many pest thrips have short generation times and relatively high fecundity, for example, *Frankliniella occidentalis* completes one life cycle (egg to adult) in two to three weeks and each female can lay 150 to 300 eggs (Cloyd 2009), which allows them to rapidly establish new populations and adapt to new environments. Generally, the complete life cycle lasts 10 to 30 days, depending on temperature. Pest thrips may complete 12 or 15 generations in warm regions and in greenhouses, and one or two generations in cooler regions each year (Lewis 1997c).

In theory, a single mated female for most thrips species or a single unmated female for the parthenogenetic species would be able to initiate a population. The likelihood of establishment for thrips would increase with pioneer population size and rates of incipient infestations and would be positively associated with the numbers of founding individuals (Morse & Hoddle 2006), thus the more individual thrips enter with the commodities, the higher the likelihood they will establish successfully.

Cultural practice and control measures

The development of insecticide resistance in pest thrips has been well recognised. Consequently, the management of pest thrips usually involves a variety of measures, commonly termed as integrated pest management (IPM). Chemical control is usually only one of the components of IPM and is only be employed when required (Lewis 1997a). This is also the case in Australia. For example, IPM is recommended to control western flower thrips, tomato thrips, melon thrips, onion thrips and plague thrips on vegetable crops (Ausveg 2014b; Zhang & Brown 2008). IPM is also generally employed to manage pest thrips for agricultural and horticultural crops. These measures are applied to the pest species that have already established in Australia and may have some impact on the establishment of newly introduced exotic species, particularly where very low numbers are introduced.

Chemical control is usually the first method considered when an exotic thrips is discovered. However, there are relatively few examples in which a newly introduced thrips species has been discovered soon enough after introduction such that eradication is attempted and successful, because of the cryptic nature of thrips and the difficulty in monitoring incipient infestations (Morse & Hoddle 2006). In addition, the application of pesticides would not be effective on introduced thrips populations which have already developed resistance. Pesticide resistance may also place the introduced thrips at an advantage in heavily treated areas due to the removal of predators, parasitoids and other competitors (AgAware Consulting 2009). For example, pesticide resistance may have aided the establishment of Western Flower Thrips (*Frankliniella occidentalis*) in Australia, as the largest established populations occurred in heavily sprayed areas where few other insects were present (Malipatil et al. 1993).

Summary

Widely available host plants of pest thrips, such as weeds, garden plants, agricultural and horticultural crops, suitable climatic conditions, effective reproductive strategies including parthenogenesis, and an ability to adapt to new environments including developing resistance to pesticides all support an assessment for the likelihood of establishment as High, which is consistent with results for 12 of 13 pest thrips species in previous assessments conducted by Australia.

5.4 Likelihood of spread

The likelihood that a quarantine pest thrips 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 2016b).

The supporting evidence for this assessment is provided.

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

Climatic conditions (Bureau of Meteorology 2011a) are suitable for the natural spread of pest thrips throughout most of the year in northern Australia, and in all seasons other than winter in southern Australia. Suitable climatic conditions, particularly humid conditions associated with thunderstorm formation, can induce large numbers of thrips to become airborne simultaneously, resulting in mass flights often containing thousands of individuals (including pest species such as *Frankliniella occidentalis* and *F. intonsa*) (Lewis 1997b).

Long distance natural dispersal of thrips requires wind assistance. On a broad scale, Australia is dominated by eastern-western winds (trade winds) in the northern parts and western-eastern winds in southern parts of the continent (Bureau of Meteorology 2011b). The eastern-western trade winds would assist pest thrips disperse from coastal areas, where exotic pest thrips are likely to be introduced due to the concentration of trade and distribution of the imported commodities, into inland agricultural production areas.

Greenhouse environments have been shown to be suitable in aiding the spread of pest thrips. Like other countries, Australia uses greenhouses to produce many crops such as tomatoes, capsicum, cucumber and eggplant (Ausveg 2014a).

Presence of natural barriers

Natural barriers exist between different areas within Australia. For example, the arid area of the Nullarbor Plain, and long geographic distances separate the east and the west, and the Bass Strait divides the mainland from Tasmania. Climatic differentials also occur between the north and the south. It would be difficult for the adults to naturally disperse unaided from one such area to another. However, at least some pest thrips would likely be able to overcome these natural barriers because they can be carried by winds for long distances. Australia's eastern-western winds in the north and western-eastern winds in the south would assist thrips to overcome the natural barriers. Pest thrips have been caught at 300 to 3,100 m altitudes and can even remain airborne during the night, although flights mostly take place during the warmest period of the day. They can exploit prevailing winds as aerial plankton for longer-distance movement that may allow them to overcome geographic barriers, such as oceans, to the point of being able to move between continents and between countries, such as between Australia and New Zealand, separated by the 1,500 km wide Tasman sea (Lewis 1991; Lewis 1997b).

Some thrips species are renowned for 'mass' flights, usually occurring when populations on heavily infested crops build up and reach flight maturity over a short time, and then take off in response to favourable weather, such as *Taeniothrips* spp. observed in England and California, and *F. intonsa* in Hungary (Lewis 1991; Lewis 1997b).

After long-distance flight and when they are near vegetation level, pest thrips can have some control and choose to alight on host crops (Lewis 1991), probably responding to the scent produced from the hosts as visual and olfactory cues (Kirk 1985).

Short-range dispersal of pest thrips by flight from breeding sites is a regular event in the life cycle of many species. Host plants of pest thrips are widely available between commercial crops in different areas or states, in house gardens, and on weeds in the environment, and this would help the spread of pest thrips.

It has been suggested that the spread of *F. occidentalis* in China appeared to follow the invasive bridgehead effect (Yang et al. 2012), a hypothesis to explain how many widespread invasions could have stemmed not from sources in the native range, but from a particularly successful invasive population, which serves as the source of colonists for remote new territories (Lombaert et al. 2010). Pest thrips introduced into Australia may also follow the bridgehead effect to spread.

The potential for movement with commodities or conveyances

Pest thrips can be spread artificially due to being associated with commercial crops, such as bananas and orchids, which are frequently transported as fresh plants or cuttings, as they are easily carried concealed under bracts and in buds and leaf bases. Polyphagous species such as

Thrips tabaci, and *Fulmekiola serrata* hidden in hay, straw or stems are also widespread for the same reason (Lewis 1997b).

Thrips 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 thrips directly into areas of uninfested hosts at a faster rate than thrips would naturally spread. Although thrips are also known to be spread on birds and other organisms, this method is unlikely to be significant because it does not necessarily ensure thrips will be deposited onto suitable hosts (Lewis 1997b).

Intended use of the commodity

Pest thrips infest a large number of host plants, and the intended uses of the commodities derived from the hosts include human consumption, decoration and animal feeds. The commodities themselves include fresh fruit, vegetables and cut-flowers and foliage. These commodities would be moved around the country, and eggs, larvae and adults that are associated with these commodities would also be spread.

Potential vectors of the pest in the PRA area

Pest thrips do not require a vector for their dispersal. Both adult males and females of most species are winged and are capable of flight. Wingless species may be carried by wind.

Potential natural enemies of the pest in the PRA area

Thrips are attacked by a range of natural enemies, which are mainly other arthropods. These include predatory mites, for example Phytoseiidae, other thrips (Aeolothripidae, including *Franklinothrips* spp.), sucking bugs (Hemiptera; especially Anthocoridae), lacewings (Neuroptera), ladybeetles (Coleoptera: Coccinellidae), some flies (Diptera) and parasitic wasps (Hymenoptera: Chalcidoidea) (Loomans, Murai & Greene 1997; Morse & Hoddle 2006; Sabelis & van Rijn 1997). Representatives of these groups are present in Australia.

The most likely natural enemies to have any effect on introduced thrips populations are generalist predators, most of which also utilise a range of other arthropods in addition to thrips (Sabelis & van Rijn 1997), as the receiving ecosystem will typically lack specialist natural enemies (Morse & Hoddle 2006). In some instances, the use of predators in agricultural systems is of limited effectiveness, such as with major pests like *Thrips tabaci* and *Frankliniella occidentalis* (Loomans, Murai & Greene 1997). Although thrips-specific parasitic wasps can affect significant percentages of thrips populations (sometimes exceeding 50 per cent), the interaction between parasitoid and host is more complex. Most parasitoid wasps are specific to a few genera or species of thrips, which may make some endemic parasitoids ineffective against exotic thrips. The relationship between wasp parasitoids and their hosts is also density dependent and maximum densities of some wasp species are only reached after the thrips populations peak. Even high parasitism rates may not have a significant effect on large thrips populations, probably due to thrips fecundity (Loomans, Murai & Greene 1997).

Predators and parasitoids are also vulnerable to chemical controls applied against insect pests, including thrips (Loomans, Murai & Greene 1997). Pesticide resistance traits of some thrips has allowed their populations to reach high numbers in the absence of other insects, including predators and parasitoids, as was the case for *Frankliniella occidentalis*, which was initially reported in Perth, Western Australia (Malipatil et al. 1993).

Summary

The suitability of the natural and/or managed environment including greenhouses, the regular short-range dispersal in their life cycles, and the long-range dispersal by wind to overcome natural barriers, other passive dispersal capacities on live plants through human activities, and their reproductive strategy including parthenogenesis, all support a likelihood of spread of High, which is consistent with results for all 13 pest thrips species in previous assessments conducted by Australia.

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

The overall likelihood (indicative) 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 5.3.

The overall likelihood (indicative) that quarantine pest thrips 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 5.3 Likelihood of entry (indicative), establishment and spread for thrips

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

5.6 Consequences

The overall consequences for quarantine pest thrips is estimated to be: **Low**.

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

Impact scores for consequences are summarized in Table 5.4.

Table 5.4 Summary of consequences for thrips

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	Major significance at the local level	D
	Significant at the district level	
	Minor significance at the regional level	
Indirect impact on the environment	Minor significance at the local level	B
Overall consequences rating	–	Low

The assessment of consequences considered only the impacts caused by quarantine pest thrips species. It did not consider any additional impacts caused by orthospoviruses that they may transmit. A separate risk assessment was undertaken for orthospoviruses (Chapter 6).

The overall consequences rating of Low for quarantine pest thrips is consistent with all previous assessments conducted by Australia, although on one specific occasion the same species was also assessed as having a rating of Moderate.

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 thrips 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. The damage on host plants by pest thrips includes weakening and defoliating plants to decrease yield, and impacting the appearance of produce to reduce market value. Pest thrips are polyphagous and would affect multiple industries, such as fruit trees, vegetables, cereals and cut-flowers. 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 and physically dispersed.

This impact score is also consistent with results for all previous risk assessments of thrips conducted by Australia.

Pest thrips cause significant damage to a wide range of agricultural crops, including wheat and barley; horticultural fruit trees, including citrus, grapevines, and avocados; vegetables, including capsicum, tomatoes, and cucurbits, ornamentals; trees and grasses. Due to their polyphagous ability, a single pest thrips species can have direct impact on multiple crops. Australia has significant primary industries, for example, fruit production in 2010/11 was about 1.7 million tonnes with gross value of close to \$2.8 billion, and vegetable production in 2008/09 was 3.9 million tonnes with gross value close to \$3 billion (Horticulture Australia Limited 2012).

The direct impact of pest thrips could be through weakening or defoliating plants, causing yield loss, and damaging the appearance of produce to reduce the market value.

Damage caused by pest thrips is a result of their feeding on leaves, flowers, fruit or petals. On leaves, thrips feed on the contents of epidermal, palisade and spongy mesophyll cells, leaving collapsed cell walls or destroyed cells with scattered contents (Kirk 1997b). Thrips in flowers feed on pollen in anthers or pollen scattered over floral surfaces (Kirk 1997b). Symptoms of pest thrips damage can be quite variable depending upon the pest species and host or cultivar. Typical symptoms are bronzing, flecking, silvering and curling on leaves, browning and early flower drop on flowers, and scarred, deformed or aborted fruit (Hodges et al. 2009).

The scale of their damage in the field can be very serious. Initial infestation by airborne pests can spread quickly to cover large areas. For example, *Corynothrips stenopterus* Williams almost totally defoliated a landscape of cassava in Colombia, and *Taeniothrips inconsequens* (Uzel) partially defoliated 20,000 and 40,000 sugar maple trees in the states of Vermont and Pennsylvania, respectively (Lewis 1997c). Extensive thrips damage can spread from the initial infestation at the edges of plantings to large arable fields such as cabbage, cereals, onions and soybeans, or tree plantations such as citrus, stone fruit, tea and coffee (Lewis 1997c).

Thrips feeding damage can cause significant losses of yield. Lewis (1997c) provides examples of percentage loss for some field crops from direct impact by a single species or collectively by more than one species, ranging from 2 to 100 per cent on various crops such as cassava, citrus, cowpea, onion, rice and tea in a number of countries. For example, *Scirtothrips* spp. caused citrus crop loss up to 80 per cent in California and 50 per cent in Zimbabwe in the early twentieth century before modern control methods were available; *Scirtothrips citri* (Moulton) alone still has the potential to cause loss of 8 to 25 per cent of navel oranges in California if no control measures are applied; *Heliethrips haemorrhoidalis* and *Scirtothrips* spp. collectively caused 100 per cent loss of tea in Kenya (Lewis 1997c). Grain losses of wheat, barley and rye typically ranged from 2 to 10 per cent in Europe and slightly higher in North America (Lewis 1997c). Significant losses have also been reported for fruit crops, such as apple, cashew and vegetables, including peppers, cucumber, aubergines, cowpea, and peas (Childers 1997; Lewis 1997c).

It is considered that the mentioned total defoliated damage and up to 100 per cent yield losses can occur only in some localities, in some years and for some host plants. These are not expected to occur in Australia where IPM is widely employed to manage thrips pests, such as *Frankliniella occidentalis* (Cook 2001; Herron, Broughton & Clift 2007; Ullio 2002) and *Thrips palmi* (Zhang & Brown 2008).

Cosmetic damage to the plant's leaves, flowers and fruit may lower their values substantially, through localised scarring on the surfaces of fruit, vegetables, stems or leaves, blemished skin, distorted fruit, and discoloured petals in ornamental flowers, making them unmarketable and resulting in financial loss to growers (Childers 1997; Lewis 1997c).

Many pest thrips are polyphagous and are also able to exploit new food sources as opportunists. Introduced thrips could have the potential to switch hosts and feed on Australian native plants. Mound and Teulon (1995) note that thrips appear not to have evolved along the phylogenetic lines of their host plants, but have 'captured' the available dominant elements in any given flora.

Direct impact on other aspects of the environment

Impact score is estimated as **B**.

The direct impact of a pest thrips 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 thrips, predators and parasitoids or compete for resources locally with these organisms.

This impact score is also consistent with results for 12 of 13 pest thrips species in previous risk assessments conducted by Australia.

Factors to be considered for the direct impact on other aspects of the environment include the physical environment or other life forms such as micro-organisms. The thrips may compete for resources with the current Australian fauna of thrips. They may also impact populations of native predators and parasitoids. For example, some phytophagous thrips species are facultative predators and have the potential to prey on native insects and mites such as scale insects, lepidopteran species and spider mites (Kirk 1997b).

Indirect impact on eradication and control

Impact score is estimated as **D**.

The indirect impact of a pest thrips on eradication and control 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 is 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 also consistent with results for nine of 13 pest thrips species in previous risk assessments conducted by Australia.

To date, it appears that the only successful eradications of exotic thrips have taken place in greenhouse production systems in cold temperate areas where the outside environment is unsuitable for thrips survival for much of the year, such as the case for *Scirtothrips dorsalis* in the Netherlands (Plant Protection Service 2009) and *Thrips palmi* in both the Netherlands and the United Kingdom (Cannon et al. 2007). Several pest thrips such as *Frankliniella occidentalis* and *Thrips palmi* were accidentally introduced into Australia, and had spread sufficiently such that eradication was not considered feasible at the time of their discovery.

Eradication of pest thrips would be unlikely to succeed unless the incursion was discovered at a very early stage (Mound & Teulon 1995). The possibility of eradication of *Thrips palmi* in the Northern Territory was considered in 1989, but rejected because of the wide range of host plants and the area of distribution at the time of detection (Australian Academy of Science 1996). Once established, factors likely to limit the success of any eradication attempt of pest

thrips include delayed discovery due to small size and concealment in host plants, polyphagy, ability to disperse over long distances by wind, and spread on plant material.

In Australia, notification of an incursion of an exotic agricultural pest will trigger immediate consideration of an eradication response by Australian federal, state and territory governments and relevant industries that are signatories to the Emergency Plant Pest Response Deed (PHA 2015). While the eradication response is being considered, the affected jurisdiction will work to contain and delimit the pest. If the eradication response proceeds it will involve a cost shared budget.

Once exotic pest thrips become established, it is necessary to manage the pests. Control of pest thrips usually involves integrated pest management (IPM), which incorporates cultural, physical, biological and chemical control methods. IPM for pest thrips has been reviewed for field crops (Parrella & Lewis 1997), tree crops (Parker & Skinner 1997) and glasshouse crops (Jacobson 1997). In Australia, management of pest thrips also typically uses the IPM approach, as the case of *Frankliniella occidentalis* (Cook 2001; Herron, Broughton & Clift 2007; Ullio 2002), *Thrips palmi* (Zhang & Brown 2008) and for thrips on vegetables (Ausveg 2014b).

Chemical control is used to suppress large pest thrips population sizes when cultural, physical and/or biological measures become ineffective (Cloyd 2009; Lewis 1997a; Ullio 2002; Zhang & Brown 2008). However, if applied inappropriately, chemical control may also be ineffective because thrips eggs and pupae are sheltered from pesticides due to their concealed sites, and because pesticide resistance can develop from repeated and regular applications (Cloyd 2009; Herron & James 2005; 2008; Herron et al. 2007; Lewis 1997a). Lewis (1997a) reviewed the development of pesticide resistance in pest thrips, including *Frankliniella occidentalis* in the USA and Europe, *Scirtothrips citri* in the USA, and *Thrips palmi*, *T. parvispinus* and *T. tabaci* in Indonesia. Pesticide resistance, once developed, has been demonstrated to persist for 100 generations in one culture and seven years in a strain of *Frankliniella occidentalis* (Lewis 1997a). It is therefore probable if pest thrips are introduced from populations where pesticide resistance has developed they would still carry the traits, which could limit the availability and/or efficiency of control measures.

The development of resistance may lead to other impacts from associated extensive use of chemicals. Crop loss or failure may still occur despite the frequent applications of pesticides, as is the case for vegetable crops in the Philippines (Bernardo 1991). Frequent application of pesticides could result in exceeding of maximum residue levels (MRLs) or extension of established withholding periods (WHPs), as shown for *F. occidentalis* in Australia (Herron, Broughton & Clift 2007).

The addition of a new pest thrips to any agricultural and horticultural cropping system may require changes to existing management regimes to ensure they are effective. In Australia, such research is often funded under shared government and industry arrangements and may take years to complete (Cook 2001). Australian state/territory governments consider pest thrips as significant pests that often require coordination at the regional/state level (Herron, Broughton & Clift 2007; Persley et al. 2007).

Indirect impact on international trade

Impact score is estimated as **D**.

The indirect impact of a pest thrips 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. Many thrips are important agricultural pests. It is likely that trading partners would review their phytosanitary requirements for exported host commodities, including the possibility of suspending or stopping trade. Australia is a significant exporter of agricultural commodities; if trade was suspended or stopped, it would be expected to have significant impact on affected industries at the district level. 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.

This impact score is also consistent with results for 10 of 13 pest thrips species in previous risk assessments conducted by Australia.

Although many pest thrips have been recorded in Australia (Mound & Tree 2012), most pest species are not present; if they were introduced, they may have an impact on Australia's exports. Many countries require phytosanitary measures to mitigate the risk posed by their quarantine pest thrips. Australia is a significant exporter of agricultural and horticultural commodities, including hosts of pest thrips. For example, Australia exported more than 393,987 tonnes of fresh fruit valued at about \$937 million in 2015/16, and 209,498 tonnes of vegetables valued at about \$232 million in the same period (HIA 2017). Should exotic thrips become established on crops grown for export markets, Australia's trading partners may impose phytosanitary measures, resulting in additional export costs and/or disruption to the existing trade and hampering requests for new market access.

Indirect impact on domestic trade

Impact score is estimated as **D**.

The indirect impact of a pest thrips 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'. 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 plant material out of the initial incursion area which would have a significant economic impact on plant industries and business at the district level. 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. This is expected to be of minor significance at the regional level.

This impact score is also consistent with results for 10 of 13 pest thrips species in previous risk assessments conducted by Australia.

If an exotic thrips species is detected in Australia, initially it is likely to be restricted to a particular area. Previous thrips incursions support this assertion, as has also been the case for pests in other groups, such as papaya fruit fly (Cantrell, Chadwick & Cahill 2002). Biosecurity 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 industry and business. Domestically, Australian states and territories have their own 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 are technically justified, coordinated and harmonised, and consistent with Australia's international import and export conditions and policies (SDQMA 2014). When an exotic pest is introduced and the outbreak is restricted to the detection area, the other jurisdictions where the pest has not yet been found

can restrict intra- and inter-state movement of affected commodities to prevent the pest's spread. This would impact on domestic trade.

For example, the outbreak of *Thrips palmi* in the Northern Territory in 1989 had repercussions for the economy of the Northern Territory, not only due to the damage inflicted on the crops, but also due to biosecurity restrictions imposed against the Northern Territory by the other States (Australian Academy of Science 1996). In 1988 horticultural exports from the Territory were worth close to \$7 million; by 1992 this had dropped to little more than \$2 million, and the viability of Northern Territory horticulture was threatened. In the initial outbreaks the thrips populations were so high that some crops were either abandoned or ploughed in. Subsequently, properties on which *Thrips palmi* was found, during an intensive monitoring program that followed the initial discovery, were prevented from marketing their produce in other states (Australian Academy of Science 1996). *Thrips palmi* was discovered in Queensland in 1993. Other states such as South Australia and Western Australia restricted the introduction of host crops and plants from within 100 kilometres of a detection of the pest in Queensland (DAFF Qld 2012).

Indirect impact on the environment

Impact score is estimated as **B**.

The indirect impact of a pest thrips 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 thrips may result in the additional use of pesticides for its control, resulting in minor damage to the local environment.

This impact score is also consistent with results for 11 of 13 pest thrips species in previous assessments conducted by Australia, although on four occasions the same species were assessed as having a different impact score.

Pesticide application

Increased pesticide use required to manage new thrips species could affect the environment. Spray drift of pesticides can induce soil toxicity, runoff and water system contamination (APVMA 2008; NSW DPI 2012). The Australian Pesticides and Veterinary Medicines Authority (APVMA 2008) defines spray drift as the physical movement of spray droplets (and their dried remnants) through the air from the nozzle to any non- or off-target site at the time of application or soon thereafter. Soil toxicity in agricultural systems is recorded in the US as inhibiting germination and leading to elevated pesticide residues in plants (Dalvi & Salunkhe 1975), possibly leading to issues with MRLs and saleability of crops. Runoff and leaching may affect biodiversity in aquatic ecosystems (NSW DPI 2012). Spray drift has been implicated with the decline of some butterflies in Australia (Sands & New 2002). Australia typically manages pest thrips using an IPM approach, and any increase in insecticide use for introduced thrips is expected to be small.

Impact on human activities

Thrips mating and dispersal flights have been known to cause relatively minor impact on human activities. There are a few records of thrips being nuisance pests by settling on humans in large numbers (Childers et al. 2005). It has been reported that, in the United States, flying thrips in late March were so abundant that they filled the eyes and clothes of a horse-drawn driver, who had great difficulty to hold on the reins (Lewis 1997b). In Australia, a thrips swarm disrupted school activities for several days when thrips settled in large numbers of children conducting outdoor activities (Mound, Ritchie & King 2002). In the United Kingdom, thrips were reported to shelter in fire alarms, with some infestations resulting in the false alarms being triggered (Lewis

1997b; Morse & Hoddle 2006). In other instances, thrips have contaminated stored spices and medical supplies and sanitary products (Morse & Hoddle 2006). Thrips are also commonly called ‘thunderflies’ because their mass flights, often occurring during humid conditions associated with thunderstorm formation (Lewis 1997b).

In addition to being nuisance pests, thrips are medical pests of occasional frequency, causing irritation or distress by probing humans with their mouthparts (Childers et al. 2005; Lewis 1997b). These so-called ‘bites’ are believed to cause irritation due to the action of the mouthparts on skin or the release of saliva into the skin. In most instances, probing is believed to be due to thrips seeking moisture. However, *Thrips tabaci* and *Frankliniella moultoni* have been recorded to imbibe blood, as has a predatory Phlaeothripid (Childers et al. 2005). Symptoms of thrips bites vary from passing irritation to prolonged itching sensations and development of rashes. In many instances, thrips bites have been associated with dispersal flights occurring in hot, humid weather and the mass flowering of some trees (Childers et al. 2005). Thrips are attracted to humans through skin volatiles and light reflected from clothing, vehicles and buildings, especially to white and sometimes blue objects. In some areas of the southern United States, bites from *Frankliniella bispinosa* can be a serious seasonal problem, affecting people in a wide range of situations (Childers et al. 2005).

5.7 Unrestricted risk estimate (indicative)

Unrestricted risk (indicative) is the result of combining the likelihood of entry (indicative), establishment and spread (Table 5.3) with the estimate of consequences (Table 5.4). Likelihoods and consequences are combined using the risk estimation matrix in Appendix A. The unrestricted risk (indicative), for thrips that are quarantine pests for Australia, is given in Table 5.5, and is assessed as **Low**.

Table 5.5 Unrestricted risk estimate (indicative) for thrips

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

This unrestricted risk (indicative) is consistent with 11 of the 13 pest thrips species previously assessed by Australia; on three occasions the same species were assessed as having a different unrestricted risk estimate due to a difference in the likelihood of importation.

This PRA identified 79 thrips species as quarantine pests for Australia (Table 3.3). These thrips have an unrestricted risk (indicative) that does not achieve the ALOP for Australia. Therefore, risk management measures are required for these pests in specific trade pathways when the unrestricted risk (indicative) of Low is verified.

6 Pest risk assessment of orthotospoviruses

6.1 Introduction

Pest categorisation identified 27 orthotospoviruses as quarantine pests for Australia (Table 6.1), and these viruses required further assessment.

Tomato spotted wilt orthotospovirus (TSWV) (Jones 2005; Samuel, Bald & Pittman 1930), *Iris yellow spot orthotospovirus* (IYSV) (Cortes et al. 1998) and *Capsicum chlorosis virus* (CaCV) (McMichael, Persley & Thomas 2002) are not quarantine pests for Australia because they are present and not under official control. A CaCV isolate (referred to as CaCV-Ph) derived from *Phalaenopsis* in Taiwan (Zheng et al. 2008) was formerly recognized as a distinct strain and quarantine pest for Australia. However, on the basis of current evidence this is no longer considered to be technically justified, as was explained in Chapter 4.5.

Table 6.1 Orthotospoviruses that are quarantine pests for Australia

<i>Alstroemeria necrotic streak virus</i> , ANSV (Hassani-Mehraban et al. 2010)	<i>Impatiens necrotic spot orthotospovirus</i> , INSV (Law, Speck & Moyer 1991)	<i>Soybean vein necrosis virus</i> , SVNV (Zhou et al. 2011)
<i>Bean necrotic mosaic virus</i> , BeNMV (de Oliveira et al. 2011)	<i>Lisianthus necrotic ringspot virus</i> , LNRV (Shimomoto, Kobayashi & Okuda 2014)	<i>Tomato chlorotic spot orthotospovirus</i> , TCSV (De Avila et al. 1993)
<i>Calla lily chlorotic spot virus</i> , CCSV (Chen et al. 2005)	<i>Melon severe mosaic virus</i> , MeSMV (Ciuffo et al. 2009)	<i>Tomato necrotic ringspot virus</i> , TNRV (Chiemsombat et al. 2010)
<i>Chrysanthemum stem necrosis virus</i> , CSNV (Bezerra et al. 1999)	<i>Melon yellow spot virus</i> , MYSV (Kato, Hanada & Kameya-Iwaki 2000)	<i>Tomato necrotic spot-associated virus</i> , TNSaV (Yin et al. 2014)
<i>Groundnut bud necrosis orthotospovirus</i> , GBNV (Reddy et al. 1992)	<i>Mulberry vein banding associated virus</i> , MVBaV (Meng et al. 2015)	<i>Tomato yellow ring virus</i> , TYRV (Hassani-Mehraban et al. 2005)
<i>Groundnut chlorotic fan-spot virus</i> , GCFSV (Chen & Chiu 1996)	<i>Pepper chlorotic spot virus</i> , PCSV (Cheng et al. 2013)	<i>Tomato zonate spot virus</i> , TZSV (Dong et al. 2008)
<i>Groundnut ringspot orthotospovirus</i> , GRSV (De Avila et al. 1993)	<i>Pepper necrotic spot virus</i> , PNSV (Torres et al. 2012)	<i>Watermelon bud necrosis orthotospovirus</i> , WBNV (Jain et al. 1998)
<i>Groundnut yellow spot orthotospovirus</i> , GYSV (Satyanarayana et al. 1998)	<i>Polygonum ringspot orthotospovirus</i> , PolRSV (Ciuffo et al. 2008)	<i>Watermelon silver mottle orthotospovirus</i> , WSMoV (Yeh & Chang 1995)
<i>Hippeastrum chlorotic ringspot virus</i> , HCRV (Dong et al. 2013)	L _G M ₁ S _G (Webster et al. 2011)	<i>Zucchini lethal chlorosis orthotospovirus</i> , ZLCV (Pozzer et al. 1996; Resende et al. 1996)

This pest risk assessment considers all 27 orthotospoviruses as a single group for reasons that include:

- they are all transmitted by thrips
- they share common biological characteristics
- the dominance of research focusing on TSWV and its principal vector *F. occidentalis*, and the need to extrapolate to other orthotospoviruses and the thrips that transmit them, as appropriate
- the current state of scientific knowledge and uncertainty about emerging orthotospoviruses.

Thrips reported to transmit orthotospoviruses (Table 4.2) are from five Thripidae genera, and comprise 14 species: *Ceratothripoides claratris*, *Dictyothrips betae*, *Frankliniella bispinosa*, *F. cephalica*, *F. fusca*, *F. gemina*, *F. intonsa*, *F. occidentalis*, *F. schultzei*, *F. zucchini*, *Scirtothrips dorsalis*, *Thrips palmi*, *T. setosus* and *T. tabaci*.

Three of these species, *F. schultzei*, *S. dorsalis* and *T. tabaci*, are not quarantine pests for Australia, and are not at present regulated. Collectively, these thrips transmit seven orthotospoviruses that are quarantine pests for Australia: CSNV, GBNV, GCFSV, GRSV, GYSV, TCSV and TYRV. Where appropriate, emphasis is given in this risk assessment to these seven orthotospoviruses and the thrips known to transmit them. However, the pest risk assessment applies to all orthotospoviruses that are quarantine pests for Australia.

Entry, establishment and spread, and consequences are estimated according to the method described in Appendix A.

6.2 Likelihood (indicative) of entry

The overall likelihood (indicative) that a quarantine pest orthotospovirus will enter Australia on the plant import pathway is assessed as **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 2016b).

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 shown in Appendix A.

In this Group PRA, the likelihood of entry of an orthotospovirus is assessed on an indicative basis 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 (Appendix A). These factors were considered in this Group PRA based on extensive historic and contemporary analysis of the plant import pathway. Entry is also conditional on the orthotospovirus and the thrips that transmit them being present in the export region. Table 6.3 summarises the known global distributions of orthotospoviruses and the thrips that transmit them. However, the emergence of new orthotospoviruses continues to be reported, and information on orthotospovirus species distribution, the thrips that transmit them, and their natural host plant ranges are likely to be subject to periodic revision.

When 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

There are three potential pathways for an orthotospovirus to enter Australia: (i) via viruliferous thrips on the plant import pathway, (ii) within infected plant produce on the plant import pathway, or (iii) via the infected nursery-stock pathway.

This risk assessment considers the risk that viruliferous thrips could facilitate the entry of an orthotospovirus into Australia through the plant import pathway.

The possibility that an orthotospovirus may enter via infected plant produce may be conceivable. However, such a pathway is likely to be a 'dead end' at the distribution step because

transmission of an orthotospovirus to a susceptible host, from post-harvest produce, is not likely to occur. As a result, this scenario is not considered further within this risk assessment. The rationale for this decision is explained further within Appendix E.

The nursery-stock pathway is being considered as a separate process, and the rationale for this decision is explained further within Appendix H.

Likelihood (indicative) of importation

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

The supporting evidence for this assessment is provided.

Emerging risk

Orthotospoviruses are considered to form at least five distinct ancestral groups, and like other RNA viruses, show substantial genetic variability and can evolve rapidly (Chapter 4). A range of underpinning mechanisms can have an influence on their evolution and biology (Briese, Calisher & Higgs 2013; Qiu et al. 1998; Webster et al. 2011), with some species isolates showing different genetic and biological traits, including pathogenicity (Hassani-Mehraban et al. 2007; Torres et al. 2012).

Orthotospoviruses are thus an emerging risk with accompanying uncertainty. Table 4.1 documents the first record of each described orthotospovirus—11 of which have been discovered since 2010. It is likely that new orthotospovirus species will evolve and continue to be discovered.

It is also likely that orthotospoviruses will continue to emerge in crops not previously known to be susceptible, and/or will continue to expand their distribution and economic significance (Daughtrey et al. 1997; Jones 2005; Kunkalikal et al. 2011; Pappu, Jones & Jain 2009). A number of orthotospoviruses have broad or rapidly expanding host plant ranges, and are already significant pathogens, including GBNV, INSV, TCSV, TNRV and WBNV (Table 4.2). However, there is uncertainty about the host plant ranges of several newly described orthotospoviruses, such as ASNV, BeNMV, HCRV, L_GM_TS_G, MeSMV, MVBaV, PNSV, PCSV, TNRV and SVNV (Table 4.2).

Although not a direct indicator of susceptible host plants, the host range of the thrips species that transmit a given orthotospovirus may indicate a potential pool from which prospective virus hosts may arise. As examples, *F. schultzei* is hosted by 83 species in 35 families (Milne & Walter 2000; Palmer et al. 1989); *S. dorsalis* is hosted by 150 species in 40 families (Riley et al. 2011b); and *T. tabaci* is hosted by species across 25 plant families (Mound 2007a).

A total of 14 Thripidae species are known to transmit orthotospoviruses naturally, with 11 species recognized to transmit orthotospoviruses that are quarantine pests for Australia (Table 4.3). However, the presumptive thrips vectors that transmit 10 recently discovered orthotospoviruses (BeNMV, HCRV, LNRV, MeSMV, MVBaV, PCSV, PNSV, SVNV, TNSaV and TZSV) in nature are unidentified. It is likely that some of these are transmitted by thrips species already known to transmit orthotospoviruses. However, the possibility that other thrips species transmit orthotospoviruses cannot be excluded, and is perhaps likely.

Association with export crops

Evidence for a close association of thrips species with crops that comprise the plant import pathway, including details of thrips biology and behaviour, was presented in Chapter 5.5, and this relationship is also relevant to viruliferous thrips.

As a group, orthotospoviruses are known to infect an extensive range of crops (Daughtrey et al. 1997; Gent et al. 2006; Jones 2005; Kunkalikal et al. 2011; Mandal et al. 2012; Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006), including species that comprise the plant import pathway, as illustrated and referenced in Table 4.2.

Each orthotospovirus species can infect a distinct range of host plant species, with different levels of overlap in host range between them (Table 4.2). A susceptible plant species may be a host of more than one orthotospovirus, and infections of two or more orthotospoviruses have been observed to occur within the same plant (Chiemsombat et al. 2008; Kunkalikal et al. 2011; Mullis et al. 2004; Peng et al. 2011; Webster et al. 2011).

Orthotospoviruses ordinarily reduce commercial yields, quality and marketability, but in a worst case scenario can cause near complete crop failures (Culbreath, Todd & Brown 2003; Jones 2005; Mandal et al. 2012). For example, the recorded incidence of orthotospoviruses in affected crops include up to 41 per cent for GBNV on lettuce and tomato in Argentina (Gracia et al. 1999), 27 per cent for INSV on lettuce in the USA (Kuo et al. 2014), and 23 per cent on potato and 28 per cent for soybean in Iran (Golnaraghi et al. 2008).

Thrips and the orthotospoviruses they transmit can be sustained on weeds or volunteer plants (that is, cultivated varieties growing wild or contaminating other crops), and this can provide a source for rapid infestation of newly planted crops with viruliferous thrips, and lead to subsequent orthotospovirus infection of a crop (Groves et al. 2002; Jones 2005; Kahn, Walgenbach & Kennedy 2005; Northfield et al. 2008; Okazaki et al. 2007).

Thrips interceptions by Australia

Australian interception data (Appendix D) indicate that at least eight thrips species known to transmit orthotospoviruses (Table 4.3) have been positively identified on the plant import pathway, namely *Frankliniella fusca*, *F. intonsa*, *F. occidentalis*, *F. schultzei*, *Scirtothrips dorsalis*, *Thrips palmi*, *T. setosus* and *T. tabaci*. For example, *F. occidentalis* and *T. tabaci* were intercepted at frequencies greater than 250 events per year. This provides strong evidence of the close association between these thrips species and crops that comprise the plant import pathway.

Viruliferous thrips prevalence

Several factors could influence the likelihood of viruliferous thrips being imported, including the prevalence of viruliferous thrips within the source population and the capacity of different thrips species and/or life stages to acquire a given orthotospovirus.

As explained in Chapter 4, thrips larval instars (L1 and L2) and adults can acquire orthotospoviruses (de Assis Filho, Deom & Sherwood 2004; Moritz, Kumm & Mound 2004; Van de Wetering, Goldbach & Peters 1996). However, only virus acquired by L1 and early L2 larvae can replicate within a thrips vector, and be subsequently transmitted to a host plant (de Assis Filho, Deom & Sherwood 2004; Moritz, Kumm & Mound 2004; Nagata et al. 1999; Van de Wetering, Goldbach & Peters 1996).

Only a proportion of the L1 and early L2 larvae present in an export crop are expected to have been exposed to an orthotospovirus infected host plant. In addition, not all susceptible L1 and early L2 larvae that are exposed to a virus infected host will become viruliferous but those that do can remain infected for life (Mautino et al. 2012; Nagata et al. 1999; Wijkamp, Goldbach & Peters 1996).

Within a commercial production system, orthotospovirus infection across an entire crop is relatively uncommon, and a lower incidence of infection is typical (Golnaraghi et al. 2008; Gracia

et al. 1999; Kuo et al. 2014). Even when the incidence of infection is high, this does not necessarily correlate with thrips virus acquisition, and subsequent transmission rates. For example, no correlation was found between the quantity of TSWV ingested by thrips and their ability to acquire the virus (de Assis Filho, Deom & Sherwood 2004; Moritz, Kumm & Mound 2004; Nagata et al. 1999; Van de Wetering, Goldbach & Peters 1996). Chatzivassiliou, Peters & Katis (2002) reported TSWV transmission rates of between 17 to 49 per cent by *T. tabaci* populations collected from a range of tobacco fields where the incidence of infection was estimated as 100 per cent.

Ingestion of an orthotospovirus by a thrips vector may or may not result in acquisition (infection of the thrips cells), and replication of the virus is necessary within the thrips before subsequent transmission can occur (Whitfield, Ullman & German 2005).

A relatively low orthotospovirus acquisition rate by a thrips vector species could moderate the likelihood of importation of a virus, under some circumstances. However, if large numbers of thrips were to be present on the pathway, the likelihood that viruliferous thrips would enter Australia would still remain significant. Australian border interception frequencies for *F. schultzei* and *S. dorsalis* are in the order of 10–50 events per year and greater than 250 events per year for *T. tabaci* (averaged over 26 years). Although these data do not record the absolute number of thrips that are present per interception event, these values indicate that it is feasible that a viruliferous thrips could be imported.

Specificity of thrips to transmit a given orthotospovirus

Thrips species exhibit specificity in the orthotospoviruses they acquire and transmit (Whitfield, Ullman & German 2005). Of 30 described orthotospoviruses, 12 have so far been reported to be transmitted only by a single thrips species, two by two species and three by four species. The exception is TSWV, which is reported to be transmitted by 10 thrips species (Table 4.2). As a result, not all species within a population of thrips associated with an export crop may transmit a specific orthotospovirus. This may moderate the likelihood of the importation of a given orthotospovirus.

For orthotospoviruses known to be transmitted by more than one thrips species, the historical tendency has been for additional thrips species to be identified over an extended period of time. It is credible that there are additional thrips vector species that will be recognised to be capable of transmitting these orthotospoviruses. Additionally, the thrips vector species that are presumed to transmit 10 recently described orthotospoviruses are yet to be identified.

Summary

Orthotospoviruses are an emerging risk with associated uncertainty. It is likely that they will continue to evolve and that new species will be discovered, and/or they will be reported to infect new hosts, or expand their geographic distribution or economic significance. That other thrips species will be reported to transmit a given orthotospovirus is also probable. It is likely that orthotospoviruses, along with their thrips vectors, will be associated with export crops destined for Australia. Orthotospoviruses and their thrips vectors can be sustained on weeds or volunteer plants from which they to move into newly planted crops. Known thrips vectors are also regularly intercepted on the plant import pathway by Australia.

The pest risk assessment for thrips (Chapter 5) gave an indicative likelihood of importation of thrips as High. However, there are factors that could reduce the likelihood of importation of an orthotospovirus, via its thrips vector. It is likely that only a proportion of the thrips present on the plant import pathway will be viruliferous. This is because thrips vector species exhibit high

specificity in the orthotospoviruses they vector—thus, not all thrips species in a field population will be the appropriate vector(s). It is also likely that not all infectible thrips life stages (L1 and early L2) within a population will be exposed to an orthotospovirus infected plant, or if exposed at the right life-stage, not all will become infected. In-field incidence of virus infection, virus acquisition rates, and subsequent transmission rates do not necessarily correlate, even where in-field orthotospovirus incidence is high.

Consequently, the indicative likelihood of importation of an orthotospovirus, via a viruliferous thrips, is assessed as Moderate.

Likelihood (indicative) of distribution

The likelihood (indicative) that a quarantine pest orthotospovirus will be distributed within Australia in a viable state following 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.

Viruliferous thrips dissemination

This assessment considers the scenario that viruliferous thrips could facilitate the entry of an orthotospovirus on the plant import pathway. The pest risk assessment for thrips (Chapter 5) gave an indicative likelihood for the distribution of thrips as Moderate. Effectively, this sets a maximum likelihood for distribution of an imported viruliferous thrips to a susceptible host plant (the end point of distribution).

The likelihood of the distribution of a viruliferous thrips would be influenced, in the first instance, by factors similar to those described in Chapter 5, including thrips small size, cryptic habit, natural survival and dispersal strategies and their rapid distribution via the wholesale and retail supply chains. There is no evidence to suggest non-viruliferous and viruliferous thrips would differ significantly in their ability to disseminate.

Host availability

All described orthotospoviruses have host plants available within Australia, many of which are in common commercial and/or domestic cultivation, and/or present in the environment as weeds or volunteers (that is cultivated varieties growing wild or contaminating other crops). For a given orthotospovirus, the relative abundance of its host species will fluctuate with factors that include annual cropping cycles, changes in relative demand for growing specific crops/cultivars or season. However, Australia has diverse growing regions and many crops can be grown all year round across the country. Most orthotospoviruses also have multiple host plants (Table 4.2). This implies that host plant availability is not likely to be a significant limiting factor moderating the likelihood of distribution.

Differing thrips and orthotospovirus host plant ranges

The natural host ranges of a given thrips species and the orthotospovirus it transmits commonly differ, with only partial overlap of species in common (Jones 2005). Hence, a viruliferous thrips could find its host plant, but that species may not be a susceptible host of the orthotospovirus it was carrying, moderating the likelihood of distribution of the virus. However, a thrips vector can remain viruliferous for life, and may be expected to visit a number of plant species over its lifetime, increasing the likelihood that it would eventually encounter a susceptible orthotospovirus host plant species.

For emergent orthotospoviruses, their host plant ranges and the range of thrips that vector them may be currently unknown, but they can be expected to extend over time. It is likely that susceptible hosts would be available and accessible in the cultivated and/or natural environments.

Orthotospovirus transmission

Orthotospovirus transmission is likely to be influenced by several processes relating to thrips infection biology—virus acquisition, becoming infectious, maintaining infectivity, and transmission through feeding or probing behaviours to host plants (Srinivasan et al. 2012; Wijkamp, Goldbach & Peters 1996).

The proportion of ELISA-positive adult thrips were found to be a factor of 1.2 to 2.7 higher than the proportion that transmitted TSWV (Van de Wetering et al. 1996). Additionally, the number of successive feeding events through which an individual thrips can continue to transmit an orthotospovirus to a host plant is reported to have a dose dependent relationship with accumulated virus concentration (Inoue et al. 2004; Rotenberg et al. 2009).

For thrips vectors, there are inter-species (Inoue et al. 2004; Wijkamp et al. 1995) and intra-species (Chatzivassiliou, Peters & Katis 2002; Van de Wetering et al. 1999; Wijkamp et al. 1995) differences in virus transmission rates reported. Illustrating how transmission rates differ between thrips species for the same virus (Table 6.2), L1 stage larvae fed on TSWV infected leaves as adults were reported, in a *Petunia* leaf disk assay, to transmit the virus at frequencies of about 31, 33, 9 and 6 per cent per for *F. occidentalis*, *F. intonsa*, *T. tabaci* and *T. setosus*, respectively (Inoue et al. 2004). L2 stage larvae that had developed from a colony reared on IYSV-infected lisianthus plants were subsequently observed to transmit the virus at frequencies of about 77 and 18 per cent for *T. tabaci* and *F. fusca*, respectively (Srinivasan et al. 2012). Also, *F. fusca* was reported to transmit TSWV at a higher frequency of about 90 per cent (Srinivasan et al. 2012), indicating the same thrips vector can have different transmission frequencies for different viruses. Collectively, the studies show that transmission frequencies can differ with different combinations of thrips vectors and/or viruses.

Table 6.2 Orthotospovirus transmission efficiency by different thrips vectors

Vector	Virus	Life stage and acquisition access period (AAP) conditions	Life stage and inoculation access period (IAP) conditions	Transmission (%)	Reference
<i>F. occidentalis</i>	TSWV	L1, 4 h, <i>Datura stramonium</i>	Adult, 24 h, <i>Petunia</i> leaf disks	31	(Inoue et al. 2004)
<i>F. intonsa</i>	-	-	-	33	-
<i>T. tabaci</i>	-	-	-	9	-
<i>T. setosus</i>	-	-	-	6	-
<i>T. tabaci</i>	IYSV	L1/L2, lisianthus	L2, 3 w, lisianthus plants	77	(Srinivasan et al. 2012)
<i>F. fusca</i>	-	-	-	18	-
<i>F. fusca</i>	TSWV	L1/L2, lisianthus	L2, 3 w, lisianthus plant	90	-
<i>F. occidentalis</i>	TSWV	L1, 4h, <i>D. stramonium</i>	L2, 24 h, <i>D. stramonium</i>	42	(Van de Wetering, Goldbach & Peters 1996)
<i>F. occidentalis</i>	TSWV	L1, 24 h, <i>Impatiens</i>	Adult, 24 h, <i>Petunia</i> leaf disk	35	(Wijkamp et al. 1995)

Vector	Virus	Life stage and acquisition access period (AAP) conditions	Life stage and inoculation access period (IAP) conditions	Transmission (%)	Reference
<i>F. occidentalis</i>	-	L1, 24 h, <i>D. stramonium</i>	-	33	-
<i>F. occidentalis</i>	-	L1, 24 h, <i>Nicotiana benthamiana</i>	-	30	-
<i>F. occidentalis</i>	INSV	L1, 24 h, <i>Impatiens</i>	Adult, 24 h, <i>Petunia</i> leaf disk	84	-
<i>F. occidentalis</i>	-	L1, 24 h, <i>N. benthamiana</i>	-	92	-
<i>T. tabaci</i>	TSWV	L1, whole larval stage, <i>N. tabacum</i>	Adult, 24 h, <i>Petunia</i> leaf disk	59	(Chatzivassiliou, Peters & Katis 2002)
<i>T. tabaci</i>	-	L1, whole larval stage, <i>D. stramonium</i>	-	67	-

Summary

The pest risk assessment for thrips (Chapter 5) gave an indicative likelihood of distribution of thrips as Moderate. There is no evidence that non-viruliferous and viruliferous thrips differ in their ability to disseminate. Accordingly, distribution of a viruliferous thrips would be influenced initially by factors including thrips small size, cryptic habit, natural survival and dispersal strategies, and their rapid distribution via the wholesale and retail supply chains. However, there are factors that have the potential to reduce the likelihood of distribution of an orthotospovirus, via its thrips vector.

Each orthotospovirus species can infect a distinct range of host plant species. Several key thrips vectors are highly polyphagous with host ranges broader than those of the orthotospoviruses they transmit. It is likely that a proportion of viruliferous thrips will find a host plant species that is not a host species of the orthotospovirus they vector. However, a viruliferous thrips may be expected to visit a range of plant species over its lifetime. Virus transmission rates can differ between thrips species for the same orthotospovirus, and within thrips species for different orthotospoviruses. Although this may moderate the likelihood of a thrips finding an orthotospovirus host plant under some circumstances, it is not expected to fundamentally influence this likelihood.

Consequently, an indicative likelihood of distribution of an orthotospovirus, via a viruliferous thrips is assessed as Moderate.

Notes on Table 6.3

Table 6.3 provides the known distribution of orthotospoviruses and the thrips that transmit them (as of June 2017).

Acronyms: ANSV, *Alstroemeria necrotic streak virus*; BeNMV, *Bean necrotic mosaic virus*; CaCV, *Capsicum chlorosis virus*; CCSV, *Calla lily chlorotic spot virus*; CSNV, *Chrysanthemum stem necrosis virus*; GRSV, *Groundnut ringspot orthotospovirus*; GBNV, *Groundnut bud necrosis orthotospovirus*; GCFSV, *Groundnut chlorotic fan-spot virus*; GRSV, *Groundnut ring spot virus*; GYSV, *Groundnut yellow spot orthotospovirus*; HRCV, *Hippeastrum chlorotic ringspot virus*; INSV, *Impatiens necrotic spot orthotospovirus*; IYSV, *Iris yellow spot orthotospovirus*; LNRV, *Lisianthus necrotic ringspot virus*; MeSMV, *Melon severe mosaic virus*; MYSV, *Melon yellow spot virus*; MVBaV, *Mulberry vein banding associated virus*; PolRSV, *Polygonum ringspot orthotospovirus*; PCSV, *Pepper chlorotic*

spot virus; PNSV, *Pepper necrotic spot virus*; L_GM_TS_G; SVNV, *Soybean vein necrosis virus*; TNRV, *Tomato necrotic ringspot virus*; TNSaV, *Tomato necrotic spot-associated virus*; TCSV, *Tomato chlorotic spot orthotospovirus*; TSWV, *Tomato spotted wilt orthotospovirus*; TYRV, *Tomato yellow ring virus*; TZSV, *Tomato zonate spot virus*; WBNV, *Watermelon bud necrosis orthotospovirus*; WSMoV, *Watermelon silver mottle orthotospovirus*; ZLCV, *Zucchini lethal chlorosis orthotospovirus*.

The presence of an orthotospovirus and/or the thrips that transmit them in a given region is indicated by a 'Y'. Where both are co-located in a region, both orthotospovirus and vector will have a 'Y'. Where an orthotospovirus is present in a region and its vector is unknown, a vector is presumed present and is indicated by a '?'. Where no report of presence exists for region, this is indicated by a '-'.

Where distribution is limited, the specific countries are named (AR, Argentina; BM, Bermuda; BS, Bahamas; BR, Brazil; CN, China; CO, Colombia; DO, Dominican Republic; EC, Ecuador; FI, Finland; FL, Florida; HT, Haiti; HI, Hawaii; IL, Israel; IR, Iran; IT, Italy; JP, Japan; KE, Kenya; KR, South Korea; MX, Mexico; NL, Netherlands; NY, New York; OH, Ohio; PE, Peru; PL, Poland; PR, Puerto Rico; SC, South Carolina; TH, Thailand; TW, Taiwan, ZA, South Africa).

South and Southwest (S. & SW) Asia is considered to include 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.

In relation to six specific orthotospoviruses:

- CaCV: *F. schultzei* and *T. palmi* were suggested as vectors of CaCV by Persley et al. (2006), but supporting evidence remains unpublished.
- CSNV: Declared as eradicated from Europe (EPPO 2005), except for an incursion in Italy that is under official control (EPPO 2014b). Also, an incursion in Belgium in 2012 was recently eradicated (de Jonghe, Morio & Maes 2013; EPPO 2014a). A putative strain of *F. intonsa* is reported as a poor vector of CSNV under experimental conditions (Okuda et al. 2013), but natural transmission remains unconfirmed.
- GRSV: An incursion in Finland is under official control (EPPO 2015).
- MeSMV: *F. occidentalis* was suggested as a potential vector of MeSMV due to its presence on MeSMV-infected plants (Ciuffo et al. 2009), but specific capacity to transmit MeSMV remains unconfirmed.
- SVNV: *Neohydatothrips variabilis* (syn. *Sericothrips variabilis*) was reported to experimentally transmit SVNV (Zhou & Tzanetakis 2013), but natural transmission remains unconfirmed.
- TNSaV: Yin et al. (2014) report *Thrips tabaci* and *T. palmi* as present within infected tomato crops and nearby weeds, but specific capacity to transmit TNSaV remains unconfirmed.

Table 6.3 Distribution of orthotospoviruses and the thrips that transmit them

Orthotospovirus/vector(s)	Orthotospovirus and vector references	Geographic distribution							Geographic distribution references
		Africa	S. & SW Asia	E. & SE Asia	Australasia	Europe	N. America	S. America	
ANSV	(Hassani-Mehraban et al. 2010)	-	-	-	-	-	-	CO	(Hassani-Mehraban et al. 2010)
<i>Frankliniella occidentalis</i>	(Hassani-Mehraban et al. 2010)	Y	Y	Y	Y	Y	Y	Y	(Groves et al. 2003; Kirk 2001; Kirk & Terry 2003; Mound & Walker 1982; Reitz 2009; Salguero Navas et al. 1991)
BeNMV	(de Oliveira et al. 2011)	-	-	-	-	-	-	BR	(de Oliveira et al. 2011)
Unidentified vector(s)		?	?	?	?	?	?	Y	(de Oliveira et al. 2011; de Oliveira et al. 2012)
CaCV	(McMichael, Persley & Thomas 2002)	-	Y	Y	Y	-	HI	-	(Melzer et al. 2014; Pappu, Jones & Jain 2009)
<i>Ceratothripoides claratris</i>	(Premachandra et al. 2005a)	-	Y	Y	-	-	-	-	(Mound 2005b; Premachandra et al. 2005a)
<i>Frankliniella schultzei</i>	(Premachandra et al. 2005a)	Y	Y	Y	Y	Y	HI, FL	Y	(Diffie, Edwards & Mound 2008; Nakahara 1997; Vierbergen & Mantel 1991)
<i>Thrips palmi</i>	(Persley, Thomas & Sharman 2006)	Y	Y	Y	Y	-	HI, FL	Y	(Cannon, Matthews & Collins 2007; Layland, Upton & Brown 1994; Mound 2010; Murai 2001)
CCSV	(Chen et al. 2005)	-	-	TW, CN	-	-	-	-	(Liu et al. 2012; Pappu, Jones & Jain 2009)
<i>Thrips palmi</i>	(Chen et al. 2005)	Y	Y	Y	Y	-	HI, FL	Y	(Cannon, Matthews & Collins 2007; Layland, Upton & Brown 1994; Mound 2010; Murai 2001)
CSNV	(Bezerra et al. 1999)	-	IR	JP, KR	-	IT	-	BR	(de Jonghe, Morio & Maes 2013; EPPO 2014b; Jafarpour 2010; Pappu, Jones & Jain 2009; Yoon, Choi & Choi 2016)
<i>Frankliniella occidentalis</i>	(Nagata et al. 2004; Nagata & De Ávila 2000)	Y	Y	Y	Y	Y	Y	Y	(Groves et al. 2003; Kirk 2001; Kirk & Terry 2003; Mound & Walker 1982; Reitz 2009; Riley et al. 2011b; Salguero Navas et al. 1991)
<i>F. schultzei</i>	(Nagata et al. 2004; Nagata & De Ávila 2000)	Y	Y	Y	Y	Y	HI, FL	Y	(Diffie, Edwards & Mound 2008; Nakahara 1997; Vierbergen & Mantel 1991)

Orthotospovirus/vector(s)	Orthotospovirus and vector references	Geographic distribution							Geographic distribution references
		Africa	S. & SW Asia	E. & SE Asia	Australasia	Europe	N. America	S. America	
<i>F. intonsa</i>	(Nagata et al. 2004; Nagata & De Ávila 2000)	-	Y	Y	-	Y	Y	-	(Chiasson 1986; Nakahara & Footitt 2007)
GBNV	(Reddy et al. 1992)	-	Y	Y	-	-	-	-	(Pappu, Jones & Jain 2009; Reddy et al. 1995)
<i>Frankliniella schultzei</i>	(Meena et al. 2005)	Y	Y	Y	Y	Y	HI, FL	Y	(Diffie, Edwards & Mound 2008; Nakahara 1997; Vierbergen & Mantel 1991)
<i>Scirtothrips dorsalis</i>	(German, Ullman & Moyer 1992; Meena et al. 2005)	-	IL	Y	Y	-	Y	Y	(Diffie, Edwards & Mound 2008; Hoddle, Mound & Paris 2012; Mound 2007b)
<i>Thrips palmi</i>	(Lakshmi et al. 1993; Reddy et al. 1992)	Y	Y	Y	Y	-	HI, FL	Y	(Cannon, Matthews & Collins 2007; Layland, Upton & Brown 1994; Mound 2010; Murai 2001)
GCFSV	(Chen & Chiu 1996; Elliot et al. 2000)	-	-	TW	-	-	-	-	(Chen & Chiu 1996; Chu et al. 2001)
<i>Scirtothrips dorsalis</i>	(Chen & Chiu 1996; Chu et al. 2001)	-	IL	Y	Y	-	Y	Y	(Chu et al. 2001; Diffie, Edwards & Mound 2008; Hoddle, Mound & Paris 2012; Mound 2007b)
GRSV	(De Avila et al. 1993)	ZA	-	-	-	FI	FL, NY, SC	AR, BR	(De Avila et al. 1993; EPPO 2015; Pappu, Jones & Jain 2009; Resende et al. 1996; Webster et al. 2010)
<i>Frankliniella gemina</i>	(de Borbon, Gracia & De Santis 1999)	-	-	-	-	-	-	Y	(2012; Cavalleri, Romanowski & Rodrigues Redaelli 2006; de Borbon, Gracia & De Santis 1999; 2011; Pinent et al. 2006)
<i>F. intonsa</i>	(Wijkamp et al. 1995)	-	Y	Y	-	Y	Y	-	(Chiasson 1986; Nakahara & Footitt 2007)
<i>F. occidentalis</i>	(Nagata et al. 2004; Wijkamp et al. 1995)	Y	Y	Y	Y	Y	Y	Y	(Groves et al. 2003; Kirk 2001; Kirk & Terry 2003; Mound & Walker 1982; Reitz 2009; Riley et al. 2011b; Salguero Navas et al. 1991)
<i>F. schultzei</i>	(de Borbón, Gracia & Piccolo 2006; Nagata et al. 2004; Wijkamp et al. 1995)	Y	Y	Y	Y	Y	HI, FL	Y	(Diffie, Edwards & Mound 2008; Nakahara 1997; Vierbergen & Mantel 1991)
GYSV	(Reddy et al. 1991) (Satyanarayana et al. 1998)	-	Y	Y	-	-	-	-	(Gopal et al. 2010; Pappu, Jones & Jain 2009; Wongkaew & Sae-Wien 1985)

Orthotospovirus/vector(s)	Orthotospovirus and vector references	Geographic distribution							Geographic distribution references
		Africa	S. & SW Asia	E. & SE Asia	Australasia	Europe	N. America	S. America	
<i>Scirtothrips dorsalis</i>	(Gopal et al. 2010)	-	IL	Y	Y	-	Y	Y	(Diffie, Edwards & Mound 2008; Hoddle, Mound & Paris 2012; Mound 2007b)
HCRV	(Dong et al. 2013)	-	-	CN	-	-	-	-	(Dong et al. 2013)
Unidentified vector(s)		?	-	Y	?	?	?	?	(Dong et al. 2013)
INSV	(Law, Speck & Moyer 1991)	Y	Y	Y	Y	Y	Y	Y	(El-Wahab, El-Sheikh & Elnagar 2011; Pappu, Jones & Jain 2009)
<i>Frankliniella intonsa</i>	(Sakurai, Inoue & Tsuda 2004)	-	Y	Y	-	Y	Y	-	(Chiasson 1986; Nakahara & Footitt 2007)
<i>F. occidentalis</i>	(deAngelis, Sether & Rossignol 1993); (Wijkamp et al. 1995); (Sakurai, Inoue & Tsuda 2004)	Y	Y	Y	Y	Y	Y	Y	(Groves et al. 2003; Kirk 2001; Kirk & Terry 2003; Mound & Walker 1982; Reitz 2009; Salguero Navas et al. 1991)
<i>F. fusca</i>	(Naidu, Deom & Sherwood 2001)	-	-	JP	-	-	Y	-	(Diffie, Edwards & Mound 2008; Hoddle, Mound & Paris 2012; Nakao et al. 2011)
IYSV	(Cortes et al. 1998)	Y	Y	Y	Y	Y	Y	Y	(Pappu, Jones & Jain 2009)
<i>Thrips tabaci</i>	(Cortes et al. 1998; Hsu et al. 2010)	Y	Y	Y	Y	Y	Y	Y	(Diffie, Edwards & Mound 2008; Funderburk et al. 2007; Mound 2007a)
<i>Frankliniella fusca</i>	(Mound 2002) (Srinivasan et al. 2012)	-	-	JP	-	-	Y	-	(Diffie, Edwards & Mound 2008; Hoddle, Mound & Paris 2012; Nakao et al. 2011)
LNRV	(Shimomoto, Kobayashi & Okuda 2014)	-	-	JP	-	-	-	-	(Shimomoto, Kobayashi & Okuda 2014)
Unidentified vector(s)		?	?	JP	?	?	?	?	(Shimomoto, Kobayashi & Okuda 2014)
MeSMV	(Ciuffo et al. 2009)	-	-	-	-	-	MX	-	(Pappu, Jones & Jain 2009)
Unidentified vector(s)		?	?	?	?	?	Y	?	(Ciuffo et al. 2009)
MVBaV	(Meng et al. 2015)	-	-	CN	-	-	-	-	(Meng et al. 2015)
Unidentified vector(s)		?	?	Y	?	?	?	?	(Meng et al. 2015)

Orthotospovirus/vector(s)	Orthotospovirus and vector references	Africa	S. & SW Asia	E. & SE Asia	Australasia	Europe	N. America	S. America	Geographic distribution references
MYSV	(Kato, Hanada & Kameya-Iwaki 1999, 2000)	-	-	Y	-	-	-	EC	(Chen et al. 2008b; 2010; Cortes et al. 2001; Lin et al. 2005; Pappu, Jones & Jain 2009; Quito-Avila et al. 2014)
<i>Thrips palmi</i>	(Kato, Hanada & Kameya-Iwaki 2000)	Y	Y	Y	Y	-	HI, FL	Y	(Cannon, Matthews & Collins 2007; Layland, Upton & Brown 1994; Mound 2010; Murai 2001)
PCSV	(Cheng et al. 2013)	-	-	TW	-	-	-	-	(Cheng et al. 2013)
Unidentified vector(s)		?	?	Y	?	?	?	?	(Cheng et al. 2013)
PNSV	(Torres et al. 2012)	-	-	-	-	-	-	PE	(Torres et al. 2012)
Unidentified vector(s)		?	?	?	?	?	?	Y	(Torres et al. 2012)
PolRSV	(Ciuffo et al. 2008)	-	-	-	-	Y	-	-	(Pappu, Jones & Jain 2009)
<i>Dictyothrips betae</i>	(Ciuffo et al. 2010)	-	-	-	-	Y	-	-	(Ciuffo et al. 2010)
L _G M _T S _G	(Webster et al. 2011)	-	-	-	-	-	FL	-	(Webster et al. 2011)
<i>Frankliniella occidentalis</i>	(Webster et al. 2011)	Y	Y	Y	Y	Y	Y	Y	(Groves et al. 2003; Kirk 2001; Kirk & Terry 2003; Mound & Walker 1982; Reitz 2009; Salguero Navas et al. 1991)
SVNV	(Zhou et al. 2011)	-	-	-	-	-	Y	-	(Zhou et al. 2011)
Unidentified vector(s)		?	?	?	?	?	Y	?	(Zhou et al. 2011)
TCSV	(De Avila et al. 1993)	-	-	-	-	-	FL, OH	AR, BR, DO, PR, HT	(Adegbola et al. 2016; Batuman et al. 2014; Baysal-Gurel et al. 2015; De Avila et al. 1993; Granval de Millan & Piccolo 1998; Londoño et al. 2012; Pappu, Jones & Jain 2009; Webster et al. 2013)
<i>Frankliniella intonsa</i>	(Wijkamp et al. 1995)	-	Y	Y	-	Y	Y	-	(Chiasson 1986; Nakahara & Footitt 2007)
<i>F. occidentalis</i>	(Nagata et al. 2004; Whitfield, Ullman & German 2005)	Y	Y	Y	Y	Y	Y	Y	(Groves et al. 2003; Kirk 2001; Kirk & Terry 2003; Mound & Walker 1982; Reitz 2009; Salguero Navas et al. 1991)

Orthospovirus/vector(s)	Orthospovirus and vector references	Africa	S. & SW Asia	E. & SE Asia	Australasia	Europe	N. America	S. America	Geographic distribution references
<i>F. schultzei</i>	(Nagata et al. 2004; Wijkamp et al. 1995)	Y	Y	Y	Y	Y	HI, FL	Y	(Diffie, Edwards & Mound 2008; Nakahara 1997; Vierbergen & Mantel 1991)
TNRV	(Chiemsombat et al. 2010; Seepiban et al. 2011)	-	-	TH	-	-	-	-	(Puangmalai et al. 2013)
<i>Ceratothripoides claratris</i>	(Seepiban et al. 2011)	-	Y	Y	-	-	-	-	(Mound 2005b; Premachandra et al. 2005a)
<i>Thrips palmi</i>	(Seepiban et al. 2011)	Y	Y	Y	Y	-	HI, FL	Y	(Cannon, Matthews & Collins 2007; Layland, Upton & Brown 1994; Mound 2010; Murai 2001)
TNSaV	(Yin et al. 2014)	-	-	CN	-	-	-	-	(Yin et al. 2014)
Unidentified vector(s)		?	?	Y	?	?	?	?	(Yin et al. 2014)
TSWV	(Jones 2005; Samuel 1931; Samuel, Bald & Pittman 1930)	Y	Y	Y	Y	Y	Y	Y	(Pappu, Jones & Jain 2009)
<i>Frankliniella bispinosa</i>	(Avila et al. 2006)	-	-	-	-	-	Y	BM,BS	(Diffie, Edwards & Mound 2008; Funderburk et al. 2007; Hoddle, Mound & Paris 2012)
<i>F. cephalica</i>	(Ohnishi, Katsuzaki & Tsuda 2006)	-	-	JP	-	-	Y	Y	(Diffie, Edwards & Mound 2008; Hoddle, Mound & Paris 2012; Masumoto & Okajima 2004; Nakahara 1997)
<i>F. fusca</i>	(Sakimura 1963)	-	-	JP	-	-	Y	-	(Diffie, Edwards & Mound 2008; Hoddle, Mound & Paris 2012; Nakao et al. 2011)
<i>F. gemina</i>	(de Borbón, Gracia & Piccolo 2006)	-	-	-	-	-	-	Y	(2012; Cavalleri, Romanowski & Rodrigues Redaelli 2006; de Borbon, Gracia & De Santis 1999; 2011; Pinent et al. 2006)
<i>F. intonsa</i>	(Wijkamp et al. 1995)	-	Y	Y	-	Y	Y	-	(Chiasson 1986; Nakahara & Foottit 2007)
<i>F. occidentalis</i>	(Wijkamp et al. 1995)	Y	Y	Y	Y	Y	Y	Y	(Groves et al. 2003; Kirk 2001; Kirk & Terry 2003; Mound & Walker 1982; Reitz 2009; Salguero Navas et al. 1991)
<i>F. schultzei</i>	(Wijkamp et al. 1995)	Y	Y	Y	Y	Y	HI, FL	Y	(Diffie, Edwards & Mound 2008; Nakahara 1997; Vierbergen & Mantel 1991)

Orthotospovirus/vector(s)	Orthotospovirus and vector references	Geographic distribution							Geographic distribution references
		Africa	S. & SW Asia	E. & SE Asia	Australasia	Europe	N. America	S. America	
<i>Thrips palmi</i>	(Fujisawa, Tanaka & Ishii 1988; Persley, Thomas & Sharman 2006)	Y	Y	Y	Y	-	HI, FL	Y	(Cannon, Matthews & Collins 2007; Layland, Upton & Brown 1994; Mound 2010; Murai 2001)
<i>T. setosus</i>	(Fujisawa, Tanaka & Ishii 1988; Persley, Thomas & Sharman 2006)	-	-	JP, KR	-	NL	-	-	(EPPO 2015; Mound 2005a; ThripsWiki 2017)
<i>T. tabaci</i>	(Wijkamp et al. 1995)	Y	Y	Y	Y	Y	Y	Y	(Diffie, Edwards & Mound 2008; Funderburk et al. 2007; Mound 2007a)
TYRV	(Hassani-Mehraban et al. 2005)	KE	IR	-	-	PL	-	-	(Birithia, Subramanian & Villinger 2012; Ghotbi & Shahaeren 2012; Golnaraghi et al. 2008; Hassani-Mehraban et al. 2005; Pappu, Jones & Jain 2009; Zarzynska-Nowak et al. 2016)
<i>Thrips tabaci</i>	(Golnaraghi et al. 2008)	Y	Y	Y	Y	Y	Y	Y	(Diffie, Edwards & Mound 2008; Funderburk et al. 2007; Mound 2007a)
TZSV	(Dong et al. 2008)	-	-	CN	-	-	-	-	(Dong et al. 2008; Pappu, Jones & Jain 2009)
Unidentified vector(s)		?	?	Y	?	?	?	?	(Dong et al. 2009)
WBNV	(Jain et al. 1998)	-	Y	-	-	-	-	-	(Jain et al. 1998; Pappu, Jones & Jain 2009)
<i>Thrips palmi</i>	(Jain et al. 1998)	Y	Y	Y	Y	-	HI, FL	Y	(Cannon, Matthews & Collins 2007; Layland, Upton & Brown 1994; Mound 2010; Murai 2001)
WSMoV	(Iwaki et al. 1984; Yeh & Chang 1995; Yeh et al. 1997)	-	-	Y	-	-	-	-	(Kameya-Iwaki et al. 1988; Pappu, Jones & Jain 2009; Yeh et al. 1992)
<i>Thrips palmi</i>	(Iwaki et al. 1984)	Y	Y	Y	Y	-	HI, FL	Y	(Cannon, Matthews & Collins 2007; Layland, Upton & Brown 1994; Mound 2010; Murai 2001)
ZLCV	(Pozzer et al. 1996; Resende et al. 1996)	-	-	-	-	-	-	Y	(Bezerra et al. 1999; Resende et al. 1996)
<i>Frankliniella zucchini</i>	(Nakahara & Monteiro 1999)	-	-	-	-	-	-	BR	(Nakahara & Monteiro 1999)

6.3 Likelihood of establishment

The likelihood that a quarantine pest orthotospovirus will establish within Australia following its 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 2016b).

The supporting evidence for this assessment is provided.

Orthotospovirus perpetuation

Orthotospoviruses, like all viruses, need a host in which to replicate. The weight of evidence is that orthotospoviruses are not transmitted via seed (Albrechtsen 2006; Pappu et al. 1999b). There is a single report of seed transmission for an isolate of *Soybean vein necrosis virus* under laboratory conditions (Groves et al. 2015), but this has not been observed in soybean grown under field conditions (Hajimorad et al. 2015).

Some orthotospoviruses, for example ANSV, CCSV, HCRV, INSV, IYSV, TSWV and TYRV, have host plant species that can propagate vegetatively, either naturally or through assisted means. Orthotospovirus transmission to such host plants may allow establishment without the ongoing presence of a thrips that can transmit it, but in most circumstances, absence of a thrips vector is likely to cause establishment to fail.

Other than in cases of vegetative propagation or artificial transmission, a thrips vector is essential for orthotospovirus '*perpetuation for the foreseeable future*' in the natural environment. For example, in the absence of its vector, an orthotospovirus would not be perpetuated beyond the life-cycle of an individual annual or biennial host plant. Without a reservoir of virus infection in a host plant, the orthotospovirus would also be rapidly lost from the thrips population as viruliferous adults die, and no re-infection of the next generation of L1 or early L2 larvae occurs. This has implications in considering establishment, because the likelihoods of thrips and orthotospovirus establishment are not always independent events. This is complicated further by the fact that several orthotospovirus vectors are already present within Australia. Hence, there are four possible scenarios when considering establishment: (i) an orthotospovirus and its introducing thrips vector establish; (ii) only the orthotospovirus establishes (iii) only the thrips vector establishes; or (iv) neither establish. Only, (i) and (ii) will support orthotospovirus perpetuation.

Distribution of the orthotospovirus to an annual crop

Many orthotospovirus hosts are annual crops (Tables 4.2 and 6.5). If an orthotospovirus were to be distributed to such a crop, the source of introduced virus infection could be removed from the environment before the virus could establish if the crop was harvested, or removed as part of routine commercial pest management activities. In the absence of a source of re-infection of the next generation of thrips larvae, the virus would then be lost from the thrips population, and establishment of the virus would fail. Although a plausible scenario in certain circumstances, thrips and the orthotospoviruses they transmit can be sustained on weeds or volunteer plants to then infect the next susceptible crop planted (Groves et al. 2002; Jones 2005; Kahn, Walgenbach & Kennedy 2005; Northfield et al. 2008; Okazaki et al. 2007).

Orthotospovirus establishment via viruliferous thrips

The pest risk assessment for thrips (Chapter 5) gave a likelihood of establishment for thrips as High. Factors supporting this conclusion include their broad host range, and reproductive and adaptive survival strategies.

Orthotospovirus infection has been reported to influence thrips biology and behaviour (reviewed in Chapter 4.2), but this evidence is inconclusive regarding the precise effect(s) orthotospovirus infection has on thrips biology and behaviour, with a number of observed inconsistencies. It cannot be concluded that orthotospovirus infection would have any significant impact on the likelihood of establishment for viruliferous thrips. Thus, either scenarios (i) and (iii), where the introduced thrips establish, may be expected to occur.

Orthotospovirus acquisition and transmission

The prospect that an orthotospovirus will be perpetuated for the foreseeable future would be influenced by both virus acquisition and transmission efficiency rates as the virus must continually cycle between plant host and thrips vector. The combined effects of a decrease in the efficiency in both or either acquisition or transmission by a thrips vector could moderate the likelihood of establishment of an orthotospovirus. As discussed (see Chapter 6.2), several factors influence efficiency, including that not all susceptible L1 and early L2 larvae that are exposed to a virus infected host will become viruliferous (Mautino et al. 2012; Nagata et al. 1999; Wijkamp, Goldbach & Peters 1996). There is also intra-species (Inoue et al. 2004; Wijkamp et al. 1995) and inter-species (Chatzivassiliou, Peters & Katis 2002; Srinivasan et al. 2012 ; Van de Wetering et al. 1999; Wijkamp et al. 1995) variation in both acquisition and transmission frequencies.

Concurrent infection of thrips species with multiple orthotospoviruses has been observed (Chiemsombat et al. 2008). If a thrips was viruliferous for multiple orthotospoviruses, this may influence the likelihood of establishment of an orthotospovirus, but further scientific evidence is required to verify the frequency at which this may occur in nature.

Differences occur in the pathogenicity of orthotospovirus strains (isolates), considered to be of the same species, for susceptible host plants, and can influence host plant range (Hassani-Mehraban et al. 2007; Torres et al. 2012). This could either moderate or promote establishment subject to the specific circumstances.

Naturally occurring or introduced viral resistance mechanisms bred into commercial cultivars may impede virus infection (Aramburu & Marti 2003; Dianese et al. 2011; Mandal et al. 2012; Puangmalai et al. 2013), and inhibit establishment. In many plant-pathogen interactions, a plant's resistance to viruses can differ with development stage, plant age or tissue maturity (Develey-Riviere & Galiana 2007). Age-related enhancement of resistance can be broad-spectrum or specific, and may be associated with developmental transitions (juvenile to adult vegetative growth, flowering, senescence, maturity of a given tissue or organ. Mature-plant resistance has been observed for TSWV in peanut (Mandal, Pappu & Caulbreath 2001), tobacco (Mandal, Pappu & Caulbreath 2001) and peppers (Beaudoin, Kahn & Kennedy 2009).

As discussed under consideration of the likelihood of distribution (Chapter 6.2), each orthotospovirus species can infect a distinct range of host plant species, with different levels of overlap in host range between them (Table 4.2). Several key thrips vector species are highly polyphagous with host ranges significantly greater than most orthotospoviruses they transmit. It is thus likely that a proportion of thrips will find a host that is not a host of the orthotospovirus they carry. If this scenario were to occur, establishment could still fail because the orthotospovirus would not be perpetuated beyond the life span of the primary host plants

infected. Granting, a viruliferous thrips may be expected to visit a range of plant species over their lifetime, potentially reducing this moderating influence.

Thrips that transmit orthotospoviruses are already present within Australia

Several thrips species known to transmit orthotospoviruses are already present within Australia—*F. schultzei*, *F. occidentalis*, *S. dorsalis*, *T. palmi* and *T. tabaci*. Collectively, these species transmit at least 14 quarantine pest orthotospoviruses. ANSV, CCSV, GCFSV, GYSV, INSV, L_GM_TS_G, MYSV, TYRV, WBNV and WSMoV have a single local thrips vector; CSNV, GRSV and TCSV have two; and GBNV has three.

Ten orthotospoviruses (BeNMV, HCRV, LNRV, MeSMV, MVBaV, PCSV, PNSV, SVNV, TNSaV and TZSV) have unknown vectors, resulting in uncertainty about their local vector(s) status.

The likelihood of establishment of orthotospovirus may be greater where the introduced viruliferous thrips establishes, because of factors including the pre-selected compatibility between vector and orthotospovirus and their co-location. However, local thrips vectors may facilitate and expedite orthotospovirus establishment under certain circumstances. These thrips species are already widely distributed and therefore prepositioned in agricultural or horticultural production areas, domestic gardens and the natural environment.

Orthotospoviruses transmitted by a broader range of thrips species would be expected to have a greater likelihood of contact with susceptible host plants because of the greater potential that vector and virus share common host species. An additional and important factor is that establishment of the introduced orthotospovirus might not necessarily be limited by the population dynamics of the thrips population causing its entry into Australia. For example, an orthotospovirus could establish (and spread), with the assistance of a local vector species, even where the thrips population causing virus entry itself fails to establish (scenario ii).

Previous orthotospovirus establishment events within Australia

Three orthotospovirus species have established within Australia—TSWV (Jones 2005; Samuel, Bald & Pittman 1930), CaCV (McMichael, Persley & Thomas 2002), and IYSV (Coutts et al. 2003). Additionally, an INSV incursion occurred in 2010, but was successfully eradicated (PHA & NGIA 2011). Although the pathway(s) for the entry of these orthotospoviruses cannot be identified with certainty, these events clearly demonstrate that the Australian environment can sustain orthotospovirus establishment, and that host plants were accessible. It also implies that factors that moderate orthotospovirus establishment in Australia are not insurmountable barriers, and that future orthotospovirus establishment events are feasible.

Summary

Except under circumstance of vegetative propagation or artificial transmission, a thrips vector is essential for orthotospovirus ‘perpetuation for the foreseeable future’ in the natural environment.

The pest risk assessment of thrips (Chapter 5) gave a likelihood of establishment for thrips as High. Factors supporting this conclusion include their broad host range, and reproductive and adaptive survival strategies. There is no conclusive evidence that non-viruliferous and viruliferous thrips differ in their ability to establish.

Local thrips vector species could facilitate and expedite orthotospovirus establishment in some circumstances. Five thrips species that vector at least 14 quarantine pest orthotospoviruses are present within Australia. Ten orthotospoviruses have unidentified vectors, and it is uncertain if they have local thrips vectors. Therefore, in a scenario where introduced thrips failed to

establish, local thrips could potentially facilitate the establishment of several, but probably not all, orthotospoviruses.

However, there are several factors that have the potential to reduce the likelihood of establishment of an orthotospovirus, via its thrips vector, under certain circumstances. Many orthotospovirus hosts are annual crops, and if an orthotospovirus were distributed to such a crop, the primary source of virus infection could be removed before the virus established. The efficiency of virus acquisition and transmission are both relevant at the establishment step. As noted previously, both virus acquisition and transmission rates differ with different combinations of thrips vectors and/or viruses. The combined effects of a decrease in the efficiency of either or both acquisition or transmission by a thrips vector could moderate the likelihood of establishment of an orthotospovirus. A proportion of viruliferous thrips are also likely to find a host that is not a host of the orthotospovirus they carry.

Consequently, an indicative likelihood of establishment of an orthotospovirus, via a viruliferous thrips, is assessed as Moderate.

6.4 Likelihood of spread

The likelihood that a quarantine pest orthotospovirus 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 2016b).

The supporting evidence for this assessment is provided.

In nature, orthotospovirus existence ordinarily requires its continuous cycling from plant to thrips and back again. The weight of evidence is that orthotospoviruses are not transmitted via seed (Albrechtsen 2006; Pappu et al. 1999b). A thrips vector can only acquire an orthotospovirus from infected plant material, as transmission between individual thrips or from parent to offspring (transovarially) does not occur (Chapter 4.3), and each generation of thrips must reacquire the virus for it to persist in future generations of the vector (Nagata et al. 1999; Van de Wetering, Goldbach & Peters 1996; Wijkamp et al. 1996). These constraints have the potential to influence the likelihood of spread (or at least the rate of spread) of an orthotospovirus via viruliferous thrips.

In considering spread, the premise is that an orthotospovirus has already established. For an orthotospovirus to establish in nature, ordinarily either the introducing thrips vector has established and/or a local thrips vector facilitated its establishment. That each of the virus, its vector and a plant host are therefore present within Australia provides an enduring source of infection, and a principal means of spread via viruliferous thrips.

Orthotospoviruses can spread via (i) viruliferous thrips or (ii) the movement of infected plants and propagation materials.

Orthotospovirus spread via viruliferous thrips

The pest risk assessment for thrips (Chapter 5) gave a likelihood of spread for thrips within Australia as High. This rating is supported by factors that include their active aerial dispersal capabilities via flight or on wind currents and dispersal as contaminants on plant produce, vehicles or clothes (Chapter 5.4).

There is no conclusive evidence that non-viruliferous and viruliferous thrips differ in their ability to spread (Chapter 4.2). Orthotospoviruses are transmitted in a persistent and

propagative manner (Whitfield, Ullman & German 2005), which would enable their long distance dispersal by viruliferous thrips.

In a scenario where a local thrips vector was present, orthotospovirus spread would not necessarily be limited by the population dynamics of the thrips population that introduced it into Australia. This may enable and expedite spread in certain circumstances. For example, the introduction of a new orthotospovirus may result in its contact with a range of new vectors.

Orthotospovirus dispersal via nursery-stock

Orthotospovirus host plants (Table 3.2) include species that are expected to be present in nurseries servicing both commercial and domestic activities. Very large volumes of whole plants and propagative materials are traded across Australia. Nursery-stock is a significant pathway for the spread of plant pests (McNeill et al. 2006) including orthotospoviruses (de Jonghe, Morio & Maes 2013; Elliott et al. 2009). Infected plants and propagation materials are likely to be traded if orthotospovirus disease expression is not apparent, or is localised, rather than systemic (Jones & Sharman 2005; Smith et al. 2006), or present as asymptomatic infection (Smith et al. 2006).

In addition to nursery-stock plants being infected with an orthotospovirus, these plants could be infested with viruliferous thrips. The likelihood that a viruliferous thrips would be dispersed as contaminants on nursery-stock is facilitated by factors that include thrips' small size, cryptic habit, and survival and dispersal strategies.

Orthotospovirus spread, via infected nursery-stock, or infestation with viruliferous thrips would be aided by the extensive wholesale and retail supply chains that exist within Australia for the movement of nursery-stock. However, commercially produced plants or propagation materials with easily observable orthotospovirus disease (or infestation) symptoms may be unmarketable. In addition, the interstate movement of a range of plants species is subject to a range of domestic biosecurity arrangements within Australia. These factors would be expected to moderate the likelihood of spread via this pathway, but it is credible that it could remain a significant pathway for orthotospovirus spread under certain circumstances.

Host plant availability

Orthotospoviruses, as a group, have an extensive range of host plants including ornamental species (Chen et al. 2005; Daughtrey et al. 1997; de Jonghe, Morio & Maes 2013; Dong et al. 2013; Elliott et al. 2009; Hassani-Mehraban et al. 2010; Liu et al. 2012; Momonoi, Moriwaki & Morikawa 2011; Mumford et al. 2003) and cultivated fruit, vegetable and herb crops (Jones 2005; Mandal et al. 2012; Pappu, Jones & Jain 2009).

Host plants of orthotospoviruses and their thrips vectors are common in commercial and/or domestic cultivation and/or present in the environment as weeds or volunteers (that is cultivated varieties growing wild or contaminating other crops). Most orthotospoviruses also have multiple host plants (Table 4.2).

Australia has diverse growing regions with some crops grown throughout the year, although the relative abundance of susceptible host plants may fluctuate. Infection of annual/biennial crops may lead to fluctuations in the prevalence of orthotospovirus in the environment, which may influence the availability of virus to be acquired and subsequently transmitted by thrips. However, thrips and the orthotospoviruses they transmit can be sustained on weeds and volunteers, from which viruliferous thrips can infest newly planted crops (Groves et al. 2002; Jones 2005; Kahn, Walgenbach & Kennedy 2005; Northfield et al. 2008; Okazaki et al. 2007).

Consequently, host plant availability is not expected to be a major limiting factor to the spread of orthotospoviruses.

Orthotospovirus acquisition and transmission

Orthotospovirus acquisition and transmission rates are likely to be influenced by several processes relating to thrips infection biology: virus acquisition, becoming infectious, maintaining infectivity, and transmission through feeding or probing behaviours to host plants (Srinivasan et al. 2012; Wijkamp, Goldbach & Peters 1996). Critically, acquisition and transmission rates of orthotospoviruses differ (Inoue et al. 2004; Srinivasan et al. 2012), and inter-species (Inoue et al. 2004; Wijkamp et al. 1995) and intra-species (Chatzivassiliou, Peters & Katis 2002; Van de Wetering et al. 1999; Wijkamp et al. 1995) differences are reported.

Each orthotospovirus species can infect a distinct range of host plant species, with different levels of overlap in host range between them. Several key thrips vectors are highly polyphagous with host ranges greater than the orthotospoviruses they transmit. A proportion of these thrips are likely to find a host which is a non-host of the orthotospovirus they carry.

Consequently, these factors are expected to moderate orthotospovirus acquisition and transmission frequencies. However, the fact that both the virus and its vector are established, and a suitable host plant is present, is likely to overwhelm these inhibitory factors, and virus spread is still likely to occur.

Effect of orthotospovirus infection on thrips

Orthotospovirus infection has been reported to influence thrips biology and behaviour (reviewed in Chapter 4.2), but the evidence is inconclusive regarding the precise effects caused, with a number of observed inconsistencies. Therefore, it cannot be concluded that the effect(s) of orthotospovirus infection would have any substantial impacts on the likelihood of spread of the virus.

Australian environment

Natural barriers exist between the different areas of Australia. Arid areas and long geographic distances exist between the east and the west, such as the Nullarbor Plain, and the Bass Strait that separates the mainland from Tasmania. Climatic differentials occur between the north and the south. It would be difficult for adult viruliferous thrips vectors to disperse unaided from one area to another. However, it may be feasible for thrips to overcome these natural barriers because they can be carried on the wind for long distances, as discussed in Chapter 5.4. Such natural barriers would not inhibit expansion of a pest's geographical distribution at smaller scales—such as at local or district levels.

Three orthotospovirus species are already established and widespread within Australia (TSWV, CaCV and IYSV). Both CaCV (McMichael, Persley & Thomas 2002) and IYSV (Couatts et al. 2003) rapidly spread within Australia following their introduction. This is evidence that the Australian environment is favourable to orthotospovirus spread, and that if host plants persist within the Australian environment, so too can the orthotospoviruses that infect them.

Summary

In nature, orthotospovirus existence ordinarily requires its continuous cycling from plant to thrips and back again, because each generation of thrips must reacquire the virus for its continuance in their population. In considering spread, the premise is that an orthotospovirus has already established. For an orthotospovirus to establish, ordinarily either the introducing

thrips vector has established and/or a local thrips vector facilitated its establishment. The fact that both the orthospovirus and its vector, together with a suitable host plant, are present provides an enduring source of virus infection and a principal mechanism for its spread.

The pest risk assessment of thrips (Chapter 5) gave a likelihood of spread for thrips as High. There is no conclusive evidence that non-viruliferous and viruliferous thrips would differ in their ability to spread. Orthospovirus spread within Australia can occur via the dispersal of (i) infected plant material, or (ii) viruliferous thrips. Primary means of spread include orthospovirus infected nursery-stock (including propagative plant materials), active aerial dispersal of viruliferous thrips via flight or wind currents, or passive dispersal of viruliferous thrips as contaminants on nursery-stock, vehicles or clothes.

Consequently, the indicative likelihood of spread of an orthospovirus is assessed as High.

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

The overall likelihood (indicative) that a quarantine pest orthospovirus 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 **Low**.

The overall likelihood (indicative) 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 6.4.

Table 6.4 Likelihood of entry (indicative), establishment and spread for orthospoviruses

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

6.6 Consequences

The overall consequences rating for quarantine pest orthospoviruses is estimated as: **Moderate**.

The potential consequences of the establishment of quarantine orthospoviruses in Australia have been estimated according to the method described in Appendix A. Impact scores for consequences ratings are summarized in Table 6.5.

Table 6.5 Summary of consequences for orthospoviruses

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	E

Consequences criterion	Impact (magnitude and geographic scale)	Impact score
	Significant at the regional level Minor significance at the national level	
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 the environment	Indiscernible at the local, district, regional and national levels	A
Overall consequences rating		Moderate

The assessment of consequences considered only the impacts caused by quarantine pest orthotospoviruses. It did not consider any additional impacts caused by the thrips that transmit them. A separate risk assessment was undertaken for thrips (Chapter 5 of this report).

The supporting evidence for this assessment is provided.

Direct impact on plant life or health

Impact score is estimated as **E**.

The direct impact of an orthotospovirus 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. Orthotospoviruses infect plants and cause necrosis, chlorosis, ring patterns, mottling, silvering, stunting and lesions. Once infected, a host plant would continue to be impacted for life. This can result in near complete crop failures, but typically reduces commercial yields, quality and marketability. The annual gross value of production for 'at risk' crops, which include potatoes, tomatoes, onions, melons, capsicums and chillies, is about \$3 billion. Hosts include key agricultural commodities, and multiple 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

Internationally, orthotospoviruses cause significant economic consequences to fruit, vegetable, legume and ornamental crop production (Daughtrey et al. 1997; Gent et al. 2006; Kunkalikal et al. 2011; Mandal et al. 2012; Mumford, Barker & Wood 1996; Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006). This includes host plant species that comprise the plant import pathway, as illustrated and referenced in Table 4.2 and summarised in Table 6.6, for quarantine pest orthotospoviruses.

Table 6.6 Orthotospovirus host crops

Orthotospovirus (a)	Host crops, include (b)
ANSV	Alstroemeria, tomato, pepper [cucumber, petunia] (c)
BeNMV	Common bean (<i>Phaseolus vulgaris</i>)
CCSV	Calla lily (<i>Zantedeschia</i> spp.), zucchini, wax gourd, spider lily (<i>Hymenocallis littoralis</i>)
CSNV	Tomato, chrysanthemum, aster, lisianthus (<i>Eustoma grandiflorum</i>) [capsicum, aubergine]
GBNV	Potato, tomato, onion, watermelon, peanut, soybean, peas, mungbeans, jute, taro
GCFSV	Peanut
GRSV	Potato, tomato, pepper, peanut, cucumber, soybean, coriander, lettuce, aster, begonia
GYSV	Peanut
HCRV	<i>Hippeastrum</i> spp., <i>Philodendron</i> sp. [tomato, capsicum]
INSV	Potato, pepper, peanut, cucumber, lettuce, herbs, many ornamentals
LNRV	Lisianthus
MeSMV	Melon spp., zucchini, cucumber
MVBaV	Mulberry
MYSV	Melon spp., cucumber
PCSV	Sweet/chilli pepper
PNSV	Tomato, sweet/chilli pepper
PolRSV	<i>Polygonum</i> species [Solanaceous spp.]
L _G M _T S _G	Tomato
SVNV	Soybean
TCSV	Potato, tomato, sweet pepper, lettuce, endive, peanut, gilo (<i>Solanum gilo</i>), celery, lisianthus, <i>Portulaca oleracea</i> , cape gooseberry (<i>Physalis peruviana</i>)
TNRV	Tomato, sweet pepper
TNaSV	Tomato
TYRV	Potato, tomato, peppers, soybean, many ornamentals
TZSV	Tomato, chilli pepper, potato
WBNV	Tomato, chilli pepper, watermelon, other cucurbits
WSMoV	Watermelon, other cucurbits, calla lily
ZLCV	Zucchini, melon spp., cucumber

a. ANSV, *Alstroemeria necrotic streak virus*; BeNMV, *Bean necrotic mosaic virus*; CCSV, *Calla lily chlorotic spot virus*; CSNV, *Chrysanthemum stem necrosis virus*; GBNV, *Groundnut bud necrosis orthotospovirus*; GCFSV, *Groundnut chlorotic fan-spot virus*; GRSV, *Groundnut ring spot orthotospovirus*; GYSV, *Groundnut yellow spot orthotospovirus*; HRCV, *Hippeastrum chlorotic ringspot virus*; INSV, *Impatiens necrotic spot orthotospovirus*; MeSMV, *Melon severe mosaic virus*; MVBaV, *Mulberry vein banding associated virus*; MYSV, *Melon yellow spot virus*; PolRSV, *Polygonum ringspot orthotospovirus*; PCSV, *Pepper chlorotic spot virus*; PNSV, *Pepper necrotic spot virus*; L_GM_TS_G; SVNV, *Soybean vein necrosis virus*; TNRV, *Tomato necrotic ringspot virus*; TNSaV, *Tomato necrotic spot-associated virus*; TCSV, *Tomato chlorotic spot orthotospovirus*; TYRV, *Tomato yellow ring virus*; TZSV, *Tomato zonate spot virus*; WBNV, *Watermelon bud necrosis orthotospovirus*; WSMoV, *Watermelon silver mottle orthotospovirus*; ZLCV, *Zucchini lethal chlorosis orthotospovirus*. **b.** Host crops are illustrative of consequences impact, and do not necessarily represent a comprehensive list of the natural host plants of each orthotospovirus, which is extensive for some species. **c.** Host plants derived from mechanical transmission trials only are given in square brackets and are illustrative only.

Symptoms and disease incidence

Orthotospoviruses ordinarily reduce commercial yields, quality and marketability, but in the worst case scenario can cause near complete crop failures (Culbreath, Todd & Brown 2003; Jones 2005; Mandal et al. 2012). Once a plant becomes infected with an orthotospovirus, it will remain infected for life and continue to be subject to the ongoing impacts of disease caused by the virus. Disease symptoms caused by orthotospovirus infection of host plants include necrosis, chlorosis, ring patterns, mottling, silverying, stunting and lesions (Jones 2005). However, disease occurrence and symptom expression are influenced by a broad range of factors that include the specific orthotospovirus species or isolate, plant-host species or cultivar, plant-host maturity, season and environment (German, Ullman & Moyer 1992). Examples of the impact and incidence of orthotospoviruses on selected crops reported internationally are given in Table 6.7.

Table 6.7 Impact and incidence of orthotospoviruses on host crops

Orthotospovirus	Crop(s)	Region	Impact/Incidence	Reference
GBNV	Various, including potato, tomato, peppers, soybean	Pan-Asia	US \$89 million annually	(Reddy et al. 1995)
GBNV	Onion	India	Necrosis, flower abortion and plant death (no incidence data)	(Sujitha et al. 2012)
GRSV	Lettuce, tomato	Argentina	Significant, sporadic losses (incidence up to 41%)	(Gracia et al. 1999)
INSV	Lettuce	USA	Stunted, necrotic and distorted leaves (incidence up to 27%)	(Kuo et al. 2014)
MYSV	Melon spp.	Taiwan	Complete crop loss in early development stage infections	(Peng et al. 2011)
TCSV	Tomato	USA	Extensive necrosis, fruit unmarketable (no incidence data)	(Polston et al. 2013)
TYRV	Soybean	Iran	Chlorotic and necrotic symptoms (incidence up to 28%)	(Golnaraghi et al. 2007a)
TYRV	Potato	Iran	Leaf and stem necrosis (incidence up to 23%)	(Golnaraghi et al. 2008)
TNRV	Tomato, pepper	Thailand	Widespread, severe losses (no incidence data)	(Puangmalai et al. 2013)
ZLCV	Zucchini, cucumber, melon spp.	Brazil	High yield losses of marketable fruits (no incidence data)	(Bezerra et al. 1999)

Australian gross crop value

Australia produces a broad range of agricultural commodities (arable and livestock) with the sector as a whole valued at about \$53.6 billion in Financial Year (FY) 2014–15. During this period, all arable agricultural/horticultural crops contributed about \$26.8 billion to the Australian economy (ABS 2016).

Orthotospoviruses can infect multiple hosts, with various levels of overlap in their respective host plant ranges. Accordingly, specific consequences will depend on the particular orthotospovirus introduced. However, significant reductions in crop yield, quality or marketability would be expected to result from most orthotospoviruses.

Illustrating the scale of various ‘at risk’ industries, Australia’s annual gross value of production (GVP)—the value of production at the point of sale—for selected orthotospovirus host plant

crops for the FY 2014–15 was potatoes (\$617.9 million), tomatoes (\$311.3 million), onions (\$240.2 million), lettuce (167.9 million), melons (\$216.1 million), capsicums, excluding chillies (\$114.7 million), peanuts (\$15.5 million) (ABS 2016); and for cucumber (\$214.5 million), zucchini (\$62 million), celery (\$56.3 million), and chillies \$11.1 million (HIA 2016), giving a total GVP of about \$2 billion. In addition, several orthotospoviruses also have host plant ranges that include species used as nursery-stock and/or cut-flowers, and for the financial year 2014–15, these sectors had a GVP of about \$738.1 million for nursery-stock and \$296.2 million for cut-flowers (ABS 2016), giving a total GVP of about \$1 billion. 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.

Direct impact on other aspects of the environment

Impact score is estimated as **A**.

The direct impact of an orthotospovirus on other aspects of the environment would be indiscernible at the local, district, regional and national levels, which has an impact score of 'A'. Internationally and domestically no impact of any orthotospovirus on the environment is reported.

Weeds

Many weed species are known to be orthotospovirus hosts and potential reservoirs of infection for cultivated crops (Jones 2005). However, any direct impact on weed species in the environment is unlikely to cause negative consequences.

Native flora

Susceptibility of native flora to orthotospoviruses is uncertain. Published data focus on cultivated species, but susceptible orthotospovirus host crops may have wild relatives, and related species, present in the environment. However, no orthotospovirus-related impact on plant life in the environment has been reported internationally. Likewise, there is no evidence of any significant orthotospovirus susceptibility in Australian flora (Mound 2001). Gibbs et al. (2000) report presence of a widespread, but otherwise uncharacterised, orthotospovirus in an Australian native orchid, *Pterostylis*. Three orthotospoviruses, TSWV, CaCV and IYSV are now widespread within Australia, but their presence, in combination with current vectors, has not seemingly caused environmental consequences. Persley et al. (2006) advised *Hoya australis* to be a susceptible host of CaCV, but further data were not published. TSWV has an extensive host range (Parrella et al. 2003), and has been present in Australia since at least 1915 (Samuel, Bald & Pittman 1930); four thrips species that transmit TSWV (Table 4.3), including its major vector *F. occidentalis*, are also present within Australia, although two of these species are regional pests and under official control. Nevertheless, native species were not found to be a reservoir for TSWV infection in a survey of crops, natives and weeds in Western Australia (Latham & Jones 1998). In that study, only a single *Calectasia cyanea* sample gave a positive ELISA result, but the donor plant was symptomless, virus recovery failed, and no later samples were positive. The only other reports of native plant susceptibility concern nursery-stock of Kangaroo paw (*Anigozanthos* hybrids) and *Bracteantha bracteata* (everlasting daisy) that were infected with TSWV (Hill & Moran 1996; Tesoriero & Lidbetter 2001). It is plausible to expect there has been opportunity for native species to have been exposed to the combination of orthotospoviruses and thrips that transmit them that are currently present in Australia, with no impact reported. Equally, no impacts of orthotospoviruses are reported on the natural environment internationally. In the absence of evidence to the contrary it is concluded that orthotospoviruses are unlikely to have direct consequences on the natural environment. However, such impact

cannot be totally excluded because Australia's native flora has not been exposed to all potential virus/vector combinations.

Indirect impact on eradication and control

Impact score is estimated as **E**.

The indirect impact of an orthotospovirus 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 has an impact score of 'E'. It is expected that efforts would be taken to contain and possibly eradicate an incursion of a quarantine pest orthotospovirus 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. These actions would also cause significant disruption to affected agribusiness and associated trades. Should eradication and containment fail, commercial production practices would need to change to mitigate the impact from an orthotospovirus as infected plants would need to be removed and destroyed since no other control measure is possible. The introduction of a new orthotospovirus would provide opportunity for novel orthotospovirus and thrips combinations to occur, which may increase their impacts. 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 significant at the regional level and of minor significance at the national level.

Containment and eradication

Australia has emergency response systems and protocols in place to respond appropriately to plant pest incursions. For example, 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). This provides a consistent and agreed national approach for managing pest incursions, which allows industries and governments to respond quickly and effectively to a pest incursion. Under this framework, or other provisions, it is expected that biosecurity action(s) would be taken to contain and possibly attempt to eradicate an incursion of a quarantine pest orthotospovirus within Australia.

Internationally, attempts to contain and eradicate orthotospovirus incursions have met with both success (de Jonghe, Morio & Maes 2013) and failure (Elliott et al. 2009). An incursion of INSV into Australia in 2010 was successfully eradicated (PHA & NGIA 2011). However, success depends on several factors, with early detection being vital, and incursions into Australia of CaCV, first detected in 1999 (McMichael, Persley & Thomas 2002) and IYSV, first detected in 2002 (Coutts et al. 2003), could not be eradicated. Any action in response to a quarantine pest orthotospovirus incursion, whether successful or not, would undoubtedly be costly and cause significant disruption to agribusiness and associated trades.

New orthotospovirus and thrips vector combinations

Three orthotospoviruses (CaCV, TSWV and IYSV) and five thrips species (*F. occidentalis*, *F. schultzei*, *T. palmi*, *T. tabaci* and *S. dorsalis*) that transmit orthotospoviruses are present in Australia. Therefore, 27 orthotospoviruses and nine known thrips vectors are absent. Although specificity in the relationship between an orthotospovirus and the thrips that transmit it appears strong, several orthotospoviruses are transmitted by multiple thrips species (Table 4.3). This suggests there may be significant opportunity for novel orthotospovirus/thrips combinations to occur following an incursion, potentially resulting in synergistic pathogenic impacts. For example, the introduction of a new vector may enhance transmission of currently present

orthotospoviruses or the introduction of a new orthotospovirus may result in its contact with a more efficient vector. Illustrating this point, TSWV has an extensive history of association with cultivation (Jones 2005; Samuel, Bald & Pittman 1930), but it was not until the late 1980s and the global spread of *F. occidentalis* that TSWV became a major global pest (Jones 2005). Similarly, INSV emergence as a major pest was also associated with the spread of *F. occidentalis* (Daughtrey et al. 1997).

Commercial production

Should containment and eradication be attempted and fail, industry might need to adjust production practices to mitigate the impact from the introduced orthotospovirus. This is likely to have significant cost implications. Significantly, should a crop become infected by an orthotospovirus there is no remedial action possible, other than the removal and destruction of infected plants. There is also significant lack of understanding about emergent orthotospoviruses, and it is likely that some Australian scientific research effort may be diverted, post incursion, into further resolving orthotospovirus epidemiology and appropriate production and pest management responses, within the Australian context.

Indirect impact on international trade

Impact score is estimated as **D**.

The indirect impact of an orthotospovirus 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'. Orthotospoviruses are considered major global pests. It is likely that trading partners would 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 would be expected to threaten economic viability through loss of trade and export markets at the local level. If trade were to be suspended or stopped, it could be expected to have significant impact on several industries at the district level. The export of crops such as potatoes, tomatoes, alliums and leguminous crops, nursery-stock and cut-flowers would be affected. The state or territory government would have to expend resources to support affected industries and assist in regaining market access, which would have minor impact at the regional level.

Orthotospoviruses are considered major global pests (Jones 2005; Mandal et al. 2012; Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006). In response to an orthotospovirus being introduced into Australia's agricultural sectors, it is likely that trading partners would review their phytosanitary requirements for affected exported host commodities. Trading partners might restrict, at least temporally, 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 a trading partner's 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.

Orthotospoviruses with hosts within the Solanaceae, Alliaceae and Cucurbitaceae families are common. Table 6.8 shows exports for selected commodities in these families, where a total of 101,766 tonnes valued at \$90.1 million of fresh produce were exported in the financial year 2015–16 (HIA 2017). Seventeen of the main export destinations for these commodities are also identified, including Belgium, Brunei Darussalam, Canada, Fiji, Hong Kong, Indonesia, Japan,

Kuwait, Malaysia, New Caledonia, New Zealand, Papua New Guinea, Qatar, Singapore, South Korea, Thailand and United Arab Emirates (HIA 2017).

Table 6.8 Australian exports of selected orthotospovirus host crops (2015–16)

Commodity	Volume (Tonnes)	Value (\$m)	Major export destinations
Onions	43,888	28.6	Belgium, Malaysia, Japan, Thailand, United Arab Emirates.
Ware potatoes	37,212	25.9	South Korea, Malaysia, United Arab Emirates, Indonesia, Singapore.
Melons	19,243	31.0	United Arab Emirates, Singapore, New Zealand, Hong Kong, Malaysia, Kuwait, Qatar
Tomatoes	939	3.0	New Zealand, Singapore, Hong Kong, Canada, New Caledonia
Capsicums	484	1.6	New Zealand, Papua New Guinea, Fiji, Brunei Darussalam, New Caledonia
Total	101,766	90.1	

Several orthotospoviruses have hosts that include species used as cut-flowers or nursery-stock. During the financial year 2015–16, Australia exported \$7.8 million worth of cut-flowers and \$5.7 million worth of nursery-stock plants (HIA 2017).

These examples illustrate the scale of potential consequences to Australian exports if a quarantine pest orthotospovirus was introduced. 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.

Indirect impact on international trade might divert produce intended for export onto the domestic market. In the short term, this might depress the domestic market price in affected commodities, although unmarketable domestic produce might cause localised supply and demand variations. However, industry adjustment would be expected in line with demand.

Indirect impact on domestic trade

Impact score is estimated as **D**.

The indirect impact of an orthotospovirus 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'. 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 plant material out of the initial incursion area, which would have significant economic impact on plant industries and business at the district level. 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. This is expected to be of minor significance at the regional level.

Regional biosecurity

In addition to Australia's international biosecurity activities, at state and territory level Australia operates a biosecurity system that regulates domestic (interstate) movement of a range of plants and plant produce to mitigate the risk from regional pests. The introduction of an orthotospovirus into Australia's agricultural 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 sectors. Depending on the

specific circumstance, this might render part of existing and/or future interstate trade in affected commodities uneconomical. However, it is plausible that the introduced orthotospovirus 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 score is estimated as **A**.

The indirect impact of an orthotospovirus on the environment would be indiscernible at the local, district, regional and national levels, which has an impact score of 'A'. This is because no evidence was found that indicated that an orthotospovirus would have indirect impact on the environment.

6.7 Unrestricted risk estimate (indicative)

Unrestricted risk (indicative) is the result of combining the likelihood of entry (indicative), establishment and spread (Table 6.4) with the estimate of consequences (Table 6.5). Likelihoods and consequences are combined using the risk estimation matrix in Appendix A. The unrestricted risk (indicative) for orthotospoviruses that are quarantine pests for Australia is given in Table 6.9, and is assessed as **Low**.

Table 6.9 Unrestricted risk estimate (indicative) for orthotospoviruses

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

This PRA identified 27 orthotospoviruses as quarantine pests for Australia (Table 6.1). These orthotospoviruses had an unrestricted risk (indicative) that does not achieve the ALOP for Australia. Therefore, risk management measures are required for these pests in specific trade pathways when the unrestricted risk (indicative) of Low is verified.

7 Key findings

7.1 Scoping assessment for thrips

Scoping assessment identified thrips families that are not likely to be associated with the plant import pathway, except as rare contaminating pests, and/or have no potential economic consequences for Australia, and therefore cannot meet the definition of a quarantine pest. For this reason the Aeolothripidae, Fauriellidae, Heterothripidae, Melanthripidae, Merothripidae, fungivorous and predatory Phlaeothripidae, Stenurothripidae, obligate predatory Thripidae and the Uzelothripidae required no further risk assessment.

7.2 Pest risk categorisation of thrips

Pest categorisation determines whether a pest has the characteristics of a quarantine pest (FAO 2016b). The identified thrips families that required further pest categorisation were the phytophagous Thripidae and phytophagous Phlaeothripidae (excluding potential biocontrol agents for weeds). Based on seven selection criteria (Table 3.1), a total of 112 species (92 Thripidae and 20 Phlaeothripidae) were assessed by pest categorisation, as detailed in Table 3.2. A total of 79 of these species met the definition of a quarantine pest and were considered further (Table 3.3). An additional three species were considered further because they transmit orthotospoviruses.

7.3 Pest categorisation of orthotospoviruses

Pest categorisation (Table 4.2) identified 30 orthotospoviruses, 27 of which are quarantine pests for Australia: ANSV, BeNMV, CCSV, CSNV, GBNV, GCFSV, GRSV, GYSV, HCRV, INSV, LNRV, MeSMV, MVBaV, MYSV, PCSV, PNSV, PoIRSV, L_GM_TS_G, SVNV, TCSV, TNRV, TNSaV, TYRV, TZSV, WBNV, WSMoV and ZLCV.

Tomato spotted wilt orthotospovirus (TSWV) (Jones 2005; Samuel, Bald & Pittman 1930), *Iris yellow spot orthotospovirus* (IYSV) (Cortes et al. 1998) and *Capsicum chlorosis virus* (CaCV) (McMichael, Persley & Thomas 2002) are not quarantine pests for Australia because they are present and not under official control. A CaCV isolate derived from *Phalaenopsis* in Taiwan (CaCV-Ph) (Zheng et al. 2008) was formerly recognised as a distinct strain and a quarantine pest for Australia. However, on the basis of current evidence, this assessment is no longer considered to be technically justified.

7.4 Thrips that transmit orthotospoviruses

Fourteen thrips species are known to naturally transmit orthotospoviruses. Eleven of these thrips species are quarantine pests, and are presently regulated. Three of these—*Frankliniella bispinosa*, *F. cephalica* and *Thrips setosus*—transmit only TSWV, which is not a quarantine pest for Australia. Eight of these thrips species—*Ceratohripoide claratris*, *Dictyothrips betae*, *F. fusca*, *F. gemina*, *F. intonsa*, *F. occidentalis*, *F. zucchini* and *T. palmi*—have the potential to transmit a total of 14 orthotospoviruses that are quarantine pests for Australia: ANSV, CCSV, CSNV, GBNV, GRSV, INSV, L_GM_TS_G, MYSV, PoIRSV, TCSV, TNRV, WBNV, WSMoV and ZLCV.

The three thrips species which are not quarantine pests—*F. schultzei*, *Scirtothrips dorsalis* and *T. tabaci*—are recommended to be regulated because they have the potential to transmit a total of seven orthotospoviruses that are quarantine pests for Australia, namely CSNV, GBNV, GCFSV,

GRSV, GYSV, TCSV and TYRV. This change in regulatory status is not expected to significantly affect trade.

The thrips species that are presumed to naturally transmit 10 recently described orthospoviruses—BeNMV, HCRV, LNRV, MeSMV, MVBaV, PCSV, PNSV, SVN, TNSaV and TZSV—remain unidentified.

7.5 Outcomes of pest risk assessments

This Group PRA undertook a pest risk assessment for:

- phytophagous thrips
- orthospoviruses.

Unrestricted risk estimates (UREs) were calculated for each pest group by combining their respective likelihood for entry (indicative), establishment and spread, with an estimate of consequences (Table 7.1).

Table 7.1 Unrestricted risk estimates (indicative) for pest thrips and orthospoviruses

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

The assessed unrestricted risk (indicative) for both pest thrips and orthospoviruses is Low. An unrestricted risk of Low does not achieve the ALOP for Australia. Therefore, risk management measures are required for these pests in specific trade pathways when the unrestricted risk (indicative) of Low is verified.

7.6 Regulatory changes to pest thrips

Three thrips species, which are not quarantine pests, are capable of harbouring and spreading quarantine orthospoviruses for Australia. They are:

- *Frankliniella schultzei*
- *Scirtothrips dorsalis*
- *Thrips tabaci*

These three thrips species are now deemed by Australia to be ‘regulated articles’, which are defined by the IPPC as ‘Any plant, plant product, storage place, packaging, conveyance, container, soil and any other organism, object or material capable of harbouring or spreading pests, deemed to require phytosanitary measures, particularly where international transportation is involved’ (FAO 2016b). For readability and simplicity, they are referred to as ‘regulated thrips’ in this document, where appropriate.

This regulatory change is not expected to significantly affect trade.

7.7 Additional viruses transmitted by thrips

A risk analysis of the other viruses transmitted by thrips was out of scope of this group PRA, but an initial evaluation was made to determine if additional work might be required. The outcomes of this initial evaluation are presented in Appendix F and summarised here.

Six viruses other than orthospoviruses were identified as being transmitted by thrips.

Maize chlorotic mottle virus is a quarantine virus for Australia. It is transmitted by *Frankliniella williamsi*, and possibly *F. occidentalis*. These species are already regulated pests (*F. williamsi* as a regional pest for Western Australia). However, other potential pathways for this virus to enter Australia were identified, including beetles, seeds and nursery-stock. These will be assessed further as a separate process.

Prunus necrotic ringspot virus is not a quarantine pest for Australia.

Pelargonium flower break virus is transmitted by *F. occidentalis* which is a quarantine pest (NT). Therefore, no further action is recommended for this species.

Sowbane mosaic virus grapevine strain is a quarantine pest for Australia (DAFF 2013), which is transmitted by *T. tabaci*. Its vector *T. tabaci* is already recommended to be regulated because it transmits the quarantine orthospovirus TYRV. Therefore, no further action is recommended for this species.

Tobacco streak virus is a declared prohibited organism under the Western Australia *Biosecurity and Agriculture Management Act 2007* (BAM Act), and *Strawberry necrotic shock virus* may be considered a regional pest for WA although not yet listed under the BAM Act. However, for both viruses it appears that not all the thrips that transmit them are regulated by WA. In order for a virus to be considered as a regional quarantine pest both the virus and all its vectors would be required to be regulated.

7.8 Nursery-stock as an orthospovirus pathway

This Group PRA identified nursery-stock species as orthospovirus hosts, and nursery-stock imports are a significant commercial pathway for the possible introduction of these pests. However, the risk profile of this pathway is significantly different to the plant import pathway (Appendix H). Consequently, a review of nursery-stock orthospovirus hosts will be undertaken in a separate process. The department will consult with stakeholders before any changes are made to existing risk management measures for nursery-stock.

8 Pest risk management

The Group PRA has identified thrips and orthospoviruses of biosecurity importance to Australia.

Imported commodities infested with quarantine pest thrips or regulated thrips that transmit quarantine orthospoviruses 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 quarantine pest thrips 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.

8.1 Measures for quarantine and regulated thrips

Freedom from quarantine and regulated thrips

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 and regulated thrips. This will reduce the risk posed by quarantine thrips and quarantine orthospoviruses transmitted by thrips 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 and regulated thrips means that these thrips 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 thrips may be subject to mandatory treatment. Methyl bromide fumigation is an effective treatment currently used for quarantine pest thrips. 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 8.2.

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 NPPO 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 NPPO or under its authority in accordance with ISPM 23: *Guidelines for inspection* (FAO 2016j) and consistent with the principles of ISPM 31: *Methodologies for sampling of consignments* (FAO 2016k).

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 2016f) and ISPM 7: *Phytosanitary certification system* (FAO 2016c).

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 2016k), 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.

Consignments that do not comply with Australia's import conditions may be subject to remedial treatment, or destroyed or exported, as appropriate.

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.

8.2 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 2016b). ISPM 24 (FAO 2017b) 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, as outlined in ISPM 18: *Guidelines for the use of irradiation as a phytosanitary measure* (FAO 2016h). This ISPM recognises irradiation as an appropriate phytosanitary measure for thrips. Appendix 1 of ISPM 18 (FAO 2016h) specifies a minimum absorbed irradiation dose of 150 to 250 Gy for the sterilisation of thrips. 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 thrips.

- 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 2016d)
- ISPM 14: *The use of integrated measures in a systems approach for pest risk management* (FAO 2016g)
- ISPM 22: *Requirements for the establishment of areas of low pest prevalence* (FAO 2016i).

8.3 Review of policy

The department reserves the right to review this Group PRA for thrips and orthotospoviruses 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.

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 2016b). A pest is ‘any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products’ (FAO 2016b).

International Standard for Phytosanitary Measures Number 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.

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 procedures set out in this 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 2016e), and the requirements of the SPS Agreement (WTO 1995).

The department recognises there may be exceptional circumstances where risk(s) posed by specific pests differ significantly from those of the other members of 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 insect order Thysanoptera (commonly referred to as thrips) and all members of the genus *Orthotospovirus*, which are transmitted by thrips, and that are, or are likely to be associated with fresh fruit, vegetables and cut-flowers or foliage imported into Australia as commercial consignments. These commodities are referred to as the plant import pathway in this report.

The Thysanoptera comprise more than 6,000 described thrips species, which represent a diverse range of feeding strategies—herbivores, fungivores and predators. Therefore, a scoping

assessment was undertaken to identify thrips that have potential to be on the plant import pathway and cause damage to plants, and thus have the potential to be quarantine pests for Australia.

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 2016b).

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

Pest categorisation

Pest categorisation in this Group PRA was undertaken on (i) phytophagous thrips identified in the scoping assessment, and (ii) orthospoviruses they transmit, both of which have the potential to be quarantine pests for Australia.

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 2016b).

It is not practical or necessary to categorise all phytophagous thrips, which contain thousands of species. Selection criteria (Table 3.1) were used to identify species of phytophagous thrips for inclusion in the pest categorisation.

The pest categorisation process of both the thrips species and orthospoviruses considers the:

- 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 3.2 for the phytophagous thrips and Table 4.2 for orthospoviruses. The quarantine pests identified during pest 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 (FAO 2016e). The SPS Agreement (WTO 1995) uses the term 'likelihood' rather than 'probability' for these estimates. In qualitative PRAs, the department 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 of entry) in 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.

The need to evaluate specific sub-pathways for thrips within the importation step of this risk analysis was considered, but ultimately found to be unnecessary. The likelihood of importation of thrips was estimated to be High for all potential plant sub-pathways that were considered.

Factors considered in assessing the ratings for likelihood of establishment and spread, and the estimate of consequences, are in effect 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 2016b).

For the purpose of considering the likelihood of entry, the department 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, as bulk or packed commodity)
- volume and frequency of movement of the commodity along each pathway
- seasonal timing of imports
- pest management, cultural and commercial procedures applied at the place of origin
- speed of transport and conditions of storage compared with the duration of the life cycle of the pest
- vulnerability of the life-stages of the pest during transport or storage

- incidence of the pest likely to be associated with a consignment
- commercial procedures 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 2016b). 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 2016b). 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	$0.7 < to \leq 1$
Moderate	The event would occur with an even likelihood	$0.3 < to \leq 0.7$
Low	The event would be unlikely to occur	$0.05 < to \leq 0.3$
Very low	The event would be very unlikely to occur	$0.001 < to \leq 0.05$
Extremely low	The event would be extremely unlikely to occur	$0.000001 < to \leq 0.001$
Negligible	The event would almost certainly not occur	$0 < to \leq 0.000001$

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

A 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's method that uses the estimated volume of one year's trade are consistent with Australia's policy on appropriate level of protection and meet the Australian Government's requirement for ongoing quarantine protection. Of course if there are substantial changes in the volume and nature of the trade in specific commodities then the department 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 2016b) and ISPM 11 (FAO 2016e).

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 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 2016e) 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.

Appendix B Summary of previous thrips pest risk assessments

Table 8.6 Summary of previous thrips pest risk assessments

Species	Policy (commodity and origin)	Likelihood of (a)						Consequences	URE
		Importation	Distribution	Entry	Establishment	Spread	EES		
<i>Chaetanaphothrips orchidii</i>	Unshu Mandarin (Japan)	h (b)	m	M	H	H	L	L	L
<i>Chaetanaphothrips signipennis</i>	Banana (Philippines)	h	h	H	H	H	H	L	L
<i>Drepanothrips reuteri</i>	Grapes (Chile)	l	m	L	H	H	L	L	VL
	Grapes (Japan)	h	m	M	H	H	M	L	L
<i>Elixothrips brevisetis</i>	Banana (Philippines)	h	h	H	H	H	H	L	L
<i>Frankliniella australis</i>	Grapes (Chile)	l	m	L	H	H	L	L	VL
<i>Frankliniella intonsa</i>	Capsicum (Korea)	h	m	M	H	H	M	L	L
	Stonefruit (USA: CA, ID, OR, WA)	h	m	M	H	H	M	L	L
	Unshu Mandarin (Japan)	h	m	M	H	H	M	L	L
<i>Frankliniella occidentalis</i>	Sweet Orange (Italy)	h	m	M	H	H	M	L	L
	Stonefruit (New Zealand)	h	m	M	H	H	M	L	L
	Truss Tomatoes (Netherlands)	m	h	M	H	H	M	L	L
	Capsicum (Korea)	h	m	M	H	H	M	L	L
	Stonefruit (USA: CA, ID, OR, WA)	h	m	M	H	H	M	L	L
	Unshu Mandarin (Japan)	h	m	M	H	H	M	L	L
	Grapes (Chile)	l	m	L	H	H	L	L	VL
	Grapes (Korea)	h	m	M	H	H	M	L	L
	Grapes (China)	h	m	M	H	H	M	L	L
Grapes (Japan)	h	m	M	H	H	M	L	L	
<i>Frankliniella tritici</i>	Stonefruit (USA: CA, ID, OR, WA)	h	m	M	H	H	M	L	L

Species	Policy (commodity and origin)	Likelihood of (a)						Consequences	URE
		Importation	Distribution	Entry	Establishment	Spread	EES		
<i>Retithrips syriacus</i>	Persimmon (Japan, Korea, Israel)	h	h	H	H	H	H	L	L
<i>Rhipiphorothrips cruentatus</i>	Mango (Taiwan)	m	m	L	H	H	L	L	VL
	Mango (Pakistan)	m	m	L	H	H	L	L	VL
	Grapes (China)	h	m	M	H	H	M	L	L
<i>Taeniothrips inconsequens</i>	Stonefruit (USA: CA, ID, OR, WA)	h	m	M	H	H	M	L	L
<i>Thrips obscuratus</i>	Stonefruit (New Zealand)	h	m	M	M	H	M	M	L
	Cherries (New Zealand)	m	m	L	M	M	L	L	VL
<i>Thrips palmi</i>	Capsicum (Korea)	h	m	M	H	H	M	L	L
	Unshu Mandarin (Japan)	h	m	M	H	H	M	L	L

a. Only plant import policies that used the current rules are listed. **b.** Values are rated H = High, M = Moderate, L = Low, and VL = Very low.

Appendix C Thrips interceptions (identified to family)

A total of about 34,000 thrips interception events were recorded over a 26 year period (1986–2012; Table 8.7). Of these interceptions, about 84 per cent were positively identified to family level as Thripidae, and nine per cent as Phlaeothripidae; less than one per cent were assigned to other families, and six per cent remained unassigned to family. This clearly shows that Thripidae is the dominant family recorded as intercepted on the plant import pathway.

Table 8.7 Thrips interceptions (identified to family)

Family	Proportion (%) of all interception events (a)
Thripidae	84
Phlaeothripidae	9
Aeolothripidae	Less than 1
Merothripidae	Less than 1
Fauriellidae	0
Heterothripidae	0
Melanthripidae	0
Stenurothripidae (syn. Adiheterothripidae)	0
Uzelothripidae	0
Unassigned to family	6

a. Calculated on basis of interception events recorded by Australia over a 26 year period (1986–2012).

Appendix D Thrips interceptions (identified to species)

The breakdown of thrips interception events that were positively assigned to species is considered here (Table 8.8). A total of about 17,500 interceptions were identified to species level, with 116 species recorded, representing just over half of all recorded thrips interception events.

Interception events are averaged over 26 years (1986–2012) and expressed as a range and grouped within five cohorts A to E:

- A = greater than 250 events per year
- B = 10 to 50 events per year
- C = 0.5 to 5 events per year
- D = 0.1 to less than 0.5 events per year
- E = less than 0.1 events per year.

The interception data are non-continuous because, for example, there are no yearly average interception events between 51 and 249 for any thrips species.

A criterion for a specific thrips species to be included in pest categorisation (Chapter 3, Table 3.1) was that it was intercepted with a yearly average frequency greater than 0.5 events per year (Interception groups A–C in Table 8.8). This criterion identifies 26 thrips species which represent about 98 per cent of all thrips identifications to species level.

About 97 per cent of thrips identified to species level were Thripidae. For Phlaeothripidae, *Haplothrips gowdeyi*, which is not a quarantine pest for Australia, was the most frequently intercepted species.

Table 8.8 Thrips interceptions (identified to species)

Group	Yearly average range (a)	Family	Thrips	Orthotospovirus vector	Current quarantine pest status (b)
A	Greater than 250	Thripidae	<i>Frankliniella occidentalis</i>	Yes	Regulated
-	-	-	<i>Thrips tabaci</i>	Yes	Unregulated
B	10–50	Phlaeothripidae	<i>Haplothrips gowdeyi</i>	-	Unregulated
-	-	Thripidae	<i>Caliothrips fasciatus</i>	-	Regulated
-	-	-	<i>Frankliniella schultzei</i>	Yes	Unregulated
-	-	-	<i>Scirtothrips dorsalis</i>	Yes	Unregulated
-	-	-	<i>Thrips palmi</i>	Yes	Regulated
C	0.5–5	Phlaeothripidae	<i>Haplothrips ganglbaueri</i>	-	Regulated
-	-	-	<i>Hoplandrothrips flavipes</i>	-	Regulated
-	-	Thripidae	<i>Anaphothrips sudanensis</i>	-	Unregulated
-	-	-	<i>Arorathrips mexicanus</i>	-	Unregulated
-	-	-	<i>Frankliniella intonsa</i>	Yes	Regulated
-	-	-	<i>Frankliniella williamsi</i>	(c)	Regulated
-	-	-	<i>Heliothrips haemorrhoidalis</i>	-	Unregulated

Group	Yearly average range (a)	Family	Thrips	Orthospovirus vector	Current quarantine pest status (b)
-	-	-	<i>Kenyattathrips katarinae</i>	-	Regulated
-	-	-	<i>Megalurothrips sjostedti</i>	-	Regulated
-	-	-	<i>Neohydatothrips samayunkur</i>	-	Unregulated
-	-	-	<i>Selenothrips rubrocinctus</i>	-	Unregulated
-	-	-	<i>Thrips flavus</i>	-	Regulated
-	-	-	<i>Thrips fuscipennis</i>	-	Regulated
-	-	-	<i>Thrips hawaiiensis</i>	-	Unregulated
-	-	-	<i>Thrips imaginis</i>	-	Unregulated
-	-	-	<i>Thrips major</i>	-	Regulated
-	-	-	<i>Thrips obscuratus</i>	-	Regulated
-	-	-	<i>Thrips parvispinus</i>	-	Unregulated
-	-	-	<i>Thrips simplex</i>	-	Unregulated
D	0.1-less than 0.5	Aeolothripidae	<i>Aeolothrips collaris</i>	-	-
-	-	-	<i>Aeolothrips fasciatus</i>	-	-
-	-	-	<i>Franklinothrips megalops</i>	-	-
-	-	Phlaeothripidae	<i>Aleurodothrips fasciapennis</i>	-	-
-	-	-	<i>Gynaikothrips ficorum</i>	-	-
-	-	-	<i>Haplothrips aculeatus</i>	-	-
-	-	-	<i>Haplothrips leucanthemi</i>	-	-
-	-	-	<i>Haplothrips robustus</i>	-	-
-	-	-	<i>Karnyothrips flavipes</i>	-	-
-	-	-	<i>Leptothrips mali</i>	-	-
-	-	-	<i>Nesothrips lativentris</i>	-	-
-	-	-	<i>Nesothrips propinquus</i>	-	-
-	-	-	<i>Podothrips semiflavus</i>	-	-
-	-	Thripidae	<i>Anaphothrips obscurus</i>	-	-
-	-	-	<i>Apterothrips apteris</i>	-	-
-	-	-	<i>Bolacothrips striatopennatus</i>	-	-
-	-	-	<i>Caliothrips phaseoli</i>	-	-
-	-	-	<i>Chaetanaphothrips orchidii</i>	-	-
-	-	-	<i>Dichromothrips corbetti</i>	-	-
-	-	-	<i>Frankliniella tenuicornis</i>	-	-
-	-	-	<i>Limothrips angulicornis</i>	-	-
-	-	-	<i>Limothrips cerealium</i>	-	-
-	-	-	<i>Microcephalothrips abdominalis</i>	-	-
-	-	-	<i>Mycterothrips chaetogastra</i>	-	-
-	-	-	<i>Scirtothrips aurantii</i>	-	-
-	-	-	<i>Scolothrips sexmaculatus</i>	-	-

Group	Yearly average range (a)	Family	Thrips	Orthospovirus vector	Current quarantine pest status (b)
-	-	-	<i>Tenothrips frici</i>	-	-
-	-	-	<i>Thrips australis</i>	-	-
-	-	-	<i>Thrips coloratus</i>	-	-
-	-	-	<i>Thrips pusillus</i>	-	-
-	-	-	<i>Thrips taiwanus</i>	-	-
E	Less than 0.1	Aeolothripidae	<i>Desmothrips australis</i>	-	-
-	-	-	<i>Franklinothrips vespiformis</i>	-	-
-	-	Merothripidae	<i>Merothrips brunneus</i>	-	-
-	-	-	<i>Merothrips floridensis</i>	-	-
-	-	Phlaeothripidae	<i>Apteygothrips australis</i>	-	-
-	-	-	<i>Ecacanthothrips tibialis</i>	-	-
-	-	-	<i>Haplothrips ceylonicus</i>	-	-
-	-	-	<i>Haplothrips collyerae</i>	-	-
-	-	-	<i>Hoplothrips kea</i>	-	-
-	-	-	<i>Plicothrips apicalis</i>	-	-
-	-	-	<i>Podothrips lucasseni</i>	-	-
-	-	-	<i>Priesneriella citricauda</i>	-	-
-	-	Thripidae	<i>Anaphothrips cecili</i>	-	-
-	-	-	<i>Anaphothrips dubius</i>	-	-
-	-	-	<i>Apterothrips secticornis</i>	-	-
-	-	-	<i>Astrothrips aucubae</i>	-	-
-	-	-	<i>Baileyothrips arizonensis</i>	-	-
-	-	-	<i>Bolacothrips faurei</i>	-	-
-	-	-	<i>Ceratothripoides brunneus</i>	-	-
-	-	-	<i>Chirothrips manicatus</i>	-	-
-	-	-	<i>Dendrothrips degeeri</i>	-	-
-	-	-	<i>Elixothrips brevisetis</i>	-	-
-	-	-	<i>Ernothrips immsi</i>	-	-
-	-	-	<i>Florithrips dilutus</i>	-	-
-	-	-	<i>Frankliniella fusca</i>	Yes	Regulated
-	-	-	<i>Frankliniella gossypiana</i>	-	-
-	-	-	<i>Frankliniella insularis</i>	-	-
-	-	-	<i>Frankliniella panamensis</i>	-	-
-	-	-	<i>Frankliniella tritici</i>	-	-
-	-	-	<i>Hercinothrips bicinctus</i>	-	-
-	-	-	<i>Hercinothrips femoralis</i>	-	-
-	-	-	<i>Hydatothrips adolfifridgerici</i>	-	-
-	-	-	<i>Hydatothrips samayunkur</i>	-	-
-	-	-	<i>Mycterothrips albidicornis</i>	-	-

Group	Yearly average range (a)	Family	Thrips	Orthospovirus vector	Current quarantine pest status (b)
-	-	-	<i>Neohydatothrips gracilicornis</i>	-	-
-	-	-	<i>Parthenothrips dracaenae</i>	-	-
-	-	-	<i>Plesiothrips perplexus</i>	-	-
-	-	-	<i>Priesneriola oneillae</i>	-	-
-	-	-	<i>Proscirtothrips longipennis</i>	-	-
-	-	-	<i>Pseudanaphothrips achaetus</i>	-	-
-	-	-	<i>Pseudodendrothrips mori</i>	-	-
-	-	-	<i>Rhamphothrips parviceps</i>	-	-
-	-	-	<i>Rhipiphorothrips miemsae</i>	-	-
-	-	-	<i>Scirtothrips australiae</i>	-	-
-	-	-	<i>Scirtothrips fulleri</i>	-	-
-	-	-	<i>Scirtothrips inermis</i>	-	-
-	-	-	<i>Scirtothrips signipennis</i>	-	-
-	-	-	<i>Scolothrips asura</i>	-	-
-	-	-	<i>Sericothrips adolffriderici</i>	-	-
-	-	-	<i>Stenchaetothrips biformis</i>	-	-
-	-	-	<i>Synaptothrips distinctus</i>	-	-
-	-	-	<i>Thrips angusticeps</i>	-	-
-	-	-	<i>Thrips florum</i>	-	-
-	-	-	<i>Thrips nigropilosus</i>	-	-
-	-	-	<i>Thrips novocaledonensis</i>	-	-
-	-	-	<i>Thrips nymphal</i>	-	-
-	-	-	<i>Thrips oryzae</i>	-	-
-	-	-	<i>Thrips setosus</i>	Yes	Regulated
-	-	-	<i>Thrips vulgatissimus</i>	-	-

a. Each interception event is based on the presence of at least a single thrips taxon on a consignment. The number of thrips present per event is not generally recorded, and multiple thrips taxa can infest the same commodity. Interception events are averaged over 26 years (1986–2012) and expressed as a range and grouped A–E. Note that range values are not contiguous, but cover actual recorded values. **b.** Regulatory status is only given for species in categories A–C, and for virus vectors that fall within categories D–E. **c.** *F. williamsi* transmits *Maize chlorotic mottle virus*, a quarantine pest for Australia.

Considering thrips species identified in interception categories A–C (the most frequent 26 species intercepted), 13 species are currently regulated, and 13 are not. In terms of number of interception events, about 51 per cent were found to be currently regulated species (quarantine pests for Australia) with 49 per cent unregulated.

If the three thrips species *Thrips tabaci*, *Frankliniella schultzei* and *Scirtothrips dorsalis* were to become regulated, as is recommended on the basis that they transmit viruses that are quarantine pests for Australia, the proportion of regulated species would increase to about 96 per cent (Table 8.9).

Table 8.9 Regulatory status of the most frequently intercepted thrips (identified to species)

Interception group	Number of species in group	Interception events for the group currently regulated (%)	Interception events for the group that would be regulated in future (%)
A	2	40	77
B	5	9	17
C	19	2	2
Totals	26	51	96

Should *Haplothrips gowdeyi*, which is not a quarantine pest for Australia, be removed from the calculations the proportion of regulated species would be about 98 per cent.

It should be noted that two additional thrips species, *Frankliniella fusca* and *Thrips setosus*, transmit orthospovirus, but are not within interception categories A–C. These species are presently regulated as quarantine species. Additionally, *Frankliniella williamsi* transmits *Maize chlorotic mottle virus* (Appendix F), and has been intercepted on the plant import pathway occasionally (Interception group B). It is regulated as a quarantine pest because, although it is present in Australia, it is under official control in WA.

Appendix E Risk from orthospovirus infected plant commodities

Potential scenario

A scenario for orthospovirus entry via infected plant commodities is considered. However, the transmission of an orthospovirus from infected plant produce post-harvest, via a thrips, to other plant-hosts is considered to have a Negligible/Very low likelihood. Effectively, the pathway is a 'dead-end' for orthospovirus entry at the distribution step. The rationale for this conclusion is discussed.

Importation

Association with export crops: As a group, orthospoviruses are known to infect an extensive range of crops (Daughtrey et al. 1997; Gent et al. 2006; Jones 2005; Kunkalika et al. 2011; Mandal et al. 2012; Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006), including species on the plant import pathway, as illustrated and referenced in Table 4.2. However, the natural host ranges of orthospovirus differ between species, with some being relatively narrow and some being extensive, with varying levels of commonality. This can influence the likelihood of a given orthospovirus being imported. However, orthospoviruses can quickly establish in crops. Viruliferous thrips can be sustained on weeds or volunteer plants—cultivated varieties growing wild or contaminating other crops—to provide a source for rapid orthospovirus re-infection of newly planted crops (Groves et al. 2002; Jones 2005; Kahn, Walgenbach & Kennedy 2005; Okazaki et al. 2007). An orthospovirus could potentially infect a crop destined for export at a later stage of maturity, and symptoms may not be fully expressed at harvest.

Produce appearance: Expression of orthospovirus infection in host plants is influenced by a broad range of factors that include the specific orthospovirus species (or strain), host plant species (or cultivar), host plant maturity, season and environmental conditions (German, Ullman & Moyer 1992). This spectrum of disease expression, in addition to systemic infection, includes localised (Jones & Sharman 2005; Smith et al. 2006) and asymptomatic infections (Smith et al. 2006). However, symptoms of orthospovirus infection typically include necrosis, chlorosis, ring patterns, mottling, silverying, stunting and lesions (Jones 2005; Mandal et al. 2012; Pappu, Jones & Jain 2009) that usually become more apparent as infected plants mature and fruit ripens. Commercially produced perishable plant produce with such obvious orthospovirus symptoms would probably be unmarketable, thus significantly moderating, but not eliminating, the likelihood of orthospovirus-infected produce being imported.

Distribution

End use: Perishable plant commodities are intended to be traded and would rapidly be distributed, via the wholesale and retail supply chains, throughout Australia, and are short-lived in the environment being intended for consumption, or in the case of cut-flowers, for short-term display.

Import policy for cut-flowers requires that they are (or are rendered) non-propagatable.

The weight of evidence is that orthospoviruses are not transmitted via seed (Albrechtsen 2006; Pappu et al. 1999b). There is a single report of seed transmission for an isolate of *Soybean*

vein necrosis virus under laboratory conditions (Groves et al. 2015), but seed transmission of this virus has not been observed for soybean under field conditions (Hajimorad et al. 2015).

Consequently, under intended end use, there is probably very limited opportunity for a pathway to exist for orthotospovirus transmission from perishable plant produce, through a viruliferous thrips, to a susceptible plant host. Contributing factors include the perishable nature of these products and the biology of orthotospovirus acquisition and transmission.

Waste: A proportion of imported perishable plant products will enter the environment as waste, at multiple locations throughout Australia. Okazaki et al. (2007) observed that *F. occidentalis* populations could be sustained and reproduce on discarded green pepper fruit that were infected with TSWV. They concluded that viruliferous thrips could overwinter in the glasshouse and field by moving from these peppers when they rotted onto nearby weeds, and could provide a source of reinfection of newly planted pepper crops during the following season. Viruliferous thrips adults and larvae were collected from this fruit. It cannot be concluded from the data presented that viruliferous adults actually acquired TSWV from the fruit. However, the observation that viruliferous larvae were present implies that it is feasible for an orthotospovirus to be acquired from infected post-harvest fruit, under certain circumstances. Unfortunately, no specific data on the incidence of viruliferous larvae was given in this study, and no additional comparable studies were found. In most cases, plant waste might be expected to deteriorate rapidly after disposal, and to soon be incapable of sustaining a viable population of thrips. Each thrips generation must feed on orthotospovirus infected plant material to become infected and viruliferous. Only larval thrips, as L1 and sometimes early stage L2 instars, can become infected by an orthotospovirus and continue to transmit it as L2 instars and adults (Mautino et al. 2012; Nagata et al. 1999). As a minimum, this would necessitate a thrips laying eggs, larvae to hatch, feed and acquire orthotospovirus, and complete their life-cycle, at least up to the pre-pupal stage, on rapidly deteriorating produce. This is thought to have a Negligible/Very low likelihood of occurrence and as a result the distributed produce step is a virtual 'dead-end' for orthotospovirus entry on this pathway.

Summary

Orthotospovirus-infected produce could be imported. Evidence for this includes extensive orthotospovirus host range, uncertainty in that host range, and variable expression of infection. However, produce with obvious symptoms would likely be unmarketable, considerably moderating importation likelihood. Although orthotospovirus-infected perishable plant produce could be distributed, there is a Negligible/Very low likelihood of orthotospovirus acquisition from infected produce for subsequent transmission, via a thrips, to a susceptible host.

Appendix F Other viruses transmitted by thrips

Overview

A risk analysis of the other viruses transmitted by thrips is beyond the scope of this group PRA, but an initial evaluation was made to determine if additional work might be required, which would be undertaken as a separate process. This initial evaluation is not intended to be a comprehensive risk analysis of these viruses.

Other viruses transmitted by thrips are summarised in Table 8.10, with certain factors relevant to their potential status as a quarantine pests. Most of these viruses were also considered within the Australian biosecurity plan for the nursery and garden industry (PHA & NGIA 2011).

Table 8.10 Additional virus species transmitted by thrips

Species [genus]	Acronym	Presence within Australia	Potential quarantine pest	Transmitted by
<i>Maize chlorotic mottle virus</i> [Machlomovirus]	MCMV	Not recorded	Yes	<i>Frankliniella williamsi</i> (Cabanas et al. 2013); possibly <i>F. occidentalis</i> (Zhao et al. 2014)
<i>Pelargonium flower break virus</i> [Carmovirus]	PFBV	Not recorded	Yes	<i>F. occidentalis</i> (Krczal et al. 1995)
<i>Prunus necrotic ringspot virus</i> [Iarvirus]	PNRV	Present (Greber et al. 1991a; PHA & NGIA 2011) and not under official control	No	<i>T. tabaci</i> (Greber et al. 1991a)
<i>Sowbane mosaic virus</i> [Sobemovirus]	SoMV	Present (not SoMV grapevine strain) (PHA & NGIA 2011; Teakle 1968). SoMV is an unlisted organism for WA (Government of Western Australia 2016)	Yes. SoMV grapevine strain is a quarantine pest for Australia (DAFF 2013). SoMV is an unlisted organism for WA (Government of Western Australia 2016). However, its vector <i>T. tabaci</i> is permitted entry by WA (Government of Western Australia 2016) which could introduce to WA other strains of SoMV that are present within parts of Australia.	<i>T. tabaci</i> (Hardy & Teakle 1992)
<i>Tobacco streak virus</i> [Iarvirus]	TSV	Present (PHA & NGIA 2011; Sharman, Persley & Thomas 2009; Sharman & Thomas 2013). TSV is a declared pest, prohibited by WA (Government of Western Australia 2016)	Yes. TSV is a declared pest, prohibited by WA (Government of Western Australia 2016). However, its vectors <i>F. occidentalis</i> , <i>F. schultzei</i> , <i>T. tabaci</i> , <i>T. parvispinus</i> and <i>M. abdominalis</i> are all permitted entry by WA (Government of Western Australia 2016). Declared list A	<i>F. occidentalis</i> and <i>F. schultzei</i> (Kaiser, Wyall & Pesho 1982); <i>Thrips tabaci</i> (Sdoodee & Teakle 1987); <i>Thrips parvispinus</i> (Klose et al. 1996); <i>Microcephalothrips abdominalis</i> (Greber et al. 1991b)

			disease by Tas. (DPIPWE Tasmania 2015), but <i>T. tabaci</i> is an unwanted quarantine pest, which is not officially regulated by Tas. (DPIPWE Tasmania 2015)	
<i>Strawberry necrotic shock virus</i> [Iarvirus]	SNSV	Present in some states (Sharman et al. 2011). SNSV is an unlisted organism for WA (Government of Western Australia 2016)	Yes. SNSV is an unlisted organism for WA (Government of Western Australia 2016). However, its vectors <i>T. tabaci</i> and <i>M. abdominalis</i> are permitted entry by WA (Government of Western Australia 2016)	<i>T. tabaci</i> and <i>M. abdominalis</i> (Klose et al. 1996)

Maize chlorotic mottle virus

Maize chlorotic mottle virus (MCMV; *Tombusviridae* family, *Machlomovirus* genus) is considered to cause significant economic consequences (Nelson, Brewbaker & Hu 2011; PHA & NGIA 2011; Scheets 2004) and is not known to be present within Australia (CABI 2014b; PHA & NGIA 2011). This virus meets the IPPC definition of a quarantine pest (FAO 2016b) for Australia.

Maize is the primary host of MCMV, and until recently thought to be the only natural host (Nelson, Brewbaker & Hu 2011). However, it has more recently been reported in China naturally infecting sugarcane as a mixed infection with the potyvirus *Sugarcane mosaic virus* (SCMV) (Wang, Zhou & Wu 2014), and in sorghum (*Sorghum bicolor*) and coix (*Coix chinensis*) (Huang et al. 2016) plants as the only virus. It has been reported in Kenya as a mixed infection with SCMV where it caused a lethal necrosis disease in finger millet (*Eleusine coracana*) (Kusia et al. 2015). Conceivably, there may be additional natural hosts. Experimental hosts of MCMV appear restricted to the *Poaceae* (*Gramineae*) family, and include species within the genera of key cultivated food crops: *Avena* (oats), *Hordeum* (barley), *Secale* (rye), and *Triticum* (wheat) (Nelson, Brewbaker & Hu 2011).

Maize chlorotic mottle virus infected corn plants usually show symptoms of chlorotic mottling on leaves and stunted growth, although almost asymptomatic infection has been observed (Nelson, Brewbaker & Hu 2011). Yield reductions from MCMV infection of up to 15 per cent are common (Castillo & Hebert 1974; Nault, Gordon & Loayza 1981), but greater yield losses are feasible (Scheets 2004) depending on factors including development stage at infection, cultivar or environment conditions. However, mixed infection of MCMV with a virus from the *Potyviridae* family can synergistically cause the more severe Maize (or corn) Lethal Necrosis (MLN) disease (Goldberg & Brakke 1987; Uyemoto et al. 1981). For example, synergistic infection between MCMV and Maize dwarf mosaic virus (MDMV), or *Wheat streak mosaic virus* (WSMV) or *Sugarcane mosaic virus* (SCMV) can result in MLN disease (Xia et al. 2016). It is significant to note that WSMV and SCMV are already present within Australia and the arrival of MCMV may therefore provide the opportunity for the synergistic MLN disease to occur.

MLN disease results in severe stunting and premature death, with markedly elevated MCMV levels above that caused by MCMV infection alone (Scheets 1998), and crop yield reductions of up to 90 per cent have been reported (Niblett & Claflin 1978; Uyemoto, Bockelman & Claflin 1980). There is a significant and growing impact of MLN disease in east Africa where it is now a

major constraint on maize production since being first reported within the region during 2011 (Kiruwa, Feyissa & Ndakidemi 2016). Illustrating only the potential for consequences, the gross product value of the Australian maize and sugarcane industries were about \$120 million and \$1.1 billion, respectively for FY 2012–13 (ABS 2016).

The geographic distribution of MCMV includes Argentina (Teyssandier, Dal Bó & Nome 1982), Brazil, Mexico (Gordon et al. 1984), Colombia (Morales et al. 1999), Peru (CABI 2014b), Ecuador (Quito-Avila, Alvarez & Mendoza 2016), USA, various states—Hawaii, Kansas, Nebraska and Texas (Doupnik 1979; Jiang et al. 1992; Nelson, Brewbaker & Hu 2011; Niblett & Clafin 1978; Nyvall 1999; Uyemoto, Bockelman & Clafin 1980), Thailand (Scheets 2008), China (Xie et al. 2011), Kenya (Wangai et al. 2012), Mozambique, Tanzania, Uganda (CABI 2014b), Rwanda (Adams et al. 2014), the Democratic Republic of the Congo (Lukanda et al. 2014), Taiwan (Deng et al. 2014), and Ethiopia (Mahuku et al. 2015). This data indicates an ongoing expansion in the reported distribution of MCMV.

Maize chlorotic mottle virus is transmitted by several thrips species. It is principally transmitted by the thrips *Frankliniella williamsi* (Cabanas et al. 2013). *Frankliniella williamsi* is a regulated pest for WA, but is present in other states of Australia—Qld, Vic. and Tas. (Mound & Tree 2012).

Frankliniella occidentalis collected from natural field populations was recently shown to be competent to transmit the virus under experimental conditions (Zhao et al. 2014). However, this competency has not yet been verified in nature. *Frankliniella occidentalis* is currently regulated as a quarantine pest for Australia. It is also recommended to be regulated because it transmits several orthotospoviruses that are quarantine pests for Australia.

Significant doubt exists about the reported status of *Thrips tabaci* transmitting MCMV. It was reported to transmit MCMV in a review by Jones (2005) and this reference is cited elsewhere, including PHA and NGIA (PHA & NGIA 2011). However, Jones (2005) cited Ullman et al. (1992) for *T. tabaci* transmitting MCMV, which only stated that MCMV was transmitted by thrips, based on data by Jiang et al. that was unpublished. Subsequently, Jiang et al. (1992) did publish a paper on MCMV in Hawaii, as a first report of this virus being transmitted by a thrips, *F. williamsi*. However, *T. tabaci* was not mentioned in this publication as a vector of MCMV, and no other primary reference was found to verify that *T. tabaci* transmits MCMV.

Maize chlorotic mottle virus is also transmitted by several beetle species (Nault et al. 1978), possibly in a semi-persistent manner (Cabanas et al. 2013). For example, the key transmission of MCMV in the continental USA involves species of beetles in the family Chrysomelidae—*Diabrotica undecimpunctata* var. *howardi*, *D. barberi*, *D. virgifera* var. *virgifera*, *Oulema melanopus*, *Chaetocnema pulicaria* and *Systema frontalis* (Scheets 2008). These beetle species are not recorded in Australia (ABRS 2009) and are quarantine pests for Australia.

Maize chlorotic mottle virus has also been shown to be seed transmissible at low frequency, 0.008–0.4 per cent in maize (Jensen et al. 1991). There are several potential pathways for MCMV entry via maize seed.

Bulk maize from the USA is permitted entry into Australia for processing as animal feed, and MCMV was considered in developing the import policy (Biosecurity Australia 2002a). Import conditions, processing and end use mitigate the risk of MCMV on this pathway. No further action is recommended for this pathway.

Maize seed for sowing is permitted entry into Australia, subject to specific risk management measures. For example, in relation to MCMV, maize seed from Idaho (USA) is permitted for field sowing in Australia, based on regional freedom from this virus (Biosecurity Australia 2002b).

Maize seed for sowing that is not certified as grown in Idaho, from elsewhere in USA or from other countries must undergo post-entry quarantine, under closed conditions with visual disease inspection, for a generation to produce seed for release. However, variation in MCMV disease expression has been reported, ranging in severity from the characteristic mosaic and stunting features to plants being virtually asymptomatic (Nelson, Brewbaker & Hu 2011). Zhao et al. (2014) reported that field collected *F. occidentalis* was competent to acquire and transmit MCMV from test plants inoculated with virus derived from germinated maize seed that was undergoing post-entry quarantine in China. This may show the potential for seed for sowing as a pathway. It is recommended that the import conditions for maize seed for sowing be reviewed.

Saccharum spp. are permitted entry into Australia, subject to biosecurity conditions, as nursery-stock setts or tissue cultures. These conditions include post-entry quarantine and active testing for specific pathogens, including viruses. Wang et al. (2014) reported field grown sugarcane plants in China being naturally infected with MCMV as a mixed infection with SCMV. The current import protocol does not require active testing for MCMV. It is recommended that the import conditions for *Saccharum* nursery-stock be reviewed.

It is unknown if MCMV is transmitted via the seed of several recently described natural hosts, such as sorghum, finger millet or coix, but this risk cannot be entirely excluded. There are also a number of tentative (experimental) hosts, including clonal grasses and species within the genera of key cultivated cereal crops *Avena*, *Hordeum*, *Secale* and *Triticum* (Nelson, Brewbaker & Hu 2011). These pathways will be kept under appraisal, pending the availability of further data.

Pelargonium flower break virus

Pelargonium flower break virus is not recorded as present within Australia. It is transmitted by *F. occidentalis*. However, *F. occidentalis* is currently regulated as a quarantine pest for Australia. Consequently, no additional action on PFBV is presently required. However, should the regulatory status of *F. occidentalis* change, or additional thrips that transmit PFBV be identified, this decision would require review.

Prunus necrotic ringspot virus

Prunus necrotic ringspot virus is present within Australia, and not under official control (Table 8.10). It does not meet the definition of a quarantine pest (FAO 2016b) and requires no further action.

Sowbane mosaic virus

Sowbane mosaic virus (SoMV) is present within Australia (Guy 1982; Teakle 1968). However, grapevine is reported as a host for a strain of SoMV (Bercks & Querfurth 1969; Jankulowa 1972; Pozdena 1977) which is not recorded on grapevine within Australia (Constable & Drew 2004; Constable, Nicholas & Rodoni 2010). The SoMV grapevine strain is a quarantine pest for Australia (DAFF 2013).

Sowbane mosaic virus may be considered by WA as a regional pest although the virus has not yet been listed under the Biosecurity and Agriculture Management Act 2007 (BAM Act) by WA. In order for this virus to be a regional quarantine pest, both the virus and its vector *T. tabaci*, which occurs in other parts of Australia, would be required to be regulated by WA. It is essential that the requirements of the IPPC definition of the quarantine pests are met, specifically including demonstrable evidence of official control.

Thrips tabaci is recommended to be regulated because it transmits the quarantine orthotospovirus, TYRV. This would also mitigate the risk of *T. tabaci* facilitating the entry of

SoMV grapevine strain. Consequently, no further action on SoMV is presently recommended, from a biosecurity perspective. However, should *T. tabaci* not be regulated, or the quarantine status of TYRV change, or additional species that transmit SoMV be identified, this decision would require review.

Tobacco streak virus

Tobacco streak virus is present within parts of Australia (PHA & NGIA 2011; Sharman, Persley & Thomas 2009; Sharman & Thomas 2013). However, TSV is a declared prohibited organism under the Western Australia *Biosecurity and Agriculture Management Act 2007* (Government of Western Australia 2007); it is prohibited entry into the state, and is a regional pest for Western Australia. However, it appears that its thrips vectors including *Frankliniella occidentalis*, *F. schultzei*, *Thrips tabaci*, *T. parvispinus* and *Microcephalothrips abdominalis* are not regulated by WA. In order for this virus to be considered a regional quarantine pest for WA, both the virus and all its vectors known to occur in other parts of Australia, would be required to be regulated by WA. It is essential that the requirements of the IPPC definition of the quarantine pests are met, specifically including demonstrable evidence of official control.

Strawberry necrotic shock virus

Strawberry necrotic shock virus (SNSV) was originally considered an isolate of *Tobacco streak virus*, but was later proposed and accepted as a separate virus (Tzanetakis, Mackey & Martin 2004). SNSV can infect strawberries and *Rubus* species, and has been a chronic disease problem in strawberry, blackberry and raspberry production (Tzanetakis, Mackey & Martin 2004). Symptoms are rarely seen in commercial strawberry cultivars or *Rubus* species. However, SNSV can have synergistic effects in mixed infections and can reduce strawberry yield and runner production (Johnson et al. 1984). SNSV (TSV-S) is transmitted at relatively low frequencies by *T. tabaci* and *M. abdominalis* (Klose et al. 1996). Transmission occurs when thrips feeding results in wounding of plant tissues permitting access by infected pollen grains. The virus is also transmitted via seed (Johnson et al. 1984).

Strawberry necrotic shock virus is reported within North America, Europe, Asia and Australasia (Li & Yang 2011; Martin et al. 2013). Sharman *et al* (2011) first reported SNSV from Australia, and confirmed that a Queensland isolate previously referred to as TSV-S was SNSV. It is also present within Victoria, and not under official control within these states where it fails to meet the IPPC definition of a quarantine pest (FAO 2016b). A decline in the virus impact within these states has been attributed to the success of the certified strawberry runner scheme (Sharman 2015).

Strawberry necrotic shock virus may be considered by WA as a regional pest although the virus has not yet been listed under the *Biosecurity and Agriculture Management Act 2007* (BAM Act) by WA. In order for this virus to be a regional quarantine pest, both the virus and its vectors *T. tabaci* and *M. abdominalis* would be required to be regulated by WA. It is essential that the requirements of the IPPC definition of the quarantine pests are met, specifically including demonstrable evidence of official control.

Summary

Five quarantine pest viruses, other than orthotospoviruses, were identified as being transmitted by thrips (Table 8.11). This table summarises the current and recommended regulatory statuses of the thrips that transmit these quarantine pests.

Table 8.11 Regulatory status of quarantine pest viruses transmitted by thrips, other than orthotospoviruses

Virus	Thrips regulated	Thrips recommended to be regulated as they transmit quarantine pest orthotospoviruses	Other thrips
<i>Maize chlorotic mottle virus</i>	<i>F. williamsi</i> (WA), <i>F. occidentalis</i> (NT)	–	None
<i>Pelargonium flower break virus</i>	<i>F. occidentalis</i> (NT)	–	None
<i>Sowbane mosaic virus</i>	–	<i>T. tabaci</i>	None
<i>Tobacco streak virus</i>	<i>F. occidentalis</i> (NT)	<i>F. schultzei</i> , <i>T. tabaci</i>	<i>T. parvispinus</i> , <i>M. abdominalis</i>
<i>Strawberry necrotic shock virus</i>	–	<i>T. tabaci</i>	<i>M. abdominalis</i>

This initial evaluation found that MCMV is a quarantine virus for Australia. It is transmitted by *F. williamsi*, and possibly *F. occidentalis*. These species are already regulated pests (*F. williamsi* as a regional pest for Western Australia). This virus is also transmitted by several chrysomelid beetles and is seed transmissible at low frequency. It is recommended that these potential pathways be assessed further, including the import conditions for maize seed for sowing and *Saccharum* nursery-stock. However, this work will be undertaken as a separate process. There are also several recently described natural hosts, and tentative (experimental) hosts. These pathways will be kept under ongoing appraisal.

This initial evaluation found that *Prunus necrotic ringspot virus* is not a quarantine pest for Australia and no further action is recommended. *Pelargonium flower break virus* is transmitted by *F. occidentalis* which is a quarantine pest for Australia (NT) and no further action is recommended. *Sowbane mosaic virus* is transmitted by *T. tabaci*, which is proposed to be regulated because it transmits the quarantine orthotospovirus TYRV. Consequently, no further action is recommended from a biosecurity perspective. However, if the regulatory status of these thrips changed, or new vectors emerged, this decision would require review.

Appendix G Contaminating pests

The risks posed by contaminating pests ('contaminants') on the plant import pathway are addressed by existing standard operational procedures and do not require further consideration in this Group PRA.

Contamination is the '*presence in a commodity, storage place, conveyance or container, of pests or other regulated articles, not constituting an infestation*', and a contaminating pest is '*a pest that is carried by a commodity and, in the case of plants and plant products, does not infest those plants or plant products*' (FAO 2016b).

All plant import pathway commodities must be free from contaminating material and organisms, including plant trash, seeds, soil, animal matter/parts or other extraneous material and pests of quarantine concern to Australia. This is confirmed by inspection procedures. Export lots or consignments found to contain contaminating material or organisms should be withdrawn from export unless approved remedial action is available and applied to the export consignment, which must then be re-inspected for compliance.

Contaminating biological control agents (BCAs) on the plant import pathway are subject to additional requirements and for that reason require no further consideration in this Group PRA.

A BCA is an organism, such as an insect or pathogen that is used to manage the impact of a pest species, including insect or weeds on cultivated crops and/or the environment.

Before BCAs can be released into the Australian environment a separate risk analysis must be undertaken by the Australian Government Department of Agriculture and Water Resources. In a parallel process, the Department of Environment must also make a ruling under the *Environment Protection and Biodiversity Conservation Act 1999*.

The risk analysis for BCAs must demonstrate that the risk associated with release of a BCA achieves the appropriate level of protection (ALOP) for Australia. The risk analysis takes account of any negative impact on non-target species and the potential magnitude of consequences. Rigorous host specificity testing is required to ensure that the proposed BCA is specific to its target pest. This minimises the risk of any significant negative consequences as a result of the BCA release.

Appendix H Nursery-stock that are orthotospovirus hosts

Nursery-stock risk profile

In undertaking this Group PRA nursery-stock species were identified as an area requiring additional consideration in relation to orthotospovirus risk. However, nursery-stock was excluded from the scope of this Group PRA for several key reasons.

The risk of orthotospovirus entry via nursery-stock has two potential sub-pathways:

- viruliferous thrips associated with the nursery-stock pathway
- nursery-stock infected with orthotospoviruses.

For the nursery-stock pathway viruliferous thrips are not the only means for orthotospovirus to be introduced, contrasting with the plant import pathway. The nursery-stock pathway also differs from that of the plant import pathway because as live plants their intended end-use is to be sustained, dispersed and propagated within Australia. These differences influence the risk profile of the nursery-stock pathway and thus likelihoods of entry, establishment and spread. As a result, it was considered inappropriate to assess nursery-stock as a sub-pathway of the plant import pathway commodities.

Nursery-stock imports

Nursery-stock is permitted entry into Australia subject to specific import conditions. This includes live plant material in the form of bare-rooted plants, bulbs, seeds, cuttings, bud-wood and tissue cultures (micro-propagated plantlets). Existing conditions are specific to the nursery-stock species and the form in which it is imported. For example, medium risk nursery-stock plants (other than tissue cultures) are routinely subjected to on-arrival inspection, risk management measures for arthropods, and growth in a closed government or government-approved post-entry Quarantine (Pequeno & Lamilla) facility with visual disease screening. Specific conditions for import are available in the biosecurity import conditions database (BICON) on the department's website.

A previous analysis undertaken by the department into the importation of nursery-stock over a two year period (2008–10) indicated that about 2.2 million live plants were imported into Australia, with nine genera comprising about 83 per cent of all imports for this pathway. These genera were: *Anthurium* (four per cent), *Gymnocalycium* (six per cent), *Dendrobium* (four per cent), *Dracaena* (43 per cent), *Mamillaria* (two per cent), *Phalaenopsis* (eight per cent), *Sansevieria* (two per cent), *Tillandsia* (10 per cent) and *Yucca* (four per cent). Nursery-stock from these genera were regularly imported in consignments in excess of 10,000 plants for direct commercial sale to the public following release from post-entry quarantine. This trend of high volume nursery-stock imports continues to the present day, and differs from the approach used for the introduction of high risk nursery-stock, where only a limited quantity of new germplasm is imported for multiplication in Australia before release from biosecurity control.

Potential for nursery-stock as orthotospovirus hosts

Nursery-stock is considered a potential pathway for pathogen distribution internationally (Elliott et al. 2009; Lawson & Hsu 2006). For example, CSNV-infected Brazilian chrysanthemum cuttings were alleged to have caused several incursions in Europe (de Jonghe, Morio & Maes 2013; Mumford et al. 2003; Ravnkar et al. 2003; Verhoeven & Roenhorst 1998). Reported INSV incursions in Israel (Gera et al. 1999) and the Czech Republic (Mertelik et al. 2002) have also

been alleged to be associated with imported nursery-stock. INSV has also been detected by Australia on imported *Begonia*, lisianthus and *Spathipillum* propagative material and successfully eradicated following an incursion in 2010 (PHA & NGIA 2011).

Orthotospoviruses that infect nursery-stock

This Group PRA identified 12 quarantine orthotospoviruses with nursery-stock hosts: ANSV, CCSV, CSNV, GRSV, HCRV, INSV, LNRV, MVBaV, TCSV, TYRV, TZSV and WSMoV.

Orthotospovirus symptom expression

The expression of orthotospovirus infection symptoms in ornamental species can vary significantly, ranging from subtle to severe, and can be influenced by several factors, including plant cultivar, development stage, and environment (Daughtrey et al. 1997; Hausbeck et al. 1992; Llamas-Llamas et al. 1998). It is feasible that plants exhibiting mild orthotospovirus infection could be overlooked or the symptoms attributed to other causes (Elliott et al. 2009; Hausbeck et al. 1992).

Limited symptomless orthotospovirus infection has been reported. Ruter and Gitatis (1993) reported 22 of 49 ornamental species sampled from apparently asymptomatic plants that were growing in a commercial nursery in the USA as being positive for INSV. Miller et al. (1998) reported similar findings for INSV in *Veronica sp.*, *Tradescantia*, and *Aucuba*, as did Roggero et al. (1999) for *Dianthus chienthsis*. By its very nature, the incidence of asymptomatic orthotospovirus infection may be under-reported. However, there is uncertainty in these reports about the time elapsed since these plants acquired the orthotospovirus and were subsequently tested. Possibly, such asymptomatic plants may have had insufficient time for symptom expression to develop before being tested. If so, the observations may correspond to a latency period prior to expression, rather than the lack of symptom expression. If this is correct, the precise meaning of asymptomatic and the duration of this latency period are of relevance to disease screening efficacy.

Variability in orthotospovirus symptom expression has also been reported in crops. For example, Culbreath et al. (2003) report the incidence of TSWV infection as comparable in samples taken from symptomatic and asymptomatic peanut plants, and Smith et al. (2006) concluded that the incidence of IYSV was underestimated due to localization of infection within plants. Moreover, asymptomatic orthotospovirus infection has been reported in weeds (Latham & Jones 1997). Environmental factors are also reported to influence orthotospovirus symptom expression, for example, Lavina and Batlle (1993) report that TSWV symptom expression in *Ficus* was only apparent between 25 °C to 35 °C. Similarly, Allen and Matteoni (1988) observed that *Cyclamen persicum* expressed symptoms at 13 °C but not at 22 °C. These observations may be pertinent to orthotospovirus expression more broadly, and may add weight to the potential for the expression of orthotospovirus infection in nursery-stock to be overlooked under certain conditions.

Summary

Nursery-stock species were identified as an area requiring additional work in relation to orthotospovirus risk. Consequently, a review of nursery-stock species that are orthotospovirus hosts will be undertaken as a separate process, and released for stakeholder consultation.

Appendix I Responses to key issues raised by stakeholders

This section provides the department's responses to key issues raised by stakeholders on the draft Group PRA for thrips and orthotospoviruses.

The adequacy of the number of thrips species assessed

An issue was raised about the adequacy of the number of thrips species assessed.

More than 6,000 Thysanoptera species have been described to date. A scoping assessment was undertaken to identify thrips that have the potential to be on the plant import pathway and cause damage to plants. This assessment indicated that most thrips species are not plant pests because they do not feed on plants. Only the phytophagous Thripidae and phytophagous Phlaeothripidae (referred to as phytophagous thrips) are plant pests with the potential to be on the plant import pathway.

It is not practical or necessary to categorise all phytophagous thrips, which contain thousands of species. Selection criteria (Table 3.1) were used to identify 112 species of phytophagous thrips for pest categorisation. The pest categorisation process confirmed 82 species as quarantine pests and/or vectors of orthotospoviruses which required further pest risk assessment. The results of the pest risk assessment are to be applied to all other quarantine pest thrips, even if they are not specifically listed in the pest categorisation.

The conclusion of the risk assessment is that quarantine pest thrips pose an unacceptable level of risk for Australia and risk management measures are required to reduce the risk to an acceptable level. The inclusion of more species is unlikely to change this conclusion.

Previous risk assessments of thrips and an analysis of interception data clearly show that certain thrips species are 'repeat offenders'—occurring on many different commodities from many different sources. These assessments also demonstrate the marked consistency in the level of risk posed by pest thrips relative to the ALOP for Australia. These risk assessments have been extensively reviewed and endorsed by stakeholders.

The basis for assessing thrips as a group

Stakeholders requested clarification of the term 'similar biological characteristics' used in the draft report, and questioned the basis in logic of assessing thrips as a group.

The term 'similar biological characteristics' has now been replaced by the phrase 'share common biological characteristics' as used in the *International Standard for Phytosanitary Measures Number 2: Framework for pest risk analysis* (FAO 2016a).

ISPM 2 states that '*Specific organisms may then 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 resulting in similar likelihoods of entry, establishment and spread and comparable consequences—thus posing a similar level of biosecurity risk.

The Thysanoptera comprise more than 6,000 described thrips species, which represent a diverse range of feeding strategies—herbivores, fungivores and predators.

A scoping assessment was undertaken to identify thrips that have potential to be on the plant import pathway and cause damage to plants, and thus have the potential to be quarantine pests for Australia. Phytophagous thrips were identified as having such potential.

Phytophagous thrips of biosecurity concern share common biological characteristics including plant feeding behaviours, relatively small size and cryptic habits, high levels of natural or human assisted mobility, lack of an obligate diapause life stage, high fecundity, and a predisposition to parthenogenesis in some species.

Determination of a quarantine pest

Stakeholders questioned the inclusion and/or quarantine status of some species in the pest categorisation process.

All species included in the pest categorisation process met one or more of the criteria for inclusion given in Table 3.1, as indicated in column 2 of Table 3.2.

The IPPC defines a pest as '*Any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products*', whereas 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 2016a).

Review of the total of 22 species questioned by the stakeholders confirmed that (i) *Neoheegeria mangiferae* is not recognised in the current taxonomic literature, (ii) the 21 remaining species met the definition of a pest, of which 20 met the definition of a quarantine pest, and (iii) *Pseudophilothrips adisi* is not a quarantine pest as it has no potential to cause economic consequences. The report was amended accordingly.

Viruses other than orthospoviruses vectored by thrips

A stakeholder suggested it would be useful for all viruses vectored by thrips to be considered fully within this Group PRA.

A risk analysis of the other viruses transmitted by thrips is beyond the scope of this Group PRA. However, an initial evaluation was made to determine if additional work may be required, which would be undertaken as a separate process.

This initial evaluation identified that these viruses have (i) different modes of transmission, (ii) vectors other than thrips, and (iii) other pathways beyond that of the plant import pathway. These issues significantly influence the relationships between these viruses, their vectors and their hosts, and accordingly, with plant import pathways. Thus, detailed pest risk analysis of these viruses will be undertaken as a separate process when resources permit.

Seed transmission of orthospoviruses

A stakeholder was concerned about the seed transmission of orthospoviruses.

The evidence for seed transmission as a pathway was fully considered in this Group PRA, and concluded that the weight of evidence is that seed is not an import pathway. However, the analysis does acknowledge one preliminary experiment that implies seed transmission of *Soybean vein necrosis virus* may be feasible under laboratory conditions (Groves et al. 2015). However, no evidence was found for seed transmissibility of this virus in soybean grown under field conditions (Hajimorad et al. 2015). No other published research supports seed transmission of orthospoviruses. However, the department would consider any new evidence that might arise in the future.

Quarantine status of *Capsicum chlorosis virus – Phalaenopsis strain (CaCV-Ph)*

A stakeholder requested further evidence to support the removal of CaCV-Ph as a quarantine pest for Australia.

Australia regulated CaCV-Ph as a quarantine pest. However, current molecular and biological data do not provide technical justification that CaCV-Ph from Taiwan is a distinct strain of *Capsicum chlorosis virus* that differs from those already present within Australia.

Orthotospovirus species are defined primarily on a molecular basis using their N protein sequence (King et al. 2012). Those with an N protein identity of 90 per cent or greater are viewed as the same species, and if less than 80 per cent, as different species. Those with an intermediate N protein identity (80–89 per cent) are considered either different strains or different species depending on their biological properties, including host-plant range or thrips vectors.

Although Zheng et al. (2008) reported a CaCV isolate from *Phalaenopsis* in Taiwan that shared 96.1 per cent N gene nucleotide and 97.5 per cent amino acid identity with the Australian isolate CaCV-958, they still considered this *Phalaenopsis* isolate as a distinct strain. This was mainly based on the comparison of disease expression and/or host plant range differences of CaCV-Ph, derived from mechanical inoculations, with that of Australian isolate CaCV-958 (McMichael, Persley & Thomas 2002). For example, Zheng et al. (2008) reported *Capsicum annuum* mechanically inoculated with CaCV-Ph showed necrotic ringspots and deformations on both inoculated and systemic leaves, and plants eventually wilted. However, isolate CaCV-958 caused mottling on systemic leaves of *C. annuum* and did not show any symptoms on inoculated leaves. *Lycopersicon esculentum* infected by CaCV-Ph or CaCV-958 showed necrotic spots systemically, but only CaCV-Ph caused chlorotic or necrotic spots on inoculated leaves. Therefore, host data for CaCV-Ph was based on a mechanical inoculations, and there is no published evidence of any naturally occurring differences in economic impact.

There are other isolates of CaCV present in Australia, such as CaCV-Qld3432. Widana et al. (2015) advised from sequence and phylogenetic analyses that CaCV-Ph is more closely related to the Australian isolate CaCV-Qld3432 than isolates from Thailand (CaCV-AIT) and China (CaCV-CP). They also stated that if only N protein phylogeny and sequence identity are considered the Chinese and Thai isolates appeared to be CaCV, but differences in the intergenic region (IGR) sequence identities of the M and S RNA could imply these two isolates may be distinct orthotospoviruses. Huang et al. (2017) studied the evolutionary origin of CaCV isolates through analysis of IGR sequences, concluding CaCV-Ph was derived from CaCV-Qld3432 with the deletion of 218-nt S RNA IGR sequences, and that isolates from mainland China (CaCV-Hainan) and Thailand (CaCV-NRA) were also most likely derived from CaCV-Qld3432.

Zheng et al. (2008) also reported that *T. palmi* was not capable of transmitting CaCV-Ph (based on unpublished data), whereas the authors stated that *T. palmi* was able to transmit CaCV (isolate not specified) in Australia, citing Persley, Thomas and Sharman (2006) also on the basis of their unpublished data. This comparison is across two independent unsubstantiated studies, where any variances could equally be attributed to dissimilar experimental conditions.

On the basis of the evidence, there is no data that shows significant differences in economic consequences between CaCV-Ph and Australian CaCV isolates, and CaCV-Ph is considered to be the same as CaCV-Qld3432.

Rating of establishment and spread for orthotospoviruses

A stakeholder requested further clarity on the evidence to support the likelihoods of establishment and spread for orthotospoviruses.

The department reviewed the evidence presented in the report, and concluded that the assessed likelihood of establishment of Moderate is appropriately supported by the evidence. However, for clarity, additional text has been presented in this report.

The likelihood of establishment for thrips was assessed as High, which sets a maximum likelihood value for establishment of an orthotospovirus. Several factors reduce the potential likelihood of establishment for an orthotospovirus from High to Moderate. These factors include (i) a thrips vector is essential for orthotospovirus 'perpetuation for the foreseeable future' in the field, (ii) thrips and the orthotospovirus have divergent host plant ranges, (iii) many virus host plants are annual crops, and the virus would not be perpetuated beyond the life-cycle of an individual plant, and (iv) virus acquisition and transmission rates differ with different combinations of thrips vectors and/or orthotospoviruses.

The department also reviewed the evidence presented for the likelihood of spread, and revised the rating from Moderate to High. The report was amended accordingly.

Indirect impact on eradication and control

A stakeholder questioned if the process of assessment of indirect impact on eradication and control took into account the geographic location where a potential incursion may occur.

Incursions in different geographic locations may result in differences in the costs and outcomes of eradication and control. This scenario is taken into account in the application of the method for pest risk analysis (Appendix A).

Consequence is expressed over four magnitudes (Indiscernible, Minor significance, Significant, and Major significance) and four geographic scales (Local, District, Regional, and National). 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 of Appendix A. Therefore, the magnitude of impact expressed by the qualitative impact score for a pest at a given geographic scale is based on the pest's impact on the relevant industries within the incursion area.

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 2016b).
Biological control agents (BCAs)	A biological control agent is an organism, such as an insect or plant disease, that is used to control a pest species. Before a biological control agent is released into the Australian environment, it must be established, via risk analysis, that the risk associated with its release, including host specificity, achieves the appropriate level of protection (ALOP) for Australia.
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 measures	The <i>Biosecurity Act 2015</i> defines biosecurity measures as measures to manage any of the following: biosecurity risk, the risk of contagion of a listed human disease, the risk of listed human diseases entering, emerging, establishing themselves or spreading in Australian territory, and biosecurity emergencies and human biosecurity emergencies.
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.
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 2016b).
Establishment (of a pest)	Perpetuation, for the foreseeable future, of a pest within an area after entry (FAO 2016b).
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).
Infection	The internal 'endophytic' colonisation of a plant, or plant organ, which 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 2016b).
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 2016b).
Intended use	Declared purpose for which plants, plant products, or other regulated articles are imported, produced or used (FAO 2016b).

Interception (of a pest)	The detection of a pest during inspection or testing of an imported consignment (FAO 2016b).
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 2016b).
Introduction (of a pest)	The entry of a pest resulting in its establishment (FAO 2016b).
National Plant Protection Organization (NPPO)	Official service established by a government to discharge the functions specified by the IPPC (FAO 2016b).
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 2016b).
Pathogen	A biological agent that can cause disease to its host.
Pathway	Any means that allows the entry or spread of a pest (FAO 2016b).
Pest	Any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products (FAO 2016b).
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 2016b).
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 2016b).
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 2016b).
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 2016b).
Pest risk management (for quarantine pests)	Evaluation and selection of options to reduce the risk of introduction and spread of a pest (FAO 2016b).
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 2016b).
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 2016b).
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 2016b). In this risk analysis the term 'phytosanitary measure' and 'risk management measure' may be used interchangeably. The term phytosanitary relates to the health of plants.
Plant import pathway	Fresh fruit, vegetables and cut-flowers or foliage imported into Australia as commercial consignments from any country.

PRA area	Area in relation to which a pest risk analysis is conducted (FAO 2016b).
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 2016b).
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 2016b).
Regulated article	Any plant, plant product, storage place, packaging, conveyance, container, soil and any other organism, object or material capable of harbouring or spreading pests, deemed to require phytosanitary measures, particularly where international transportation is involved (FAO 2016b).
Regulated non-quarantine pest	A non-quarantine pest whose presence in plants for planting affects the intended use of those plants with an economically unacceptable impact and which is therefore regulated within the territory of the importing contracting party (FAO 2016b).
Regulated pest	A quarantine pest or a regulated non-quarantine pest (FAO 2016b).
Restricted risk	Restricted risk is the risk estimate when risk management measures are 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 2016b).
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 2016b).
The department	The Australian Government Department of Agriculture and Water Resources.
Trash	Soil, splinters, twigs, leaves, and other plant material, other than fruit stalks.
Treatment	Official procedure for the killing, inactivation or removal of pests, or for rendering pests infertile or for devitalisation (FAO 2016b).
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.

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