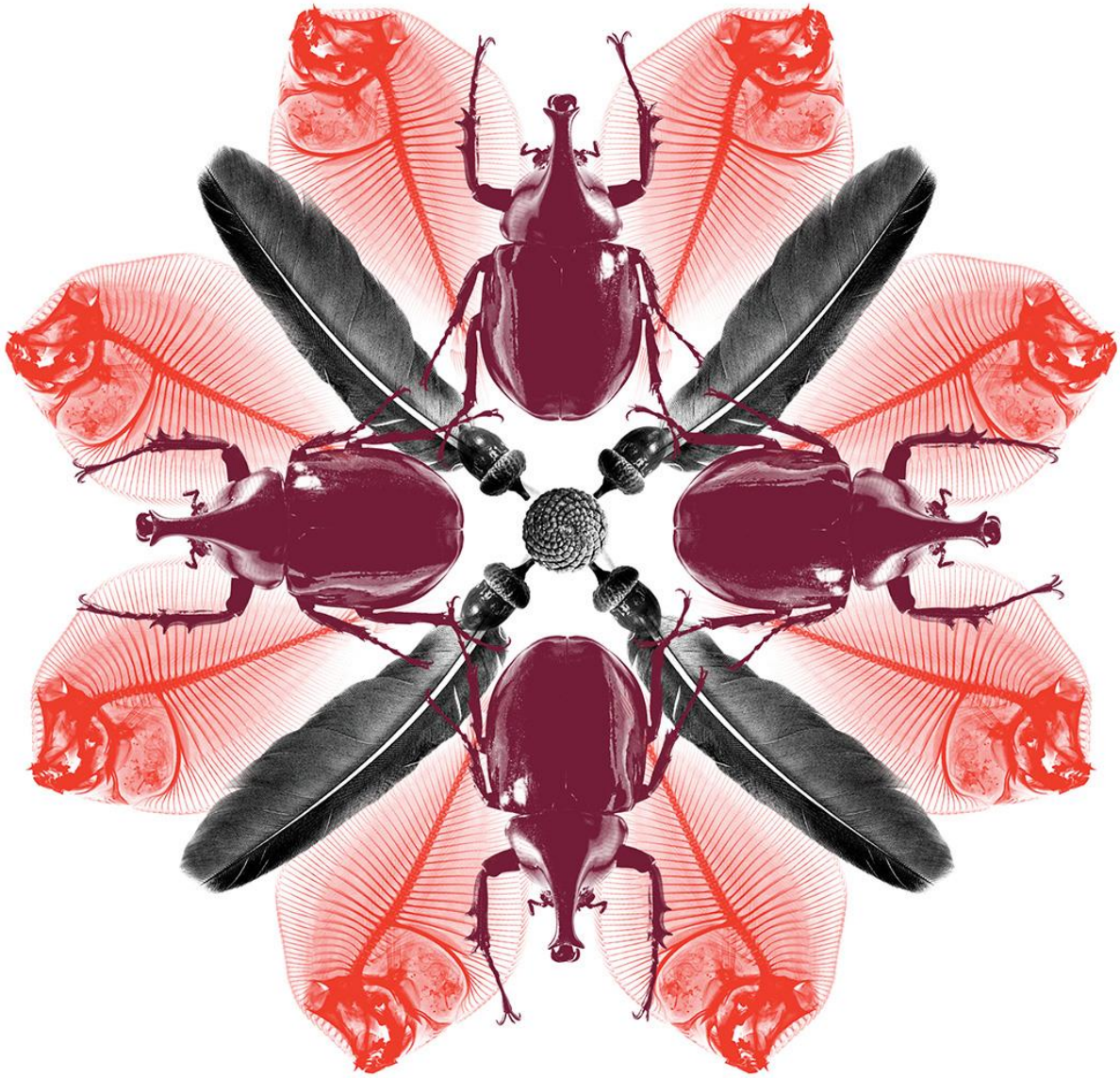
Australian Government
Department of Agriculture and Water Resources

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

December 2016



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Australian Government Department of Agriculture and Water Resources
GPO Box 858 Canberra ACT 2601

Switchboard: +61 2 6272 3933 or 1800 900 090

Facsimile: +61 2 6272 3307

Email: plant@agriculture.gov.au

Stakeholder submissions on draft reports

This draft report has been issued to give all interested parties an opportunity to comment on relevant technical biosecurity issues, with supporting rationale. A final report will then be produced taking into consideration any comments received.

Submissions should be sent to the Australian Government Department of Agriculture and Water Resources following the conditions specified within the related Biosecurity Advice, which is available at:
http://www.agriculture.gov.au/biosecurity/risk-analysis/memos

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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 Pest Risk Analysis (PRA). A key step in this process 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.

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 2015). International Standard for Phytosanitary Measures (ISPM) 2: Framework for pest risk analysis (FAO 2007), states that 'organisms may ... be analysed individually, or in groups where individual species share common characteristics'. This is the basis for the group PRA in which organisms are grouped if they have similar biological characteristics resulting in similar likelihoods of entry, establishment and spread and comparable consequences – thus posing a similar level of biosecurity risk.

Undertaking PRAs on groups of pests with similar biological characteristics provides significant opportunities to improve effectiveness and consistency 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. It is a 'building block' that can be used to review existing trade pathways or it can 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 released for public consultation—further group PRAs are underway. 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 *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 tospoviruses, which are transmitted by some thrips.

Thrips and the tospoviruses they transmit can cause considerable economic consequences across a wide range of fruit, vegetable, legume and ornamental crops by reducing yield, quality and marketability. Tospoviruses 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, by Australian industry and those identified by states and territories as regional pests for Australia.

An early draft report was provided to jurisdictions of all Australian states and territories in late 2015. The department received supportive, positive and constructive feedback for the new group PRA approach as well as specific comments on regional differences. All feedback and specific comments were carefully considered and addressed in the draft report.

This report does not address the risk posed by thrips and tospoviruses 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 6000 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. Only the phytophagous (plant-eating) Thripidae and phytophagous Phlaeothripidae were identified as potential quarantine pests for Australia.

A range of selection criteria were used to identify thrips species within the phytophagous Thripidae and the phytophagous Phlaeothripidae with potential biosecurity importance for Australia. Within this group, 80 thrips species were confirmed as quarantine pests for Australia. The draft group PRA also identified 27 tospoviruses that are quarantine pests for Australia.

These thrips and tospovirus 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 tospoviruses. 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 proposes that the quarantine status of these three thrips species be changed from their current non-regulated status to regulated—*Frankliniella schultzei*, *Scirtothrips dorsalis* and *Thrips tabaci*—because these thrips can carry and transmit quarantine tospoviruses. This change is not expected to significantly affect trade.

Initial evaluation of six viruses other than tospoviruses 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*). Two viruses (*Pelargonium flower break virus* and *Prunus necrotic ringspot virus*) require no additional action at this time.

Phytosanitary measures are identified in this draft 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 tospoviruses they transmit.

Measures include:

- For fresh fruit and vegetables, consignments must be verified as not infested with quarantine thrips by standard visual inspection procedures. Consignments found to be infested with quarantine thrips require appropriate remedial action(s).
- For cut flowers and foliage, which are routinely found to be infested with quarantine thrips, mandatory fumigation is an appropriate risk management option unless equivalent arrangements have been approved.

Further details are available in this draft report which has been published on the department's website to allow interested parties to provide comments and submissions within the consultation period.

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 2015). The 'PRA area', the area in relation to which the PRA is conducted (FAO 2015) is defined as Australia within this report. A pest is any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products (FAO 2015). 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 2015).

Scope

This PRA considered all members of the insect order Thysanoptera (commonly referred to as thrips) and all members of the genus *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.

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 tospoviruses 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 is 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). A key step in this process 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 scientific knowledge available to the department including pest interception data and previous PRAs.

Underpinning principles

Shared common biological characteristics

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

The group PRA 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 consistency in the level of biosecurity risk posed by the pests relative to the appropriate level of protection (ALOP) for Australia. They also indicate that certain species are associated with a broad range of plant commodities from many countries.

Supported by and validated with available scientific information

The conclusions of the group PRA are validated with available scientific evidence including 26 years (or more) of interception data collected at Australia's borders, similar records available from other countries and extensive literature review. The group PRA includes significant pests that have been recognised internationally, by Australian industry and those identified as regional pests for Australia in consultation with the states and territories.

Consistent with international standards and requirements

The group PRA is consistent with relevant international standards and requirements - including ISPM 2: Framework for Pest Risk Analysis, ISPM 11: Pest Risk Analysis for Quarantine Pests, (FAO 2013) and the SPS Agreement (WTO 1995).

Clear scope

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

Benefits of group PRA

Undertaking PRAs on groups of pests with similar biological characteristics provides significant opportunities to increase efficiency, improve consistency 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. It is a 'building block' that can be used to review existing trade pathways or be applied to prospective pathways for which a specific PRA is required.

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

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

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

1.3 This group PRA

This is the first group PRA to be released for public consultation—further group PRAs are underway. 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 *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 tospoviruses, which are transmitted by some thrips.

Thrips and the tospoviruses they transmit can cause considerable economic consequences across a wide range of fruit, vegetable, legume and ornamental crops by reducing yield, quality and marketability. Tospoviruses 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 the plant import pathway show a marked consistency in the estimated level of biosecurity risk posed by thrips 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 rare exceptions.

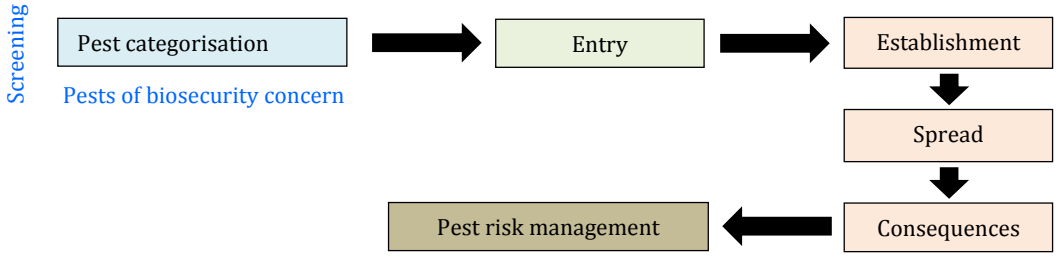
Identification of key pests

Most thrips species described in the literature are not of biosecurity concern. The purpose of this group PRA was to focus on and identify those that are of biosecurity significance to Australia. Pest categorisation was included for both thrips and tospoviruses. The categorisation of thrips was undertaken as part A and part B to screen out thrips families or sub-groups within these families that are unlikely to have the potential to be on the plant import pathway and/or cause economic (including environmental) consequences. A range of selection criteria were then used to identify which thrips species to categorise in detail.

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 likelihood of pest entry in this group PRA is indicative only.

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

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

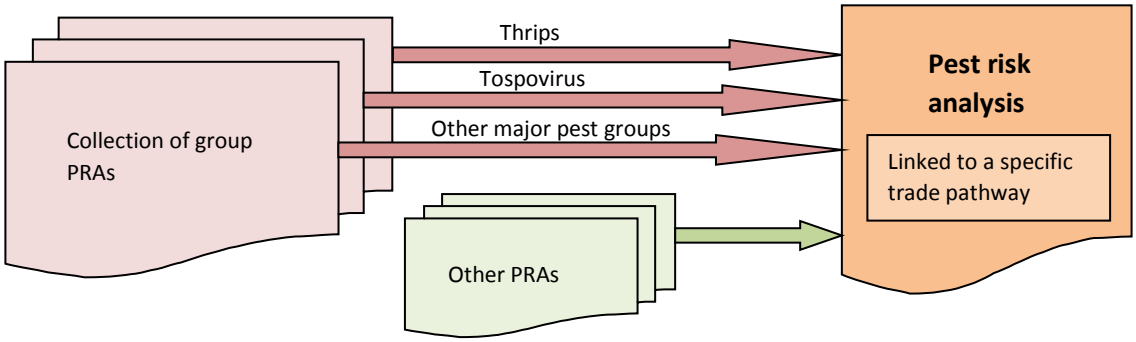
Phytosanitary measures are identified in this draft report for use in specific trade pathways when the unrestricted risk is verified and does not achieve the ALOP for Australia.

1.4 Future of group PRA

In addition to thrips and tospoviruses, the department intends to apply the group PRA approach to other key pest groups.

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

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



1.5 Australia's biosecurity policy framework

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

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

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

Australia's 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 provided in the Biosecurity Import Risk Analysis Guidelines 2016 located on the Australian Government Department of Agriculture and Water Resources website.

2 Pest categorisation of thrips (part A)

2.1 Introduction

The pest categorisation process identifies pests with the potential to be on the plant import pathway that are quarantine pests for Australia and as a result require pest risk assessment. 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 2015).

Pest categorisation confirms the identity of a pest, its absence or presence and regulatory status within the PRA area, its potential for establishment and spread and its potential for economic and environmental consequences in the PRA area (FAO 2013).

Pest categorisation of thrips (part A) eliminates from further consideration thrips families (or sub-groups within these families) that are unlikely to have the potential to:

- be on the plant import pathway and/or
- cause economic (including environmental) consequences.

Factors taken into consideration included:

- feeding strategies—herbivores, fungivores or predators
- Australian thrips interception data (1986–2012) for the plant import pathway
- 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 of thrips (part B).

2.2 Thrips families

The order Thysanoptera comprise more than 6000 described thrips species (ThripsWiki 2016), divided into two sub-orders, the Terebrantia and Tubulifera, with a total of nine families (Table 2.1). The Tubulifera comprise a single family, the Phlaeothripidae, which is the largest in the Thysanoptera, with more than 3600 described species (ThripsWiki 2016), split into two sub-families, the Idolothripinae and Phlaeothripinae. The Terebrantia comprise eight families of about 2500 species, with the 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 2016). Note, the Stenurothripidae includes 18 species but only six are still in existence (extant), and often referred to as the Adiheterothripidae (ThripsWiki 2016).

Table 2.1 Thrips classification (the Thysanoptera)

Order	Thysanoptera	
Sub-order	Terebrantia	Tubulifera
Family and sub-family, if applicable	Aeolothripidae (204) Fauriellidae (5) Heterothripidae (89) Melanthripidae (67) Merothripidae (15)	Phlaeothripidae (3664)—sub-families Idolothripinae and Phlaeothripinae –

	Stenurothripidae (6) Thripidae (2079)—sub-families Dendrothripinae, Panchaetothripinae, Sericothripinae and Thripinae Uzelothripidae (1)

2.3 Family pest categorisation

Aeolothripidae

This family contain 204 species in 23 genera distributed worldwide (Mound & Marullo 1998; Mound, Paris & Fisher 2009; ThripsWiki 2016). 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 comprising more than 60 per cent of species in the family, live in flowers, feed on plant tissues and are also facultative predators, but a few are obligate predators of small arthropods (Kirk 1997b; Mound & Marullo 1998; Mound & Reynaud 2005; ThripsWiki 2016). Whereas, 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 *Franklinothrips* (16 species) and *Mymarothrips* (3 species) are probably all obligate predators of small arthropods (Mound & Marullo 1998; Mound & Reynaud 2005; ThripsWiki 2016), and those of the genus *Stomatothrips* (8 species) are also probably all predatory (ThripsWiki 2016). *Franklinothrips* 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 but often little host specificity is shown (Kirk 1997b; Mound, Paris & Fisher 2009; Mound & Reynaud 2005).

Aeolothripidae are not regarded to be plant pests of economic consequences (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 (yearly average range 0.1 to less than 0.5; *Aeolothrips collaris*, *Aeolothrips fasciatus* and *Franklinothrips megalops*) and two in interception group E (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 2016), the United States has also reported infrequent interceptions of 12 identified species of Aeolothripidae 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 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 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, Aeolothripidae will be excluded from further consideration in this PRA.

Fauriellidae

This family contains five species (Mound, Paris & Fisher 2009; ThripsWiki 2016). 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 host of Fauriellidae species.

There is no available evidence indicating that the Fauriellidae are plant pests of economic consequences. 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 either 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 Fauriellidae will be 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 2016). Adult Heterothripidae have also been found on the flowers of Asteraceae, Fabaceae, Caesalpiniaceae, Mimosaceae, and Cactaceae, but their juvenile development 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 consequences, 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 (Cavalleri, Kaminski & Mendonca 2010; Cavalleri, Kaminski & Mendonça 2012).

There is no available evidence indicating that the Heterothripidae are plant pests of economic consequences (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 report any interceptions at its ports of entry over the period 1983 to 1999 from either 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, Heterothripidae will be 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 2016). Many species seem likely to be both host specific and with 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 consequences. 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, Melanthripidae will be 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 consequences. They are rarely intercepted by Australia (Appendices C and D). Over a 26 year period only two species have been intercepted by Australia, both within interception group E (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 either Europe, the Mediterranean or Africa (Nickle 2003). Japan has reported interception of one species of Merothripidae 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, Merothripidae will be excluded from further consideration in this PRA.

Phlaeothripidae

This is the largest family in the Thysanoptera with 3664 described species in two subfamilies, the Idolothripinae (83 genera and 737 species) and the Phlaeothripinae (374 genera and 2927 species) (ThripsWiki 2016). The majority of species are not known to be pests of economic consequences—only a few are regarded as pests (Lewis 1997c; Mound & Morris 2007). The Phlaeothripidae comprise about nine per cent of overall Thysanoptera interceptions across the plant import pathway. Some species in the subfamily Phlaeothripinae are plant feeders with potential to be pests of economic consequences. The family Phlaeothripidae is discussed in three separate groups based on their feeding behaviours: fungivorous, predatory and phytophagous, respectively.

Fungivorous Phlaeothripidae: About 60 per cent of Phlaeothripidae species feed on fungi including all of the subfamily Idolothripinae and species in the large genera *Hoplandrothrips*, (105 species), *Holothrips* (125 species) and *Hoplothrips* (130 species) in the subfamily Phlaeothripinae (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 (yearly average range 0.5 to 5; *Hoplandrothrips flavipes*), two in interception group D (yearly average range 0.1 to less than 0.5; *Nesothrips laventris* and *Nesothrips propinquus*) and three in interception group E (yearly average less than 0.1; *Ecacanthothrips tibialis, Hoplothrips kea* and *Priesneriella citricauda*). Only one of these 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 consequences (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 Phlaeothripidae will be 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 (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 (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).

Interceptions of predatory Phlaeothripidae are 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 be present on plant import pathway as contaminants. These risks are also addressed by existing requirements for BCAs (Appendix G). For these reasons, predatory Phlaeothripidae will be excluded from further consideration in this PRA.

Phytophagous Phlaeothripidae: Plant feeding Phlaeothripidae are 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 in their host plants and most of these species are found within the *Liothrips* genus (Crespi, Carmean & Chapman 1997).

Haplothrips mainly live 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* that are absent from Australia include *H. aculeatus, H. chinensis, H. tritici* and *H. ganglbaueri* (ThripsWiki 2016), with the former three species reported as being abundant on cereal crops (Mound 1997).

Leaf-feeding *Liothrips* can be serious pests, but generally they are only 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. vaneeckei*, 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 (*P. Persea* and *P. avocadis*) and *Paullinia cupana* trees in Brazil (*P. adisi*) (Mound & Morris 2007; Mound, Wheeler & Williams 2010). Mound (2010) identifies *L. karynyi*

and *P. adisi* as particularly significant pests. The Australian olive industry has also identified *L. oleae* as a high priority pest not present in Australia (Plant Health Australia 2009).

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: 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 (yearly average range 0.5 to 5; *Haplothrips ganglbaueri* and *Hoplandrothrips flavipes*). Of the remaining six species, four were in interception group 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 (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 and to be consistent, potential BCA species for weeds are excluded from further consideration in this PRA, even though they are also plant feeders.

Only phytophagous Phlaeothripidae with potential economic consequences will be considered further in this PRA. This includes species in the genera *Haplothrips, Liothrips, Pseudophilothrips* and *Gynaikothrips* identified in this section.

Stenurothripidae

This family contains 12 fossil and six extant (present-day) species (ThripsWiki 2016). Present-day species are often placed in a separate family Adiheterothripidae and they breed on dead twigs, presumably feeding on fungal hyphae (Mound, Paris & Fisher 2009). The six present-day species are described in three genera, four in *Holarthrothrips*, and one in each of *Heratythrips* and *Oligothrips* (ThripsWiki 2016). Species of *Holarthrothrips* have been reported between India and the Mediterranean area including the Canary Islands and those of *Heratythrips* and *Oligothrips* are known only from western North America (Mound, Paris & Fisher 2009; ThripsWiki 2016).

There is no available evidence indicating that the Stenurothripidae are plant pests of economic consequences 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 either 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, Stenurothripidae will be excluded from further consideration in this PRA.

Thripidae

This family contains about a third (2079) of all thrips species, placed within four subfamilies: Thripinae, Panchaetothripinae, Dendrothripinae and Sericothripinae (Mound, Paris & Fisher 2009; ThripsWiki 2016). 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 the *Chirothrips* and *Limothrips* feeding mainly on florets and *Aptinothrips* and *Stechaetothrips* 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 Thripidae are plant pests of economic consequences 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, Thripidae (excluding the predatory species) are 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 six kilometres apart 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 consequences 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, Uzelothripidae will be excluded from further consideration in this PRA.

2.4 Conclusion

The outcome of pest categorisation of thrips (part A) is summarised in Table 2.2.

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

These families are not likely to be associated with the plant import pathway, except occasionally as contaminants on the plant import pathway, and/or have no potential economic consequences for Australia. The risks posed by contaminants on plant import pathways 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 (excluding potential BCAs for weeds) required further consideration in this group PRA.

Table 2.2 Outcome of pest categorisation of thrips (part A)

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 thrips (part B)

3.1 Introduction

In pest categorisation of thrips (part A), the phytophagous Thripidae and phytophagous Phlaeothripidae (excluding those species that are used as BCAs for weeds) have been identified to contain species that have potential to be on the pathway and cause damage to plants (Table 2.2). This chapter considers the 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 2013).

The phytophagous Thripidae and phytophagous Phlaeothripidae (referred to as pest thrips hereafter) collectively contain a few thousand species, but it is not practical or necessary to categorise them all. Instead, a set of criteria (Table 3.1) were used to identify pest thrips species for inclusion in pest categorisation of thrips (part B), with inclusion dependent on meeting one or more criterion.

Table 3.1 Criteria for pest thrips species inclusion in pest categorisation of thrips (part B)

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 1 interception event per year over a 26 year period; Appendix C and D)
2	Species is known to transmit tospoviruses of quarantine concern to Australia (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 pest categorisation of thrips (part A)
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 pest categorisation of thrips (part A)
7	Species that is under official control as a regional pest within Australia

Based on the selection criteria, 113 thrips species were included for pest categorisation of thrips (part B) (Table 3.2) to provide representative pest thrips of the phytophagous Thripidae and phytophagous Phlaeothripidae. This produced a list of species likely to be important from a biosecurity perspective associated with the plant import pathway. Subsequent inclusion in pest categorisation of additional species that meet one or more of the selection criteria will be considered on a case-by-case basis.

3.2 Biology

The outcome of pest categorisation of thrips (part A) indicates that pest thrips are among the phytophagous Thripidae and phytophagous Phlaeothripidae, therefore the biological information presented is focused on these groups.

Thrips are small, slender insects that are only 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).

Thripidae species 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 adult. Members of the Phlaeothripidae 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).

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

Thrips can 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 larva in soil or as adults among dead plant litter, tree bark or crop debris (Lewis 1997c).

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 2015), and spread is defined as 'the expansion of the geographical distribution of a pest within an area' (FAO 2015).

Pest thrips would have the potential to establish and spread in Australia because they have the relevant biological attributes and the environmental conditions within Australia are suitable.

Biological attributes

Thrips species that have successfully established in new regions often exhibit a typical range of biological attributes (Morse & Hoddle 2006):

- small size and cryptic habits
- are typically abundant in their native region, exhibit high levels of natural or human assisted mobility, and have close association with human activity, such as farming or trade
- lack obligate diapause life stage
- exhibit high fecundity, with short generation times, many generations per year, and a predisposition to parthenogenesis
- are polyphagous feeders
- can quickly synchronize their life-cycle in new environments.

Although these attributes are mainly based on the genera *Frankliniella, Scirtothrips, and Thrips* (Morse & Hoddle 2006), these attributes can be extrapolated, for the most part, to other members of phytophagous Thripidae and phytophagous Phlaeothripidae.

Climatic conditions

Many pest thrips occur in the tropics and subtropics of the world (Mound 2012) and suitable conditions for establishment and spread are available in Australia, which covers tropical, subtropical, temperate, and cool temperate regions (Bureau of Meteorology 2013). In addition, Australia

produces many crops, such as tomatoes, capsicum, cucumber and eggplant under protected conditions (Ausveg 2014a), which can assist the establishment and spread of pest thrips.

Hosts plants

Many crops, including a range of fruit, vegetables and cut-flowers and foliage that are hosts of thrips are grown within the Australian field and greenhouses environments. These hosts are widespread in all the states and territories. In addition, Australia also has extensive 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 been successfully introduced and established within Australia. These include common grass-living Thripidae of Europe, such as species of *Aptinothrips, Chirothrips* and *Limothrips*, and leaf-feeding tropical species, such as *Chaetanaphothrips, Heliothrips, Hercinothrips, Parthenothrips, Selenothrips, Scirtothrips* and *Thrips* (Mound & Tree 2012). Probably, many of these species established years ago, but relatively recent introductions have included *Frankliniella occidentalis, Liothrips vaneeckei* and *Thrips palmi*.

Summary

All pest thrips among the phytophagous Thripidae and phytophagous Phlaeothripidae are considered to have the potential to establish and spread in the PRA area because these thrips occur in regions with similar climate and agricultural production systems to Australia. Establishment and spread are also facilitated by the biological attributes of thrips, including small size, polyphagous feeding, survival and reproductive strategies. This is supported by the outcome of all previous pest categorisations undertaken by Australia where every included species had been assessed as 'feasible' for establishment and spread in Australia, when the species was also found to be on the pathway.

3.4 Potential for economic consequences

Thrips have the potential to become key economic pests because they feed regularly on the cell contents of leaves, petals, fruit and seeds, and on pollen grains (Kirk 1997b). This feeding behaviour 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 damage is likely to affect yields and marketability directly due to damage to fruit intended for sale, and indirectly through stress caused by damage elsewhere on the hosts (Lewis 1997c).

It should be noted that even the 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 had this pest (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 the presumed native Mexico and Central

America, where exploration of potential classical biological control agents had been attempted (Hoddle, Nakahara & Phillips 2002).

After a comprehensive review of thrips, Mound (2005d) emphasises the unpredictability and opportunism that is so characteristic of this group of insects. Indeed, thrips are very opportunistic in exploring available resources. Some monophagous species exhibit remarkable host shifts, such that they become pests on plants unrelated to their natural hosts (Marullo 2009; Mound 1997). For example, *Apterothrips apteris* is restricted to *Erigeron* in California but become 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 become well known pest of grape vines in other parts of the world. The highly polyphagous species, *Heliothrips haemorrhoidalis* (Bouchè) produces large natural populations on many unrelated plants including *Camellia, Citrus, Pinus* and *Dicksonia* (Marullo 2009).

Summary

All pest thrips among phytophagous Thripidae and phytophagous Phlaeothripidae were considered to have the potential to cause economic (including environmental) consequences in Australia. This is supported by the outcome of previous pest categorisations undertaken by Australia where every included species, except one, has been assessed to have the potential to cause economic consequences in Australia, when the species was found to be on pathway and to also have the potential for establishment and spread. Many of the 113 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

Pest categorisation of thrips (part B) is presented in Table 3.2. The pest categorisation process identifies pests, with the potential to be on the plant import pathway, that are quarantine pests for Australia and as a result require a pest risk assessment.

Notes on Table 3.2

Pest categorisation of thrips (part B) was considered in the following manner in Table 3.2:

- the identity of the pest (Column 1), the criteria for its inclusion (Column 2), and the absence or presence and regulatory status in the PRA area (Column 4) are considered 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 considered for individual species in the categorisation table, rather they were addressed for all the pest thrips as a group in chapters 3.3 and 3.4, respectively. This approach is consistent with the ISPM 11 categorisation guideline (FAO 2013). The determination of the quarantine pest status for each species (Column 7) took account of information in chapters 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 tospovirus vector (Column 8).

In Column 2, the criteria for the inclusion of a species are given, as defined in Table 3.1. In Column 6, each interception event is based on the 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 infest the same commodity. Interception events are averaged over 26 years (1986–2012) and expressed as a range and grouped A to E (see Appendix D). Yearly average ranges for these groups are:

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

Table 3.2 Pest categorisation of thrips (part B)

Thrips	Criteria for inclusion	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 it transmits tospoviruses
THRIPIDAE							
Anaphothrips obscurus (Müller) Grass thrips	6	Worldwide in temperate areas (CABI 2013a; Mound & Tree 2012)	Yes, Southern Australia (Mound & Tree 2012) and not under official control	Leaves, commonly in leaf axils of grasses (Mound & Tree 2012), and seedling cereals and young grasses (CABI 2013a)	Interception group D; on *Asparagus* spears.14 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, *Cichorium intybus* from USA, strawberry from Korea and cut-flowers of *Dianthus* sp. from China to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003; 2005)	No	No
Anaphothrips sudanensis Trybom	1, 6	Worldwide in tropical and subtropical areas (CABI 2013a; Mound & Tree 2012)	Yes, widespread (Mound & Tree 2012) and not under official control	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 *Allium fistulosum* from China, *Asparagus officinalis* from Thailand and cut-flowers from Zimbabwe to Japan (Masumoto, Oda & Hayase 2003; 2005)	No	No
Arorathrips mexicanus (Crawford)	1	Widespread throughout the world in tropics and subtropics (Hoddle, Mound & Paris 2012)	Yes, Qld, NSW and NT (Mound 2012a) and not under official control	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 *Asparagus officinalis* from Thailand and New Zealand and *Chrysanthemum morifolium* from South Africa to Japan (Masumoto, Oda & Hayase 2003; 2005)	No	No

Thrips	Criteria for inclusion	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 it transmits tospoviruses
Asprothrips seminigricornis (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 *Gardenia, Citrus* and *Ricinus* (Mound & Tree 2012)	None	Yes (WA)	No
Caliothrips fasciatus (Pergande) Californian bean thrips	1, 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)	Interception group B; from Citrus fruit pathways. Intercepted on asparagus and citrus from Mexico and USA to Japan (Hayase 1991)	Yes	No
Caliothrips impurus (Priesner) African cotton thrips	6	Africa and India (ThripsWiki 2016)	No record found (Mound 2005c; Mound & Tree 2012)	Leaves of cotton and other fibres and grasses (Mound 2005c; ThripsWiki 2016)	None	Yes	No
Caliothrips indicus Bagnall Groundnut thrips	6	India (ThripsWiki 2016)	No record found (Mound 2012a; Mound & Tree 2012)	Leaves, polyphagous (Butani 1993)	Intercepted on *Anethum glaveolens* from Thailand to Japan (Masumoto, Oda & Hayase 2003)	Yes	No
Caliothrips phaseoli (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 *Citrus* fruit and *Asparagus* spears. Intercepted on *Asparagus officinalis* from Peru to Japan (Oda & Hayase 1994)	Yes	No
Caliothrips striatopterus (Kobus)	6	Java, Philippines, Solomon Islands and Australia	Yes, QLD, NSW, NT, WA (Mound & Tree 2012) and not	Leaves of various Poaceae, including sugar cane and *Zea mays*	None	No	No

Thrips	Criteria for inclusion	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 it transmits tospoviruses
Mangosteen thrips		(Mound 2012a; Mound & Tree 2012)	under official control	(Mound & Tree 2012), also on mangosteen (Pableo & Velasco 1994)			
Ceratothripoides claratris (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)
Chaetanaphothrips leeuweni (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 *Musa* spp. (Mound & Tree 2012)	None	Yes (WA)	No
Chaetanaphothrips orchidii (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 *Anthurium* sp. from Hawaii to Japan (Oda & Hayase 1994)	Yes (WA)	No
Chaetanaphothrips signipennis (Bagnall)	4, 6, 7	Australasia, Asia and North, Central and South	Yes, NT, QLD, NSW (Mound & Tree 2012).	Foliage and fruits of host plants, including *Anthurium* and *Musa* (CABI 2013a). Assessed	Intercepted on cut-flowers of *Anthurium* sp. from Philippines to Japan (Masumoto et al. 2005)	Yes (WA)	No

Thrips	Criteria for inclusion	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 it transmits tospoviruses
		America (CABI 2013a)	Declared Pest, prohibited by WA (Government of Western Australia 2016)	as on pathway for Bananas from the Philippines (Biosecurity Australia 2008b)			
Chirothrips manicatus (Haliday)	6	Widespread in temperate regions (Mound & Tree 2012)	Yes, NSW, TAS, SA, WA (Mound & Tree 2012) and not under official control	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 *Ranunculus* sp. from New Zealand to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)	No	No
Chirothrips molestus Priesner	6	Widely spread in Eurasia (ThripsWiki 2016)	No record found (Mound & Tree 2012)	Flowers of wheat and barley (Minaei & Mound 2010)	None	Yes	No
Danothrips trifasciatus 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 *Anthurium* sp (Araceae), *Citrus paradisi* (Rutaceae), *Musa* sp (Musaceae) (Mound & Tree 2012)	None	Yes (WA)	No
Dendrothrips minowai Priesner Minowai thrips	6	Taiwan, Mainland China and Japan (Wang 2013)	No record found (Mound & Tree 2012)	On *Camellia sinensis*, *Cocculus trilobus* and *Diospyros kaki* (Chen 1979; ThripsWiki 2016; Wang 2013)	None	Yes	No
Dendrothrips saltator Uzel	6	Europe (ThripsWiki 2016)	No record found (Mound & Tree 2012)	On *Peucedanum officinale* (ThripsWiki 2016)	Two interceptions from Europe at US ports from 1983-1999 (Nickle 2003)	Yes	No

Thrips	Criteria for inclusion	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 it transmits tospoviruses
Dichromothrips corbetti (Priesner)	6	Widespread around the world (Mound & Tree 2012)	Yes, NT, QLD (Mound & Tree 2012) and not under official control	Leaves and flowers of *Vanda* 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 *Aranda* sp., *Cattleya* sp., *Dendrobium* sp. and/or *Vanda* sp. from Singapore, Thailand and Hawaii to Japan (Hayase 1991)	No	No
Dictyothrips betae Uzel	2, 6	Palaearctic 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)
Drepanothrips reuteri Uzel	6	Widespread in Europe, also California, Illinois and Chile (Hoddle, Mound & Paris 2012)	No record found (Mound & Tree 2012)	Leaves of *Vitis Vinifera*, *Quercus robur*, *Betula* and *Corylus* (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
Echinothrips americanus Morgan Poinsettia thrips	3, 7	North and Central America, Europe and Asia (CABI 2013a)	Yes, Qld (Plant Health Australia 2001). Declared Pest, prohibited by WA (Government of Western Australia 2016)	Mainly foliage, and flowers when population levels increase; polyphagous on numerous plants, including species traded as nursery-stock (PaDIL 2010b). Identified as high priority pest for nursery and garden industry by Plant Health Australia	One interception from Europe at US ports from 1983-1999 (Nickle 2003). Intercepted on *Capsicum annuum* from Netherland and *Echinodorus* sp. from Singapore to Japan (Masumoto, Oda & Hayase 2003; 2005)	Yes (WA)	No

Thrips	Criteria for inclusion	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 it transmits tospoviruses
Elixothrips brevisetis (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
Ernothrips lobatus (Bagnall)	6	Asia (Masumoto & Okajima 2002)	No record found (Mound & Tree 2012)	Flowers and leaves of many plants (Masumoto & Okajima 2002)	None	Yes	No
Frankliniella australis Morgan	6	Chile, Argentina and Brazil (Cavalleri & Mound 2012; ThripsWiki 2016)	No record found (Mound & Tree 2012)	Flowers of *Cestrum parqui* (Cavalleri & Mound 2012). Assessed as on pathway for table grapes from Chile (Biosecurity Australia 2005b)	Intercepted on *Rubus* sp. from Chile to Japan (Masumoto, Oda & Hayase 2003)	Yes	No
Frankliniella bispinosa (Morgan) Florida flower thrips	2, 6	South eastern USA, Bermuda and the Bahamas (Hoddle, Mound & Paris 2012)	No record found (Mound & Tree 2012)	Flowers and young fruit of *Citrus* and other various plant species (Hoddle, Mound & Paris 2012)	None	Yes	Yes (Avila et al. 2006)
Frankliniella cephalica (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 *Mangifera*, *Ligustrum* and *Bidens pilosa* (Hoddle, Mound & Paris 2012)	Intercepted on seedlings of *Chrysanthemum morifolium* from Costa Rica to Japan (Masumoto et al. 2005)	Yes	Yes (Ohnishi, Katsuzaki & Tsuda 2006)

Thrips	Criteria for inclusion	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 it transmits tospoviruses
Frankliniella fusca (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 *Capsicum* and *Solanum* (CABI 2013a)	Interception group E; from fig fruit. Seven interceptions from Europe at US ports from 1983-1999 (Nickle 2003)	Yes	Yes (Mound 2002)
Frankliniella gemina Bagnall	2, 6	South America (Riley et al. 2011b; ThripsWiki 2016)	No record found (Mound & Tree 2012)	Flower of various plants, including *Persea*, *Lycopersicon* and *Lactuca* (Riley et al. 2011b)	None	Yes	Yes (de Borbon, Gracia & De Santis 1999)
Frankliniella intonsa (Trybom)	1, 2, 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 *Asparagus, Capsicum, Fragaria, Gossypium, Prunus* and *Rosa* (CABI 2013a). Assessed as on pathways for *Citrus* fruit from Japan (Biosecurity Australia 2009b), *Capsicum* fruit from South Korea (Biosecurity Australia 2009a), stone fruit from USA (Biosecurity Australia 2010a), and *Phalaenopsis* orchids from Taiwan (Biosecurity Australia 2010b)	Interception group C; from cut-flowers, *Asparagus* spears, *Capsicum* fruit and *Actinidia* 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 Italy to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)	Yes	Yes (Wijkamp et al. 1995)
Frankliniella minuta (Moulton) Minute flower thrips	6	North, Central and South America and Hawaii (Hoddle,	No record found (Mound & Tree 2012)	Flowers of usually Asteraceae (Hoddle, Mound & Paris 2012)	Intercepted on *Craspedia* sp. and *Limonium* sp. from USA to Japan (Hayase 1991)	Yes	No

Thrips	Criteria for inclusion	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 it transmits tospoviruses
		Mound & Paris 2012)					
Frankliniella occidentalis 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 (DPIPWE Tasmania 2015) Vic prohibiting the import of any nursery plants, cut-flowers, leafy vegetables, potato tubers, *Rubus* spp. or strawberry plants into the Toolangi Plant Protection District unless the import conditions of entry are satisfied (DPI Victoria 2013)	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 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)	Interception group A; from numerous pathways including cut-flowers, garlic bulbs, *Asparagus* 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)
Frankliniella schultzei (Trybom) Cotton thrips	1, 2, 4, 6	Pantropical (CABI 2013a; Mound & Tree 2012)	Yes, widespread (Mound & Tree 2012) and not under official control	Flowers, leaves and fruit, polyphagous (CABI 2013b)	Interception group B; from cut-flowers, *Asparagus* spears and sugar snap peas. 55 interceptions from Europe, Mediterranean and/or Africa from 1983-1999 and 7 interceptions	No	Yes (Nagata et al. 2004; Wijkamp et al. 1995)

Thrips	Criteria for inclusion	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 it transmits tospoviruses
					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)		
Frankliniella tritici (Fitch) Eastern flower thrips	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 USA (Biosecurity Australia 2010a)	Interception group E; from *Asparagus* spears. Three interceptions from Europe, Mediterranean and/or Africa at US ports from 1983-1999 (Nickle 2003). Intercepted on *Vaccinium* sp. from USA to Japan (Masumoto, Oda & Hayase 2003)	Yes	No
Frankliniella williamsi 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 Zea mays* and probably other Poaceae including *Saccharum* (Mound & Tree 2012)	Interception group C; from *Asparagus* spears, *Citrus* fruit and cut-flowers. Intercepted on *Asparagus officinalis* from Mexico, *Coriandrum sativa* from Thailand, and *Zea mays* from Australia and USA to Japan (Masumoto, Oda & Hayase 2003)	Yes (WA)	No, but it is a vector of *Maize chlorotic mottle virus* (considered further in Appendix F)
Frankliniella zucchini 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)
Fulmekiola serrata (Kobus) Sugarcane thrips	3, 4	Asia, Africa, and Central and northern South America (Sugar Research Australia 2013; ThripsWiki 2016)	No record found (Mound & Tree 2012)	Leaves of mainly sugarcane (Sugar Research Australia 2013). Identified as high priority pest for sugarcane industry by Plant Health Australia	None	Yes	No

Thrips	Criteria for inclusion	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 it transmits tospoviruses
Heliothrips haemorrhoidalis (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) and not under official control	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 *Anigozanthos* sp. from USA, *Erica* sp. from Australia, *Citrus aurantiifolia* from Mexico, *Viburnum* sp. from Italy and *Vaccinium* sp. and kiwifruit from New Zealand to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003; Masumoto et al. 2005)	No	No
Heliothrips sylvanus Faure	6	South Africa (ThripsWiki 2016)	No record found (Mound & Tree 2012)	Leaves of grapevines (Schwartz 1989)	None	Yes	No
Hercinothrips femoralis Reuter Banded greenhouse thrips	4, 6	Pantropical; also in greenhouses in temperate areas (Mound & Tree 2012)	Yes, WA (CABI 2013a; Mound 2012a) and not under official control	Leaves; polyphagous (Hoddle, Mound & Paris 2012)	Interception group E; from stone fruit	No	No
Holopothrips ananasi Da Costa Lima	6	South America (ThripsWiki 2016)	No record found (Mound & Tree 2012)	Potentially on flowers, fruit and leaves of pineapples (Plant Health Australia 2008)	None	Yes	No
Kenyattathrips katarinae Mound	1	Kenya (ThripsWiki 2016)	No record found (Mound 2009; Mound & Tree 2012)	Leaves of *Catha edulis* (khat) (ThripsWiki 2016)	Interception group C; from *Catha* leaves	Yes	No
Limothrips cerealium (Haliday) Corn thrips	4, 6	Worldwide in temperate areas (Mound & Tree 2012)	Yes, Tas, SA, ACT, NSW and WA (Mound & Tree 2012) and not	Leaves of grasses and cereal crops (Mound & Tree 2012)	Interception group D; from cut-flowers, *Asparagus* spears, kiwifruit and fresh berries. Eighteen interceptions from Europe, Mediterranean and/or Africa from	No	No

Thrips	Criteria for inclusion	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 it transmits tospoviruses
			under official control		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 Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)		
Limothrips denticornis (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 *Brassica* (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 *Abies* sp. from Denmark to Japan (Hayase 1991)	Yes (WA)	No
Megalurothrips distalis (Karny)	6, 7	Asia and Australia (CABI 2013a; ThripsWiki 2016)	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 *Cymbidium* sp. from New Zealand to Japan (Hayase 1991). Intercepted on *Capsicum annuum* from Korea to Japan (Masumoto, Oda & Hayase 2003)	Yes	No
Megalurothrips sjostedti (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 *Anigozanthos* sp. from Zimbabwe to Japan (Masumoto, Oda & Hayase 2003)	Yes	No
Megalurothrips typicus Bagnall [syn: *Taeniothrips varicornis* Moulton]	6	South-east Asia and Australia (Mound & Tree 2012)	Yes, WA, NT (Mound & Tree 2012) and not	Flowers of Fabaceae such as crops *Glycine* (Mound & Tree 2012)	None	No	No

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			under official control				
Megalurothrips usitatus (Bagnall) Bean flower thrips	4, 6	Australasia and Asia (CABI 2013a)	Yes, WA, NT, QLD, NSW (Mound & Tree 2012) and not under official control	Flowers of various Fabaceae (Mound & Tree 2012)	Intercepted on *Limonium* sp., *Oncidium* sp., *Phalaenopsis* sp. and *Pisum sativum* from Taiwan to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)	No	No
Microcephalothrips abdominalis (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) and not under official control	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 *Chrysanthemum* sp. from Taiwan, *Dianthus* sp. from Kenya, *Gomphrena* sp. from Hawaii and *Oncidium* sp. from Thailand to Japan (Hayase 1991)	No	No
Neohydatothrips gracilicornis (Williams)	6	England and Japan (ThripsWiki 2016)	No record found (Mound & Tree 2012)	On clover and meadow grasses (ThripsWiki 2016)	Interception group E; on kiwifruit. Intercepted on leaves of *Viburnum* sp. from Italy to Japan (Masumoto et al. 2005)	Yes	No
Neohydatothrips samayunkur Kudo	1	North and central Americas, Africa, Asia and Australia (Mound & Tree 2012)	Yes, Eastern Australia (Mound & Tree 2012) and not under official control	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
Neohydatothrips variabilis (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	None	Yes	No

Thrips	Criteria for inclusion	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 it transmits tospoviruses
				associated with peach orchards in Georgia, USA (Yonce et al. 1990).			
Pezothrips kellyanus Bagnall	6	Europe, New Caledonia and Australia (Mound & Tree 2012)	Yes, ACT, NSW, Qld, SA and WA (Mound & Tree 2012) and not under official control	Scented flowers and immature fruit of various unrelated plants with scented and white flowers, hosts including citrus (Mound & Tree 2012)	None	No	No
Pseudodendrothrips mori (Niwa) Mulberry thrips	4, 6	Western Europe, North and South America, Asia and Australia (Hoddle, Mound & Paris 2012)	Yes (Mound & Tree 2012) and not under official control	Leaves of *Morus* and *Ficus* 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
Retithrips syriacus (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 *Rosa, Vitis* and *Eucalyptus* (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
Rhipiphorothrips cruentatus 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, *Anacardium occidentale, Juglans, Syzygium, Terminalia, Ricinus* (Hoddle, Mound & Paris 2012). Assessed as on	None	Yes	No

Thrips	Criteria for inclusion	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 it transmits tospoviruses
				pathways for mangoes from Taiwan (Biosecurity Australia 2006b), from India (Biosecurity Australia 2008a) and from Pakistan (Biosecurity Australia 2011b) and table grapes from China (Biosecurity Australia 2011a)			
Rubiothrips vitis (Priesner) European grape thrips	6	Israel and Romania (ThripsWiki 2016)	No record found (Mound & Tree 2012)	Shoots, buds, leaves and fruit of grape (Vasiliu-Oromulu, Barbuceanu & Ion 2009)	None	Yes	No
Scirtothrips albomaculatus 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 *Dodonaea viscosa* (Sapindaceae), adults collected from many plants, including *Citrus, Rosa* and *Acacia* (Mound & Tree 2012)	None	Yes (WA)	No
Scirtothrips aurantii 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). As of 2015, this species is not known to be a pest of citrus in Australia (Garms,	Young leaves and fruits, highly polyphagous, including *Bryophyllum delagoense* 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	Interception group D; from cut-flowers and snow peas. Five interceptions from Africa at US ports from 1983-1999 (Nickle 2003)	Yes (WA)	No

Thrips	Criteria for inclusion	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 it transmits tospoviruses
			Mound & Schellhorn 2013; Rafter, Hereward & Walter 2013)				
Scirtothrips citri (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 *Citrus*, and also *Rhusa* (Anacardiaceae) (Hoddle, Mound & Paris 2012)	None	Yes	No
Scirtothrips dorsalis 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) and not under official control	Young leaves and sometimes flowers, highly polyphagous (Hoddle, Mound & Paris 2012)	Interception group B; from numerous pathways, including cut-flowers, *Actinidia*, *Citrus* fruit, *Asparagus spear.* Three interceptions from Africa at US ports from 1983-1999 (Nickle 2003). Intercepted on *Acacia jarnesian, Asparagus* and *Oncidium* from Philippines and/or Thailand to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)	No	Yes (Chen & Chiu 1996; Chu et al. 2001)
Scirtothrips mangiferae 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
Scirtothrips oligochaetus Karny Mangosteen thrips	6	India and central Africa, Barbados (Mound & Stiller 2011)	No record found (Mound & Tree 2012)	Flowers and shoots of pomegranate, cotton and other hosts (Mound & Palmer 1981); foliage and immature fruit of mangosteen (DAFF 2004b)	None	Yes	No

Thrips	Criteria for inclusion	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 it transmits tospoviruses
Scirtothrips perseae 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 *Persea americana,* 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
Selenothrips rubrocinctus (Giard) Red banded thrips	1, 4, 6	Pantropical and subtropical (Denmark & Wolfenbarger 1999; Mound & Tree 2012)	Yes, Qld, NT (Mound 2012a) and not under official control	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 *Garcinia mangostana* from Colombia, *Gomphrena* sp. from Hawaii and *Litchi chinensis* from Mexico to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)	No	No
Sigmothrips aotearoana Ward	6	New Zealand (ThripsWiki 2016)	No record found (Mound & Tree 2012)	Leaf litter of forests (Mound & Walker 1982)	None	Yes	No
Stenchaetothrips biformis (Bagnall) Oriental rice thrips	4	Europe, South America, Asia and Australia (Mound & Tree 2012)	Yes, Qld, NSW (Mound & Tree 2012) and not under official control	Young leaves, particularly seedling rice plants, but probably other Poaceae including sugarcane (Mound & Tree 2012)	Interception group E; from fresh baby corn. Intercepted on *Asparagus officinalis* from Philippines and *Dendrobium* sp. from Thailand to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)	No	No
Stenchaetothrips fusca (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

Thrips	Criteria for inclusion	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 it transmits tospoviruses
Taeniothrips inconsequens (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 *Acer*, *Malus, Prunus* and *Pyrus* (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
Tenothrips frici (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) and not under official control	Flower of Asteraceae, particularly weedy species (Hoddle, Mound & Paris 2012; Mound & Tree 2012), and *Luffa cylindrical* (Cucurbitaceae) (Mirab-balou & Tong 2013)	Interception group D; from kiwifruit, blueberries, *Citrus* fruit, cut *Lavendula* flowers, and *Asparagus* spears Four interceptions from Mediterranean at US ports from 1983-1999 (Nickle 2003)	No	No
Thrips alni Uzel	6	Europe and Japan (Masumoto & Okajima 2013; ThripsWiki 2016)	No record found (Mound & Tree 2012)	Leaves and flowers of Betulaceae, Fabaceae, Polygonaceae and Ranunculaceae (Masumoto & Okajima 2013)	None	Yes	No
Thrips angusticeps Uzel Field thrips	4	South and southwest Asia, Africa and Europe (CABI 2013a)	No record found (Mound & Tree 2012)	Seedling and young plants, leaves, flowers, stems and fruit; highly polyphagous (CABI 2013a)	Interception group E; from cut *Dianthus* flowers. 24 interceptions from Europe, Mediterranean and/or 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)	Yes	No

Thrips	Criteria for inclusion	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 it transmits tospoviruses
Thrips australis (Bagnall) Gum tree thrips	6	Widespread around the world (Mound & Tree 2012)	Yes, all states (Mound & Masumoto 2005; Mound & Tree 2012) and not under official control	Flowers of *Eucalyptus* and *Melaleuca*(Mound & Tree 2012)	Interception group D; from *Citrus* fruit, table grapes, broccoli and *Asparagus* 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
Thrips coloratus Schmutz	6	Widespread from Pakistan to Japan, Australia (Mound & Tree 2012)	Yes, Qld, NSW (Mound & Tree 2012) and not under official control	Flower of many plants including *Citrus* and *Ficus* (Mound & Tree 2012)	Interception group D; from cut-flowers. Intercepted on *Pisum sativum* from Taiwan to Japan (Oda & Hayase 1994)	No	No
Thrips flavus Schrank Honeysuckle 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 *Asparagus* 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 *Pisum sativum* from Taiwan to Japan (Oda & Hayase 1994)	Yes	No
Thrips florum Schmutz	6	Widespread across Asia and Pacific, Florida, and the Caribbean Islands (Mound & Tree 2012)	Yes, NT, Qld (Mound & Tree 2012) and not under official control	Flower, highly polyphagous (Mound & Tree 2012)	Interception group E; from various cut-flowers. Intercepted on *Hedychium coronarium* from Hawaii to Japan (Hayase 1991)	No	No

Thrips	Criteria for inclusion	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 it transmits tospoviruses
Thrips fulvipes Bagnall	6	England (ThripsWiki 2016)	No record found (Mound & Tree 2012)	On *Mercurialis perennis* (Euphorbiaceae) (DBIF 2014)	Six interceptions from Europe at US ports from 1983-1999 (Nickle 2003)	Yes	No
Thrips fuscipennis Haliday Rose thrips	1	Europe and North America (ThripsWiki 2016)	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 *Eryngium* sp. from Netherlands, *Cynara scolymus* from France] and *Rubus* sp. from USA to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)	Yes	No
Thrips hawaiiensis (Morgan)	1, 4, 6	Widespread across Asia and the Pacific Islands, Southern USA, and Jamaica (Mound & Tree 2012)	Yes, NT, Qld, NSW (Mound & Tree 2012) and not under official control	Flowers, highly polyphagous (Mound & Tree 2012)	Interception group C; from cut-flowers, *Asparagus* 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
Thrips imaginis Bagnall Plague thrips	1, 4, 6	Oceania (Mound & Tree 2012)	Yes, all states (Mound & Houston 1987) and not under official control	Flowers, polyphagous (Mound & Tree 2012)	Interception group C; from cut-flowers, *Asparagus* 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
Thrips major Uzel Rubus thrips	1	Europe (ThripsWiki 2016)	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).	Yes	No

Thrips	Criteria for inclusion	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 it transmits tospoviruses
					Intercepted on *Agapanthus* sp. and *Anemone* sp. from France, *Chamelaucium* sp. from Israel, *Citrus paradise* from USA and *Acacia* sp. from Italy to Japan (Hayase 1991; Masumoto, Oda & Hayase 2003)		
Thrips obscuratus (Crawford) New Zealand flower thrips	1, 6	New Zealand (ThripsWiki 2016)	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
Thrips palmi 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). 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, *Asparagus* 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, WA)	Yes (Jain et al. 1998)

Thrips	Criteria for inclusion	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 it transmits tospoviruses
Thrips parvispinus (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) and not under official control	Flowers and leaves, polyphagous (Mound & Tree 2012)	Interception group C; from cut-flowers and citrus fruit. Intercepted on *Heliconia* sp. from Mauritius to Japan (Masumoto, Oda & Hayase 2003)	No	No
Thrips physapus Linnaeus	6	Europe (ThripsWiki 2016)	No record found (Mound 2005a)	Leaves, polyphagous, hosts including *Leontodon hispidus* (Vasiliu-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
Thrips pillichi Priesner	6	Europe (ThripsWiki 2016)	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
Thrips setosus Moulton Japanese flower thrips	2, 6	Japan and Korea (Mound 2005a; ThripsWiki 2016), Netherlands (EPPO 2015)	No record found (Mound 2005a)	Flowers and leaves of many plants including *Capsicum* and *Cucumis* (Mound 2005a)	Interception group E; from cut-flowers and onion bulbs	Yes	Yes (Fujisawa, Tanaka & Ishii 1988; Persley, Thomas & Sharman 2006)
Thrips simplex (Morison) Gladiolus thrips	1, 6	Widespread around the world (Mound & Tree 2012)	Yes, local, wherever *Gladiolus* is grown (Mound & Tree 2012) and not under official control	Flowers and leaves of mainly *Gladiolus* (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	No	No

Thrips	Criteria for inclusion	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 it transmits tospoviruses
					(Hayase 1991; Masumoto, Oda & Hayase 2003).		
Thrips subnudula (Karny)	6	India, Pakistan, Nigeria and Australia (Mound & Masumoto 2005; Mound & Tree 2012)	Yes, Qld (a single female was recorded near Brisbane) (Mound & Masumoto 2005) and WA (Poole 2010) (citing an internal report), and not under official control.	Flowers, possibly polyphagous, including *Parnthenium hysterophorus* (Mound & Masumoto 2005; Mound & Tree 2012)	None	No	No
Thrips tabaci 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 *Thrips tabaci* identified as high priority pest for onion industry by Plant Health Australia	Interception group A; on cut-flowers and foliage, *Asparagus* 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)
Thrips urticae 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
Thrips validus Uzel	6	Europe and USA Europe (ThripsWiki 2016)	No record found (Mound & Tree 2012)	Flowers of many herbaceous species, especially in Asteraceae (Barbuceanu & Vasiliu-Oromulu 2012)	None	Yes	No

Thrips	Criteria for inclusion	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 it transmits tospoviruses
PHLAEOTHRIPIDAE							
Gynaikothrips ficorum (Marchal) Cuban laurel thrips	4, 5	Pantropical (Mound 2012a)	Yes, WA, NT, Qld, NSW (Mound 2012a) and not under official control	Within rolled-leaf galls, apparently specific to *Ficus microcarpa* (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 *Chrysanthemum* sp. from Taiwan to Japan (Oda & Hayase 1994)	No	No
Haplothrips acanthoscelis (Karny)	6	Austria (ThripsWiki 2016)	No record found (Mound 2012a)	Grasses (ThripsWiki 2016)	None	Yes	No
Haplothrips aculeatus (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 *Asparagus* spears. Four interceptions from Europe and/or Africa at US ports from 1983-1999 (Nickle 2003). Intercepted on *Brassica* spp. and *Amaranthus* sp. from China and *Cynara scolymus* from Italy to Japan (Masumoto, Oda & Hayase 2003; Masumoto et al. 2005)	Yes	No
Haplothrips chinensis Priesner	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 *Oryza* (Wang & Hsu 1996; Woo 1988)	Intercepted on *Chrysanthemum* sp. from Taiwan to Japan (Hayase 1991)	Yes	No
Haplothrips ganglbaueri 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 *Oryza*, *Sorghum* and *Triticum* (Ananthakrishnan & Thangavelu 1976)	Interception group C; from cut-flowers, baby corn and *Asparagus* spears. Intercepted on *Asparagus officinalis* from Thailand to Japan (Oda & Hayase 1994)	Yes	No
Haplothrips gowdeyi (Franklin)	1, 6	Widespread in tropical and subtropical countries	Yes, WA, NT, Qld, NSW (Mound 2012a) and not	Flowers of a wide range of plants, possibly also a facultative predatory	Interception group B; from cut-flowers, *Asparagus* spears and a number of tropical fruit species	No	No

Thrips	Criteria for inclusion	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 it transmits tospoviruses
		(Hoddle, Mound & Paris 2012)	under official control	(Hoddle, Mound & Paris 2012)	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 *Anigozanthos* sp. from Zimbabwe, *Brodiaea* sp. *Leucospermum* sp. from South Africa and *Rosa* sp. from India to Japan (Masumoto, Oda & Hayase 2003; Oda & Hayase 1994)		
Haplothrips leucanthemi (Schrank) [Syn: *Haplothrips niger* 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 *Trifolium* sp. (Fabaceae) and *Plantago* sp. (Plantaginaceae) (Hoddle, Mound & Paris 2012)	Interception group D; from cut-flowers, *Citrus* and kiwifruit	Yes (WA)	No
Haplothrips nigriconis Bagnall	6	South Africa (ThripsWiki 2016)	No record found (Mound & Tree 2012)	Flowers of *Diplopappus, Europs, Olipterus* and *Sebaea* (ThripsWiki 2016)	12 interceptions from Africa from 1983-1999 and 4 interceptions from Europe and Africa from 1994-1999 at US ports (Nickle 2003). Intercepted on *Leucospermum* sp. and *Telopea* sp. from South Africa to Japan (Oda & Hayase 1994)	Yes	No
Haplothrips tenuipennis Bagnall	6	China, India and Indonesia (Mirab-balou et al. 2011)	No record found (Mound & Tree 2012)	Flowers of host plants including rose and *Mangifera* (ThripsWiki 2016)	None	Yes	No
Haplothrips tritici (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

Thrips	Criteria for inclusion	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 it transmits tospoviruses
Hoplandrothrips flavipes Bagnall	1	Africa, Pacific, Asia, Central and South America (ThripsWiki 2016)	Yes, Qld (Mound 2012a) and not under official control	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 *Cocos nucifera* from Thailand to Japan (Masumoto, Oda & Hayase 1999)	No	No
Liothrips karnyi (Bagnall) Pepper leaf gall thrips	5	Sri Lanka (ThripsWiki 2016)	No record found (Mound 2012a)	Marginal leaf galls of *Piper nigrum* (ThripsWiki 2016)	None	Yes	No
Liothrips oleae Costa Olive thrips	3, 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). Identified as high priority pest for olive industry by Plant Health Australia	None	Yes	No
Liothrips piperinus Priesner	5	China and Japan (ThripsWiki 2016)	No record found (Mound 2012a)	Leaves. Hosts including *Castanopsis cuspidate, C. sieboldii, Elaeocarpus sylvestris, Piper kadzura* and *Piper* sp. (ThripsWiki 2016)	None	Yes	No
Liothrips vaneeckei Priesner Lily thrips	5, 7	Widespread (Hoddle, Mound & Paris 2012; ThripsWiki 2016)	Yes, Vic (Malipatil et al. 2002). Declared pest, prohibited by WA (Government of Western Australia 2016)	bulbs of lilies and corms of orchids (Hoddle, Mound & Paris 2012)	Intercepted on Fritillaria sp. from Netherlands to Japan (Hayase 1991)	Yes (WA)	No

Thrips	Criteria for inclusion	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 it transmits tospoviruses
Liothrips wasabiae Haga & Okajima	5	Japan (ThripsWiki 2016)	No record found (Mound 2012a)	On *Wasabia japonica* (ThripsWiki 2016)	None	Yes	No
Neoheegeria mangiferae Priesner	6	India (Srivastava 1997)	No record found (Mound & Tree 2012)	Flowers and leaves of *Mangifera* (Srivastava 1997)	None	Yes	No
Ponticulothrips diospyrosi Haga & Okajima Japanese gall thrips	5, 6	Japan (ThripsWiki 2016), Korea (Park et al. 2009)	No record found (Mound & Tree 2012)	Leaves *of Diospyros kaki* (Park et al. 2009)	None	Yes	No
Pseudophilothrips adisi (zur Strassen)	5	Brazil (Mound, Wheeler & Williams 2010)	No record found (Mound 2012a)	*Paullinia cupana* (Sapindaceae) (Mound, Wheeler & Williams 2010)	None	Yes	No
Pseudophilothrips avocadis Hood	5	Panama and Costa Rica (Mound, Wheeler & Williams 2010)	No record found (Mound 2012a)	Leaves of *Persea* species (Hoddle, Mound & Paris 2012)	None	Yes	No
Pseudophilothrips perseae Watson	5	Mexico (Hoddle et al. 2002) Guatemala and Honduras (Mound, Wheeler & Williams 2010)	No record found (Mound 2012a)	Leaves and young fruit of *Persea Americana* (Hoddle, Mound & Paris 2012)	None	Yes	No

3.6 Conclusion

Based on the criteria for inclusion of thrips species in pest categorisation of thrips (part B) (Table 3.1), a total of 113 species from the phytophagous Thripidae (92 species) and phytophagous Phlaeothripidae (21 species) were categorised (Table 3.2).

As an outcome of pest categorisation 80 species were confirmed as quarantine pests for Australia, including eleven known to transmit tospoviruses (Table 3.3). Three additional species, *Frankliniella schultzei*, *Scirtothrips dorsalis* and *Thrips tabaci* are not quarantine pests for Australia, but they are known to transmit tospoviruses which have the potential to be quarantine pests for Australia. Consequently, 83 thrips species were considered further in the pest risk assessment.

Table 3.3 Outcome of the pest categorisation of thrips (part B)

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

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

Thrips	Common name if available	Quarantine pest	Known to transmit tospoviruses
Thrips urticae Fabricius	–	Yes	No
Thrips validus Uzel	–	Yes	No
Phlaeothripidae			
Haplothrips acanthoscelis (Karny)	–	Yes	No
Haplothrips aculeatus (Fabricius)	Grass thrips	Yes	No
Haplothrips chinensis Priesner	–	Yes	No
Haplothrips ganglbaueri Schmutz	–	Yes	No
Haplothrips leucanthemi (Schrank)	–	Yes (WA)	No
Haplothrips nigriconis Bagnall	–	Yes	No
Haplothrips tenuipennis Bagnall	–	Yes	No
Haplothrips tritici (Kurdjumov)	Wheat thrips	Yes	No
Liothrips karnyi (Bagnall)	Pepper leaf gall thrips	Yes	No
Liothrips oleae Costa	Olive thrips	Yes	No
Liothrips piperinus Priesner	–	Yes	No
Liothrips vaneeckei Priesner	Lily thrips	Yes (WA)	No
Liothrips wasabiae Haga & Okajima	–	Yes	No
Neoheegeria mangiferae Priesner	–	Yes	No
Ponticulothrips diospyrosi Haga & Okajima	Japanese gall thrips	Yes	No
Pseudophilothrips adisi (zur Strassen)	–	Yes	No
Pseudophilothrips avocadis Hood	–	Yes	No
Pseudophilothrips perseae Watson	–	Yes	No

4 Pest categorisation of Tospoviruses

4.1 Introduction

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

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

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

4.2 Biology

In 1930, *Tomato spotted wilt virus* (TSWV) was first reported as the causal agent of spotted wilt disease (Samuel 1931; Samuel, Bald & Pittman 1930), a plant disease first recorded in Australia in 1915 (Brittlebank 1919), but thought not to originate from Australia (Best 1968; Mound 2001). For many years TSWV was considered the only tospovirus. However, the genus *Tospovirus* now comprises eleven species officially recognised by the International Committee on Taxonomy of Viruses (ICTV) and a number of proposed species that are not yet officially recognised. Milne and Francki (1984) first proposed TSWV as being related to members of the family *Bunyaviridae*, where it is now placed. The family *Bunyaviridae* has not yet been assigned to a virus order.

There are over 300 members of the family *Bunyaviridae*, which contains five genera: *Orthobunyavirus*; *Hantavirus*; *Nairovirus*; *Phlebovirus*; and *Tospovirus* (Briese, Calisher & Higgs 2013). Members of this family include viruses that are pathogenic to humans and animals. However, the genus *Tospovirus* is the only genus in the family that contains viruses that can infect both thrips and plants, and are pathogenic to plants. That tospoviruses infect and replicate both within thrips and plants is significant because virus replication exploits host derived resources. This has the potential to cause physiological and/or behavioural changes in thrips that may influence their ability to transmit tospoviruses, in addition to the pathogenic impacts they have on their host plants. This may provide opportunities for complex biological interactions between virus, thrips and host plants.

Tospovirus structure

The tospovirus virion consists of a quasi-spherical (80–120 nm diameter) membrane-like envelope which contains the viral genome. The genome consists of three single-stranded RNA segments, denoted S (small), M (medium) and L (large). The S and M RNAs are positive-sense (ambisense) and the L RNA is negative-sense (Adkins 2000; Geerts-Dimitriadou et al. 2012; Moyer 2000).

Tospoviruses have five open reading frames (ORFs) that encode four structural and two non-structural proteins (Eifan et al. 2013; Moyer 2000). The S RNA encodes for the non-structural N and NSs proteins. The three RNA segments of the genome are encapsidated by the nucleocapsid N protein to form viral ribonucleocapsids. Plants can defend against viruses with an RNA interference system, and the NSs protein is an RNA silencing suppressor (Takeda et al. 2002). The M RNA encodes for the precursor to the structural glycoproteins Gn and Gc, and a non-structural protein, NSm. The glycoproteins Gn and Gc are embedded within, and form projections on, the viral envelope. Plants

have cellulose containing cell walls which are a barrier to virus movement, and cell-to-cell movement of viruses occurs through an intracellular channel, the plasmodesmata. The NSm protein is a transport protein that complements the cell-to-cell movement of tospoviruses via the plasmodesmata (Lewandowski & Adkins 2005). The L RNA encodes RNA-dependent RNA polymerase (RdRp) which specifically replicates the viral RNA genome (German, Ullman & Moyer 1992).

Tospovirus diversity

RNA viruses show high genetic variability and are known to evolve rapidly (Moya et al. 2000). The high mutation rate inherent to RNA replication results from RNA replicase lacking a proofreading mechanism (Crotty, CE & Andino 2001). Related to this, RNA viruses are present in high numbers within infected hosts, have a high replication rate, short generation time, and a small genome size (Moya et al. 2000).

Infections of two or more tospoviruses have been observed within a single plant (Chiemsombat et al. 2008; Kunkalikar et al. 2011; Mullis et al. 2004; Peng et al. 2011; Webster et al. 2011). This provides opportunities for the exchange of genetic material between tospoviruses and a potential mechanism that may influence their evolution and biology under appropriate selection pressure (Bag et al. 2012; Qiu et al. 1998; Webster et al. 2011). The exchange of complete genomic RNA segments (reassortment) between parent tospoviruses has been demonstrated. For example, Qiu et al. (1998) showed experimentally that reassortment between tospoviruses could create progeny with stable novel phenotypes that could be mapped to the specific RNA genome segments. Webster et al. (2011) reported the appearance of a new tospovirus species in the USA, designated as $L_GM_TS_G$, which is the product of natural genomic RNA reassortment between two tospoviruses. The parental tospoviruses of $L_GM_TS_G$ are not known to be present in the USA, and it is thought not to originate from there. Briese et al. (2013) has proposed that most, if not all, members of the family *Bunyaviridae* may be reassortants.

Tospovirus isolates classified as being the same species can exhibit different genetic and biological traits, including pathogenicity. For example, Hassani-Mehraban et al. (2007) described two isolates of *Tomato yellow ring virus* (TYRV) one that infected tomato, the other that infected soybean and potato. In their study, sequence comparison of N protein and double-antibody sandwich enzyme linked immunosorbent assay (DAS-ELISA) indicated the isolates belonged to the same species. However, their respective experimental host plant ranges differed, with both causing systemic infection in *Nicotiana* species, but with only one causing a localized infection in tomato. Similarly, Torres et al. (2012) described isolates of *Pepper necrotic spot virus* (PNSV), one from pepper and the other from tomato. The isolate from tomato was unable to infect pepper, while the isolate from pepper could infect both host species.

Bag et al. (2012) reported a further mechanism behind observed diversity in tospoviruses. The infection of plants with two tospoviruses (IYSV and TSWV) caused a synergistic interaction that altered the expression of disease symptoms. They showed that functional complementation occurred between the two tospoviruses at the molecular level which resulted in greater suppression of the host plant's RNA silencing system in the presence of NSs proteins (RNA silencing suppressors) from both tospoviruses, relative to only the NSs protein from TSWV.

Tospovirus species are defined primarily on a molecular basis using the N protein sequence (King et al. 2012). Tospoviruses with an N protein identity of 90 per cent or greater are viewed as members of the same species. Those with an N protein identity of less than 80 per cent are considered to be distinct species. Tospoviruses with an intermediate N protein identity (80–89 per cent) are considered as either different strains or distinct species depending on their biological properties,

including their range of host plants and thrips species that transmit them. However, Hassani-Mehraban et al. (2007) and Webster et al. (2011) both advised that these criteria may require revision considering the range of genetic and biological diversity observed within the genus *Tospovirus*.

Tospoviruses fall into two main ancestral groups—the Eurasian and Americas (Pappu, Jones & Jain 2009). However, de Oliveria et al. (2012) proposed a novel evolutionary lineage containing two recently discovered tospoviruses, BeNMV (de Oliveira et al. 2011) and SVNV (Zhou et al. 2011). De Oliveria et al. (2012) stated that more species related to the BeNMV-SVNaV group probably remain to be discovered, suggesting that the specificity of some molecular diagnostics tools may result in members of this group being overlooked.

Based solely on the regions where tospoviruses were first recorded, Asia and South America appear as regions of high tospovirus diversity. The number of tospoviruses that were first recorded in each geographical region are: Asia with 15, South America with seven, North America with three, Europe with two, Australasia with two, and Africa with one occurrence. However, the region where a tospovirus was first recorded and the region where it in fact originated may not necessarily be the same.

Tospovirus acquisition by thrips

For a tospovirus to infect a host plant, a thrips must: (i) acquire sufficient virus for infection; (ii) undergo an incubation—latency—period to become viruliferous (competent to infect plants); (iii) and transmit sufficient virus to a susceptible host plant. Thrips can only acquire a tospovirus from infected host plant material; viral transmission between thrips or from parent to offspring (transovarially) is not known to occur, and each generation of thrips must reacquire the tospovirus for its continuance in the thrips population (Nagata et al. 1999; Van de Wetering, Goldbach & Peters 1996; Wijkamp et al. 1996).

Thrips species that transmit tospoviruses develop from eggs through two feeding larval instars (L1 and L2) followed by relatively inactive, non-feeding pupal instars (pre-pupa and pupa) before becoming adults. Only larval thrips, L1 and occasionally early stage L2 instars, can become infected with tospovirus and become viruliferous as L2 instars and adults (Mautino et al. 2012; Nagata et al. 1999). In probably the most accepted theory, Moritz et al. (2004) proposed that the loss of physical association between mid-gut, visceral muscles and salivary glands, as thrips developed, caused the failure of later stage (L2) instars and adults to become viruliferous, even after prolonged feeding on tospovirus 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). In this practice, the single mandible is used to puncture the leaf epidermis, followed by insertion of a pair of maxillary stylets, salivation, and ingestion of the cytoplasm from the mesophyll. The tospovirus is imbibed during this process. Acquiring sufficient virus is probably related to how long larvae feed on infected host plants. However, not all thrips feeding on infected host plants become viruliferous, though, those that do can remain so for life (Mautino et al. 2012; Nagata et al. 1999; Wijkamp, Goldbach & Peters 1996).

Tospovirus transmission by thrips

Tospoviruses are transmitted in a persistent and propagative manner (Whitfield, Ullman & German 2005) by viruliferous L2 instars and adult thrips. This requires replication (amplification) of the

ingested tospovirus, which may occur in the mid-gut and salivary glands, as a requisite to becoming viruliferous (Van de Wetering, Goldbach & Peters 1996). Salivary gland infection is necessary for transmission (Nagata et al. 1999; 2002), and tospoviruses 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 a tospovirus to a host plant has been reported to have a dose dependent relationship with the concentration of virus it has accumulated (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 with female thrips of the same cohort, although females contained up to three times more copies of TSWV RNA per insect (Rotenberg et al. 2009). Hence, absolute virus titer may not the only factor involved. Male *F. occidentalis* thrips infected with TSWV made three times more non-ingestion probes than uninfected males (Lewandowski & Adkins 2005; Stafford, Walker & Ullman 2011). Short- and long-ingestion probes are known to be destructive to plant tissues, which has been hypothesized to result in lower rates of tospovirus infection. Conversely, short non-ingestion probes have been hypothesized to be more likely to result in infection of host plants because they cause less severe tissue damage, and conceivably less likely to inhibit the initial cell-to-cell movement of tospovirus from epidermal/mesophyll cells at the point of virus entry (Lewandowski & Adkins 2005; Stafford, Walker & Ullman 2011).

Chiemsombat et al. (2008) reported the natural occurrence of two thrips species (*S. dorsalis* and *T. palmi*) that both carried mixed infections within their bodies of three tospoviruses—WSMV, CaCV and MYSV. However, virus viability or competency to transmit these viruses was not examined in this study. If this is a common occurrence, this may provide opportunities for tospovirus genome recombination and reassortment within thrips. The simultaneous transmission of different tospovirus by a thrips may also facilitate an increased impact on hosts because of synergistic interactions caused by co-infection, as was observed by Bag et al. (2012).

Tospovirus transmission efficiency

Transmission efficiency is a complex outcome of host plant susceptibility and several processes relating to thrips infection biology: virus acquisition, becoming infectious, maintaining infectivity, and transmission-through feeding (Srinivasan et al. 2012; Wijkamp, Goldbach & Peters 1996). The competency of thrips to transmit tospoviruses 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) differences. Although, most virus-vector combinations have not been tested, current knowledge is that each tospovirus is transmitted only by a limited number of thrips species (Table 4.2 and 4.3).

Tospoviruses can be transmitted mechanically to plants, and many studies have artificially tested the theoretical range of susceptible plant species that can be infected by a given tospovirus. Data from these studies although useful should be treated with caution since the natural transmission of a given tospovirus to a theoretically susceptible host plant may be infeasible or an improbable occurrence in nature. For example:

- the relative distributions of a tospovirus, a thrips that can transmit it, and its theoretically susceptible host plant may not overlap in nature
- a thrips species that can transmit a given tospovirus may not have the theoretically susceptible host plant as its host.

Host plant susceptibility

Host plant susceptibility can vary considerably between different species with some requiring a higher titre (concentration) of virus particles or repeated transmission events to become infected. Susceptibility can depend on plant physiology with younger, vigorously growing plants most likely to be susceptible, and host species that were susceptible when young can become insusceptible as they mature. Host species may have genotypes with various levels of tospovirus resistance (or tolerance), including insusceptible cultivars (Mandal et al. 2012; Puangmalai et al. 2013). For example, a range of tomato cultivars have been identified that differ in their relative resistance to TSWV infection, including complete insusceptibility (Aramburu & Marti 2003). Similar differences in susceptibility have also been observed in uncultivated plant species, which provides potential sources of untapped resistance for incorporation into crop plant breeding strategies (Dianese et al. 2011).

Tospovirus effects on thrips

Tospovirus infection has been reported to influence thrips behaviour and physiology (Belliure et al. 2005; Ogada, Maiss & Poehling 2013; Shrestha et al. 2012; Stafford, Walker & Ullman 2011). The observed effects were attributed to either the direct effects on a thrips from being infected, or indirect effects on a thrips caused by their host plant being infected. Effects observed include:

- TSWV infection of *F. occidentalis* triggered an immune response including the activation of genes encoding antimicrobial peptides and those involved in pathogen recognition and signal transduction pathways (Medeiros, Resende & De Ávila 2004).
- TSWV infection of *F. occidentalis* increased the frequency of the non-ingestion and short-ingestion probes made by male thrips, but had no significant impact on female behaviour (Stafford, Walker & Ullman 2011). Note, thelytokous (consisting of only females with parthenogenetic reproduction) and arrhenotokous (consisting of males and females reproducing sexually) thrips populations occur naturally, with diploid females produced from fertilized eggs and haploid males from unfertilized eggs. However, female populations frequently predominate, and for some species males are often rare or unknown (Vasiliu-Oromulu 2001).
- TSWV infection of *F. occidentalis* increased thrips longevity, and reduced daily and lifetime fecundity (Ogada, Maiss & Poehling 2013).
- TSWV infection of host plants raised their attractiveness to *F. occidentalis*, which was considered to be caused by tospovirus induced suppression of the plant's anti-herbivore defences (Abe et al. 2012; Belliure et al. 2005; Ogada, Maiss & Poehling 2013).
- Maris et al. (2004) observed that TSWV infection of host plants raised their attractiveness to *F. occidentalis* and more offspring were produced on the virus infected-plants and eggs hatched earlier and larvae pupated faster.
- INSV infection of *F. occidentalis* extended development time from second instar to adults, and reduced daily survival and reproductive rates (deAngelis, Sether & Rossignol 1993).
- TSWV infection of host plants increased *F. fusca* ovipositing and probing rates—a result considered to to be caused by an increased 15 fold concentration of free amino acids which would enhance food quality (Shrestha et al. 2012). However, thrips development was delayed and fewer adults emerged.

- Wijkamp et al. (1996) observed that TSWV infection of *F. occidentalis* had no significant effects on thrips reproductive physiology. However, this result differs from other studies where effects on thrips behaviour and physiology were observed.

The existing evidence shows the precise effect tospovirus infection has on thrips biology and behaviour remains inconclusive with a number of observed inconsistencies—reports imply that infection promotes thrips survival and/or development (Medeiros, Resende & De Ávila 2004), with others being neutral (Wijkamp et al. 1996) or deleterious (deAngelis, Sether & Rossignol 1993). Factors that include the use of different tospovirus isolates, host plants or experimental conditions, including temperature may explain some of the observed inconsistencies among published reports, as discussed by Stumpf and Kennedy (2007). Belliure et al. (2005) also concluded that mechanically induced tospovirus infection, a method used in some of these studies, may not induce the full spectrum of natural plant defence responses, and is potentially a contributing factor in the observed inconsistencies.

Summary

The genus *Tospovirus*, family Bunyaviridae, comprises eleven officially recognised species and a number of 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 four structural and two non-structural proteins. RNA viruses show high genetic variability and are known to evolve rapidly, and *Tospovirus* exhibits genetic and biological diversity. Thrips must acquire a tospovirus from a plant host. Viral transmission between thrips or from parent to offspring is not known to occur. Only larval thrips, L1 and rarely early stage L2 instars can become infected, and can remain infective for life to transmit tospoviruses in a persistent and propagative way during feeding. Tospovirus transmission efficiency is a complex outcome of host plant susceptibility and several processes relating to thrips infection biology—virus acquisition, becoming infectious, and maintaining infectivity. Tospovirus infection may influence thrips biology and behaviour, but the precise effects remain inconclusive.

4.3 Potential for establishment and spread

Establishment is defined as the 'perpetuation for the foreseeable future, of a pest within an area after entry' (FAO 2015), and spread is defined as 'the expansion of the geographical distribution of a pest within an area' (FAO 2015).

Quarantine pest tospoviruses would 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.

Tospovirus perpetuation

Tospoviruses must have a host in which to replicate. There is no significant evidence for tospovirus transmission via seed (Albrechtsen 2006; Pappu et al. 1999b), apart from limited preliminary research about a *Soybean vein necrosis virus* isolate being transmitted via soybean seed (Groves et al. 2015). However, no evidence was found for seed transmissibility of this tospovirus in soybean grown under field conditions (Hajimorad et al. 2015). Additionally, a thrips can only acquire a tospovirus from infected plant material; transmission between individual thrips or from parent to offspring (transovarially) is not known to occur, and each generation of thrips must reacquire a tospovirus for its continuance in the thrips population (Nagata et al. 1999; Van de Wetering, Goldbach & Peters 1996; Wijkamp et al. 1996).

Excluding vegetative propagation or artificial transmission, a tospovirus would not be perpetuated beyond the life-cycle of individual host plants. Therefore, an ongoing thrips presence to transmit the virus is essential for tospovirus '*perpetuation for the foreseeable future*' within the natural environment.

Thrips

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

Viruliferous thrips could facilitate the spread tospoviruses 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.

Tospoviruses and their vectors already present within Australia

Three tospovirus species are reported as 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 tospoviruses is uncertain, this shows that the Australian environment can support tospovirus establishment and that host plants were and are likely to remain accessible.

Several thrips species that transmit tospoviruses are also present within Australia—*F. schultzei*, *F. occidentalis*, *S. dorsalis*, *T. 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 tospovirus are likely to be present. The presence of these thrips may further facilitate establishment and spread of a number of tospoviruses. That tospoviruses have previously established and spread within Australia may indicate that natural barriers, including deserts, arid areas, and distance between production areas within Australia cannot stop the spread of tospoviruses within Australia.

Global distribution of tospoviruses

Table 4.1 documents the timetable of new tospovirus discovery, the region where they were first reported, which may or may not be their true origin, and their current known distribution. If it was assumed that a given tospovirus has a discrete origin, differences between their initial and current reported distributions may be a potential indicator of their tendency to spread globally and ability to establish in new locations. This information does show that tospoviruses as a group are present within a broad range of regions, including those likely to have similar climate and agricultural production systems to Australia.

Table 4.1 First recorded appearance and current known distribution of tospoviruses

Date (a)	**Tospovirus** (b)	**Initial location**	**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

Date (a)	**Tospovirus** (b)	**Initial location**	**Current distribution** (c, d)
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)
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	$L_GM_TS_G$	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	TNSV	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 tospovirus 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 virus*; GCFSV, *Groundnut chlorotic fan-spot virus*; GRSV, *Groundnut ring spot virus*; GYSV, *Groundnut yellow spot virus*; HRCV, *Hippeastrum chlorotic ringspot virus*; INSV, *Impatiens necrotic spot virus*; IYSV, *Iris yellow spot virus*; LNRV, *Lisianthus necrotic ringspot virus*; MeSMV, *Melon severe mosaic virus*; MYSV, *Melon yellow spot virus*; MVBaV, *Mulberry vein banding associated virus*; PolRSV, *Polygonum ringspot virus*; PCSV, *Pepper chlorotic spot virus*; PNSV, *Pepper necrotic spot virus*; $L_GM_TS_G$; SVNV, *Soybean vein necrosis virus*; TNRV, *Tomato necrotic ringspot virus*; TNSV, *Tomato necrotic spot virus*; TCSV, *Tomato chlorotic spot virus*; TSWV, *Tomato spotted wilt virus*; TYRV, *Tomato yellow ring virus*; TZSV, *Tomato zonate spot virus*; WBNV, *Watermelon bud necrosis virus*; WSMoV, *Watermelon silver mottle virus*; ZLCV, *Zucchini lethal chlorosis virus*. **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

Tospoviruses 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 tospoviruses currently occur and there are susceptible host plants readily available. This conclusion is supported by the fact that three tospoviruses are already established within Australia and a number of thrips species that transmit tospoviruses are also present to facilitate establishment and spread.

4.4 Potential for economic consequences

Tospoviruses cause substantial economic consequences across an extensive range of fruit, vegetable, legume and ornamental crops (Jones 2005; Kunkalikar et al. 2011; Mandal et al. 2012; Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006). Impacts from tospoviruses on host crops include yield losses and reduced commercial quality and marketability of produce. Tospoviruses 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 1090 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 tospoviruses.

Tospovirus host plants are likely to continue to emerge in crops not previously known to be susceptible and continue to expand their distribution and economic significance (Daughtrey et al. 1997; Jones 2005; Kunkalikar et al. 2011; Pappu, Jones & Jain 2009). A number of tospoviruses have existing broad and/or rapidly expanding natural host plant ranges, including: *Groundnut bud necrosis virus*, GBNV (Reddy et al. 1992); *Impatiens necrotic spot virus*, INSV (Law, Speck & Moyer 1991); *Tomato chlorotic spot virus*, TCSV (De Avila et al. 1993); *Tomato necrotic ringspot virus*, TNRV (Chiemsombat et al. 2010; Seepiban et al. 2011); and *Watermelon bud necrosis virus*, WBNV (Jain et al. 1998).

There are also several newly emergent tospoviruses 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); and *Lisianthus necrotic ringspot virus*, LNRV (Shimomoto, Kobayashi & Okuda 2014); and *Mulberry vein banding associated virus*, MVBaV (Meng et al. 2015).

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

Summary

Tospoviruses have the potential for economic consequences because they have been demonstrated to cause substantial economic impacts across an extensive range of crops. Evidence for this is also accumulating as new hosts continue to emerge in crops not previously known to be susceptible and tospoviruses continue to expand their distribution and economic significance. The magnitude of economic impact of several newly emergent tospoviruses is likely to increase in significance.

4.5 Pest categorisation

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

Notes on Table 4.2

Tospovirus species: Eleven tospoviruses have been officially recognized as species (as of August 2016) by the International Committee on Taxonomy of Viruses (ICTV).These species are: *Groundnut bud necrosis virus*; *Groundnut ringspot virus*; *Groundnut yellow spot virus*; *Impatiens necrotic spot virus*; *Iris yellow spot virus*; *Polygonum ringspot virus*; *Tomato chlorotic spot virus*; *Tomato spotted wilt virus*; *Watermelon bud necrosis virus*; *Watermelon silver mottle virus*; and *Zucchini lethal chlorosis virus*. Tospoviruses that are proposed as species and likely to be recognized by ICTV as species, given current genetic sequence differences and published analyses, are also included within this pest categorisation table.

Italicized scientific names: It is acknowledged that the scientific names of tospoviruses 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.

Pest presence and absence: In considering whether a tospovirus is present or absent from the PRA area, for several recently emergent tospoviruses no references are citable because no pertinent data pre-dates the first reported record of that tospovirus. The default position in such cases has been to presume it is absent. Tospoviruses identified in pest categorisation as present in Australia and not under official control require no further consideration in this risk assessment because they cannot meet the IPPC definition of a quarantine pest.

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 tospovirus, 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 2015).

Tospoviruses can be transmitted experimentally to plants, and many studies have tested the theoretically range of susceptible plant species. These studies can provide information about prospective hosts, but in most cases they do not provide comparable evidence to natural transmission. Transmission to a theoretically susceptible host species may be infeasible or improbable in nature for a number of reasons, including non-overlapping natural distributions of a tospovirus, a thrips that transmits it, and a theoretically susceptible host plant. Similarly, a thrips that can theoretically transmit a given tospovirus may not have the theoretically susceptible host plant as its host 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 (Kunkalikar et al. 2007) and chilli (Krishnareddy et al. 2008). In China, CaCV is reported 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).

Zheng et al. (2008) considered a CaCV isolate from *Phalaenopsis* as a distinct strain—designated CaCV-Ph. This conclusion was based mainly on disease expression and host plant range differences derived from mechanical inoculation experiments, with comparison drawn between CaCV-Ph and the Australian isolate CaCV-958 (McMichael, Persley & Thomas 2002). However, this comparison was made across two independent studies and could equally be attributed to dissimilar experimental conditions, or the use of different cultivars of capsicum and tomato used by the two laboratories. Zheng et al. (2008) also stated that CaCV-Ph shared 96.1 per cent N gene nucleotide and 97.5 per cent amino acid identity with the Australian isolate CaCV-958 (McMichael, Persley & Thomas 2002). Subsequently, Widana et al. (2015) advised from sequence and phylogentic analyses that CaCV-Ph is more closely related to Australian isolate CaCV-Qld3432 than isolates from Thailand (CaCV-AIT) and China (CaCV-CP). They also suggested that if only N protein phylogeny and sequence identity are viewed the Chinese and Thai isolates all appeared to be CaCV. However, differences in the intergenic region sequence identities of the M and S RNA could imply these two isolates may be distinct tospoviruses. However, no pathogenicity differences relevant to biosecurity significance have been proven.

Table 4.2 Pest categorisation of tospoviruses

Tospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
Alstroemeria necrotic streak virus	ANSV	S. America (Colombia) (Hassani-Mehraban et al. 2010)	No records found (recently described)	*Frankliniella occidentalis* (Hassani-Mehraban et al. 2010)	Yes. ANSV was described in Colombia infecting *Alstroemeria* sp. causing necrotic streaks on leaves (Hassani-Mehraban et al. 2010). The extent of ANSV natural host plant range is unknown. Transmission by mechanical inoculation to petunia and cucumber caused localized symptoms, while pepper and tomato became systemically infected (Hassani-Mehraban et al. 2010). This initial data might suggest host plants beyond *Alstroemeria*. The full economic impact of ANSV is still to be determined, but there is potential for economic consequences to Australia from this tospovirus.	*Alstroemeria* sp.	Yes
Bean necrotic mosaic virus	BeNMV	S. America (Brazil) (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 *Phaseolus vulgaris* (common bean) (de Oliveira et al. 2011) 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 *P. vulgaris* exhibited systemic infection, symptoms observed in the field were not totally reproducible. *Datura stramonium* (Solanaceae) symptoms consisted of mottling, necrotic lesions, foliar deformation and stunting, while *Physalis pubescens* plants exhibited mottling and stunting. Local symptom expression occurred in Cucurbitaceae plants. This initial data may suggest a limited host plants. The full economic impact of BeNMV is still to be determined, but there is potential for economic consequences to Australia from this tospovirus.	common bean	Yes

Tospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
Calla lily chlorotic spot virus	CCSV	E. & SE Asia (Pappu, Jones & Jain 2009)	No records found (Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006)	*Thrips palmi* (Chen et al. 2005)	Yes. CCSV was isolated from *Zantedeschia* 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 *Hymenocallis litteralis* (spider lily) and tobacco in the South-west of China. Of 35 plant species mechanically inoculated, 24 were susceptible to CCSV, including wax gourd (*Benincasa hispida*) and zucchini squash (*Cucurbita pepo*). *Thrips palmi* 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 tospovirus.	calla lily, spider lily, tobacco	Yes
Capsicum chlorosis virus (syn. Gloxinia ringspot virus, Gloxinia tospovirus, Thailand tomato tospovirus, Tomato necrosis virus TD8, *Capsicum chlorosis virus Phalaenopsis* strain–CaCV-Ph)	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 *F. schultzei* is permitted entry by WA (Government of Western Australia 2016) and not regulated by Tas. (DPIPWE Tasmania 2015)	*Ceratothripoides claratris* (Premachandra et al. 2005a); *Frankliniella schultzei* (Persley, Thomas & Sharman 2006)—stated as being a vector, but on the basis of unpublished data; *Thrips palmi* (McMichael, Persley & Thomas 2002)	No. Zheng et al. (2008) considered a CaCV isolate from *Phalaenopsis* in Taiwan as a distinct strain—designated CaCV-Ph. On the basis of this intial report, Australia regulated CaCV-Ph as a quarantine pest on *Phalaenopsis* orchids from Taiwan. Later molecular data by Widana et al. (2015) confirmed CaCV-Ph is closely related to Australian CaCV isolates. 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 *Phalaenopsis* spp.	No

Tospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
Chrysanthemum stem necrosis virus	CSNV	E. & SE Asia (Japan, South Korea) (Yoon, Choi & Choi 2016), S. and SW Asia (IR) (Jafarpour 2010), S. America (Brazil) (Pappu, Jones & Jain 2009), Europe (de Jonghe, Morio & Maes 2013) — declared eradicated from Europe (EPPO 2005), except for a recent incursion in Italy, that is under official control (EPPO 2014b)	No records found (Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006)	*F. occidentalis* (Nagata et al. 2004; Nagata & De Ávila 2000); *F. schultzei* (Nagata et al. 2004; Nagata & De Ávila 2000); *F. intonsa* Okuda et al. (2013) report a strain of *F. Intonsa* that acquired CSNV, but only as a very weak transmitter and under experimental conditions. This is not considered sufficient evidence of this species being a natural vector. However, this should be kept under review.	Yes. CSNV was first recorded in Brazil on chrysanthemum during a survey in the mid-1990s (Nagata et al. 1994). 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). It was designated as CSNV by Bezerra et al. (1999). CSNV infected Brazilian chrysanthemum cuttings were alleged as causing several incursions in Europe (de Jonghe, Morio & Maes 2013; Mumford et al. 2003; Ravnikar 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 (*Callistephus chinensis*) and lisianthus (*Eustoma grandiflorum*) 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 tospovirus.	tomato, chrysanthemum, aster, lisianthus	Yes
Groundnut bud necrosis virus (syn. Peanut bud necrosis virus)	GBNV	Asia (Pappu, Jones & Jain 2009)	No records found (Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006)	*Frankliniella schultzei* (Meena et al. 2005); *Scirtothrips dorsalis* (German, Ullman & Moyer 1992; Meena et al. 2005); *Thrips*	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, India, Iran, Nepal, Sri	potato, tomato, onion, soybean, peanut, peas, mungbeans, watermelon, jute, taro	Yes

Tospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
				palmi (Lakshmi et al. 1993; Reddy et al. 1992)	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 Sothern India, GBNV has been reported as being responsible for farmers abandoning watermelon production (Singh & Krishnareddy 1996). GNBV has been reported as widely distributed and having significant impacts on peanut production in Thailand (Chiemsombat 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 tospovirus.		
Groundnut chlorotic fan-spot virus (syn. Peanut chlorotic fan-spot virus)	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 from Asia referencing Chen and Chiu	No records found (Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006)	*Scirtothrips dorsalis* (Chen & Chiu 1996; Chu et al. 2001)	Yes. GCFSV was first observed during 1992 as a tospovirus-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	peanut	Yes

Tospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
		(1996) who report GCFSV in Taiwan. Chu et al. (2001) confirm GCFSV presence in Taiwan.			(July to September). There is potential for economic consequences to Australia from this tospovirus.		
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)	*Frankliniella gemina* (de Borbon, Gracia & De Santis 1999); *F. intonsa* (Wijkamp et al. 1995); *F. occidentalis* (Nagata et al. 2004; Wijkamp et al. 1995); *F. schultzei* (de Borbón, Gracia & Píccolo 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 (*Solanum sessiliflorum*) (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 (*Callistephus* sp.) and lisianthus (*Eustom grandiflorum*). For lisianthus this was in mixed infections with other tospoviruses—CSNV, TCSV or TSWV. Recently, cucumber (*Cucumis sativus*) and chilli pepper (*Capsicum annuum*) were infected in commercial glasshouse production in Brazil (Spadotti et al. 2014). GRSV was also detected in a commercial crop of potted Begonia spp. in Northern Finland but is under official control (EPPO 2015). There is potential for economic consequences to Australia from this tospovirus.	potato, tomato, peanut, soybean , chilli pepper, coriander, lettuce, cucumber, aster, begonia and possibly lisianthus	Yes

Tospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
Groundnut yellow spot virus (syn. 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)	*Scirtothrips dorsalis* (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 tospoviruses because it only causes occasional impacts beyond peanut (Kunkalikar 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 tospovirus.	peanut	Yes
Hippeastrum chlorotic ringspot virus (syn. Spider lily necrotic spot virus)	HCRV	E. & SE Asia (China) (Dong et al. 2013)	No records found (recently described)	Species unknown (Dong et al. 2013)	Yes. HCRV was isolated from *Hippeastrum* 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 *Philodendron bipinnatifidum* with symptoms of vein necrosis and chlorotic lesions; *Hippeastrum rutilum* with concentric rings; and *Nicotiana tabacum* 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 *Phalaenopsis* resulting in systemic infection of new growth. Xu et al. (2013) also report mechanical inoculation studies of HCRV which resulted in systemic expression on tomato (*Solanum lycopersicum*), winter squash (*Cucurbita moschate*),	various ornamentals including *Hippeastrum* spp. and *Philodendron bipinnatifidum*, and tobacco (*Nicotiana tabacum*)	Yes

Tospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
					cucumber (*Cucumis sativus*), bean (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata*), nasturtium (*Tropaeolum majus*) lilac tasselflower (*Emilia sonchifolia*) and lettuce (*Lactuca sativa*). This may suggest a broader range of crops are at potential risk from HCRV. There is potential for economic consequences to Australia from this tospovirus.		
Impatiens necrotic spot virus	INSV	Africa, Asia, Australasia, Europe, N. America, S. America (Pappu, Jones & Jain 2009)	Not present, eradicated, following an incursion in 2010 (PHA & NGIA 2011)	*Frankliniella intonsa* (Sakurai, Inoue & Tsuda 2004); *F. occidentalis* (deAngelis, Sether & Rossignol 1993; Sakurai, Inoue & Tsuda 2004; Wijkamp et al. 1995); *F. fusca* (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 *at al*. (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 *Oncidium* orchids (Koike & Mayhew 2001), *Phalaenopsis* and *Dendrobium* orchids (Zhang, Ding & Li 2010), *Anthurium* (Ghotbi 2013; Mertelik et al. 2002), *Amaryllis* (Verhoeven & Roenhorst 1998), chrysanthemum (Verhoeven & Roenhorst 1998), *Alstroemeria* (Ghotbi 2013; Verhoeven & Roenhorst 1998), *Dracaena* (Ghotbi 2013; Ghotbi & Shahraeen 2012; Hausbeck et al. 1992), *Ficus* spp.(Ghotbi 2013; Ghotbi, Shahraeen & Winter 2005), *Gerbera jamesonii* (Elliott et al. 2009; Hausbeck et al. 1992), Kalanchoe (McDonough, Gerace & Ascerno 1999), *Impatiens* spp. (Hausbeck et al. 1992), *Pelargonium* spp. (Daughtrey 1996; Daughtrey et al. 1997; Ghotbi, Shahraeen & Winter 2005; Hausbeck et al. 1992; Shahraeen, Ghotbi & Mehraban 2002), *Oncidium* (Koike & Mayhew 2001), *Rosa spp.* (Ghotbi & Shahraeen 2012), *Schlumbergera truncata* (Hausbeck et al. 1992) and *Zantedeschia* (Elliott et al. 2009; Rizzo et al. 2012; Verhoeven & Roenhorst 1998). INSV also infects a range of	potato, peanut, sweet pepper, lettuce, cucumber, tobacco, herbs, vegetables, many ornamentals, including *Alstroemeria*, *Phalaenopsis, Oncidium* and *Dendrobium* orchids, *Dracaena Anthurium*, *Rosa*, *Ficus, Gerbera, Kalanchoe, Pelargonium, Impatiens, Schlumbergera*, *Zantedeschia* and several weed species	Yes

Tospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
					vegetables and herbs. In the Netherlands, INSV hosts include pepino (*Solanum muricatum*), spinach and sweet pepper (Verhoeven & Roenhorst 1998). In Italy, field lettuce, glasshouse cucumber and nursery sweet pepper 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 (*Ocimum basilicum*), rocket (*Eruca sativa*) and chervil (*Anthriscus cerefolium*) 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 hoFennst plant range and distribution of INSV are still expanding. There is potential for economic consequences to Australia from this tospovirus.		
Iris yellow spot virus	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 2016). Declared list A disease by Tas. (DPIPWE Tasmania 2015), but its vector *T. tabaci* is an unwanted quarantine pest,	*Thrips tabaci* (Cortes et al. 1998; Hsu et al. 2010); *Frankliniella fusca* (Mound 2002; Srinivasan et al. 2012)	Yes. IYSV was first isolated from iris in the Netherlands in 1992, and characterized as a distinct tospovirus 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) 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	onion, garlic, leeks, cowpea, iris and several ornamentals	No

Tospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
			which is not officially regulated by Tas. (DPIPWE Tasmania 2015)		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 tospovirus/thrips combination could emerge that increases the economic impact of endemic tospoviruses; as was the case for the global emergence *F. occidentalis* with TSWV (2005) and INSV (Daughtrey et al. 1997). Only three tospoviruses (CaCV, TSWV, and IYSV) and five thrips species (*F. occidentalis*, *F. schultzei*, *T. palmi*, *T. tabaci* and *S. dorsalis*) that transmit tospoviruses are present in Australia (Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006). Introduction of new vectors into Australia could lead to further, economic consequences from endemic tospoviruses, including IYSV. This may result from factors that include expansion of host plant range, greater tospovirus transmission efficiency, and/or geographic spread, within the Australia context. However, IYSV is present in Australia and not under official control, and consequently not a quarantine pest for Australia.		
Lisianthus necrotic ringspot virus	LNRV	E. & SE Asia (Japan) (Shimomoto, Kobayashi & Okuda 2014)	No records found (recently described)	Species unknown (Shimomoto, Kobayashi & Okuda 2014)	Yes. LNRV was recently reported infecting lisianthus (*Eustoma grandiflorum*) in Japan (Shimomoto, Kobayashi & Okuda 2014). Several new tospoviruses have become a significant threat to crops and lisianthus 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,	lisianthus	Yes

Tospovirus	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 LNRV is still to be determined, but there is potential for economic consequences to Australia from this tospovirus.		
Melon severe mosaic virus	MeSMV	N. America (Mexico) (Ciuffo et al. 2009)	No records found (Pappu, Jones & Jain 2009)	Species unknown, but *F. Occidentalis* was present on MeSMV-infected plants (Ciuffo et al. 2009)	Yes. MeSMV was recently reported from Mexico (Ciuffo et al. 2009). Symptoms reported on infected melon (*Cucumis melo*) 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 tospovirus.	melon, watermelon zucchini, cucumber	Yes
Melon yellow spot virus (syn. Physalis severe mottle virus)	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)	*Thrips palmi* (Kato, Hanada & Kameya-Iwaki 2000)	Yes. MYSV was identified as causing an outbreak of a serious disease in netted melon (*Cucumis melo*) 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 also reported to also infect cucumber in Japan (Okuda et al. 2004). Peng et al. (2011) conclude that MYSV has become a serious threat to commercial watermelon (*Citrullus lanatus*) and melon production in Taiwan. There is potential for economic consequences to Australia from this tospovirus.	melon, watermelon cucumber	Yes
Mulberry vein banding associated virus	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) recently identified MVBaV as a new tospovirus infecting mulberry plants (*Morus spp*.) in China (Meng et al.	Mulberry	Yes

Tospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
					2015). MVBaV infected plants display typical vein banding symptoms. Also, MVBaV is considered to 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 tospovirus		
Pepper chlorotic spot virus	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 tospovirus, *Pepper chlorotic spot virus* (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 (*Vigna radiata*) and *Phalaenopsis* 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 tospovirus.	sweet pepper	Yes
Pepper necrotic spot virus	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	tomato, pepper	Yes

Tospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
					economic consequences to Australia from this tospovirus.		
Polygonum ringspot virus	PolRSV	Europe (Pappu, Jones & Jain 2009)	No records found (Pappu, Jones & Jain 2009)	*Dictyothrips betae* (Ciuffo et al. 2010)	Yes. PolRSV was first isolated in Italy from wild buckwheat (*Polygonum convolvulus*) by Ciuffo et al. (2008) and *Dictyothrips betae* 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 *Polygonum* (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 *Polygonum* 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 tospovirus.	*Polygonum* sp.	Yes
Reassortant from *Groundnut ringspot virus* and *Tomato chlorotic spot virus* (syn. $L_GM_TS_G$)	$L_GM_TS_G$	N. America (Florida) (Webster et al. 2011)	No records found (recently described)	*Frankliniella occidentalis* (Webster et al. 2011)	Yes. Webster et al. (2011) reported a virus causing severe tospovirus 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 *Groundnut ringspot virus* (GRSV) and *Tomato chlorotic spot virus* (TCSV). Neither parental genotype is known to be present in the USA, implying it was introduced in its current form.	tomato	Yes

Tospovirus	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 $L_G M_T S_G$ is still to be determined, but there is potential for economic consequences to Australia from this tospovirus.		
Soybean vein necrosis virus (syn. Soybean vein necrosis-associated virus)	SVNV	N. America (Zhou et al. 2011)	No records found (recently described)	Species unknown (Zhou et al. 2011), but soybean thrips *Neohydatothrips variabilis* (syn. *Sericothrips variabils*) are competent to transmit SVNV experimentally (Zhou & Tzanetakis 2013)	Yes. Tzanetakis et al. (2009) first reported tospovirus 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 intravenial 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. There is no significant evidence for tospovirus seed transmission (Albrechtsen 2006; Pappu et al. 1999b), although limited preliminary research implying seed transmission by *Soybean vein necrosis virus* has been suggested (Groves et al. 2015). However, no evidence was found for seed transmissibility of this tospovirus in soybean grown under field conditions (Hajimorad et al. 2015). The full economic impact of SVNV is still to be determined, but there is potential for economic consequences to Australia from this tospovirus.	soybean	Yes
Tomato chlorotic spot virus	TCSV	N. America (Florida) and S. America (Brazil, Argentina, Haiti) (Adegbola et al. 2016; Londoño et al. 2012) (Pappu, Jones & Jain 2009)	No records found (Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006)	*Frankliniella intonsa* (Wijkamp et al. 1995), *F. occidentalis* (Nagata et al. 2004; Whitfield, Ullman & German 2005), *F. schultzei* (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 (*Cichorium endiva*) (Colariccio et al. 2001a) and gilo (*Solanum gilo*) (Eiras et al. 2002; Rabelo et al. 2002). TCSV has recently been reported infecting cape gooseberry in Brazil (*Physalis peruviana*) causing stunting, mosaic,	potato, tomato, sweet pepper, celery, lettuce, peanut, endive, gilo, lisianthus, weeds, *Portulaca oleracea*, cape gooseberry	Yes

Tospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
				2004; Wijkamp et al. 1995)	necrosis and foliar distortion (Eiras et al. 2012). In Argentina, TCSV has been reported infecting celery, lettuce, lisianthus, potato, sweet pepper, tomato, weed species including *Portulaca oleracea* (Dal Bó et al. 1999; Gracia et al. 1999; Granval de Millan & Piccolo 1998; Jones 2005). During 2012, tospovirus like symptoms were observed on tomatoes in Florida and confirmed as the first incidence of TCSV in the USA (Londoño et al. 2012). 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 tospovirus.		
Tomato necrotic ringspot virus	TNRV	E. & SE Asia [Thailand] (Puangmalai et al. 2013)	No records found (recently described)	*Ceratothripoides claratris* (Seepiban et al. 2011); *Thrips palmi* (Seepiban et al. 2011)	Yes. TNRV was first reported in Thailand (Chiemsombat et al. 2010; Hassani-Mehraban et al. 2011; Seepiban et al. 2011). In 2008, tomato plants showing distinctive tospovirus 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 tospovirus.	tomato, chilli peppers	Yes
Tomato necrotic spot virus	TNSV	E. & SE Asia [China] (Yin et al. 2014)	No records found (recently described)	Species unknown (Yin et al. 2014), although *Thrips tabaci* and *T. palmi* were found within tomato fields and the nearby weeds	Yes. TNSV, a putative new tospovirus, was recently reported infecting tomato crops in Guizhou province, southwest China (Yin et al. 2014). TNSV symptoms include necrotic and concentric ringspots on fruits. Mechanical transmission studies imply TNSV may have a wider host plant range, including solanaceous species (Yin et al. 2014). Although, the full economic impact of TNSV is still to be determined, there is potential for economic consequences to Australia from this tospovirus.	tomato	Yes

Tospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
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) and not under official control.	*Frankliniella bispinosa* (Avila et al. 2006); *F. cephalica* (Ohnishi, Katsuzaki & Tsuda 2006); *F. fusca* (Sakimura 1963); *F. gemina* (de Borbón, Gracia & Píccolo 2006); *F. intonsa* (Wijkamp et al. 1995); *F. occidentalis* (Wijkamp et al. 1995); *F. schultzei* (Wijkamp et al. 1995); *Thrips palmi* (Fujisawa, Tanaka & Ishii 1988; Persley, Thomas & Sharman 2006); *T. setosus* (Fujisawa, Tanaka & Ishii 1988; Persley, Thomas & Sharman 2006); *T. tabaci* (Wijkamp et al. 1995)	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 *Solanaceae*, *Asteraceae* and *Fabaceae* 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 *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 can trigger a hypersensitive response *in planta* that can inhibit systemic TSWV infection, under certain conditions. The *Sw-5* gene may also offer some protection against other tospoviruses, for example TCSV or GRSV (Soler, Cebolla-Cornejo & Nuez 2003). TSWV isolates can show genetic variability (Kaye et al. 2011; Tsompana et al. 2005), and TSWV induced disease expression is probably a function of isolate, host plant and environment. TSWV resistance-breaking isolates have been reported globally overcoming the *Sw-5* gene, for example, in South Africa (Thompson & van Zijl 1996); Australia (Latham & Jones 1998); Spain (Aramburu & Marti	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 tospoviruses	No

Tospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
					2003); and Italy (Ciuffo et al. 2005) and for the *Tsw* gene 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). Theories differ for the basis of this breakdown in resistance, including mutations in the tospovirus NSs (Margaria et al. 2007; Tentchev et al. 2011) or NP (Lovato et al. 2008) viral genes for *Tsw*/pepper, and the NSm viral gene for *Sw-5*/tomato (Hoffmann, Qiu & Moyer 2001; Jahn et al. 2000; López et al. 2011). The reliance on narrow gene resistance is inherently vulnerable to this kind of breakdown, as was seen with *Tsw* gene resistance being rapidly overcome about a year after its introduction in Italy and Spain (Garcia-Arenal & McDonald 2003). Lopez et al. (2011) report convergent evolution and positive selection as likely factors in the global emergence of TSWV *Sw-5* resistance breakdown, which is consistent with the results of Tentchev et al. (2011). Furthermore, resistance breaking *Sw-5* and *Tsw* isolates have emerged in Australia and are not under official control (Latham & Jones 1998; Sharman & Persley 2006). Consequently, there is no scientific evidence that supports considering individual TSWV isolates as quarantine pests for Australia.		
Tomato yellow ring virus (syn. Tomato fruit yellow ring virus, TFYRV). TFYRV is stated to be an isolate of TYRV	TYRV	S. & SW Asia, Africa (Birithia, Subramanian & Villinger 2012; 2008; Golnaraghi et al. 2007a; Hassani-Mehraban et al. 2005; Pappu,	No records found (recently described)	*Thrips tabaci* (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	potato, tomato, soybean, peppers, rosemary, weeds and many ornamentals that include rose,	Yes

Tospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
(Pappu, Jones & Jain 2009)		Jones & Jain 2009), Europe (Poland) (Zarzynska-Nowak et al. 2016)			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 *Senecio cruentus* (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 tospovirus.	alstroemeria, dracaena, chrysanthemum, *Senecio cruentus*	
Tomato zonate spot virus	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). 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 *Hymenocallis littoralis, Iris tectorum* and *Phalaenopsis amabilis* 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 tospovirus.	tomato, chilli peppers, potato, *Hymenocallis littoralis*, *Iris tectorum* and *Phalaenopsis amabilis*	Yes
Watermelon bud necrosis virus	WBNV	S. & SW Asia (Pappu, Jones & Jain 2009)	No records found (Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006)	*Thrips palmi* (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 (*Citrullus lanatus*) include leaf mottling, yellowing and necrotic streaks	Tomato, chilli peppers, watermelon and other cucurbits	Yes

Tospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
					on veins, shortened internodes, necrosis and dieback of buds (Jain et al. 1998). WBNV has also been reported in ridge gourd *(Luffa acutangula*) (Mandal et al. 2003), cucumber (*Cucumis sativus*) and bitter gourd (*Momordica charantia*) (Jain et al. 2007). WBNV has also been reported infecting tomato and chilli pepper crops in India (Kunkalikar 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 tospovirus.		
Watermelon silver mottle virus	WSMoV	E. & SE Asia (Pappu, Jones & Jain 2009)	No records found (Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006)	*Thrips palmi* (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 tospovirus (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 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 is first report of natural infection of watermelon by WSMoV in China (Rao et al. 2001). Chen et al. (2008a) report WSMoV natural infection of *Zantedeschia* (calla lily). There is potential for economic consequences to Australia from this tospovirus.	watermelon and other cucurbits, and calla lily	Yes

Tospovirus	Acronym	Distribution	Present within Australia	Transmitted by thrips	Potential for economic consequences to Australia	Natural hosts include	Consider further as quarantine pest
Zucchini lethal chlorosis virus	ZLCV	S. America (Pappu, Jones & Jain 2009)	No records found (Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006)	*Frankliniella zucchini* (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 tospovirus.	zucchini, melon, watermelon, cucumber	Yes

Table 4.3 Outcome of pest categorisation of tospoviruses

Thrips	Thrips interception events (a)	Thrips is a quarantine pest	Thrips transmits a quarantine pest tospovirus	Tospoviruses transmitted	
				Quarantine pests	Non-quarantine pests
Ceratothripoides claratris	None recorded	Yes	Yes	TNRV	CaCV
Dictyothrips betae	None recorded	Yes	Yes	PolRSV	–
Frankliniella bispinosa	None recorded	Yes	No	–	TSWV
F. cephalica	None recorded	Yes	No	–	TSWV
F. fusca	Interception group E	Yes	Yes	INSV	IYSV, TSWV
F. gemina	None recorded	Yes	Yes	GRSV	TSWV
F. intonsa	Interception group C	Yes	Yes	GRSV, INSV, TCSV	TSWV
F. occidentalis (b, c)	Interception group A	Yes (NT)	Yes	ANSV, CSNV, GRSV, INSV, $L_GM_TS_G$, TCSV	TSWV
F. schultzei (d, e)	Interception group B	No	Yes	CSNV, GBNV, GRSV, TCSV	CaCV, TSWV
F. zucchini	None recorded	Yes	Yes	ZLCV	–
Scirtothrips dorsalis (d)	Interception group B	No	Yes	GBNV, GYSV, GCFSV	–
Thrips palmi (b)	Interception group B	Yes (SA, WA)	Yes	CCSV, GBNV, MYSV, WBNV, WSMoV	CaCV, TSWV
T. setosus	Interception group E	Yes	No	–	TSWV
T. tabaci (d)	Interception group A	No	Yes	TYRV	IYSV, TSWV
Unidentified vector(s) (f, g, h)	?	?	Yes	BeNMV, HCRV, LNRV, MeSMV, PCSV, PNSV, SVNV, TNSV, 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 (see 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 tospovirus species that are quarantine pests for Australia. **e.** Persley et al. (2006) report *F. schultzei* 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 variabils*) 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 TNSV remains unconfirmed. Where a vector is unidentified this is indicated by a '?'.

4.6 Conclusion

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

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

The tospoviruses that are quarantine pests for Australia are: ANSV, BeNMV, CCSV, CSNV, GBNV, GCFSV, GRSV, GYSV, HCRV, INSV, LNRV, MeSMV, MVBaV, MYSV, PCSV, PNSV, PolRSV, $L_GM_TS_G$, SVNV, TCSV, TNRV, TNSV, 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 tospoviruses: *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 which—*F. bispinosa*, *F. cephalica* and *T. setosus*—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 tospoviruses that are quarantine pests for Australia: ANSV, CCSV, CSNV, GBNV, GRSV, INSV, $L_GM_TS_G$, MYSV, PolRSV, 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 proposed to be regulated because they have the potential to transmit a total of seven tospoviruses 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 tospoviruses remain unidentified: BeNMV, HCRV, LNRV, MeSMV, MVBaV, PCSV, PNSV, SVNV, TNSV and TZSV (Table 4.3). These viruses remain under periodic review to identify the thrips species that transmit them, pending the availability of additional data, and appropriate actions considered.

Tospoviruses 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 at present regulated.

5 Pest risk assessment of thrips

5.1 Introduction

Pest categorisation of thrips (part A) (Chapter 2) identified the phytophagous Thripidae and phytophagous Phlaeothripidae (Table 2.2) for further consideration in pest-categorisation (part B). Based on the criteria listed in Table 3.1, a total of 113 species were included in pest-categorisation (Table 3.2), and 83 thrips species were identified as requiring further consideration as quarantine pests. However, the results of this risk assessment could apply to other quarantine pest thrips species within the phytophagous Thripidae and phytophagous Phlaeothripidae.

Fourteen Thripidae species were identified as capable of transmitting tospovirus, but 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 October 2015, a total of 103 Thysanoptera species (75 Thripidae, 21 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 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 thrips importation was assessed as high, the URE did not achieve the ALOP for Australia and when the likelihood of thrips importation 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 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: **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 2015).

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.

At this stage, the likelihood of entry in this group PRA is assessed as indicative because it is not linked to a specific plant import pathway. The likelihood of importation and likelihood of distribution are influenced by a range of factors. Most of these factors can be considered fully at the group level, but some cannot (see Appendix A). These factors were considered in this group PRA 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 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.

Likelihood (indicative) of importation

The likelihood (indicative) that a quarantine pest thrips will be imported into Australia on the plant import pathway is: **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 2000 species of Thripidae have been described. However, the Thripidae fauna in many parts of the world are poorly known such as for 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 pest categorisation of thrips (part A) 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 grown for international trade for fresh fruit including 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 on leaves, such as *Dendrothrips* and *Scirtothrips* including on old and mature leaves, such as Panchaetothripinae, *Anaphothrips* and *Stenchaetothrips* on grass leaves; some only in flowers, such as *Odontothrips* in Europe and *Odontothripiella* in Australia, species of both genera are often host specific and associated with Fabaceae, *Chirothrips* and related taxa in the flowers of grasses; many feeding both in flowers and on leaves, some of which are major pests such as *Thrips tabaci* and *Frankliniella occidentalis*, and some on leaves and flowers of grasses such as *Limothrips* (Mound 2012b). For Phlaeothripidae, species of *Haplothrips* mainly live in flowers, including Poaceae florets, those of *Liothrips* and *Pseudophilothrips*

are leaf feeding (ThripsWiki 2016). Both leaf and flower thrips can sometimes be pests of fruit (Kirk 1997b).

The pest thrips are well known for seeking out narrow spaces on the plants in which to live, such as within leaf sheaths or deep within inflorescences (Kirk 1997a). This habit provides a microclimate, protecting thrips from natural enemies, desiccation, solar radiation, rains or adverse temperatures. Thrips living in cereal crops show a particular attachment to small space, and this behaviour is also described as thigmotaxis (Kirk 1997a). The small size and their 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 adult thrips and larvae of pests 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 outside of their host plants (Morse & Hoddle 2006).

These characteristics make them most likely to be associated with export crops on fresh fruit, vegetables, cut-flowers and foliage, which typically arrive in Australia as non-refrigerated air freight, but 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 *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 0–5°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 survivability 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), while *F. occidentalis* survived for longer at temperatures below freezing if reared at cooler temperatures (Tsumuki et al. 2007). Cold tolerance data for thrips demonstrates 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	3I62 (9)	122

Thripidae	28 871 (84)	1110
Unassigned to family	2123 (6)	82
Total	34 199 (100)	1315

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, Scirtothrips dorsalis* (Appendix D). With the exception of *H. gowdeyi*, which is Phlaeothripidae, the most frequently intercepted other species 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), 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 inflorescence, such as asparagus spears, but exclude vegetables that meet the botanical definition of fruit, such as capsicums, and a complex breakdown was 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 8–30 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 reminder 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	2422 (91)	151
Total	2657 (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 plenty of examples of international trade providing opportunity for thrips to enter new regions. Morse and Hoddle (2006) summarise some of the cases including: 55 thrips entering the Netherlands from 30 countries over a 13-year period (1980–93); 20 per cent of cuttings and 12 per cent of plants imported into Switzerland 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, 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 the countries which Australia trades with, on a wide range of host plants, including many important agricultural and horticultural crops and plants growing for export such as fruit, vegetables and cut-flowers and foliage. They are minute and usually only a few millimetres long. They lay small eggs on plants surfaces or within tissues. Such factors make detection of thrips difficult during quality control inspections for export commodities. Effective inspection techniques of thrips rely on a combination of physical and visual inspection methods, such as shaking produce to dislodge thrips and visual examination. Microscopic inspection can be effective in some instances, and dissection may be required for some commodities. These methods are not necessarily used during quality control inspections, which instead tend to focus on grading produce according to size, colour and appearance of the commodities. 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, which is supported 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 11 of the 13 pest thrips species in the 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: **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 into the environment during the process of unpacking, transportation, retail sale, and most importantly from wastes 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 the 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, any thrips present on the wastes 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 presenting 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 5–12 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 take off from 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 thrips can take off at the minimum temperature of 17 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 of 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* on a diversity of 52 species of host plants including many economically important species—stone fruit, brassica, melons, and daisy; *Haplothrips tritici* on 20 cultivated cereal and wild hosts; *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. The host plants, such as citrus, grapevines, wheat, barley, capsicum, tomatoes, daisy, 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 the thrips would need to launch themselves into flight from a height which may or may not be available at the waste site.

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 nine of the 13 pest thrips species in the 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: **High**

Establishment is defined as the ‘perpetuation for the foreseeable future, of a pest within an area after entry’ (FAO 2015).

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, as garden plants and as weed plants. 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 of Phlaeothripidae and Thripidae 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 obligate parthenogenetic and unfertilised eggs 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 can 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 green houses and one or two generations in cooler regions each year (Lewis 1997c).

Minimum population needed for establishment

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. However, there has been, apparently, no report of such a case in reality for exotic species introduced into new regions with international trade. The likelihood of thrips establishment would increase with pioneer population size and rates of incipient infestations are positively associated with the numbers of founding individuals (Morse & Hoddle 2006), thus the more individual thrips entered with the commodities, the higher likelihood they would 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 should

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.

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; ability to adapt to new environments including developing resistance to pesticides all support a likelihood of establishment of high, which is consistent with 12 of the 13 pest thrips species in the 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: **High**

Spread is defined as ‘the expansion of the geographical distribution of a pest within an area’ (FAO 2015).

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 the pest thrips throughout most of the year in northern Australia and 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 from coastal areas, where exotic pest thrips are likely to be introduced due to the concentration of the trade and distribution of the imported commodities, into inland agricultural production areas.

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

Presence of natural barriers

There are natural barriers existing between the different areas of Australia, including arid areas and long geographic distances between the east and the west, such as the Nullarbor Plain, climatic differentials between the north and the south, Bass Straight between the mainland and Tasmania. It would be difficult for the adults to disperse unaided from one area to another. However, at least some pest thrips would be able to overcome these natural barriers because they can be carried by winds for long distance dispersal. Australia's eastern-western winds in the north and western-eastern in the south would assist thrips to overcome the natural barriers. Pest thrips have been caught at 300–3100 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 1500 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 the 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 the commercial crops in different areas or states, in house gardens, and 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 that many widespread invasions could have stemmed not from 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, 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 wide spread due to 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 this method of spread 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 use of the commodities derived from the hosts would include human consumption, decoration and animal feeds, such as fresh fruit, vegetables, cut-flowers and foliage, and cereal crops. These commodities would be moved around the country, and eggs, larvae and adults that are associated with these commodities would also be spread.

Some host plants would be used as nursery-stock. Infested nursery-stock has been implicated with the spread of thrips between production areas. Nursery-stock is an ideal material for the spread of thrips, as it provides thrips with living hosts that can be used as a food source during transport and can carry relatively large numbers of individuals, including immature stages.

Potential vectors of the pest in the PRA area

Pest thrips do not require a vector for their dispersal. Both the adult male and female 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 the 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 typically lacks the 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). While 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 wasps are only reached after 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 carried by 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 on other live plants including nursery-stock through human activities and their reproductive strategy including parthenogenesis all support a likelihood of spread of high,

which is consistent with all the 13 pest thrips species in the previous assessments conducted by Australia.

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

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: **Moderate**

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.

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 Significant at the district level Minor significance at the regional level	D
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 Significant at the district level Minor significance at the regional level	D
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	Minor significance at the local level	B

Consequences criterion	Impact (magnitude and geographic scale)	Impact score
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 tospoviruses that they may transmit. A separate risk assessment was undertaken for tospoviruses (Chapter 6).

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

The supporting evidence for this assessment is provided.

Direct impact on plant life or health

Impact score: **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 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, the 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 on three aspects: weakening or defoliating plants, causing yield loss, and damaging cosmetic appearance 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; *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 2–100 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 20th century before modern control methods were available; *Scirtothrips citri* (Moulton) alone still has the potential to cause loss of 8–25 per cent of navel oranges in California if no control measures are applied; *Heliothrips 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 2–10 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).

Cosmetic damage to the plant's leaves, flowers and fruit may lower their values substantially, due to 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: **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 12 of the 13 pest thrips species in the 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: **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 Australia's 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 nine of the 13 pest thrips species in the 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 accidently introduced into Australia, and they had spread sufficiently so that eradication was considered not to be feasible at the time of their discovery. Eradication for 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 it is 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 Deeed (PHA 2015). While the eradication response is being considered, the combat 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 control and 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 reserved 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, *Thrips palmi, Thrips parvispinus*, and *Thrips 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 ability, which could complicate control measures.

The development of resistance may lead to other impacts from extensive use of chemicals. Crop loss or failure may still occur despite the frequent applications of pesticides, as the case for vegetable crops in the Philippines (Bernardo 1991). Application of current permit rate for established pest thrips may 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: **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 the trade is suspended or stopped, it is 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 10 of the 13 pest thrips species in the previous risk assessments conducted by Australia.

Although many pest thrips have been recorded in Australia (Mound & Tree 2012), most species are still not yet present in Australia and, if they are introduced, would have impact on Australia's export markets, where these thrips currently do not occur. 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 17 3511 tonnes of fruit (more than 10 per cent of the total production) worth $310 million to its top three markets alone in 2010/11, and 20 2423 tonnes of vegetables valued at about $179 million also to the top three markets in the same period (Horticulture Australia Limited 2012). 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 trades and hampering requests for new market access.

Indirect impact on domestic trade

Impact score: **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 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 10 of the 13 pest thrips species in the previous risk assessments conducted by Australia.

If an exotic thrips species is detected in Australia, initially it is likely to be restricted to a relatively circumscribed 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 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, 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 jurisdictions where the pest has not yet become established 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 serious 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 at stake. 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 kilometre of a detection of the pest in Queensland (DAFF Qld 2012).

Indirect impact on the environment

Impact score: **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 11 of the 13 pest thrips species in previous assessments conducted by Australia, although in 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 pesticide application can induce soil toxicity, runoff and water system contamination (APVMA 2008; NSW DPI 2012). APVMA (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 to inhibit germination and lead 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).

Impact on human activities

Thrips mating and dispersal flights have been known to disrupt human activities in a number of ways. 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 occur during humid conditions associated with thunderstorm formation (Lewis 1997b), which can affect human activities.

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: **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; three occasions the same species was assessed as having a different unrestricted risk estimate due to a difference in the likelihood of importation.

This PRA identified 80 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 Tospoviruses

6.1 Introduction

Pest categorisation identified 27 tospoviruses as quarantine pests for Australia (Table 6.1). These tospoviruses require further assessment.

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 as was explained in Chapter 4.5.

Table 6.1 Tospoviruses that are quarantine pests for Australia

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

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

- comparable biological attributes of tospoviruses, and the thrips that transmit them
- current state of scientific knowledge and uncertainty about emergent tospoviruses
- dominance of research focusing on TSWV and its principal vector F. occidentalis, and the need to extrapolate to other tospoviruses and the thrips that transmit them, as appropriate.

Thrips reported to transmit tospoviruses (Table 4.2) are from five Thripidae genera, and comprised 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 tospoviruses 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 tospoviruses and the thrips known to transmit them. However, the pest risk assessment applies to all tospoviruses 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 tospovirus will enter Australia on the plant import pathway is: **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 2015).

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.

At this stage, entry in this group PRA is assessed as indicative because it is not linked to a specific market access request for the plant import pathway. The likelihood of importation and likelihood of distribution are influenced by a range of factors. Most of these factors can be considered fully at the group level, but some cannot (see Appendix A). These factors were considered in this group PRA based on extensive historic and contemporary analysis of the plant import pathway. Entry is also conditional on the tospovirus and the thrips that transmit them being present in the export region. Table 6.2 summarises the known global distributions of tospoviruses and the thrips that transmit them. However, the emergence of new tospoviruses continues to be reported and information on species distribution, the thrips that transmit them, and their range of natural host plants are likely to be subject to periodic revision.

If this group PRA is applied to 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 a tospovirus to enter Australia: via viruliferous thrips on the plant import pathway; infected plant produce of the plant import pathway; or via the infected nursery-stock pathway. This risk assessment considers the risk that viruliferous thrips could facilitate the entry of a tospovirus into Australia through the plant import pathway. That a tospovirus may enter via infected plant produce may be conceivable. However, such a pathway is a ‘dead end’ at the distribution step because transmission of a tospovirus to a susceptible host is not likely to occur. As a result, this scenario is not considered further. The rationale for this decision is explained further within Appendix E. The nursery-stock pathway is being considered as a separate process, the rationale for this decision is explained further within Appendix H.

Likelihood (indicative) of importation

The likelihood (indicative) that a quarantine pest tospovirus will be imported into Australia on the plant import pathway is: **Moderate**

The supporting evidence for this assessment is provided.

Emerging risk

RNA viruses show genetic variability and are known to evolve rapidly (Chapter 4), and genetic mechanisms can influence the evolution and biology of tospoviruses (Briese, Calisher & Higgs 2013; Qiu et al. 1998; Webster et al. 2011). Tospovirus isolates classified as being the same species can also exhibit different genetic and biological traits, including pathogenicity (Hassani-Mehraban et al. 2007; Torres et al. 2012). Table 4.1 documents the first record of new tospoviruses, with 11 being discovered since 2010. It is likely that new tospoviruses will evolve and continue to be discovered.

It is likely that tospovirus will continue to emerge in new crops not previously known to be susceptible and/or continue to expand their distribution and economic significance (Daughtrey et al. 1997; Jones 2005; Kunkalikar et al. 2011; Pappu, Jones & Jain 2009). A number of tospoviruses have broad or rapidly expanding ranges of natural host plants and are already significant pathogens, including: GBNV, INSV, TCSV, TNRV and WBNV (Table 4.2). However, there is uncertainty about the range of natural host plants of several newly described tospoviruses, 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 tospovirus indicates prospective hosts. For example, *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 tospoviruses, with 11 species recognized to transmit tospoviruses that are quarantine pests for Australia (Table 4.3). However, the thrips species that transmit 10 recently discovered tospoviruses (BeNMV, HCRV, LNRV, MeSMV, MVBaV, PCSV, PNSV, SVNV, TNSV and TZSV) are unidentified. It is likely that some of these are transmitted by thrips species already known to transmit tospoviruses. However, that further thrips species may transmit tospoviruses cannot be excluded.

Association with export crops

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

As a group, tospoviruses are known to infect an extensive range of crops (Daughtrey et al. 1997; Gent et al. 2006; Jones 2005; Kunkalikar et al. 2011; Mandal et al. 2012; Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006). This includes species that comprise the plant import pathway, as illustrated and referenced in Table 4.2. Each tospovirus species can infect a distinct group of host plant species; the number of species contained within each group varies, as does the overlap in mutual host plants between tospoviruses (Table 4.2). Therefore, a susceptible plant species may be a host of more than one tospovirus. Additionally, infections of two or more tospoviruses have been observed to occur within the same plant (Chiemsombat et al. 2008; Kunkalikar et al. 2011; Mullis et al. 2004; Peng et al. 2011; Webster et al. 2011).

Thrips and tospoviruses can be sustained on weeds or volunteers (cultivated varieties growing wild or contaminating other crops) and provide a source for rapid re-infestation of newly planted crops

with viruliferous thrips and subsequent tospovirus re-infection (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) indicates that at least eight thrips species known to transmit tospovirus (Table 4.3) have been positively identified on the plant import pathway. This provides evidence of a close association between these thrips species and crops that comprise the plant import pathway. However, several factors could influence the likelihood of viruliferous thrips being imported, including the prevalence of viruliferous thrips within the population and the specificity of thrips to transmit a given tospovirus.

Viruliferous thrips prevalence

Tospovirus acquisition by thrips was discussed in detail within Chapter 4. Notably, only larval thrips, L1 and occasionally early stage L2 instars, can become infected with tospoviruses and become viruliferous as L2 instars and adults (Mautino et al. 2012; Nagata et al. 1999), and are transmitted in a persistent and propagative manner (Whitfield, Ullman & German 2005). However, within a population of thrips not all become infected and viruliferous during their lifetime, even when fed on infected plants as larvae (Mautino et al. 2012; Nagata et al. 1999), but those that do can remain infected for life (Mautino et al. 2012; Nagata et al. 1999; Wijkamp, Goldbach & Peters 1996).

The proportion of thrips that become viruliferous and the frequency at which they transmit tospoviruses has been shown to differ between thrips species and tospoviruses. For example, *T. tabaci* and *F. fusca* larvae fed on IYSV infected plants became viruliferous adults at about 24 and five per cent, respectively. Adult *F. fusca* and *T. tabaci* subsequently transmitted IYSV at a frequency of about 18 and 77 per cent, respectively (Srinivasan et al. 2012). In the same study, viruliferous *F. fusca* adults transmitted TSWV at a frequency of about 90 per cent. Such variation may influence tospovirus importation likelihood. However, if significant numbers of thrips were 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). These values indicate that the likelihood that viruliferous thrips would enter Australia is significant, although this data does not record the absolute number of thrips that are present per interception event.

Specificity of thrips to transmit a given tospovirus

Thrips species exhibit specificity in the tospoviruses they transmit (Whitfield, Ullman & German 2005). Of 30 described tospoviruses, 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 tospovirus. This may moderate the likelihood of the importation of a given tospovirus. For tospoviruses transmitted by more than one thrips species, the tendency was that additional thrips species were usually identified over an extended period of time. It is credible that additional thrips species will be observed to transmit these tospoviruses. Additionally, the thrips species that transmit 10 recently described tospoviruses are unidentified.

Summary

The pest risk assessment for Thysanoptera (Chapter 5) gave an indicative likelihood of importation for thrips of high. If a tospovirus were present in the export production area, it is likely that viruliferous thrips will also be present. Thrips species known to transmit tospoviruses are also regularly intercepted on the plant import pathway. However, several factors can mitigate importation likelihood. These include thrips vector specificity and the prevalence of viruliferous thrips within the total population. On balance, such factors are considered sufficient to reduce the indicative likelihood of importation for tospovirus via a viruliferous thrips to a moderate likelihood.

Likelihood (indicative) of distribution

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

The supporting evidence for this assessment is provided.

Viruliferous thrips dissemination

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 tospoviruses 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 (i.e. cultivated varieties growing wild or contaminating other crops). For a given tospovirus, the relative abundance of its host species will fluctuate because of 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 tospoviruses also have multiple host plants (Table 4.2). This implies that host plants would be readily available, and not likely to be a significant factor moderating the likelihood of distribution, in most circumstances.

Divergent host plant ranges

The natural host ranges of a given thrips species and that of the tospovirus it transmits usually differ, with only partial overlap of species they both have in common (Jones 2005). Hence, a viruliferous thrips could find its host, but that species might not be a susceptible host of the tospovirus it was carrying, moderating distribution likelihood. However, viruliferous thrips might be expected to visit several plant species over its lifetime, and/or hosts of a tospovirus with a relatively narrow host plant range might be grown in abundance, negating this effect. For emergent tospoviruses, uncertainty also exists about their natural host plant ranges and the thrips that transmit them, both of which are expected to increase overtime. Consequently, it is unlikely that susceptible hosts would not be accessible in the cultivated and/or natural environments, even if at lower abundance.

Summary

The pest risk assessment of thrips (Chapter 5) gave an indicative likelihood for thrips distribution as moderate. However, several factors could mitigate tospovirus distribution likelihood, including differences between thrips and tospovirus host plant ranges, the relative abundance of these plant-hosts and the proportion of thrips that are viruliferous. Conversely, susceptible host plants are likely to be common in commercial and/or domestic cultivation and/or present in the environment as weeds or volunteers, and accessible to viruliferous thrips. Such factors are viewed as insufficient to significantly influence the indicative likelihood of distribution for tospovirus via viruliferous thrips which remains as a moderate likelihood.

Notes on Table 6.2

This table provides the known distribution of tospoviruses and the thrips that transmit them (as of November 2016).

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 virus*; GBNV, *Groundnut bud necrosis virus*; GCFSV, *Groundnut chlorotic fan-spot virus*; GRSV, Groundnut ring spot virus; GYSV, *Groundnut yellow spot virus*; HRCV, *Hippeastrum chlorotic ringspot virus*; INSV, *Impatiens necrotic spot virus*; IYSV, *Iris yellow spot virus*; LNRV, *Lisianthus necrotic ringspot virus*; MeSMV, *Melon severe mosaic virus*; MYSV, *Melon yellow spot virus*; MVBaV, *Mulberry vein banding associated virus;* PolRSV, *Polygonum ringspot virus*; PCSV, *Pepper chlorotic spot virus*; PNSV, *Pepper necrotic spot virus*; $L_GM_TS_G$; SVNV, *Soybean vein necrosis virus* ; TNRV, *Tomato necrotic ringspot virus*; TNSV, *Tomato necrotic spot virus*; TCSV, *Tomato chlorotic spot virus*; TSWV, *Tomato spotted wilt virus*; TYRV, *Tomato yellow ring virus* ; TZSV, *Tomato zonate spot virus*; WBNV, *Watermelon bud necrosis virus*; WSMoV, *Watermelon silver mottle virus*; ZLCV, *Zucchini lethal chlorosis virus*.

Presence of a tospovirus 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 tospovirus and vector will have a 'Y'. Where a tospoviruses 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 '–'.

If 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.

Additional comments on specific tospoviruses:

- CaCV: *F. schultzei* was suggested as a vector 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).

- GRSV: An incursion in Finland is under official control (EPPO 2015).
- CSNV: Okuda et al. (Okuda et al. 2013) reported a putative strain of F. intonsa as a very weak transmitter of CSNV under experimental conditions, but natural transmission remains unconfirmed.
- MeSMV: F. occidentalis was suggested as a potential transmitter of MeSMV due to its presence on MeSMV-infected plants (Ciuffo et al. 2009), but that it actually transmits MeSMV remains unconfirmed.
- SVNV: Neohydatothrips variabilis (syn. Sericothrips variabils) was reported to experimentally transmit SVNV (Zhou & Tzanetakis 2013), but natural transmission remains unconfirmed.
- TNSV: Yin et al. (2014) report Thrips tabaci and T. palmi as present within infected tomato crops and nearby weeds, but that they actually transmit TNSV remains unconfirmed.

Table 6.2 Distribution of tospoviruses and the thrips that transmit them

Tospovirus/vector(s)	Tospovirus and vector references	Africa	S .& SW Asia	E. & SE Asia	Australasia	Europe	N. America	S. America	Distribution references
ANSV	(Hassani-Mehraban et al. 2010)	–	–	–	–	–	–	CO	(Hassani-Mehraban et al. 2010)
Frankliniella occidentalis	(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)
Ceratothripoides claratris	(Premachandra et al. 2005a)	–	Y	Y	–	–	–	–	(Mound 2005b; Premachandra et al. 2005a)
Frankliniella schultzei		Y	Y	Y	Y	Y	HI, FL	Y	(Diffie, Edwards & Mound 2008; Nakahara 1997; Vierbergen & Mantel 1991)
Thrips palmi	(McMichael, Persley & Thomas 2002)	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)
Thrips palmi	(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)
Frankliniella occidentalis	(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)
F. schultzei	(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)
F. intonsa		–	Y	Y	–	Y	Y	–	(Chiasson 1986; Nakahara & Foottit 2007)

Tospovirus/vector(s)	Tospovirus and vector references	Africa	S .& SW Asia	E. & SE Asia	Australasia	Europe	N. America	S. America	Distribution references
GBNV	(Reddy et al. 1992)	–	Y	Y	–	–	–	–	(Pappu, Jones & Jain 2009; Reddy et al. 1995)
Frankliniella schultzei	(Meena et al. 2005)	Y	Y	Y	Y	Y	HI, FL	Y	(Diffie, Edwards & Mound 2008; Nakahara 1997; Vierbergen & Mantel 1991)
Scirtothrips dorsalis	(German, Ullman & Moyer 1992; Meena et al. 2005)	–	IL	Y	Y	–	Y	Y	(Diffie, Edwards & Mound 2008; Hoddle, Mound & Paris 2012; Mound 2007b)
Thrips palmi	(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)
Scirtothrips dorsalis	(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)
Frankliniella gemina	(de Borbon, Gracia & De Santis 1999)	–	–	–	–	–	–	Y	(2012; Cavalleri, Romanowski & Rodrigues Redaelli 2006; de Borbon, Gracia & De Santis 1999; 2011; Pinent et al. 2006)
F. intonsa	(Wijkamp et al. 1995)	–	Y	Y	–	Y	Y	–	(Chiasson 1986; Nakahara & Foottit 2007)
F. occidentalis	(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)
F. schultzei	(de Borbón, Gracia & Píccolo 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	–	–	–	–	(Chu et al. 2001; Pappu, Jones & Jain 2009)
Scirtothrips dorsalis	(Gopal et al. 2010)	–	IL	Y	Y	–	Y	Y	(Diffie, Edwards & Mound 2008; Hoddle, Mound & Paris 2012; Mound 2007b)

Tospovirus/vector(s)	Tospovirus and vector references	Africa	S .& SW Asia	E. & SE Asia	Australasia	Europe	N. America	S. America	Distribution references
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)
Frankliniella intonsa	(Sakurai, Inoue & Tsuda 2004)	–	Y	Y	–	Y	Y	–	(Chiasson 1986; Nakahara & Foottit 2007)
F. occidentalis	(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)
F. fusca	(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)
Thrips tabaci	(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)
Frankliniella fusca	(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)
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)

Tospovirus/vector(s)	Tospovirus and vector references	Africa	S .& SW Asia	E. & SE Asia	Australasia	Europe	N. America	S. America	Distribution references
Thrips palmi	(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)
Dictyothrips betae	(Ciuffo et al. 2010)	–	–	–	–	Y	–	–	(Ciuffo et al. 2010)
$L_GM_TS_G$	(Webster et al. 2011)	–	–	–	–	–	FL	–	(Webster et al. 2011)
Frankliniella occidentalis	(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)
Frankliniella intonsa	(Wijkamp et al. 1995)	–	Y	Y	–	Y	Y	–	(Chiasson 1986; Nakahara & Foottit 2007)
F. occidentalis	(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)
F. schultzei	(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)

Tospovirus/vector(s)	Tospovirus and vector references	Africa	S .& SW Asia	E. & SE Asia	Australasia	Europe	N. America	S. America	Distribution references
Ceratothripoides claratris	(Seepiban et al. 2011)	–	Y	Y	–	–	–	–	(Mound 2005b; Premachandra et al. 2005a)
Thrips palmi	(Seepiban et al. 2011)	Y	Y	Y	Y	–	HI, FL	Y	(Cannon, Matthews & Collins 2007; Layland, Upton & Brown 1994; Mound 2010; Murai 2001)
TNSV	(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)
Frankliniella bispinosa	(Avila et al. 2006)	–	–	–	–	–	Y	BM,BS	(Diffie, Edwards & Mound 2008; Funderburk et al. 2007; Hoddle, Mound & Paris 2012)
F. cephalica	(Ohnishi, Katsuzaki & Tsuda 2006)	–	–	JP	–	–	Y	Y	(Diffie, Edwards & Mound 2008; Hoddle, Mound & Paris 2012; Masumoto & Okajima 2004; Nakahara 1997)
F. fusca	(Sakimura 1963)	–	–	JP	–	–	Y	–	(Diffie, Edwards & Mound 2008; Hoddle, Mound & Paris 2012; Nakao et al. 2011)
F. gemina	(de Borbón, Gracia & Píccolo 2006)	–	–	–	–	–	–	Y	(2012; Cavalleri, Romanowski & Rodrigues Redaelli 2006; de Borbon, Gracia & De Santis 1999; 2011; Pinent et al. 2006)
F. intonsa	(Wijkamp et al. 1995)	–	Y	Y	–	Y	Y	–	(Chiasson 1986; Nakahara & Foottit 2007)
F. occidentalis	(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)
F. schultzei	(Wijkamp et al. 1995)	Y	Y	Y	Y	Y	HI, FL	Y	(Diffie, Edwards & Mound 2008; Nakahara 1997; Vierbergen & Mantel 1991)
Thrips palmi	(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)

Tospovirus/vector(s)	Tospovirus and vector references	Africa	S .& SW Asia	E. & SE Asia	Australasia	Europe	N. America	S. America	Distribution references
T. setosus	(Fujisawa, Tanaka & Ishii 1988; Persley, Thomas & Sharman 2006)	–	–	JP, KR	–	NL	–	–	(EPPO 2015; Mound 2005a; ThripsWiki 2016)
T. tabaci	(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 & Shahraeen 2012; Golnaraghi et al. 2008; Hassani-Mehraban et al. 2005; Pappu, Jones & Jain 2009; Zarzynska-Nowak et al. 2016)
Thrips tabaci	(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)
Thrips palmi	(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)
Thrips palmi	(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)
Frankliniella zucchini	(Nakahara & Monteiro 1999)	–	–	–	–	–	–	BR	(Nakahara & Monteiro 1999)

6.3 Likelihood of establishment

The likelihood that a quarantine pest tospovirus will establish within Australia following its entry on the plant import pathway is: **Moderate**

Establishment is defined as the 'perpetuation for the foreseeable future, of a pest within an area after entry' (FAO 2015).

The supporting evidence for this assessment is provided.

Tospovirus perpetuation

Tospoviruses like all viruses need a host in which to replicate. There is no significant evidence for tospovirus seed transmission (Albrechtsen 2006; Pappu et al. 1999b), although limited preliminary research implying seed transmission by *Soybean vein necrosis virus* has been reported (Groves et al. 2015). However, no evidence was found for seed transmissibility of this tospovirus in soybean grown under field conditions (Hajimorad et al. 2015).

Some tospoviruses, for example ANSV, CCSV, HCRV, INSV, IYSV, TSWV and TYRV have host plants that include species that can propagate vegetatively, either naturally or assisted. Tospovirus 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. Therefore, excluding vegetative propagation or artificial transmission, a thrips vector is essential for tospovirus '*perpetuation for the foreseeable future*' in the natural environment. For example, without its vector being present, a tospovirus would not be perpetuated beyond the life-cycle of individual annual or biennial host plants. Without a reservoir of infection in host plants, the tospovirus would also be rapidly lost from the thrips population as viruliferous adults die and no re-infection of larvae occurs. This has implications in considering establishment, because the likelihoods of thrips and tospovirus establishment are not always independent events. This is complicated further because several tospovirus vectors are already present within Australia. There are four possible outcomes when considering establishment: (i) tospovirus and its introducing vector establish; (ii); only the tospovirus establish (iii) only the vector establish; or (iv) neither establish.

Viruliferous thrips establishment

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, reproductive and adaptive survival strategies. Tospovirus infection has been reported to influence thrips biology and behaviour (reviewed in Chapter 4.2), but this evidence shows the precise effect tospovirus infection has on thrips biology and behaviour remains inconclusive with a number of observed inconsistencies. It cannot be concluded that tospovirus infection would have any impact on the likelihood of establishment for viruliferous thrips.

Tospovirus transmission

The likelihood that a tospovirus will be perpetuated for the foreseeable future would be influenced by factors that influence virus transmission efficiency, including:

- differences in pathogenicity of tospovirus strains (isolates), considered to be the same species, towards susceptible host plants (Hassani-Mehraban et al. 2007; Torres et al. 2012).

- intra-species (Inoue et al. 2004; Wijkamp et al. 1995) and inter-species (Chatzivassiliou, Peters & Katis 2002; Van de Wetering et al. 1999; Wijkamp et al. 1995) variation in the transmission efficiency of tospoviruses by thrips.
- host plant physiology, including maturity and vigour, genetic resistance (or tolerance) (Aramburu & Marti 2003; Dianese et al. 2011; Mandal et al. 2012; Puangmalai et al. 2013). This may moderate likelihood of establishment, but for most tospoviruses a range of susceptible host plants are likely to be available either in the cultivated and/or natural environment.
- concurrent infection of thrips species with multiple tospoviruses (Chiemsombat et al. 2008). If a thrips were viruliferous for multiple tospoviruses, this would be expected to increase the likelihood of establishment for tospovirus, but further scientific evidence is required to verify that this occurs in nature.

Thrips that transmit tospovirus that are already present within Australia

Several thrips species, known to transmit tospoviruses, are present in Australia—*F. schultzei*, *F. occidentalis*, *S. dorsalis*, *T. palmi* and *T. tabaci*. Collectively, these species transmit, at least, 14 quarantine pest tospoviruses. ANSV, CCSV, GCFSV, GYSV, INSV, $L_GM_TS_G$, MYSV, TYRV, WBNV, and WSMoV have a single endemic thrips vector; CSNV, GRSV and TCSV have two; and GBNV has three. Additionally, 10 tospoviruses (BeNMV, HCRV, LNRV, MeSMV, MVBaV, PCSV, PNSV, SVNV, TNSV and TZSV) have unknown vectors, resulting in uncertainty about their endemic vector(s) status. Only three tospoviruses (GCFSV, PolRSV and TNRV) are positively identified as not having an endemic vector presently in Australia.

The likelihood of establishment for tospovirus may be greater where the introduced viruliferous thrips establishes because of factors including the pre-selected compatibility between vector and tospovirus and their co-location. However, endemic tospovirus vectors may facilitate and expedite tospovirus establishment, under certain circumstances. These thrips species are already widely distributed (pre-positioned) in agricultural or horticultural production areas, domestic gardens and the natural environment. Tospoviruses 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 tospovirus might not necessarily be limited by the population dynamics of the thrips population causing its entry into Australia. For example, a tospovirus could establish (and spread), with the assistance of a local vector species, even where the thrips population causing virus entry itself fails to establish.

Previous tospovirus establishment events within Australia

Three tospovirus 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 tospoviruses cannot be certain, this clearly demonstrates that the Australian environment can sustain tospovirus establishment and that host plants were accessible. It also implies that factors that moderate tospovirus establishment are not insurmountable barriers, and that future tospovirus establishment events are likely.

Summary

The pest risk assessment of thrips (Chapter 5) gave a likelihood of establishment for thrips as high, and there no significant evidence that this would differ for viruliferous thrips. A pest is usually

considered to have dissociated from the original entry pathway when considering establishment. However, in most circumstances, a thrips vector is required for the perpetuation of a tospovirus for the foreseeable future. This requirement could moderate establishment likelihood. However, presence of local tospovirus vectors may facilitate and expedite tospovirus establishment, under certain circumstances. That tospoviruses have already established in Australia implies that potential barriers to establishment are not insurmountable. Nevertheless, tospovirus transmission may be reduced by several factors, including: differing pathogenicity of tospovirus strains; differing thrips intra- and inter-species transmission efficiencies; and differing host plant susceptibilities. On balance, these factors are considered sufficient to reduce likelihood of establishment for a tospovirus to moderate.

6.4 Likelihood of spread

The likelihood that a quarantine pest tospovirus will spread within Australia following its establishment is: **Moderate**

Spread is defined as 'the expansion of the geographical distribution of a pest within an area' (FAO 2015).

The supporting evidence for this assessment is provided.

Tospoviruses can spread via (i) viruliferous thrips or (ii) the movement of infected plants and propagation materials. Tospoviruses are not seed transmissible and cannot be transmitted between thrips or to their offspring requiring each generation of thrips to re-acquire the virus for its continuance in the population (Chapter 4.3). These factors are expected to moderate likelihood of spread for tospoviruses, but not prevent it.

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 via flight or on wind currents—and passive—contaminant on plant produce, vehicles or clothes—mechanisms facilitating dispersal. Viruliferous thrips may have a similar likelihood of spread, but there are several factors that could influence this likelihood. Tospoviruses are transmitted in a persistent and propagative manner (Whitfield, Ullman & German 2005), factors that facilitate their long distance dispersal by thrips. As discussed, in establishment, there is also an endemic population of tospovirus transmitting thrips within Australia. Therefore, tospovirus spread would not necessarily be limited by the population dynamics of the thrips population from which it was introduced.

Tospovirus dispersal via nursery-stock

Tospoviruses, as a group, have extensive host plants in ornamentals (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 (i.e. fruit, vegetable and herb) crops (Jones 2005; Mandal et al. 2012; Pappu, Jones & Jain 2009). Numerous tospovirus host plants are likely to be present in plant 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 tospoviruses (de Jonghe, Morio & Maes 2013; Elliott et al. 2009). Infected plants and propagation materials might be traded if, for instance, tospovirus disease expression 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 by tospovirus, these

plants could be infested with viruliferous thrips when traded, facilitating spread. That a viruliferous thrips would be spread as a contaminant on nursery-stock is facilitated by factors including thrips small size, cryptic habit, survival and dispersal strategies. This would be aided by extensive wholesale and retail supply chains that exist within Australia for the movement of these commodities. However, commercially produced plants or propagation materials with obvious tospovirus disease (or infestation) symptoms would almost certainly be unmarketable. Additionally, interstate movement of a range of plants species is subject to domestic biosecurity arrangements. These factors would moderate, but not eliminate, tospovirus likelihood of spread by this means.

Host plant availability

Host plants of tospovirus and their thrips vectors are common in commercial and/or domestic cultivation and/or present in the environment as weeds or volunteers. Australia has diverse growing regions with some crops grown throughout the year although the relative abundance of susceptible host plants may fluctuate. Divergence in the range of host plants common to both viruliferous thrips and tospovirus may moderate the rate of spread, because a proportion of transmission events will occur on insusceptible host plants. Similarly, infection of hosts that are annual/biennial crops may moderate the rate of spread as their life-cycle leads to fluctuations in the prevalence of sources of virus re-infection into the thrips population. Collectively, these factors are not likely to reduce the overall high likelihood of spread.

Transmission efficiency

Thrips competency to transmit tospoviruses is probably an outcome of host plant susceptibility and thrips infection biology: becoming viruliferous (virus acquisition), becoming infectious, maintaining infectivity, and transmission-through feeding (Srinivasan et al. 2012; Wijkamp, Goldbach & Peters 1996). 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 observed in thrips competency to transmit tospoviruses. Plant physiology, such as maturity, vigour, resistance (or tolerance) (Aramburu & Marti 2003; Dianese et al. 2011; Mandal et al. 2012; Puangmalai et al. 2013) may also moderate tospovirus transmission rates. Collectively, these factors moderate the rate of spread, but are not likely to prevent it.

Effect of tospovirus infection on thrips

Tospovirus infection may directly or indirectly influence thrips behaviour and/or physiology to affect the likelihood of spread by promoting thrips survival (Medeiros, Resende & De Ávila 2004), attracting thrips to infected plants (Abe et al. 2012; Belliure et al. 2005; Maris et al. 2004; Ogada, Maiss & Poehling 2013) and altering thrips feeding habit to one more likely to transmit tospoviruses (Stafford, Walker & Ullman 2011). Although, neutral (Wijkamp et al. 1996) and negative (deAngelis, Sether & Rossignol 1993) effects have also been observed (see Chapter 4), the weight of evidence suggests tospovirus infection may have an overall positive effect on the likelihood of its spread. However, further evidence is required for this to be unequivocal.

Australian environment

Natural barriers, including deserts, arid areas, and distance between production areas within Australia can significantly moderate the spread of some pest species, and may influence the rate of unaided tospovirus spread by viruliferous thrips. However, three tospovirus species are already endemic within Australia (TSWV, CaCV and IYSV) and CaCV (McMichael, Persley & Thomas 2002), and IYSV (Coutts et al. 2003) rapidly spread within Australia following their introduction. This is evidence

that the environment is favorable to tospovirus spread, and if host plants persist within the Australian environment, so too can the tospoviruses that infect them.

Summary

The pest risk assessment for thrips (Chapter 5) gave an indicative likelihood of spread for thrips as high. Tospovirus spread within Australia can occur via dispersal of: (i) infected plant material, or (ii) viruliferous thrips. Primary pathways for spread include tospovirus infected nursery-stock (including propagative plant materials), active aerial dispersal of viruliferous thrips via flight or wind currents, or passive dispersal as contaminants on nursery-stock, vehicles or clothes. The spread of tospoviruses is also facilitated by factors that include: thrips biology and behaviour; possibly, the effects of tospovirus infection on thrips; the relative abundance of susceptible host plants; and the endemic population of tospovirus vectors. However, several factors can mitigate the likelihood of spread for tospoviruses. These factors include the unmarketability of infected/infested plants and propagation materials, and factors that influence tospovirus transmission efficiency. On balance, these factors are considered sufficient to reduce the indicative likelihood of spread for tospoviruses to a moderate.

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

The overall likelihood (indicative) that a quarantine pest tospovirus 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: **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 6.3.

Table 6.3 Likelihood of entry (indicative), establishment and spread for tospoviruses

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

6.6 Consequences

The overall consequences rating for quarantine pest tospoviruses is estimated to be: **Moderate**

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 ratings are summarized in Table 6.4.

Table 6.4 Summary of consequences for tospoviruses

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

Consequences criterion	Impact (magnitude and geographic scale)	Impact score
Direct impact on other aspects of the environment	Indiscernible at the local, district, regional and national levels	A
Indirect impact on eradication and management	Major significance at the district level Significant at the regional level Minor significance at the national level	E
Indirect impact on international trade	Major significance at the local level Significant at the district level Minor significance at the regional level	D
Indirect impact on domestic trade	Major significance at the local level Significant at the district level Minor significance at the regional level	D
Indirect impact on 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 tospoviruses. It did not consider any additional impacts caused by the thrips that transmit them. A separate risk assessment was undertaken for thrips (Chapter 5).

The supporting evidence for this assessment is provided.

Direct impact on plant life or health

Impact score: **E**

The direct impact of a tospovirus 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. Tospoviruses 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, tospoviruses cause significant economic consequences to fruit, vegetable, legume and ornamental crop production (Daughtrey et al. 1997; Gent et al. 2006; Kunkalikar 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 6.5, for quarantine pest tospoviruses.

Table 6.5 Tospovirus host crops

Tospovirus (a)	Host crops, include (b)
ANSV	Alstroemeria [tomato, pepper, cucumber, petunia] (c)
BeNMV	Common bean (*Phaseolus vulgaris*)
CCSV	Calla lily (*Zantedeschia* spp.), zucchini, wax gourd, spider lily (*Hymenocallis litteralis*)
CSNV	Tomato, chrysanthemum, aster, lisianthus (*Eustoma grandiflorum*) [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	*Hippeastrum* spp., *Philodendron* 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	*Polygonum* species [Solanaceous spp.]
$L_GM_TS_G$	Tomato
SVNV	Soybean
TCSV	Potato, tomato, sweet pepper, lettuce, endive, peanut, gilo (*Solanum gilo*), celery, lisianthus, *Portulaca oleracea*, cape gooseberry (*Physalis peruviana*)
TNRV	Tomato, sweet pepper
TNSV	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*; GRSV, *Groundnut ringspot virus*; GBNV, *Groundnut bud necrosis virus*; GCFSV, *Groundnut chlorotic fan-spot virus*; GRSV, Groundnut ring spot virus; GYSV, *Groundnut yellow spot virus*; HRCV, *Hippeastrum chlorotic ringspot virus*; INSV, *Impatiens necrotic spot virus*; MeSMV, *Melon severe mosaic virus*; MVBaV, *Mulberry vein banding associated virus*; MYSV, *Melon yellow spot virus*; PolRSV, *Polygonum ringspot virus*; PCSV, *Pepper chlorotic spot virus*; PNSV, *Pepper necrotic spot virus*; $L_GM_TS_G$; SVNV, *Soybean vein necrosis virus* ; TNRV, *Tomato necrotic ringspot virus*; TNSV, *Tomato necrotic spot virus*; TCSV, *Tomato chlorotic spot virus*; TYRV, *Tomato yellow ring virus* ; TZSV, *Tomato zonate spot virus*; WBNV, *Watermelon bud necrosis virus*; WSMoV, *Watermelon silver mottle virus*; ZLCV, *Zucchini lethal chlorosis virus*. **b.** Host crops are illustrative of consequences impact, and do not necessarily represent a comprehensive list of the natural host plants of each tospovirus, 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

Tospoviruses can cause near complete crop failures, but typically they reduce commercial yields, quality and marketability (Culbreath, Todd & Brown 2003; Jones 2005; Mandal et al. 2012). Once a plant becomes infected with a tospovirus, they will remain infected for life and continue to be subject to the ongoing impacts of disease caused by the virus—there is no cure once a plant becomes infected. Disease symptoms caused by tospovirus infection of host plants include necrosis, chlorosis, ring patterns, mottling, silvering, stunting and lesions (Jones 2005). However, disease occurrence and symptom expression are influenced by a broad range of factors that include the specific tospovirus 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 tospoviruses on selected crops reported internationally are given in Table 6.6.

Table 6.6 Impact and incidence of tospoviruses on host crops

Tospovirus	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 $48 billion in Financial Year (FY) 2012–13. During this period, all arable agricultural/horticultural crops contributed about $28 billion to the Australian economy (ABS 2014).

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

Illustrating only 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 tospovirus host plant crops for the FY 2012–13 was: potatoes ($690.2 million); tomatoes ($438.8 million); onions ($199.6 million);

melons ($234.3 million); capsicums, excluding chillies ($96.8 million); peanuts ($19 million) (ABS 2014); and for other commodities with available data from FY 2008–09, lettuce (187 million); zucchini ($65.2 million); celery ($44.7 million); cucumber ($28.2 million) (HIA 2012), making a total GVP of about $2 billion. In addition, several tospoviruses also have host plant ranges that include species used as nursery-stock and/or cut-flowers, and for the financial year 2012–13, these sectors had a GVP of about $736.7 million for nursery-stock and $309 million for cut-flowers (ABS 2014).

Direct impact on other aspects of the environment

Impact score: **A**

The direct impact of a tospovirus 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 tospovirus on the environment is reported.

Weeds

Many weed species are known to be tospovirus hosts and potential reservoirs for infection and/or re-infection of cultivated species (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 tospoviruses is uncertain. Published data focus on cultivated species, but susceptible tospovirus host crops will have wild relatives, and related species, present in the environment. However, no tospovirus related impact on plant life in the environment has been reported internationally. Likewise, there is no evidence of any significant tospovirus susceptibility in Australian flora (Mound 2001). Gibbs et al. (2000) report presence of a widespread, but otherwise uncharacterised, tospovirus in an Australian native orchid, *Pterostylis.* Three tospoviruses, TSWV, CaCV and IYSV are now endemic within Australia, but their presence, in combination with current vectors, has not seemingly caused environmental consequences. Persley et al. (2006) advise *Hoya australis* as a susceptible host of CaCV, but further data was 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), and four thrips species that transmit TSWV (Table 4.3), including its major vector *F. occidentalis*, are 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 this 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 that there has been opportunity for native species to have been exposed to the combination of tospoviruses and thrips that transmit them that are currently present in Australia and no impact reported. Equally, no impacts of tospoviruses are reported on the natural environment internationally. In the absence of evidence to the contrary it is concluded that tospoviruses are unlikely to have direct consequences on the natural environment. However, this 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: **E**

The indirect impact of a tospovirus 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 tospovirus 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 Australia's agribusiness and associated trades at the regional level. Should eradication and containment fail, commercial production practices would need to change to mitigate the impact from a tospovirus as infected plants must be removed and destroyed because no other control measure is possible. The introduction of a new tospovirus provides opportunity for novel tospovirus and thrips combinations to occur which may increase their impacts. The costs associated with the initial response to an incursion and ongoing control of 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. There is a formal, legally binding agreement between Plant Health Australia, the Australian Government, all state and territory governments and plant industry signatories, covering the management and funding of responses to Emergency Plant Pests—the Emergency Plant Pest Response Deed (PHA 2015). Under this framework, 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 tospovirus within Australia.

Internationally, attempts to contain and eradicate tospovirus 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, 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 tospovirus incursion, whether successful or not, would undoubtedly be costly and cause significant disruption to Australia's agribusiness and associated trades.

New tospovirus and thrips vector combinations

Three tospoviruses (CaCV, TSWV and IYSV) and five thrips species (*F. occidentalis*, *F. schultzei*, *T. palmi*, *T. tabaci* and *S. dorsalis*) that transmit tospoviruses are present in Australia. Therefore, 27 tospoviruses and nine known thrips vectors are absent. Although, specificity in the relationship between a tospovirus and the thrips that transmit it appears strong, several tospoviruses are transmitted by multiple thrips species (Table 4.3). This provides significant opportunity for novel tospovirus/thrips combinations to occur following an incursion resulting in synergistic pathogenic impacts. For example, the introduction of new vector may enhance transmission of current tospoviruses or the introduction of a new tospovirus may result in its exposure to 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 1980's 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 tospovirus. This is likely to have significant cost implications. Significantly, should a crop become infected by a tospovirus there is no remedial action possible, other than the removal and destruction of infected plants. There is also significant uncertainty about emergent tospoviruses and it is likely that some Australian scientific research effort may be diverted, post incursion, into further resolving tospovirus epidemiology and appropriate production and pest management responses, within the Australian context.

Indirect impact on international trade

Impact score: **D**

The indirect impact of a tospovirus 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'. Tospoviruses 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 is suspended or stopped, it is expected to have significant impact on a multiple 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 spend resources to support affected industries and assist in regaining market access, which would have minor impact at the regional level.

Trading partner's response

Tospoviruses are considered major global pests (Jones 2005; Mandal et al. 2012; Pappu, Jones & Jain 2009; Persley, Thomas & Sharman 2006). In response to a tospovirus 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 close, at least transiently, existing market access and/or impose additional measures, consistent with their right and obligations under the WTO SPS Agreement. Maintaining or re-establishing market access in response to trading partner's actions would place addition 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.

Markets at risk

Tospoviruses with hosts within the Solanaceae, Alliaceae and Cucurbitaceae families are common. Table 6.7 shows exports for selected commodities in these families, where a total of 115070 tonnes of fresh produce were exported in the financial year 2010–11 (HIA 2012). Twenty-six of the main export destinations for these commodities are also identified.

Table 6.7 Australian exports of tospovirus host crops (2010–11)

Commodity	Tonnes	Major export destinations
Onions	58 038	Belgium, Germany, Japan, Netherlands, United Kingdom
Ware potatoes	45 532	South Korea, Malaysia, Mauritius, Singapore, Hong Kong, Indonesia, Philippines, United Arab Emirates, Thailand, Taiwan and Brunei
Melons	8332	United Arab Emirates, Singapore, New Zealand, Hong Kong, Malaysia, Bahrain, Brunei Darussalam
Tomatoes	2385	New Zealand, Singapore, Hong Kong, Brunei, Malaysia, New Caledonia, Indonesia, French Polynesia, Fiji, and the USA
Capsicums	783	New Zealand, Papua New Guinea, Fiji, Brunei Darussalam, East Timor
Total	115070	

Several tospoviruses have hosts that include species used as cut-flowers or nursery-stock. During the financial year 2010–11, Australia exported 20.2 million cut-flowers and 47.9 million nursery-stock plants (HIA 2012). In 2012, the GPV of Australian potatoes, tomatoes, alliums, and leguminous crops exported was about $63 million, with about a further $12.6 million in cut-flowers and nursery-stock (International Trade Centre 2014). Major export destinations for these crops being: Japan, USA, the Netherlands, Germany and Canada for cut-flowers, and the Netherlands, New Zealand, United Kingdom, China and Singapore for nursery-stock (HIA 2012). These examples illustrate the scale of potential consequences to Australia exports if a quarantine pest tospovirus were introduced.

Diverted export produce

Indirect impact on international trade might divert export produce onto the domestic market. In the short term, this might depress the domestic market 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: **D**

The indirect impact of a tospovirus 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 a tospovirus 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 will impose additional costs on the agricultural sectors. Depending on the specific circumstance, this might

render part of existing and/or future inter-state trade in affected commodities uneconomical. However, it is plausible that the introduced tospovirus would establish and spread in multiple states/territories, overtime mitigating part of this impact as the biosecurity requirements between affected regions equalised.

Indirect impact on the environment

Impact score: **A**

The indirect impact of a tospovirus 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 a tospovirus 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 6.3) with the estimate of consequences (Table 6.4). Likelihoods and consequences are combined using the risk estimation matrix in Appendix A. The unrestricted risk (indicative), for tospoviruses that are quarantine pests for Australia, is given in Table 6.8, and is: **Low**

Table 6.8 Unrestricted risk estimate (indicative) for tospoviruses

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

This PRA identified 27 tospoviruses as quarantine pests for Australia (Table 6.1). These tospoviruses 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 Pest categorisation of thrips

Pest categorisation determines whether a pest has the characteristics of a quarantine pest (FAO 2015). Pest categorisation of thrips (part A) identified thrips families that are not likely to be associated with the plant import pathway, except as rare contaminants, 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.

The thrips families that require further pest categorisation (part B) are the phytophagous Thripidae and phytophagous Phlaeothripidae (excluding potential biocontrol agents for weeds). Based on seven selection criteria (Table 3.1), a total of 113 species (92 Thripidae and 21 Phlaeothripidae) underwent pest categorisation (part B), presented in Table 3.2. A total of 80 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 tospoviruses.

7.2 Pest categorisation of tospoviruses

Pest categorisation (Table 4.2) identified 30 tospoviruses, 27 of which are quarantine pests for Australia: ANSV, BeNMV, CCSV, CSNV, GBNV, GCFSV, GRSV, GYSV, HCRV, INSV, LNRV, MeSMV, MVBaV, MYSV, PCSV, PNSV, PolRSV, $L_GM_TS_G$, SVNV, TCSV, TNRV, TNSV, 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.

7.3 Thrips that transmit tospoviruses

Fourteen thrips species are known to naturally transmit tospoviruses. Eleven of these thrips species are quarantine pests, and are presently regulated. Three of which—*F. bispinosa*, *F. cephalica* and *T. setosus*—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 tospoviruses that are quarantine pests for Australia: ANSV, CCSV, CSNV, GBNV, GRSV, INSV, $L_GM_TS_G$, MYSV, PolRSV, TCSV, TNRV, WBNV, WSMoV and ZLCV.

The three thrips species—*F. schultzei*, *S. dorsalis* and *T. tabaci*—which are not quarantine pests are proposed to be regulated because they have the potential to transmit a total of seven tospoviruses that are quarantine pests for Australia: CSNV, GBNV, GCFSV, GRSV, GYSV, TCSV and TYRV. This regulatory change in regulated status is not expected to significantly affect trade.

The thrips species that naturally transmit 10 recently described tospoviruses remain unidentified: BeNMV, HCRV, LNRV, MeSMV, MVBaV, PCSV, PNSV, SVNV, TNSV and TZSV.

7.4 Outcomes of pest risk assessments

This group PRA undertook a pest risk assessment for:

- Phytophagous Thripidae and phytophagous Phlaeothripidae
- Tospoviruses.

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 Summary of unrestricted risk estimates (indicative) for thrips and tospoviruses

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

The unrestricted risk (indicative) for both thrips and tospoviruses are 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.

7.5 Regulatory changes to thrips that transmit tospoviruses

The quarantine status of three thrips species, which are not quarantine pests, are proposed to change to become regulated pests because they carry and transmit tospoviruses identified as quarantine pests for Australia. This regulatory change is not expected to significantly affect trade. These thrips species are:

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

7.6 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 may be required. The outcomes of this initial evaluation are presented in Appendix F and summarised here.

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

Maize chlorotic mottle virus 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). 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). *Sowbane mosaic virus* is transmitted by *T. tabaci* which is proposed to be regulated because it transmits the quarantine tospovirus TYRV. No further action is proposed for these 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 of 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.

7.7 Nursery-stock as a tospovirus pathway

This group PRA identified nursery-stock species as tospovirus 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 tospovirus 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 measures

8.1 Freedom from quarantine pest thrips

The pest risk analysis identified the quarantine pests with 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) is verified and does not achieve the ALOP for Australia.

Where risk management measures are required in order to achieve the ALOP for Australia, plant import pathway consignments must be free from quarantine pest thrips.

To achieve this objective, consignments must be verified as either not infested with quarantine pest thrips (through standard visual inspection or equivalent arrangements have been approved) or, where consignments are found to be infested with quarantine pest thrips, they must be subjected to an appropriate risk management measures.

ISPM 11 (FAO 2013) provides details on the identification and selection of appropriate risk management options. Australia, in considering risk management options, recognises the concept of equivalence (of phytosanitary measures): '*the situation where, for a specified pest risk, different phytosanitary measures achieve a contracting party's Appropriate Level of Protection*' (FAO 2015).

Visual inspection and remedial actions

For practical purposes, most fresh fruit and vegetables are visually inspected on arrival and subjected to remedial action, as required. This is an appropriate risk management option for thrips on most fresh fruit and vegetables because of the level of risk involved and since these pests are relatively easily detected by appropriately trained staff, using suitable techniques, during visual inspection.

Australia's standard biosecurity sampling protocol requires inspection of 600 units for quarantine pests from systematically selected random samples per 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/infected. The level of confidence depends on each unit in the consignment having similar likelihood of being affected by a quarantine pest and the inspection technique being able to reliably detect all quarantine pests in the sample. If no live quarantine pests are detected in the sample, the consignment is considered to be free from quarantine pests.

If a quarantine pest thrips is intercepted in a sample, remedial actions may be undertaken and include treatment of the consignment, re-export of the consignment from Australia, or the destruction of the consignment.

Mandatory fumigation

For cut flowers and foliage, which are routinely found to be infested with quarantine thrips, mandatory fumigation is an appropriate risk management option unless equivalent arrangements have been approved.

Irradiation

The '*International Standards for Phytosanitary Measures (ISPM) no. 18: Guidelines for the use of irradiation as a phytosanitary measure'* (FAO 2003) provides guidance on the use of ionising

irradiation as a phytosanitary treatment for regulated pests or articles. The Food Standards Code '*Standard 1.5.3, Irradiation of Food*' permits an absorbed irradiation dose between 150–1000 Gy as a phytosanitary measure for a range of fruit within Australia (FSANZ 2015), and Australia accepts irradiation as an effective phytosanitary measure for specific insect pests.

Appendix 1 of ISPM 18 (FAO 2003) specifies a minimum absorbed irradiation dose of 150–250 Gy for the sterilisation of thrips.

8.2 Review of policy

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

8.3 Meeting Australia's food standards

Imported food for human consumption must comply with the requirements of the *Imported Food Control Act 1992*, as well as Australian state and territory food laws. Among other things, these laws require all food, including imported food, to meet the standards set out in the Australia New Zealand Food Standards Code (the Code).

The Australian Government Department of Agriculture and Water Resources administers the *Imported Food Control Act 1992*. This legislation provides for the inspection and control of imported food using a risk-based border inspection program, the Imported Food Inspection Scheme. More information on this inspection scheme, including the testing of imported food, is available from the department's website.

Food Standards Australia New Zealand (FSANZ) is responsible for developing and maintaining the Code, including Standard 1.4.2 - Agvet chemicals. This standard is available on the Federal Register of Legislation or through the FSANZ website.

Standard 1.4.2 and Schedules 20 and 21 of the Code set out the maximum residue limits (MRLs) and extraneous residue limits (ERLs) for agricultural or veterinary chemicals that are permitted in food, including imported food.

Standard 1.1.1 of the Code specifies that a food must not have, as an ingredient or a component, a detectable amount of an agvet chemical or a metabolite or a degradation product of the agvet chemical; unless expressly permitted by the Code.

Anyone may apply to change the Code whether they are an individual, organisation or company. The application process, including the explanation of establishment of MRLs in Australia, is described at the FSANZ website.

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 2015). A pest is 'any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products' (FAO 2015).

International Standard for Phytosanitary Measures (ISPM) 2: Framework for pest risk analysis (FAO 2007), states that 'organisms may … be analysed individually, or in groups where individual species share common characteristics'. This is the basis for the group PRA in which organisms are grouped if they have similar biological characteristics (with reference to their biosecurity significance), similar likelihoods of entry, establishment and spread and comparable consequences.

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

When linked to a specific trade pathway using the rules set out in the report, it will be consistent with the principles of the International Standards for Phytosanitary Measures (ISPMs), including ISPM 2: Framework for Pest Risk Analysis (FAO 2007) and ISPM 11: Pest Risk Analysis for Quarantine Pests (FAO 2013) and the requirements of the SPS Agreement (WTO 1995).

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

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

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

Stage 1: Initiation

This group pest risk analysis was initiated by the department.

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

This group PRA considered all members of the insect order Thysanoptera (commonly referred to as thrips) and all members of the genus *Tospovirus*, which are transmitted by thrips, 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. Referred to as the plant import pathway in this report.

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 2015).

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

Pest categorisation of thrips

The pest categorisation process identifies pests with the potential to be on the plant import pathway that are quarantine pests for Australia and as a result require pest risk assessment. A quarantine pest is 'a pest of potential economic importance to the area endangered thereby and not yet present there, or present and not widely distributed and officially controlled' (FAO 2015).

Pest categorisation of thrips (part A) in this group PRA eliminated from further consideration thrips families (or sub-groups within these families) that did not have the potential to:

- be on the plant import pathway and/or
- cause significant economic (including environmental) consequences, and as a result could not meet the IPPC definition of a quarantine pest (FAO 2015).

In assessing the potential for thrips family members to be associated with the plant import pathway and/or causing economic (including environmental) consequences, factors taken into consideration included:

- feeding strategies—herbivores, fungivores or predators
- Australian and international (if available) interception data
- 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 this group PRA, pest categorisation of thrips (part B).

Pest categorisation identified which pests with the potential to be on the plant import pathway were quarantine pests for Australia and required further consideration.

Pest categorisation of thrips (part B) in this group PRA was undertaken on two pest groups:

- Phytophagous Thripidae and phytophagous Phlaeothripidae (excluding those species that are used as BCAs for weeds) that were identified in pest categorisation of thrips (part B) as requiring further consideration. This representative group of the foremost pest thrips species likely to be important from a biosecurity perspective on the plant import pathway were selected on the basis of the criteria listed in table 3.1.
- Tospoviruses known (or likely) to be transmitted by Thripidae species.

Factors considered in the pest categorisation of both the thrips species and all the tospoviruses were:

- identity of the pest
- presence or absence of the pest in the PRA area
- regulatory status of the pest in the PRA area

- potential for pest establishment and spread in the PRA area
- potential for the pest to cause economic consequences (including environmental consequences) in the PRA area.

The results of pest categorisation are given in Tables 3.2 for the phytophagous Thripidae and phytophagous Phlaeothripidae, and Table 4.2 for tospoviruses. 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 11 (FAO 2013). 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 entry) in the terms of likely commercial conditions and procedures based on extensive contemporary and historic analysis of the plant import pathway. For this reason, the likelihood of entry in this group PRA is indicative only and potentially subject to revision when all trade related factors are known. Accordingly, these factors must be verified, on a case-by-case basis, as part of a specific market access request.

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

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 2015).

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, bulk, packed)
- volume and frequency of movement of the commodity along each pathway
- seasonal timing of imports
- pest management, cultural and commercial procedures applied at the place of origin
- speed of transport and conditions of storage compared with the duration of the life cycle of the pest
- vulnerability of the life-stages of the pest during transport or storage
- incidence of the pest likely to be associated with a consignment
- commercial procedures applied to consignments during transport and storage in the country of origin, and during transport to Australia.

Factors considered in the likelihood of distribution include:

- commercial procedures applied to consignments during distribution in Australia
- dispersal mechanisms of the pest, including vectors, to allow movement from the pathway to a host
- whether the imported commodity is to be sent to a few or many destination points in the PRA area
- proximity of entry, transit and destination points to hosts
- time of year at which import takes place
- intended use of the commodity
- risks from by-products and waste.

Likelihood of establishment

Establishment is defined as the 'perpetuation for the foreseeable future, of a pest within an area after entry' (FAO 2015). 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 2015). 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 ≤ 1
Moderate	The event would occur with an even likelihood	0.3 < to ≤ 0.7
Low	The event would be unlikely to occur	0.05 < to ≤ 0.3
Very low	The event would be very unlikely to occur	0.001 < to ≤ 0.05
Extremely low	The event would be extremely unlikely to occur	0.000001 < to ≤ 0.001
Negligible	The event would almost certainly not occur	0 < to ≤ 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 epartment 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 2015) and ISPM 11 (FAO 2013).

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 2013) 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		
Chaetanaphothrips orchidii	Unshu Mandarin (Japan)	h (b)	m	M	H	H	L	L	L
Chaetanaphothrips signipennis	Banana (Philippines)	h	h	H	H	H	H	L	L
Drepanothrips reuteri	Grapes (Chile)	l	m	L	H	H	L	L	VL
	Grapes (Japan)	h	m	M	H	H	M	L	L
Elixothrips brevisetis	Banana (Philippines)	h	h	H	H	H	H	L	L
Frankliniella australis	Grapes (Chile)	l	m	L	H	H	L	L	VL
Frankliniella intonsa	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
Frankliniella occidentalis	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
Frankliniella tritici	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		
Retithrips syriacus	Persimmon (Japan, Korea, Israel)	h	h	H	H	H	H	L	L
Rhipiphorothrips cruentatus	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
Taeniothrips inconsequens	Stonefruit (USA: CA, ID, OR, WA)	h	m	M	H	H	M	L	L
Thrips obscuratus	Stonefruit (New Zealand)	h	m	M	M	H	M	M	L
	Cherries (New Zealand)	m	m	L	M	M	L	L	VL
Thrips palmi	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 period (1986–2012; Table 8.7). Of these interceptions, about 84 per cent were positively identified to family level as Thripidae with nine per cent Phlaeothripidae, less than one per cent assigned to other families, and six per cent remained unassigned to family. This explicitly shows that Thripidae is the dominant family being 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—just over half of all recorded thrips interception events.

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

Proportion of identified species that were Thripidae: 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	Tospovirus vector	Current quarantine pest status (b)
A	Greater than 250	Thripidae	*Frankliniella occidentalis*	Yes	Regulated
–	–	–	*Thrips tabaci*	Yes	Unregulated
B	10–50	Phlaeothripidae	*Haplothrips gowdeyi*	–	Unregulated
–	–	Thripidae	*Caliothrips fasciatus*	–	Regulated
–	–	–	*Frankliniella schultzei*	Yes	Unregulated
–	–	–	*Scirtothrips dorsalis*	Yes	Unregulated
–	–	–	*Thrips palmi*	Yes	Regulated
C	0.5–5	Phlaeothripidae	*Haplothrips ganglbaueri*	–	Regulated
–	–	–	*Hoplandrothrips flavipes*	–	Regulated
–	–	Thripidae	*Anaphothrips sudanensis*	–	Unregulated
–	–	–	*Arorathrips mexicanus*	–	Unregulated
–	–	–	*Frankliniella intonsa*	Yes	Regulated
–	–	–	*Frankliniella williamsi*	(c)	Regulated
–	–	–	*Heliothrips haemorrhoidalis*	–	Unregulated
–	–	–	*Kenyattathrips katarinae*	–	Regulated
–	–	–	*Megalurothrips sjostedti*	–	Regulated
–	–	–	*Neohydatothrips samayunkur*	–	Unregulated
–	–	–	*Selenothrips rubrocinctus*	–	Unregulated
–	–	–	*Thrips flavus*	–	Regulated
–	–	–	*Thrips fuscipennis*	–	Regulated
–	–	–	*Thrips hawaiiensis*	–	Unregulated
–	–	–	*Thrips imaginis*	–	Unregulated
–	–	–	*Thrips major*	–	Regulated
–	–	–	*Thrips obscuratus*	–	Regulated

Group	Yearly average range (a)	Family	Thrips	Tospovirus vector	Current quarantine pest status (b)
–	–	–	*Thrips parvispinus*	–	Unregulated
–	–	–	*Thrips simplex*	–	Unregulated
D	0.1–less than 0.5	Aeolothripidae	*Aeolothrips collaris*	–	–
–	–	–	*Aeolothrips fasciatus*	–	–
–	–	–	*Franklinothrips megalops*	–	–
–	–	Phlaeothripidae	*Aleurodothrips fasciapennis*	–	–
–	–	–	*Gynaikothrips ficorum*	–	–
–	–	–	*Haplothrips aculeatus*	–	–
–	–	–	*Haplothrips leucanthemi*	–	–
–	–	–	*Haplothrips robustus*	–	–
–	–	–	*Karnyothrips flavipes*	–	–
–	–	–	*Leptothrips mali*	–	–
–	–	–	*Nesothrips lativentris*	–	–
–	–	–	*Nesothrips propinquus*	–	–
–	–	–	*Podothrips semiflavus*	–	–
–	–	Thripidae	*Anaphothrips obscurus*	–	–
–	–	–	*Apterothrips apteris*	–	–
–	–	–	*Bolacothrips striatopennatus*	–	–
–	–	–	*Caliothrips phaseoli*	–	–
–	–	–	*Chaetanaphothrips orchidii*	–	–
–	–	–	*Dichromothrips corbetti*	–	–
–	–	–	*Frankliniella tenuicornis*	–	–
–	–	–	*Limothrips angulicornis*	–	–
–	–	–	*Limothrips cerealium*	–	–
–	–	–	*Microcephalothrips abdominalis*	–	–
–	–	–	*Mycterothrips chaetogastra*	–	–
–	–	–	*Scirtothrips aurantii*	–	–
–	–	–	*Scolothrips sexmaculatus*	–	–
–	–	–	*Tenothrips frici*	–	–
–	–	–	*Thrips australis*	–	–
–	–	–	*Thrips coloratus*	–	–
–	–	–	*Thrips pusillus*	–	–
–	–	–	*Thrips taiwanus*	–	–
E	Less than 0.1	Aeolothripidae	*Desmothrips australis*	–	–
–	–	–	*Franklinothrips vespiformis*	–	–
–	–	Merothripidae	*Merothrips brunneus*	–	–
–	–	–	*Merothrips floridensis*	–	–
–	–	Phlaeothripidae	*Apteygothrips australis*	–	–

Group	Yearly average range (a)	Family	Thrips	Tospovirus vector	Current quarantine pest status (b)
–	–	–	*Ecacanthothrips tibialis*	–	–
–	–	–	*Haplothrips ceylonicus*	–	–
–	–	–	*Haplothrips collyerae*	–	–
–	–	–	*Hoplothrips kea*	–	–
–	–	–	*Plicothrips apicalis*	–	–
–	–	–	*Podothrips lucasseni*	–	–
–	–	–	*Priesneriella citricauda*	–	–
–	–	Thripidae	*Anaphothrips cecili*	–	–
–	–	–	*Anaphothrips dubius*	–	–
–	–	–	*Apterothrips secticornis*	–	–
–	–	–	*Astrothrips aucubae*	–	–
–	–	–	*Baileyothrips arizonensis*	–	–
–	–	–	*Bolacothrips faurei*	–	–
–	–	–	*Ceratothripoides brunneus*	–	–
–	–	–	*Chirothrips manicatus*	–	–
–	–	–	*Dendrothrips degeeri*	–	–
–	–	–	*Elixothrips brevisetis*	–	–
–	–	–	*Ernothrips immsi*	–	–
–	–	–	*Florithrips dilutus*	–	–
–	–	–	*Frankliniella fusca*	Yes	Regulated
–	–	–	*Frankliniella gossypiana*	–	–
–	–	–	*Frankliniella insularis*	–	–
–	–	–	*Frankliniella panamensis*	–	–
–	–	–	*Frankliniella tritici*	–	–
–	–	–	*Hercinothrips bicinctus*	–	–
–	–	–	*Hercinothrips femoralis*	–	–
–	–	–	*Hydatothrips adolfifriderici*	–	–
–	–	–	*Hydatothrips samayunkur*	–	–
–	–	–	*Mycterothrips albidicornis*	–	–
–	–	–	*Neohydatothrips gracilicornis*	–	–
–	–	–	*Parthenothrips dracaenae*	–	–
–	–	–	*Plesiothrips perplexus*	–	–
–	–	–	*Priesneriola oneillae*	–	–
–	–	–	*Proscirtothrips longipennis*	–	–
–	–	–	*Pseudanaphothrips achaetus*	–	–
–	–	–	*Pseudodendrothrips mori*	–	–
–	–	–	*Rhamphothrips parviceps*	–	–
–	–	–	*Rhipiphorothrips miemsae*	–	–

Group	Yearly average range (a)	Family	Thrips	Tospovirus vector	Current quarantine pest status (b)
–	–	–	*Scirtothrips australiae*	–	–
–	–	–	*Scirtothrips fulleri*	–	–
–	–	–	*Scirtothrips inermis*	–	–
–	–	–	*Scirtothrips signipennis*	–	–
–	–	–	*Scolothrips asura*	–	–
–	–	–	*Sericothrips adolfifriderici*	–	–
–	–	–	*Stenchaetothrips biformis*	–	–
–	–	–	*Synaptothrips distinctus*	–	–
–	–	–	*Thrips angusticeps*	–	–
–	–	–	*Thrips florum*	–	–
–	–	–	*Thrips nigropilosus*	–	–
–	–	–	*Thrips novocaledonensis*	–	–
–	–	–	*Thrips nymphal*	–	–
–	–	–	*Thrips oryzae*	–	–
–	–	–	*Thrips setosus*	Yes	Regulated
–	–	–	*Thrips vulgatissimus*	–	–

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 range values are not contiguous to show actual 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.

The proportion of intercepted species that are regulated: Considering thrips species identified in interception categories A–C (the top 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 proposed because 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 *H. gowdeyi*, which is not a quarantine pest for Australia and distorts the figures, be removed from the calculations the proportion of regulated species would be about 98 per cent.

Other issues: It should be noted that two additional thrips species, *F. fusca* and *T. setosus*, transmit tospovirus, but they are not within interception categories A–C. These species are presently regulated as quarantine species. Additionally, *F. williamsi* transmits *Maize chlorotic mottle virus* (see Appendix F), and has been intercepted on the plant import pathway occasionally (Interception group B), but 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 tospovirus infected plant commodities

Potential senario

A scenario for tospovirus entry via infected plant commodities is considered. However, the transmission of a tospovirus 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 tospovirus entry at the distribution step. The rationale for this conclusion is discussed.

Entry (importation)

Association with export crops: As a group, tospoviruses are known to infect an extensive range of crops (Daughtrey et al. 1997; Gent et al. 2006; Jones 2005; Kunkalikar 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 tospovirus differ between species; some being relatively narrow, others extensive, with varying levels of commonality. This can influence the likelihood of a given tospovirus being imported. However, tospoviruses can quickly establish in crops. Viruliferous thrips can be sustained on weeds or volunteers—cultivated varieties growing wild or contaminating other crops—to provide a source for rapid tospovirus re-infection of newly planted crops (Groves et al. 2002; Jones 2005; Kahn, Walgenbach & Kennedy 2005; Okazaki et al. 2007). A tospovirus could potentially infect an export crop at a later stage of maturity, and symptoms may not be fully expressed at harvest.

Produce appearance: Expression of tospovirus infection in host plants is influenced by a broad range of factors that include the specific tospovirus 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 tospovirus infection typically include necrosis, chlorosis, ring patterns, mottling, silvering, stunting and lesions (Jones 2005; Mandal et al. 2012; Pappu, Jones & Jain 2009) that usually become more apparent as the plants mature and fruit ripens. Commercially produced perishable plant produce with such obvious tospovirus symptoms would probably be unmarketable, significantly moderating, but not eliminating, the likelihood of tospovirus infected produce being imported.

Entry (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 rendered) non-propagatable. There is no significant evidence for tospovirus seed transmission (Albrechtsen 2006; Pappu et al. 1999b), although limited preliminary research implying seed transmission by *Soybean vein necrosis virus* has been suggested (Groves et al. 2015). However, no evidence was found for seed transmissibility of this tospovirus in soybean grown under field conditions (Hajimorad et al. 2015). Consequently, under intended end use, there is probably very limited opportunity for a pathway to exist for tospovirus 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 tospovirus 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 reproduced 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 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, that viruliferous larvae were present implies that it is feasible for a tospovirus 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 soon be incapable of sustaining a viable population of thrips. Each thrips generation must feed on tospovirus infected plant to become infected and viruliferous. Only larval thrips, L1 and sometimes early stage L2 instars, can become infected by a tospovirus and continue to transmit it as L2 instars and adults (Mautino et al. 2012; Nagata et al. 1999). As a minimum, this would necessitate that a thrips laid eggs, larvae to hatch, feed and acquire tospovirus, 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 step is a virtual ‘dead-end’ for tospovirus entry on this pathway.

Summary

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

Appendix F Additional 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 may 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.

Additional 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
Maize chlorotic mottle virus [Machlomovirus]	MCMV	Not recorded	Yes	*Frankliniella williamsi* (Cabanas et al. 2013); possibly *F. occidentalis* (Zhao et al. 2014)
Pelargonium flower break virus [Carmovirus]	PFBV	Not recorded	Yes	*F. occidentalis* (Krczal et al. 1995)
Prunus necrotic ringspot virus [Ilarvirus]	PNRV	Present (Greber et al. 1991a; PHA & NGIA 2011) and not under official control	No	*T. tabaci* (Greber et al. 1991a)
Sowbane mosaic virus [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 *T. tabaci* 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.	*T. tabaci* (Hardy & Teakle 1992)
Tobacco streak virus [Ilarvirus]	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 *F. occidentalis, F. schultzei*, *T. tabaci*, *T. parvispinus* and *M. abdominalis* are all permitted entry by WA (Government of	*F. occidentalis* and *F. schultzei* (Kaiser, Wyall & Pesho 1982); *Thrips tabaci* (Sdoodee & Teakle 1987); *Thrips parvispinus* (Klose et al. 1996); *Microcephalothrips abdominalis* (Greber et al. 1991b)

			Western Australia 2016). Declared list A disease by Tas. (DPIPWE Tasmania 2015),but *T. tabaci* is an unwanted quarantine pest, which is not officially regulated by Tas. (DPIPWE Tasmania 2015)	
Strawberry necrotic shock virus [Ilarvirus]	SNSV	Present in some states (Sharman et al. 2011). SNSV is an unlisted organism for WA (Government of Western Australia 2016)	Yes. SNSV is unlisted organism for WA (Government of Western Australia 2016). However, its vectors *T. tabaci* and *M. abdominalis* are permitted entry by WA (Government of Western Australia 2016)	*T. tabaci and M. abdominalis* (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 2015) 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 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); *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 2014).

The 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 & Claflin 1978; Nyvall 1999; Uyemoto, Bockelman & Claflin 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 species. It is principally transmitted by the thrips *Frankliniella williamsi* (Cabanas et al. 2013). *F. williamsi* is present in Australia [Qld, Vic. and Tas. (Mound & Tree 2012)], but is a regulated pest for WA.

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 has not yet been verified in nature. *F. occidentalis* is currently regulated as a quarantine pest for Australia. It is also proposed to be regulated because it transmits several tospovirus that are quarantine pests for Australia.

Significant doubt exists about the reported status of *Thrips tabaci* transmitting MCMV. For example, *T. tabaci* is reported to transmit MCMV by Jones (2005) and cited elsewhere, including PHA and NGIA (PHA & NGIA 2011). In fact, Jones (2005) cites Ullman et al. (1992) for *T. tabaci* transmitting MCMV, but this reference does not say this. Ullman et al. (1992) stated generally that thrips can transmit MCMV, and cited unpublished data by Jiang. Subsequently, Jiang et al. (1992) published a paper about MCMV in Hawaii, as a first report of MCMV being transmitted by *F. williamsi*. However, *T. tabaci* was not mentioned in this publication, and no other primary reference was found to substantiate 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 *Systena 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 for bulk maize from the USA (Biosecurity Australia 2002a). Import conditions, processing and end use mitigate the risk of MCMV on this pathway. No further action is proposed 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 proposed 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 infected with SCMV. The current import protocol does not require active testing for MCMV. It is proposed 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), including clonal grasses and species within the genera of key cultivated cereal crops: *Avena, Hordeum*, *Secale*, *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. It also transmits several tospovirus that are quarantine pests 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. It does not meet the definition of a quarantine pest (FAO 2015) 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 all 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 evidence of official control to be in place for this pest.

Thrips tabaci is proposed to be regulated because it transmits the quarantine tospovirus TYRV. This would also mitigate the risk of *T. tabaci* facilitating the entry of SoMV grapevine strain. Consequently, no further action is presently proposed, 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), prohibited entry into this state and a regional pest for Western Australia. However, it appears that its thrips vectors such as *Frankliniella occidentalis, F. schultzei*, *Thrips tabaci, T. parvispinus*, *Microcephalothrips abdominalis* are not regulated by WA. In order for this virus to be considered as regional quarantine pests for WA, both the virus and all its vectors, occurring 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 evidence of official control to be in place for these pests.

Strawberry necrotic shock virus

Strawberry necrotic shock virus (SNSV) was originally considered as an isolate of *Tobacco streak virus* but 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 result in wounding of plant tissues permitting access by infected pollen grain. 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 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 2015). A decline 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 evidence of official control to be in place for this pest.

Summary

Six viruses other than tospoviruses were identified as being transmitted by thrips (Table 8.11). The table summarizes the current and proposed regulatory statuses of these thrips species.

Table 8.11 Regulatory status of thrips that transmit additional viruses

Virus	Thrips regulated	Thrips proposed to be regulated because it transmits tospoviruses	Other thrips
Maize chlorotic mottle virus	*F. williamsi* (WA), *F. occidentalis* (NT)	–	None
Pelargonium flower break virus	*F. occidentalis* (NT)	–	None
Prunus necrotic ringspot virus	–	–	–
Sowbane mosaic virus	–	*T. tabaci*	None
Tobacco streak virus	*F. occidentalis* (NT)	*F. schultzei, T. tabaci*	*T. parvispinus, M. abdominalis*
Strawberry necrotic shock virus	–	*T. tabaci*	*M. abdominalis*

This initial evaluation found that MCMV is a quarantine virus for Australia. It is transmitted by two thrips species—*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 Chrysomelidae beetles and is seed transmissible at low frequency. It is proposed 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 proposed. *Pelargonium flower break virus* is transmitted by *F. occidentalis* which is a quarantine pest for Australia (NT) and no further action is proposed. *Sowbane mosaic virus* is transmitted by *T. tabaci* which is proposed to be regulated because it transmits the quarantine tospovirus TYRV. Consequently, no further action is proposed from a biosecurity perspective. However, if the regulatory status of these thrips changed, or new vectors emerged, this decision would require review.

Appendix G Contaminants

The risks posed by 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 2015).

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 and then re-inspected.

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 tospovirus hosts

Nursery-stock risk profile

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

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

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

For the nursery-stock pathway viruliferous thrips are not the only means of tospovirus entry, contrasting the plant import pathway commodities. The nursery-stock pathway also differs from that of the plant import pathway because, as live plants, there intended end-use is to be sustained, dispersed and propagated within Australia. These differences influence the risk profile of this pathway and the likelihoods of tospovirus 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, budwood and tissue cultures (micro-propagated plantlets). Existing conditions are specific to the nursery-stock species and the form 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 athropods, and growth in a closed government or government approved Post Entry Quarantine (PEQ) facility with visual disease screening. Specific conditions 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 tospovirus 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 as causing several incursions in Europe (de Jonghe, Morio & Maes 2013; Mumford et al. 2003; Ravnikar 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 as associated with imported nursery-stock. INSV has also been detected by Australia on imported *Begonia, Lisianthus* and *Spathpillum* propagative material and successfully eradicated following an incursion in 2010 (PHA & NGIA 2011).

Tospoviruses that infect nursery-stock

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

Tospovirus symptom expression

The expression of tospovirus 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 tospovirus infection could be overlooked or symptoms attributed to other causes (Elliott et al. 2009; Hausbeck et al. 1992).

Limited symptomless tospovirus infection has been reported. Ruter and Gitatis (1993) report 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 tospovirus infection may be under reported. However, there is uncertainty in these reports about the time elapsed since these plants acquired the tospovirus 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 tospovirus 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 tospovirus infection has been reported in weeds (Latham & Jones 1997). Environmental factors are also reported to influence tospovirus symptom expression, for example, Lavina and Batlle (1993) report that TSWV symptom expression in *Ficus* was only apparent between 25–35 ^{O}C. Similarly, Allen and Matteoni (1988) observed that *Cyclamen persicum* expressed symptoms at 13 ^{O}C but not at 22 ^{O}C. These observations may be pertinent to tospovirus expression more broadly, and may add weight to the potential for the expression of tospovirus 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 tospovirus risk. Consequently, a review of nursery-stock species that are tospovirus hosts will be undertaken as a separate process, and released for stakeholder consultation.

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).
Appropriate level of protection (ALOP) for Australia	The *Biosecurity Act 2015* defines the appropriate level of protection (or 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 2015).
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 *Biosecurity Act 2015* 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 *Biosecurity Act 2015* 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 *Biosecurity Act 2015* 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 *Biosecurity Act 2015* 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 2015).
Establishment (of a pest)	Perpetuation, for the foreseeable future, of a pest within an area after entry (FAO 2015).
Goods	The *Biosecurity Act 2015* 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 2015).
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 2015).

Intended use	Declared purpose for which plants, plant products, or other regulated articles are imported, produced or used (FAO 2015).
Interception (of a pest)	The detection of a pest during inspection or testing of an imported consignment (FAO 2015).
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 2015).
Introduction (of a pest)	The entry of a pest resulting in its establishment (FAO 2015).
National Plant Protection Organization (NPPO)	Official service established by a government to discharge the functions specified by the IPPC (FAO 2015).
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 2015).
Pathogen	A biological agent that can cause disease to its host.
Pathway	Any means that allows the entry or spread of a pest (FAO 2015).
Pest	Any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products (FAO 2015).
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 2015).
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 2015).
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 2015).
Pest risk assessment (for regulated non-quarantine pests)	Evaluation of the probability that a pest in plants for planting affects the indented use of those plants with an economically unacceptable impact (FAO 2015).
Pest risk management (for quarantine pests)	Evaluation and selection of options to reduce the risk of introduction and spread of a pest (FAO 2015).
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 2015).
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 2015).
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 2015). 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.
PRA area	Area in relation to which a pest risk analysis is conducted (FAO 2015).

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 2015).
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 2015).
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 2015).
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 2015).
Regulated pest	A quarantine pest or a regulated non-quarantine pest (FAO 2015).
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 2015).
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 2015).
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 2015).
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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