INDUSTRY BIOSECURITY PLAN

FOR THE NURSERY & GARDEN INDUSTRY

Threat Specific Contingency Plan

Thrips transmitted viruses

Specific examples detailed in this plan:

Chrysanthemum stem necrosis virus

Tomato spotted wilt virus

Impatiens necrotic ringspot tospovirus

Pelargonium flower break virus

Plant Health Australia

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1 Purpose and background of this contingency plan

This contingency plan provides background information on the pest biology and available control measures to assist with preparedness for an incursion into Australia of a range of viruses that are transmitted by five genera of thrips (*Thrips, Frankliniella, Scirtothrips, Microcephalothrips* and *Ceratothripoides*). In this contingency plan viruses have been used as examples of those considered to be of greatest economic impact and risk to the Nursery Industry. It should be noted that some thrips transmitted viruses with a high economic impact are already present in Australia and there has been a recent incursion in Australia of *Impatiens necrotic spot virus* (INSV).

The contingency plan provides guidelines and options for steps to be undertaken and considered when developing a Response Plan for incursion of the virus pests. Any Response Plan developed using information in whole or in part from this contingency plan must follow procedures as set out in PLANTPLAN and be endorsed by the National Management Group prior to implementation.

This contingency plan was developed for the Nursery and Industry Australia (NGIA), and therefore is focused on production nurseries covered by this association. In the event of an incursion, operations that are not covered by the NGIA or another Emergency Plant Pest Response Deed (EPPRD) signatory (e.g. retail nurseries), will not be represented or have a decision making say in any arrangements for emergency response.

The information for this plan has been primarily obtained from documents as cited in the reference section. For each virus, information on background, life cycle, host range, distribution, symptoms and management/control is given.

2 Australian nursery industry

The Australian nursery industry is a significant horticultural sector with a combined supply chain (production to retail/grower) valued at more than $6 billion dollars annually. The industry employs approximately 45,000 people spread over more than 20,000 small to medium sized businesses including production nurseries and retail outlets. The industry is located predominantly along the Australian coastline and in major inland regions servicing urban and production horticulture.

Nursery production is a highly diverse primary industry servicing the broader $14 billion horticultural sector within Australia (Table 1). A pest incursion is likely to impact market access (see Appendix 3 for more information).

Table 1. *Nursery production supply sectors within Australian horticulture*

Production Nursery	Horticultural markets	Economic value
Container stock[1]	Ornamental/urban horticulture	$2 billion retail value
Foliage plants[1]	Interior-scapes	$87 million industry
Seedling stock[2]	Vegetable growers	$3.3 billion industry
Forestry stock[3]	Plantation timber	$1.7 billion industry
Fruit and nut tree stock[2]	Orchardists (citrus, mango, etc)	$5.2 billion industry
Landscape stock[1]	Domestic & commercial projects	$2 billion industry
Plug and tube stock[4]	Cut flower	$319 million industry
Revegetation stock[1]	Farmers, government, landcare	$109 million industry
Mine revegetation	Mine site rehabilitation	Value unknown
	Total horticultural market value	**$14.5 billion**

2.1 Notification process for the reporting of suspect pests

Early detection and reporting may prevent or minimise the long-term impact of an incursion into Australia of Thrips transmitted viruses.

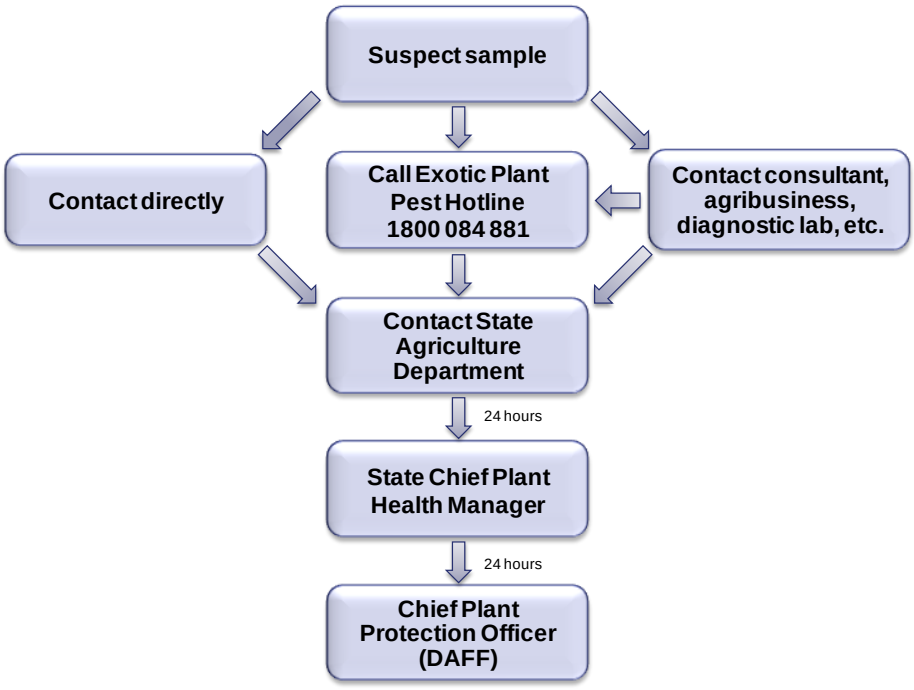


Figure 1. *Notification process for the reporting of suspect pests*

[1] Data sourced from Market Monitor

[2] Data sourced from Horticultural Handbook 2004

[3] Data sourced from ABARE 2005

[4] Data sourced from industry

3 Eradication or containment decision matrix

The decision to eradicate should be based on the potential economic impact of host damage resulting from Thrips transmitted virus infection, the cost of eradication and on technical feasibility. Eradication costs must factor in long term surveys to prove the success of the eradication program. A minimum of two years with no detections of the virus may be necessary to confirm that no thrips transmitted virus infestations remain before pest free status can be declared. The timeframe needs to be considered on a case by case basis, based both on the size of the infection, the degree and distribution of the pest with the final decision determined by the National Management Group.

No specific eradication matrix has been determined for thrips transmitted viruses; however the general decision process as outlined in Figure 2 and Table 2 should be followed in determining if an incursion of this pest will be eradicated or managed/contained. The final decision between eradication and management will be made through the National Management Group.

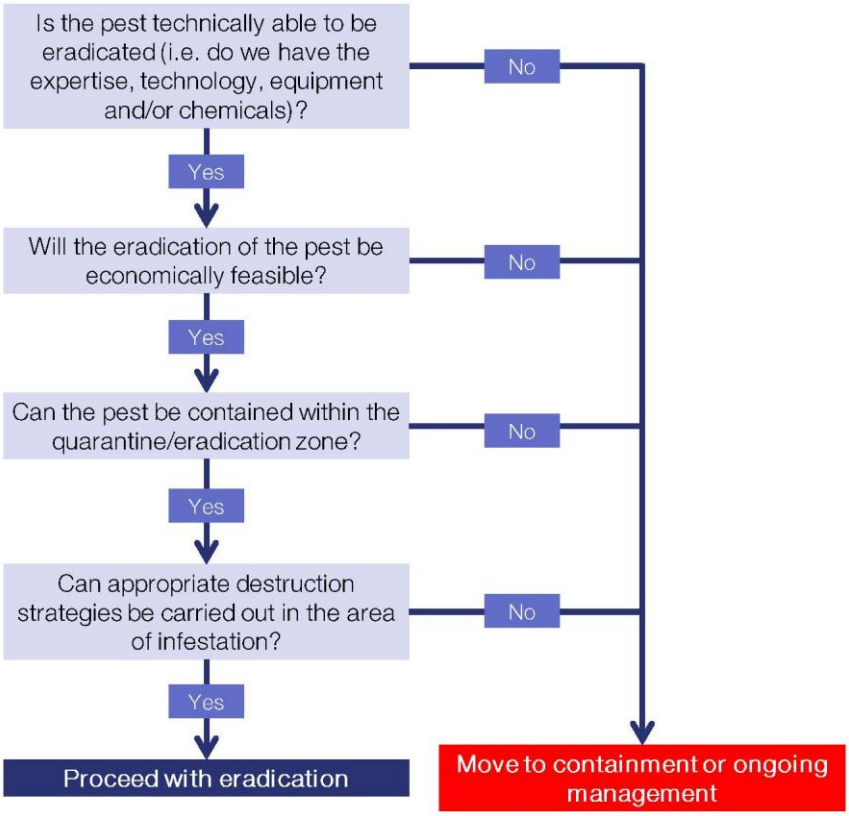


Figure 2. *Decision outline for the response to an exotic pest incursion*

Table 2. *Factors considered in determining whether eradication or alternative action will be taken for an EPP Incident (taken from Appendix 12 of PLANTPLAN)*

Factors favouring eradication	Factors favouring alternative action
• Cost/benefit analysis shows significant economic or amenity loss to industry or the community if the organism establishes. • Physical barriers and/or discontinuity of hosts between production districts. • Cost effective control difficult to achieve (e.g. limited availability of protectant or curative treatments). • The generation time, population dynamics and dispersal of the organism favour more restricted spread and distribution. • Pest biocontrol agents not known or recorded in Australia. • Vectors discontinuous and can be effectively controlled. • Outbreak(s) few and confined. • Trace back information indicates few opportunities for secondary spread. • Weather records show unfavourable conditions for pest development. • Ease of access to outbreak site and location of alternate hosts.	• Cost/benefit analysis shows relatively low economic or environmental impact if the organism establishes. • Major areas of continuous production of host plants. • Cost effective control strategies available. • Short generation times, potential for rapid population growth and long distance dispersal lead to rapid establishment and spread. • Widespread populations of known pest biocontrol agents present in Australia. • Vectors unknown, continuous or difficult to control. • Outbreaks numerous and widely dispersed. • Trace back information indicates extensive opportunities for secondary spread. • Weather records show optimum conditions for pest development. • Terrain difficult and/or problems accessing and locating host plants.

4 Pest information/status – Thrips/virus complex

4.1 Pest details

In this contingency plan specific pest information and status will be given for the thrips vector, as well as examples of virus species that are transmitted by thrips. The viruses have been chosen in consultation with the Nursery and Garden Industry Australia (NGIA) due to their economic importance and potential relevance to the Australian nursery industry. This plan will specifically examine three Tospoviruses and one Carmovirus whose vectors are already present in Australia that would potentially have a high impact on the nursery & garden industry should they enter and become established; namely, the Tospoviruses *Chrysanthemum stem necrosis virus* and *Impatiens necrotic spot virus*, the Carmovirus *Pelargonium flower break virus*, as well as the Tospovirus *Tomato spotted wilt virus* that is already present.

Five genera of thrips are known to transmit viruses: *Thrips, Frankliniella, Scirtothrips, Microcephalothrips* and *Ceratothripoides* (Jones 2005). The majority of viruses transmitted by thrips are tospoviruses which can be vectored by three species of *Thrips*, six species of *Frankliniella* and one species each of *Scirtothrips* and *Ceratothripoides* (Jones 2005). Thrips vectors of all but one virus (*Zucchini lethal chlorosis virus*) are already present in Australia (Table 3). Note that other thrips species that are serious pests to the nursery & garden industry, such as Poinsettia thrips (*Echinothrips americanus*), are not known to vector viruses.

The focus of this contingency plan is exotic viruses transmitted by thrips and specific information will be given for the thrips vector as well as three exotic and one endemic thrips-transmitted virus. These viruses have been chosen because of their economic importance and potential relevance to the nursery and garden industry and because they act as examples within different virus families. It should be noted however that for each virus in a family, specific information would be required on symptoms, host range, diagnosis, geographic distribution as well as risk ratings for entry, establishment, spread and economic impact.

Table 3. *Thrips transmitted Tospoviruses and their vectors (virus and vector data from Whitfield et al. 2005 and Persley et al. 2006). Vectors not currently present in Australia are highlighted in bold font.*

Virus	Acronym	Present in Australia	Thrips vector
Calla lily chlorotic spot virus	CCSV	No	*Thrips palmi*
Capsicum chlorosis virus	CaCV	Yes	*Frankliniella shultzei,* *Ceratothripoides claratris,* *T. palmi,*
Chrysanthemum stem necrosis virus	CSNV	No	*F. occidentalis* *F. schultzei*
Groundnut bud necrosis virus	GBNV	No	*F. schultzei* *T. palmi* *Scirtothrips dorsalis*
Groundnut ringspot virus	GRSV	No	*F. occidentalis* *F. schultzei*
Impatiens necrotic spot virus	INSV	No	*F. occidentalis*
Iris yellow spot virus	IYSV	Yes	*T. tabaci*
Melon yellow spot virus	MYSV	No	*T. palmi*
Peanut chlorotic fanspot virus	PCFV	No	*S. dorsalis*
Peanut yellow spot virus	PYSV	No	*S. dorsalis*
Tomato chlorotic spot virus	TCSV	No	***F. intonsa*** *F. occidentalis* *F. schultzei*
Tomato spotted wilt virus	TSWV	Yes	***F. bispinosa*** ***F. fusca*** ***F. intonsa*** *F. occidentalis* *F. schultzei* ***T. setosus*** *T. tabaci*
Tomato yellow fruit ring virus	Unknown	No	Unknown
Watermelon bud necrosis virus	WBNV	No	*T. palmi*
Watermelon silver mottle virus	WSMoV	No	*T. palmi*
Zucchini lethal chlorotic virus	ZLCV	No	***F. zucchini***

'Tospovirus' is derived from the type species of the genus, *Tomato spotted wilt virus* (TSWV), which was first discovered and named in Australia in the early 1900s. The *Tospovirus* genus includes 16 species presently recognised by the International Committee on Taxonomy of Viruses (ICTV)(Table 3), distinguished on the basis of the serological properties and amino acid sequence identity of the viral structural proteins (Whitfield *et al.* 2005). Two groups of viruses that appear to have evolved independently exist in the genus *Tospovirus*: an American cluster that includes TSWV, INSV, *Groundnut ringspot virus* (GRSV), *Tomato chlorotic spot virus* (TCSV), *Chrysanthemum stem necrosis virus* (CSNV) and *Zucchini lethal chlorosis virus* (ZLCV) and a Eurasian cluster which includes *Groundnut bud necrosis virus* (GBNV), *Watermelon silver mottle virus* (WSMoV) and *Iris yellow spot virus* (IYSV)(Nagata *et al.* 2007). Despite assigning various vector species to different viruses; it has become clear in recent years that individual isolates of viruses may not be transmitted by all known vectors of that virus (Persley *et al.* 2006).

Three of the Tospoviruses listed in Table 3 are already present in Australia (TSWV, IYSV and *Capsicum chlorosis virus* [CaCV]), along with five species of thrips vectors: *F. occidentalis* (Western flower thrips), *F. schultzei* (Tomato thrips), *T. palmi* (Melon thrips), *T. tabaci* (Onion thrips) and *S. dorsalis*. TSWV remains the most widespread and damaging of the Tospoviruses in Australia (Persley *et al.* 2006).

CaCV was found in capsicum and tomato crops in Qld in 1999 (McMichael *et al.* 2000), but may have been detected seven years earlier without being conclusively identified (Persley *et al.* 2006). CaCV infects capsicum, tomato, peanut and some weeds and is transmitted by Tomato thrips and Melon thrips. IYSV was detected in Australia as early as 1998 but was first confirmed and reported to be present in NSW, Vic and WA in onions and leeks in 2003 (Coutts *et al*. 2003).

In addition to the genus *Tospovirus*, there are five known viruses from four other genera that are transmitted by thrips (Table 4). The Ilarviruses, *Tobacco streak virus* (TSV) and *Prunus necrotic ringspot virus* (PNRV), the Carmovirus *Pelargonium flower break virus* (PFBV) and the Sobemovirus *Sowbane mosaic virus* (SoMV) are transmitted by thrips moving virus-infected pollen between plants, which then infects through feeding wounds (Jones 2005). SoMV can also be acquired by thrips during feeding and transmitted when infected thrips feed on healthy plants, as per Tospoviruses. The mode of transmission of the Machlomovirus *Maize chlorotic mottle virus* (MCMV) is not known, but it is thought to be transmitted by thrips (Ullman *et al*. 1992).

Table 4. *Thrips transmitted viruses from genera other than tospovirus (data from Jones 2005). Note: all Thrips vectors are currently present in Australia.*

Virus genera	Virus	Acronym	Present in Australia	Thrips vector
Carmovirus	*Pelargonium flower break virus*	PFBV	No	*F. occidentalis*
Ilarvirus	*Tobacco streak virus*	STV	Yes	*F. occidentalis* *F. schultzei* *T. tabaci* *T. parvispinus* *Microcephalothrips abdominalis*
Ilarvirus	*Prunus necrotic ringspot virus*	PNRV	Yes	*T. tabaci*
Machlomovirus	*Maize chlorotic mottle virus*	MCMV	No	*T. tabaci*
Sobemovirus	*Sowbane mosaic virus*	SoMV	Yes	*T. tabaci*

SoMV was first reported in Australia in 1968 (Teakle 1968). TSV was first reported in Australia in 1971 and has subsequently been reported on tobacco, strawberry, dahlia and various weed species, mostly from south-eastern Qld (Greber *et al.* 1991). More recently, TSV has been reported infecting sunflower, cotton, mung bean and chickpea Qld (Sharman *et al*. 2008). Typical symptoms of TSV on beans are shown in Figure 3.

PNRV is also present in Australia and has a wide host range including important commercial crops such as roses (garden roses, cut flower roses and essential oil-bearing roses), apple, peach, hop, apricot, almond and plum (Kulshrestha *et al.* 2009).

While Australia is currently free of the tospovirus ZLCV and its vector (*F. zucchini*), the control and management procedures for this pest would likely be the same as for those exotic viruses whose vectors are already present in Australia. The presumption for this is that it is highly likely that the ZLCV would only enter Australia via plant or soil material infested with eggs/larvae/pupae of a viruliferous thrips vector. The virus is not seed-borne and has a host range limited to zucchini and other cucurbits and is currently found only in Brazil. Australia does not currently import any cucurbit produce from Brazil, and all cucurbit nursery stock must pass through quarantine; hence it is extremely unlikely that the virus would enter Australia in the absence of the vector, *F. zucchini*.



Figure 3. *A common bean plant showing rednode necrosis and leaf chlorosis caused by the Tobacco streak virus (TSV). Image courtesy of Howard F. Schwartz, Colorado State University, Bugwood.org*

5 Pest information/status – the thrips vector

5.1 Pest details

Taxonomic position:

Kingdom, Animalia; Phylum, Arthropoda; Class, Insecta; Order, Thysanoptera, Haliday, 1836

5.1.1 Background

Thrips are minute insects belonging to the order Thysanoptera. Thrips have a distinctive fringe of long hairs around the wing margins and, unlike other insects, have only one mandible that is used to punch a hole in a plant to suck out the cell sap using a stylet. They also have a bladder like appendage to cling to plant surfaces. Thrips have an adult body size ranging from 0.5 to 5 mm and adults usually having four slender wings. About 5000 species of thrips have been recognised with the potential for many more. Nine families are known with 95% of the known species being members of the Thripidae and Phlaeothripidae families (Jones 2005). The species that are known virus vectors are members of the Thripidae subfamily Thripinae. This subfamily has 1400 species in 230 genera.

Thrips can be an economic problem in a wide range of crops including ornamentals, vegetables, strawberries, grapes, pome fruit and stone fruit. The main economically important thrips species in Australia are presented in Table 5. Those thrips that transmit Tospoviruses are Western flower thrips, Tomato thrips, Melon thrips and Onion thrips

Thrips cause direct damage to plants: After piercing plant cells using their mouthparts, they feed on plant juices causing collapse of plant cells results in the formation of deformed flowers, leaves, stems, shoots and fruit. Thrips can also damage buds and flowers through their egg laying.

Table 5. *Some important thrips threats in Australia (extract from 'A management guide to thrips and tospovirus' (Queensland DEEDI, Persley et al. 2007)).*

Species	Main Crops Affected	Type of Injury
Frankliniella occidentalis (Western flower thrips)	Wide range of fruit, vegetable and ornamental crops	Damage to flowers and developing fruit. Tospovirus vector.
Frankliniella schultzei (Tomato thrips)	Wide range of crop and weed hosts	Damage to leaves and young fruit. Tospovirus vector.
Thrips palmi (Melon thrips)	Potato, cucurbits, capsicum, beans, eggplant	Damage to leaves, growing points, scarring of fruit and fruit drop. Tospovirus vector.
Thrips tabaci (Onion thrips)	Onion, garlic	Damage to leaves. Tospovirus vector.
Thrips imaginis (Plague thrips)	Stone, pome fruit, lucerne	Damage to flowers and young fruit.
Thrips hawaiiensis (Banana flower thrips)	Banana	Corky scab of fruit.
Chaetanaphothrips signipennis (Banana rust thrips)	Banana	Cracking and scarring of fruit.

Species	Main Crops Affected	Type of Injury
Heliothrips haemorrhoidalis (Greenhouse thrips)	Ornamentals	Silvering of leaves.
Thrips simplex (Gladiolus thrips)	Gladiolus	Damage to leaves and flowers.
Megalurothrips usitatus (Bean blossom thrips)	French beans	Flower feeding causing twisting and curling of pods.
Limothrips cerealium	Wheat	Whitened spikelets with no or shrivelled grains.

Thrips also damage plants by transmitting viruses. Thrips acquire viruses when the newly hatched thrips (first instar nymphs) feed on a plant infected with the virus. In general older nymphs and adults cannot acquire the virus. If no source of infection is present, thrips cannot acquire or transmit the virus.



Figure 4. *Adult (bottom right) and larval stages of thrips (images source: Thrips and tospoviruses – A management guide by DEEDI 2007).*

5.1.2 Life cycle

In general, the thrips life cycle is mostly continuous and thrips can usually be found year round. In greenhouses they may produce 12-15 generations per year. Temperature determines the generation time with generation time for Western flower thrips varying from 9 days in summer to 15-20 days or more in winter.

Females of the common thrips drill a hole into a leaf, and push into this a single egg. Females lay 30 or more eggs. Eggs are laid individually just under the surface of the younger parts of leaves, stems,

flowers and inside the buds. The eggs hatch in 3-4 days, depending on temperature, with the larvae moving into more protected areas of the plant to feed.

There are four immature stages and two active larval stages which feed on leaves and in flowers, and two non-feeding pupa stages, usually in the soil. Thrips are unusual insects in that there are two pupal stages before the new adult emerges. This life cycle takes about three weeks, depending on temperature
(**http://www.sardi.sa.gov.au/pestsdiseases/horticulture/horticultural_pests/integrated_pest_management/resources/greenhouse_pests/western_flower_thrips**).

5.1.3 Dispersal

Thrips run, crawl or jump and can move rapidly. Thrips are poor fliers and their main methods of dispersal are by wind currents, or by passive dispersal by transport on affected fresh plant material, people or on equipment.

5.2 Affected hosts

5.2.1 Host range

Thrips have a wide host range with Western flower thrips (*Frankliniella occidentalis)* for example, being extremely polyphagous with over 200 plant species from more than 60 families recorded as hosts (Jones 2005).

5.2.2 Current geographic distribution

Thrips can be found in both warm and cold climates throughout Australia. For example, Onion thrips can seriously damage crops in Tasmania, Western flower thrips causing damage in temperate regions, and Melon thrips are present in the far north. In northern Australia, the native thrips are similar to species found in Indonesia, and are very different from the species that live in southern Australia. Generally, the diversity of thrips species is greater in the warmer climates than in temperate zones (**http://www.ala.org.au/explore/themes/thrips/**).

5.2.3 Symptoms

Thrips cause major damage through feeding on foliage, flowers and fruit including foliage discolouration or silvering, deformed new growth or flower buds and halo-spotting on leaves which is seen as small dark scars surrounded by white tissue.

Damage caused by Western flower thrips include discolouration of the upper leaf surface with indentations. Halo-spotting, silvering, deformity and brown bumps may also be present on leaves of ornamentals. Feeding can also cause discolouration and scarring of petals and deformity to buds (Jones 2005).

5.3 Diagnostic information

Accurate identification of thrips species is not easy and requires experience and training. Identification of thrips species by morphological procedures is restricted to adult specimens as there are no adequate keys for the identification of eggs, larvae or pupae.

5.4 Pest risk ratings and potential impacts

Thrips species can have a serious impact on the production of certain field crops as well as a wide range of protected horticultural crops. The appearance of new viruses in areas colonised by the thrips can be due to the fast development and broad host range of the thrips and transmission of the virus by the thrips.

6 Pest information/status – *Tospoviruses*

6.1 Pest details – example: Chrysanthemum stem necrosis virus

Common names:	*Chrysanthemum stem necrosis virus* (CSNV)
Scientific name:	*Chrysanthemum stem necrosis virus*
Synonyms:	Formerly thought to be a strain of *Tomato spotted wilt virus*
Taxonomic position:	Group: virus; Family: Bunyaviridae; Genus: Tospovirus

Within this contingency plan, this virus was chosen as an exemplar due to its economic impact on hosts that form a significant part of the nursery and garden industry. CSNV is listed as an EPPO A1 quarantine pest i.e. a pest that is not present in the EPPO region and is considered a significant threat (EPPO 2010a).

6.1.1 Background

Chrysanthemum stem necrosis virus (CSNV) was first recognised on chrysanthemum in Sao Paulo state in Brazil (Duarte *et al*. 1995) and described as a new virus (rather than a strain of Tomato spotted wilt virus (TSWV)) by Bezerra *et al.* (1996). The virus is spread by the thrips vectors *F. occidentalis* and *F. schultzei* (Bezerra *et al.* 1999; Nagata and de Ávila 2000), both of which are present in Australia. Studies have revealed that the virus cannot be vectored by *T. tabaci* (Bezerra *et al.* 1999). Successful transmission requires that the salivary glands contain large amounts of virus (Nagata *et al.* 1999). The failure of *T. tabaci* to transmit CSNV can be explained by the limited virus infection in the midgut and the absence of virus in the salivary glands (Nagata and de Ávila 2000).

CSNV has been successfully eradicated from the Netherlands and the UK, following its importation on chrysanthemum cuttings from Brazil (EPPO 2005). The virus has been reported in Slovakia and is under official control (Ravnikar *et al.* 2003).

CSNV is a significant threat to chrysanthemum and tomato crops where the major vector, Western flower thrips (*F. occidentalis*) is present and reported to have caused economic losses in Brazil

(Nagata *et al.* 2007). CSNV causes a more severe disease on chrysanthemum than TSWV (EPPO 2005).

6.1.2 Life cycle

CSNV has the typical biology of a tospovirus. Thrips (*F. occidentalis* and *F. shultzei*) acquire the virus in the first and early second larval stages (adult Thrips are unable to acquire the virus) and remain viruliferous for life, allowing multiple transmissions by adult insects (Sherwood *et al.* 2000).

Tospoviruses can replicate in the thrips vectors as well as in host plants (Ullman *et al.* 1993) and only short feeding periods are necessary for transmission. Thus, many plants can be infected as viruliferous vectors move through a crop. The G1 and G2 membrane glycoproteins of tospoviruses are involved in the vector-virus relationship (Jones 2005).

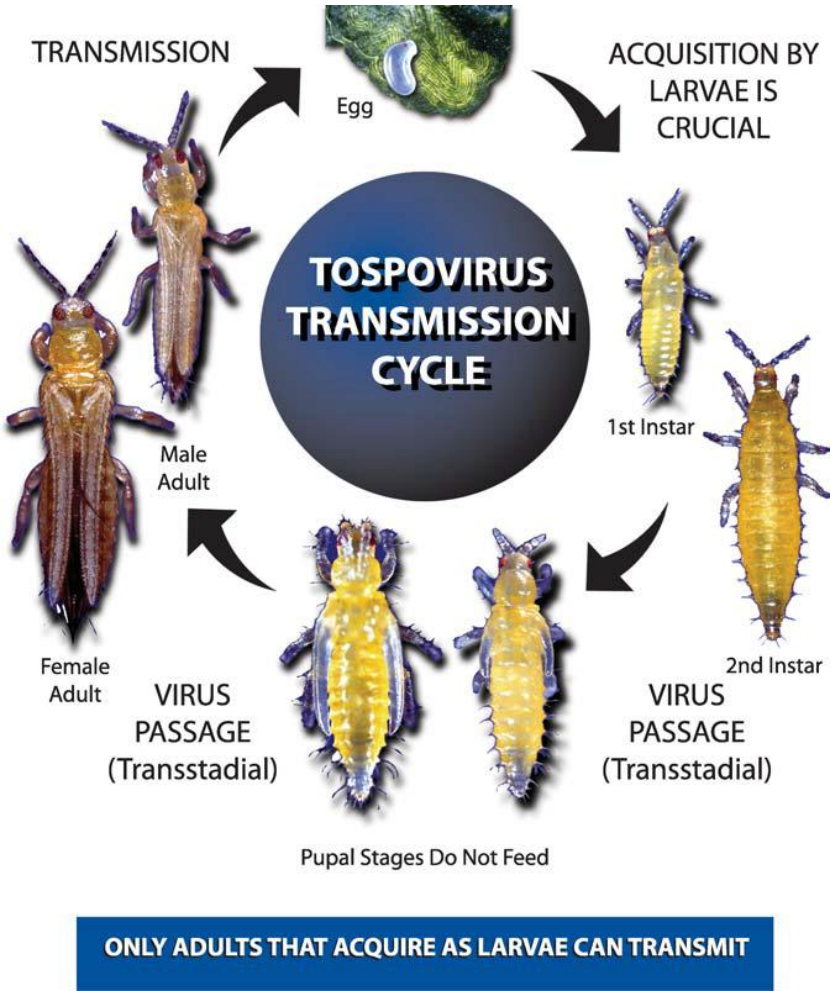


Figure 5. *Graphic representation of the thrips life cycle and the tospovirus transmission cycle (for a more detailed explanation refer to Whitfield et al. 2005).*

6.1.3 Dispersal

Dispersal over long distances is primarily due to the movement of plant material infested with infected thrips vectors *F. occidentalis* or *F. shultzei* (adults, eggs or larvae in flowers, fruit, leaves, or pupal stages in growing media). As a Tospovirus, CSNV is unlikely to be seed-transmitted (EPPO 2005).

The virus is spread from plant to plant by the vectors *F. occidentalis* and *F. schultzei*. Coutts *et al.* (2004) suggest that the spread of tospoviruses is typically monocyclic; that is, vectors introduce the virus into crops from outside sources rather than establishing foci within crops with subsequent secondary spread.

The virus could be spread over long distances with trade in cuttings and other vegetative plants for planting. CSNV is known to have spread to the Netherlands in chrysanthemum cuttings imported from Brazil (Verhoeven *et al.* 1996) as well as to the UK by the same route (Mumford *et al.* 2003). These plants may not have shown symptoms at the time of dispatch.

6.1.4 Host range

Tomato (*Lycopersicon esculentum*) and chrysanthemum (*Dendranthema grandiflorum*) are the only known natural hosts.

6.1.5 Current geographic distribution

CSNV is currently found in Brazil and Japan and is reported to be under official control in Slovakia (Ravnikar *et al.* 2003). The virus has also been eradicated from the Netherlands and the UK (EPPO 2005).

6.1.6 Potential distribution in Australia

Given the widespread presence of the Western flower thrips (*F. occidentalis*) and Tomato thrips (*F. schultzei*) vectors and host plants (tomatoes and chrysanthemums), the virus has the potential to spread to all states and territories.

6.1.7 Symptoms

CSNV causes symptoms similar to those of Tomato spotted wilt virus on chrysanthemums, and may include necrotic streaks on stems, wilting of leaves and stems, chlorotic and necrotic spots and rings on leaves, and leaf distortion (EPPO 2005; Matsuura *et al.* 2007). However, symptoms of CSNV are more severe and can cause complete necrosis of the stem leading to wilting of sections of plants (Verhoeven *et al.* 1996). Duarte *et al.* (1995) reported necrotic lesions surrounded by yellow areas on leaves followed by necrosis on stems, peduncles and floral receptacles due to CSNV in Brazil.

Table 6. *Summary of Chrysanthemum stem necrosis virus symptoms (CABI 2011).*

Plant parts	List of symptoms
Inflorescence	Lesions, flecking, streaks (not Poaceae)
Leaves	Necrotic areas, abnormal colours, abnormal patterns, wilting
Stems	Wilt, discoloration, necrosis
Whole plant	Wilt

6.1.8 Diagnostic information

Diagnosis based on symptoms is difficult because both CSNV and TSWV cause similar symptoms on chrysanthemum. Morphological characteristics can confirm the presence of a tospovirus with the following features: Tospoviruses form pleomorphic, spherical particles, 80–120 nm in diameter, that are surrounded by a lipid envelope with two surface glycoprotein (GN and GC) projections, enclosing three nucleocapsids (Persley *et al.* 2006). The RNA segments within the nucleocapsids are single-stranded, and are designated L (large), M (medium) and S (small), each associated with many copies of the virus-encoded N (nucleocapsid) protein and a few copies of RNA-dependent RNA polymerase (RdRp) (Persley *et al.* 2006).

Serological assays such as ELISA have become routine for detection and identification of tospoviruses and have been used to confirm the presence CSNV (Nagata and de Ávila 2000). Western immuno-blot analysis also distinguishes CSNV from other tospoviruses, although a slight cross-reaction with antibodies against TSWV, TCSV and GRSV was observed (Bezerra *et al.* 1999). Reverse Transcription (RT)- Polymerase Chain Reaction (PCR) can also be used to verify virus infection (Matsuura *et al.* 2007) and more recently Kuwabara *et al.* (2010) developed a multiplex RT-PCR that can detect and identify five tospovirus species, including CSNV, simultaneously.

6.1.9 Risk assessments for pathways and potential impacts

Chrysanthemum stem necrosis virus (CSNV) is not known to be present in Australia; however its vectors *F. occidentalis* and *F. schultzei* are both present and as vectors of CSNV have the potential for establishment of spread and economic consequences should CSNV enter Australia.

Within this contingency plan, a pest risk analysis has been carried out on this virus, taking into account the entry, establishment and spread potentials, together with the economic and environmental impact of establishment. A summary of these ratings are shown in Table 7. Based on this information, CSNV is considered a medium overall risk to Australia.

Table 7. *Pest risk ratings for Chrysanthemum stem necrosis virus*

Potential or impact	Rating
Entry potential	Low
Establishment potential	High
Spread potential	High
Economic impact	High
Environmental impact	Negligible
Overall risk	**Medium**

6.1.9.1 ENTRY POTENTIAL

Rating: Low

The most likely pathway for CSNV to enter Australia is via plant material infested with infected thrips vectors carried in plant parts, fruit or growing media in international trade from countries where the virus is present (Japan and Brazil). Both vector species (*F. occidentalis* and *F. shultzei*) are highly polyphagous, and could enter on any number of host plants. However, given that the virus is only present in Japan and Brazil, and that the chance that the vectors may not be infected with CSNV should they enter Australia, the risk of entry is considered **Low**.

6.1.9.2 ESTABLISHMENT POTENTIAL

Rating: High

Hosts for the thrips vectors are widespread, as are hosts for the virus (chrysanthemums and tomatoes); hence, the establishment potential is **High**.

6.1.9.3 SPREAD POTENTIAL

Rating: High

Both vector species are already present in Australia and are almost ubiquitous, suggesting that if CSNV-infected thrips entered and established in Australia their spread potential, and therefore the spread potential of CSNV, would be **High**.

6.1.9.4 ECONOMIC IMPACT

Rating: High

The virus causes economic losses in tomato and chrysanthemum crops in Brazil (Nagata *et al.* 2007). Because the control measures for CSNV is targeted at eliminating or excluding the thrips vectors (*F. occidentalis* and *F. schultzei*) and given that Western flower thrips (*F. occidentalis)* readily develops resistance to chemicals used to control Western flower thrips, effective control of Western flower thrips and CSNV may prove difficult. For this reason the economic impact on CSNV on chrysanthemum and tomato production is likely to be **High**.

6.1.9.5 ENVIRONMENTAL IMPACT

Rating: Negligible

The virus has a narrow host range (tomatoes and chrysanthemums) so the environmental impact is likely to be **Negligible**.

6.1.9.6 OVERALL RISK

Rating: Medium

Based on the individual ratings above, the combined overall risk is considered **Medium**.

6.2 Pest details – example: Tomato spotted wilt tospovirus

Common names:	Tomato spotted wilt virus
Scientific name:	*Tomato spotted wilt virus*
Synonyms:	Dahlia oakleaf virus; Dahlia ringspot virus ; Dahlia yellow ringspot virus; Groundnut ringspot virus; Mung bean leaf curl virus; Pineapple yellow spot virus; Tomato spotted wilt tospovirus; Tomato spotted wilt virus group
Taxonomic position:	Domain, virus; Group, “RNA viruses” Family: Bunyaviridae; Genus: Tospovirus

Tomato spotted wilt virus (TSWV) is widespread in Australia however was chosen as an example as it was originally included in the Nursery and Garden Industry Biosecurity Plan.

Within this contingency plan, this virus was chosen as an example due to its economic impact on hosts that form a significant part of the nursery and garden industry. TSWV is listed as an EPPO A2 quarantine pest i.e. a pest that is present in some parts of the EPPO region and is considered a threat recommended for regulation (EPPO 2010b).

6.2.1 Background

Tomato spotted wilt virus (TSWV) is one of the most widespread and damaging viruses affecting vegetable crops in Australia. Though TSWV was first identified in Australia in 1915, the severity and incidence of the disease in Australia and overseas increased substantially with the spread of Western flower thrips, the major vector (Persley *et al.* 2006). Other thrips vectors (namely *F. shultzei*, *F. intonsa*, *F. bispinosa, Thrips tabaci* and *T. setosus*) were later shown to be efficient in transmitting TSWV (Wijkamp *et al.* 1995; Webb *et al.* 1998, Jones 2005). Persley *et al.* (2006) have also shown that *T. palmi* is able to transmit Australian isolates of TSWV. The crops most frequently and severely affected by TSWV are the solanaceous vegetables including tomato, capsicum, lettuce, potato and ornamental species like for example, aster, calendula and chrysanthemum. For cucumbers infections are symptomless. The arrival of the vector Western flower thrips has seen an increase in the seriousness of the disease, particularly in hydroponic and covered systems.

Once a plant is infected with TSWV it cannot be cured and therefore prevention or the use of tolerant varieties are the only management options available.

Typical symptoms of TSWV are shown in Figure 6.



Figure 6. *Stunting and leaf necrosis on field-grown tomatoes due to TSWV. Image courtesy of Don Ferrin, Louisiana State University Agricultural Center, Bugwood.org.*

6.2.2 Life cycle

All tospoviruses are transmitted and spread in nature by insects of the family Thripidae (Thysanoptera), belonging to the genera *Frankliniella* and *Thrips*. Thrips vectors can include *Frankliniella bispinosa* (Webb *et al.* 1998), *F. intonsa* (Wijkamp *et al*. 1995), *F. fusca, F. occidentalis*, *F. schultzei, Thrips palmi, T. setosus* and *T. tabaci. T. flavus* (Singh and Krishnareddy 1996), *F. tenuicornis* (Kormelink 1994) and *Scirtothrips dorsalis* (Amin *et al.* 1981) have been reported as vectors, but their status as such has yet to be confirmed.

6.2.3 Dispersal

TSWV is liable to spread naturally with its vectors (OEPP/EPPO 1990). In international trade, it may be carried by susceptible host plants, whether pot plants or plants for planting, and will be especially liable to spread if these plants also carry vectors. Seed transmission has not been demonstrated.

6.2.4 Host range

TSWV has one of the widest host ranges of any plant virus. A list previously compiled by Peters (1998) included more than 940 species in 90 dicotylodonous and 8 monocotylodonous families of TSWV with only 100 species more listed for all tospoviruses. Capsicum, lettuce, pea, tobacco, potato, tomato, and a large number of ornamental plant species are the main hosts of TSWV.

6.2.5 Current geographic distribution

TSWV is found in Europe, Africa, Asia, North, Central and South America, Oceania including Australia (CABI 2011). TSWV is listed as an A2 quarantine pest i.e. is present in some parts of the EPPO region (EPPO 2010b).

6.2.6 Symptoms

TSWV is mainly of concern in tomatoes, capsicum and lettuce where it can cause crop losses of up to 100%. Plants infected with TSWV can show one or more symptoms of the following; irregular necrotic (dead) spots on leaves, black or purple stem streaks, chlorosis yellowing (blotching, chlorotic or necrotic ring spots and line patterns on leaves and fruits, leaf distortion and deformation, dropping of leaves or shredding of buds, dieback and leaf collapse, strips on petals or plant death caused by wilting (Broughton *et al.* 2004). The fruit may also be discoloured or abnormal shape.

Symptoms are occasionally only found on the fruits (Pavan *et al.* 1996). Some fruits of TSWV-resistant plants can show unusual ringspot symptoms caused as a response to the feeding of viruliferous thrips on the fruit during the early stages of development (de Haan *et al.* 1996; Aramburu *et al.* 2000).

6.2.7 Diagnostic information

Diagnosis may be difficult if it is based on symptoms alone. A range of diagnostic methods exist for the detection of TSWV using ELISA for plant material and real time fluorescent RT-PCR (TaqMan) for individual thrips and plant material (OEPP/EPPO 2004).

6.3 Pest details – example: Impatiens necrotic spot virus

Common names:	Impatiens necrotic spot virus (INSV)
Scientific name:	*Impatiens necrotic spot virus*
Synonyms:	Tomato spotted wilt tospovirus, impatiens strain
Taxonomic position:	Family, Bunyaviridae; Genus, Tospovirus

Within this contingency plan, this virus was chosen as an example due to its economic impact on hosts that form a significant part of the nursery and garden industry. INSV is listed as an EPPO A2 quarantine pest i.e. a pest that is present in some parts of the EPPO region and is considered a threat recommended for regulation (EPPO 2010b). An incursion of INSV occurred in Australia in 2010 in a production nursery and an eradication response was mounted to destroy infected plants, indicating that it has previously entered and become established in Australia.

6.3.1 Background

Originally considered a strain of Tomato spotted wilt virus (TSWV), INSV was later recognised as a separate species (de Ávila *et al.* 1992). The biology of INSV is very similar to that of TSWV and like TSWV, INSV is transmitted mainly by *Frankliniella occidentalis* (de Angelis *et al*. 1994). INSV causes

significant losses in many glasshouse ornamentals in Europe and the USA and is widespread in these regions. The virus was detected in New Zealand in 2003 and has since infected a range of ornamental plants (Elliot *et al.* 2009).

6.3.2 Life cycle

All tospoviruses are transmitted and spread in nature by insects of the family Thripidae (Thysanoptera), belonging to the genera *Frankliniella* and *Thrips,* see Figure 5. *Graphic representation of the thrips life cycle and the tospovirus transmission cycle (for a more detailed explanation refer to Whitfield et al. 2005).* Thrips vectors can include *Frankliniella bispinosa* (Webb *et al.* 1998), *F. intonsa* (Wijkamp *et al*. 1995), *F. fusca, F. occidentalis*, *F. schultzei, Thrips palmi, T. setosus* and *T. tabaci. T. flavus* (Singh and Krishnareddy 1996), *F. tenuicornis* (Kormelink 1994) and *Scirtothrips dorsalis* (Amin *et al.* 1981) have been reported as vectors, but their status as such has yet to be confirmed.

6.3.3 Dispersal

INSV is transmitted by adult Western flower thrips that have acquired the virus at the larval stage and so local dispersal will occur with the virus vector. The virus replicates in thrips but there is no evidence of transovarial transmission, and INSV is not transmitted congenitally or by seed. Long distance dispersal will occur through movement of nursery stock, either with plants carrying the thrips vector or through mechanical transmission to new nursery stock from infected plants introduced into new areas.

6.3.4 Host range

Hosts include the ornamental plants *Aconitum, Alstroemeria, Anemone, Antirrhinum, Asplenium, Begonia, Bouvardia, Callistephus, Chrysanthemum, Columnea, Cordyline, Cyclamen persicum, Dahlia, Dendranthema x grandiflorum, Eustoma grandiflorum, Exacum affine, Fatsia japonica, Freesia, Gerbera, Gladiolus, Impatiens, Limonium, Lobelia, Peperomia, Pittosporum, Primula, Ranunculus, Schefflera, Senecio cruentus, Sinningia speciosa, Spathiphyllum, Zantedeschia* sp. and the fern *Asplenium nidus-avis*.

Vegetable hosts include *Arachis hypogaea, Capsicum annuum, Cichorium endivia, Cucumis sativus, Lactuca sativa, Ocimum basilicum, Rubus* sp., *Solanum lycopersicum*, *Solanum tuberosum* and *Valerianella olitoria*.

6.3.5 Current geographic distribution

INSV is found in Europe, USA, Canada, Costa Rica, Chile, New Zealand, Iran, Israel, Japan and China.

6.3.6 Symptoms

Typical symptoms of INSV are necrosis on leaves, stems and flowers, stunting of plants, leaf mosaics and mottling and distortion of the plant. Symptoms vary widely depending on plant age, time of year, the strain of virus etc; thus, diagnosing the virus by visual inspection is difficult.

6.3.7 Diagnostic information

INSV can be detected by ELISA, direct tissue-blot assay, dot blot immunoassay, and direct examination of plant tissues for characteristic viral inclusions (Daughtrey *et al*. 1997), and can be distinguished from TSWV by these methods (Nagata *et al.* 1997). Standard testing kits are available from Biosense (**http://www.biosense.com/nettbutikk/display.aspx?menuid=750&prodid=5567**). Molecular diagnosis is also possible using RT-PCR (Elliot *et al*. 2009).

6.3.8 Pathogen risk ratings and potential impacts

A pest risk analysis has been carried out on this insect, taking into account the entry, establishment and spread potentials, together with the economic and environmental impact of establishment. A summary of these ratings are shown in Table 8. Based on this information, INSV is considered a **High** overall risk to Australia.

Table 8. *Pest risk ratings for Impatiens necrotic spot virus (INSV)*

Potential or impact	Rating
Entry potential	Medium
Establishment potential	High
Spread potential	High
Economic impact	High
Environmental impact	Low
Overall risk	**High**

6.3.8.1 ENTRY POTENTIAL

Rating: Medium

Australia has had a recent incursion of INSV, likely due to the virus entering on imported nursery stock. AQIS is moving to minimise the risk of entry of INVS via this pathway, however the current risk is still considered to be **Medium**.

6.3.8.2 ESTABLISHMENT POTENTIAL

Rating: High

INSV has a similar biology to Tomato Spotted Wilt Virus, which is endemic in Australia. Host plants of INSV are also widespread throughout Australia, indicating a **High** risk of establishment.

6.3.8.3 SPREAD POTENTIAL

Rating: High

Host plants and the major vector, Western flower thrips are widespread in Australia; hence, INSV has a **High** spread potential.

6.3.8.4 ECONOMIC IMPACT

Rating: High

INSV is reported to have a devastating effect on protected ornamental crops in the presence of the vector Western Flower thrips (Daughtrey *et al.* 1997), which is already present in Australia. The economic risk rating is therefore **High**.

6.3.8.5 ENVIRONMENTAL IMPACT

Rating: Low

While it is unlikely that Australian native plants will be significantly affected by INSV, the virus infects numerous amenity and landscape plants (Elliot *et al.* 2009), resulting in a **Low** environmental risk rating.

6.3.8.6 OVERALL RISK

Rating: High

Based on the individual ratings above, the combined overall risk is considered **High**.

6.4 Pest details – example: Pelargonium flower break virus

Common names:	Pelargonium flower break virus (PFBV)
Scientific name:	*Pelargonium flower break virus*
Synonyms:	n/a
Taxonomic position:	Family, Tombusviridae; Genus, Carmovirus

Within this contingency plan, this virus was chosen as an example of a Carmovirus and due to its economic impact on hosts that form a significant part of the nursery and garden industry. PFBV is listed as an EPPO A2 quarantine pest i.e. a pest that is present in some parts of the EPPO region and is considered a threat recommended for regulation (EPPO 2010b).

6.4.1 Background

Pelargonium flower break virus (PFBV) is one of the most prevalent viruses infecting geraniums (*Pelargonium* spp.) throughout the world (Adkins and Nameth 1989) and is the most common viral disease of florist's geranium (*P. x hortorum*). The virus was first reported and described in *Pelargonium zonale* in the UK (Stone and Hollings 1973). The virus does not usually kill plants but reduces growth and flower quality.

6.4.2 Life cycle

Little information is available on the life cycle of PFBV however, the virus is not known to replicate in the gut of the thrips vector in the same way that tospoviruses do. Presumably the virus replicates in live hosts. The virus remains infective after 10 minutes at 85˚C, three weeks at 20˚C or 27 weeks at

2˚C (Stone and Hollings 1973).

Krczal *et al.* (1995) showed that higher rates of transmission occurred with a combination of the thrips vector, *F. occidentalis*, and pollen taken from PFBV-infected plants compared with infected pollen alone, indicating that infected pollen and mechanical damage caused by thrips feeding increases transmission of the virus.

6.4.3 Dispersal

PFBV is mainly transmitted by vegetative propagation, mechanical inoculation, in irrigation water and by *F. occidentalis* (Krczal *et al.* 1995). Transmission by *F. occidentalis* occurs via the movement of infected pollen adhered to the thrips, which then infects through feeding wounds (Jones 2005). The virus is not transmitted by aphids or seed. International trade of floral crops is considered one of the main vehicles for introducing viruses into new countries (Diez *et al.* 1999).

6.4.4 Host range

The natural host range of PFBV is limited to geraniums (*Pelargonium* spp.).

6.4.5 Current geographic distribution

The virus is known to be present in Denmark, Germany, the Netherlands, Norway, Spain, UK and USA.

6.4.6 Symptoms

The conspicuous symptoms, when present, are a colour breaking in the flowers; specifically, white flower streaking (Stone and Hollings 1973). Chlorotic spotting of leaves and growth reduction may also be observed. However, appearance of symptoms in infected plants is strongly affected by environmental factors and many cultivars are symptomless while still providing a reservoir for the virus.

6.4.7 Diagnostic information

The concentration of the virus is typically low in pelargoniums, so propagating local lesions in experimental hosts such as *Chenopodium quinoa* or *Nicotinia clevelandii* can be used to obtain more virus sample (Stone and Hollings 1973). However, *C. quinoa* is not an ideal indicator plant because the lesions developed look similar to many other virus symptoms (Stone and Holling 1973).

PFBV isometric particles are reported to contain a single coat protein of approximately 41 kDa which encapsidates a monopartite RNA of about 4 kb (Stone and Holling 1973).

Plants are generally tested using ELISA in propagation nurseries, and this technique is reliable year-round (Bouwen and Maat 1992). A non-radioactive dot hybridisation assay has also been developed and successfully used to diagnose PFBV (Ivars *et al.* 2004). PFBV can also be detected in *Pelargonium* × *hortorum* by immunosorbent electron microscopy (ISEM) (for methods see Blystad *et al*. 1995).

For further information on standard diagnostic protocols see Appendix 1. For a list of diagnostic facilities and advisory services that can be utilised in the event of an incursion see Appendix 2.

6.4.8 Pathogen risk ratings and potential impacts

In this contingency plan, a pest risk analysis has been carried out on this insect, taking into account the entry, establishment and spread potentials, together with the economic and environmental impact of establishment. A summary of these ratings are shown in Table 9. Based on this information, PFBV is considered a Medium overall risk to Australia.

Table 9. *Pest risk ratings for Pelargonium flower break virus*

Potential or impact	Rating
Entry potential	Medium
Establishment potential	High
Spread potential	High
Economic impact	Medium
Environmental impact	Negligible
Overall risk	**Medium**

6.4.8.1 ENTRY POTENTIAL

Rating: Medium

The most likely pathway for PFBV to enter Australia are via plant material infested with adult *F. occidentalis* carrying infected pollen from countries where the virus is present (Denmark, Germany, the Netherlands, Norway, Spain, UK and USA) or through the importation of symptomless nursery stock. *F. occidentalis* is highly polyphagous, and could enter on any number of host plants. However, it is not known how long the virus would remain infective in pollen.

6.4.8.2 ESTABLISHMENT POTENTIAL

Rating: High

Pelargoniums are relatively widespread across Australia, providing hosts for both the vector and the virus hence the establishment potential if the virus entered on the vector is **High**. The establishment potential if the virus entered on symptomless nursery stock would also be **High**.

6.4.8.3 SPREAD POTENTIAL

Rating: High

Given that the vector *F. occidentalis* is widespread in Australia, as are Pelargonium host plants, the spread potential of PFBV would be **High**.

6.4.8.4 ECONOMIC IMPACT

Rating: Medium

While the incidence of PFBV is relatively high in many Western European countries (Diez *et al.* 1999), there is little information on the economic costs associated with virus outbreaks. The economic impact of PFBV on the Australian N&G industry is estimated to be **Medium**.

6.4.8.5 ENVIRONMENTAL IMPACT

Rating: Negligible

The virus has a narrow host range (*Pelargonium* spp.) so the environmental impact is likely to be **Negligible**.

6.4.8.6 OVERALL RISK

Rating: Medium

Based on the individual ratings above, the combined overall risk is considered **Medium**.

7 Pest management

7.1 Response checklist

The following checklist (Table 10) provides a summary of generic requirements to be identified and implemented within a Response Plan.

Table 10. *Checklist of requirements to be identified in a Response Plan*

Checklist item	Further information
Destruction methods for plant material, soil and disposable items	Section 8.1.1, 8.1.2
Disposal procedures	Section 8.1.5
Quarantine restrictions and movement controls	Section 8.3
Decontamination and property cleanup procedures	Section 8.5
Diagnostic protocols and laboratories	Section 5.3, 6.1.8, 6.2.7, 6.3.7, 6.4.7
Trace back and trace forward procedures	Section 8.6
Protocols for delimiting, intensive and ongoing surveillance	Section 7.2
Zoning	Section 8.4
Reporting and communication strategy	Section 7.1

For a range of specifically designed procedures for the emergency response to a pest incursion and a general communication strategy refer to PLANTPLAN (Plant Health Australia, 2010[5]). Additional information is provided by Merriman and McKirdy (2005)[6] in the Technical Guidelines for Development of Pest Specific Response Plans.

7.2 Surveys and epidemiology studies

Information provided in Sections 7.2.1 to 7.2.3 provides a framework for the development of early detection and delimiting surveys for thrips transmitted viruses.

Where thrips are found in a production nursery that is in close proximity to potential host plants, periodically inspect nearby hosts for signs of virus symptoms by examining stems, leaves and fruit. Some hosts may be asymptomatic and leaf samples may be required from all known hosts as part of a targeted survey.

Infested sources within the production nursery may provide an opportunity for thrips to spread to trees and shrubs outside the production nursery. Personnel should avoid moving infected plant material (or any *Pelargonium* spp. in the case of PFBV as symptomless plants are common) between production nurseries to limit movement of both the vector and virus infect material.

Shoes, tools and vehicle tyres should be thoroughly washed of soil and then sanitised with a registered disinfectant. Extra precaution should be taken when working in areas known to be either infected with the virus or infested with thrips vectors, including disposable overboots that may be used and disposed of on-site.

7.2.1 Technical information for planning surveys

When developing surveys for presence and/or distribution of thrips transmitted viruses, the following characteristics of the pest provide the basic biological knowledge that informs the survey strategy:

- Virus infected plant material may be asymptomatic. In the case of PFBV, many Pelargonium cultivars or individual plants are asymptomatic so visual inspection alone may not be appropriate
- Host species in Australia are likely to be numerous and widely dispersed and may be present within relevant industries, nurseries as well as home gardens, landscape plantings and weeds
- Numerous thrips vectors are already present and widespread in Australia and many thrips have wide host ranges and share many of the same hosts with that of the virus
- The risk of thrips movement on nursery stock, machinery, equipment and personal effects is high; therefore, the spread potential of the virus is high
- Virus transmission can also occur through mechanical transmission involved with plant propagation or management
- *Chenopodium quinoa*, *Nicotiana benthamiana*, *N. clevelandii* and *N. glutinosa* may be useful indicator plants for INSV

[5] Available on the PHA website (**www.planthealthaustralia.com.au/plantplan**)

[6] Available on the PHA website (**www.planthealthaustralia.com.au/go/phau/biosecurity/general-biosecurity-information**)

- Production nursery greenhouses and significant proportions of Australia have favourable climatic conditions for both virus and thrips spread and establishment

7.2.2 Surveys for early detection of an incursion in a production nursery

The survey protocol used to monitor thrips is based on the protocols developed for Western flower thrips developed by the Department of Agriculture and Food Western Australia, Department of Primary Industry New South Wales, SARDI and DEEDI to support the management of Western flower thrips.

Points to consider in effectively monitoring thrips in commercial production nurseries are:

- Thrips are small and can be difficult to see
- As the thrips (adult and larva) are small, detection is dependent on careful visual inspection, preferably supplemented by use of a hand lens magnifier
- Sticky traps, visual monitoring and vacuum samplings are methods used to monitor for thrips. Blue traps may also be used for monitoring of Western flower thrips because they can be less attractive to other non-thrips species
    - Tapping, shaking or blowing gently into flowers over a white trap is recommended when susceptible crops are flowering
    - Monitoring using stick traps can be used to search for winged adults
- The survey should consist of two parts: an initial survey using yellow sticky card traps to determine the species of thrips present and then follow up for leaf samples
    - Yellow sticky card traps will determine the presence of thrips and other insect species such as whiteflies and aphids. It is recommended that traps be placed at a density of 1 trap per 300 to 400 plants positioning the trap bottom at canopy height. The traps should remain in place for one week
    - Crop monitoring includes making routine inspection and keeping good records. Check the underside of leaves for feeding larvae and adults. Sample the plants 2 to 3 metres apart in a Z or M set pattern, after sampling 10 plants move to a new site and continue until all areas within the glasshouse have been covered. Carefully check about 1% of all plants examining for thrips and symptoms of virus disease. If thrips are detected, leaves infested with thrips (nymphs and adults if possible) should be collected for identification of the species
    - The sampling method in outdoor crops uses the same approach for the position of leaves but samples the plants 5 to 10 metres apart in a zigzag pattern, sampling 10 plants before moving to a new site and continuing until all areas of the planting have been covered. It is recommended that for plantings up to 30 hectares a sample of 100 plants will be sufficient assessment for thrips populations

Points to consider in monitoring virus infected material in commercial production nurseries are:

- The host range of the potential virus incursion must be determined and grouped into risk categories for transmission and expression of the disease (high, medium and low)

- Conditions under which transmission, amplification and expression of the disease must be determined to assess the likelihood of detection and reporting through general surveillance and to assist develop protocols for targeted surveillance
- Potential pathways for distribution of virus-infected material must be determined
- Depending on the virus, distribution of the virus in the plant may be irregular or asymptomatic and plant material that is most likely to be infected should be determined
- Depending on the virus incursion, host species in Australia are likely to be numerous and widely dispersed and may be present within relevant industries, nurseries as well as home gardens, landscape plantings and weeds
- Virologist expertise will be needed to determine diagnostic protocols and sampling requirements including the age of plant material to be sampled, time of year and the potential to bulk samples from plant species or cultivars

If an incursion of a thrips transmitted virus is to be eradicated, it must be detected early, before it has had the opportunity to disperse very far. It is therefore necessary to consider pathways and plan surveys and/or sentinel plantings accordingly. If sentinel plants are used they should be comprised of clean material (i.e. material that has been brought from a non-infected region and tested as being free of virus). Important points to consider when developing early detection surveys are:

- Awareness information should be targeted at people who are in regular close contact with potential hosts in high risk areas or movement vectors (e.g. production nursery operators)
- Systematic and careful inspection of nursery crops and propagative plant material is essential to prevent introduction of a thrips transmitted virus and limit its spread within and from contaminated nurseries. Where possible, early detection of disease symptoms while at low levels, will provide the best chance of eradication
- An inspector must be trained to recognise a particular thrips vector and the virus symptoms and other similar disorders for comparison (see Section 5.2.3). A nursery layout map that includes approximate locations of target species will be required to develop a strategy for surveys. A survey map should include species and cultivar names, locations, approximate quantity and sources of targeted plants within the area. During the survey walkthrough, record the date, observations, and sampling information directly onto the survey map. The recorded information should be reviewed and used to develop an efficient survey strategy each time the nursery is inspected

7.2.3 Delimiting surveys in the event of an incursion

- In the event of an incursion, delimiting surveys are essential to inform the decision-making process
- The size of the survey area will depend on the size of the infected area and the severity of the infection, as well as distribution pathways for plant material and potential weather patterns during the period prior to detection (Figure 7). Other considerations are for example, movement of people or plant material equipment as a result of trace-forward and trace-backs
- Thrips vectors can fly and can readily spread long distances by floating with the wind or being transported on infested plants. New introductions can pose serious threats and complicate identification of naturalised populations

- All potential host species (refer to Section 5.2) should be surveyed, with particular attention paid to the species in which the virus was initially detected
- In addition to inspection of possible host plants, material should be collected for diagnostic purposes (refer to Section 7.2.4)
- If the incursion is in a populated area, publication and distribution of information sheets and appeals for public assistance may be helpful

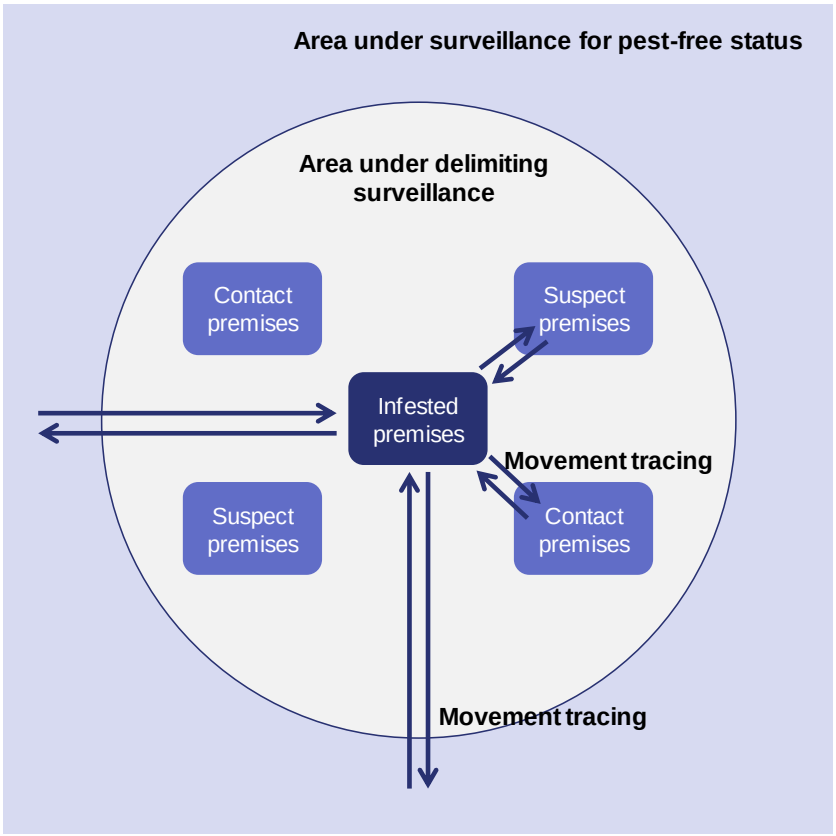


Figure 7. *Diagram of a delimiting survey showing surveillance activities from the infected premises*

7.2.4 Collection and treatment of thrips samples

Protocols for the collection, transport and diagnosis of suspect Emergency Plant Pests (EPPs) must follow PLANTPLAN (Plant Health Australia 2010). Any personnel collecting samples for assessment should notify the diagnostic laboratory prior to submitting samples to ensure expertise is available to undertake the diagnosis.

All sample containers should be clearly labelled with the name, address and contact phone number of both the sending and receiving officers. In addition containers should be clearly labelled in accordance with the requirements of PLANTPLAN (Plant Health Australia 2010). Containers should be carefully sealed to prevent loss, contamination or tampering of samples. The Chief Plant Health Manager will select the preferred laboratory. Additional labelling includes the identification of plant species/parts affected, location of nursery and affected plant within the nursery (preferably with a GPS reading) as well as symptoms and an image if available.

Refer to PLANTPLAN for packing instructions under IATA 650.

7.2.4.1 COLLECTION OF SPECIMENS

Sampling procedures

Samples can be collected on leaf samples or on yellow sticky traps (see section 7.2). The leaves should contain most thrips developmental stages.

Number of specimens to be collected

Where possible, collect multiple specimens representative of all life stages of the population available. Adult thrips are preferred, as the adult life stage is the easiest with which to confirm identification.

Record the identity of the host plant where the thrips were collected. Record the location, preferably as GPS co-ordinates, or alternatively, a map reference or distance and direction from a suitable landmark. If the land is privately owned, record the owner's details including contact telephone numbers.

How to collect and send plant samples with eggs, larvae or pupae

Leaf samples containing thrips nymphs and if possible adults are to be placed in a specimen container and placed in a portable fridge of insulated container with cool packs to prevent the insect and leaf samples from drying out.

All sample containers should be clearly labelled with the name, address and contact phone number of both the sending and receiving officers. In addition containers should be clearly labelled in accordance with the requirements of PLANTPLAN (see Appendix 3 of PLANTPLAN [Plant Health Australia 2010]). Containers should then be carefully sealed to prevent loss, contamination or tampering of samples. The Chief Plant Health Manager will select the preferred laboratory. Additional labelling includes the identification of plant species/parts affected, location of affected plant (where available include GPS reading) as well as symptoms and an image if available.

Refer to PLANTPLAN for packing instructions under IATA 650.

Precaution

Overheating or desiccation of samples prior to despatch should be prevented. Samples may be stored in a fridge (4-10°C) for a few days if necessary.

Receipt

On receipt of the samples the diagnostic laboratory should follow strict quarantine and processing guidelines. In keeping with ISO 17025 refer to PLANTPLAN (Plant Health Australia 2010).

7.2.5 Collection and treatment of virus samples

In general, plants showing virus like symptoms or suspected symptoms should be sampled. Any personnel collecting samples for assessment should notify the diagnostic laboratory prior to submitting samples to ensure expertise is available to undertake the diagnosis. General protocols for collecting and dispatching samples are available within Appendix 3 of PLANTPLAN (Plant Health Australia 2010).

Number of specimens to be collected

In general, 5-10 samples of symptomatic plants should be collected for initial identification, with a minimum of 5 symptomatic leaves from each plant (Elliot *et al.* 2009). If a survey to determine the incidence of disease within a crop or geographic area is required, then a more formalised, statistical-based sampling strategy should be employed.

It is important to record the precise location of all samples collected, preferably using GPS, or if this is not available, map references including longitude and latitude and road names should be recorded. Property and owners names should also be included where possible.

How to collect plant samples

Samples should be treated in a manner that allows them to arrive at the laboratory in a fresh, well-preserved state. An esky with ice packs or portable fridge should be carried when sampling crops.

The samples should be kept cool, out of direct sunlight and clearly labelled. Aim to keep the tissue at less than 10^{o}C. For appropriate labelling and packaging procedures for suspect emergency plant pests consult PLANTPLAN (Plant Health Australia 2010).

Sampling and collection of plant material will depend on the host and virus. Technical advice on sampling will be required for each virus if an incursion is suspected.

In general, infected plant material should be collected using scissors, with sterilisation to occur between each collection.

How to preserve plant samples

Collected material can be stored at 2-5°C. Do not expose plant samples to direct sunlight. It is important to keep the sampled plant tissue below 10°C where possible.

How to transport plant samples

Plant material should be mailed as a flat package. The samples should be either sent by a courier or by Express Post if overnight delivery to the diagnostic laboratory is guaranteed. Each laboratory has different labelling protocols and the receiving laboratory must be contacted before sending samples to ensure that these protocols are followed and that someone will be present to receive the samples. Email is not sufficient as a sole method of contact.

7.2.6 Epidemiological study

The extent of infestation in a production nursery, on a property or within a region will depend on the initial degree of virus infection (or infestation of viruliferous thrips vectors) and whether conditions have been favourable for the pest to spread from the initial location. Sampling should be based upon the origins of the initial suspect sample(s). Factors to consider will be:

- The proximity of other susceptible plants to the initial infestation source, including both current and previous crops. This will include crops in the production nursery or on the property with the initial detection and those on neighbouring properties
- Machinery or vehicles that have been into the infested area or in close proximity to the infestation source

- The extent of human movements into and around the infested area. A possible link to the recent importation of plant material from other regions should also be considered
- The source of any production nursery stock propagation material
- If any other crops have been propagated from the same source and/or distributed from the affected production nurseries
- Many vector- transmitted viruses can easily be spread by mechanical transmission in sap on contaminated machinery and equipment and also potentially be contact between plants

7.2.7 Models of spread potential

No models of spread potential have been developed for thrips transmitted viruses.

7.2.8 Pest Free Area guidelines

Determination of Pest Free Areas (PFAs) should be completed in accordance with the International Standards for Phytosanitary Measures (ISPMs) 8 and 10 (IPPC 1998a, 1999).

In the event of an incursion, specific guidelines for surveys and monitoring will be provided by the Consultative Committee on Emergency Plant Pests (CCEPP). General points to consider are:

- Design of a statistical delimiting survey for symptoms on host plants (see Section 10.2 for points to consider in the design)
- Plant sampling should be completed as described in the BioSecure HACCP manual (Nursery and Garden Industry Australia 2008), including monitoring processes (summarised in Table 11 and Table 12), indicator plants and weed monitoring
- Surveys should also consider alternative hosts and not be limited to the primary infected host.
- Information (including absence of the pest) should be recorded

Table 11. *Summary of monitoring processes for protected production areas as described in BioSecure HACCP Guidelines. Further specific guidelines may be provided by a CCEPP*

Wear protective clothing when handling suspect samples
Walk at random through the area in a zigzag pattern
Take at least 10 minutes to inspect 10-20 plants or plug trays per 100 m^2 of production area
Inspect the tops and bottoms or leaves, looking for any direct evidence of insects
Inspect the entire plant if it has less than six leaves, or from larger plants select six leaves from all parts of the plant (upper, lower, middle) and examine them individually
Inspect the length of all stems and branches for insects and symptoms
During individual plant inspection, examine the underside of the foliage for the presence of thrips
If any plants show suspect symptoms or evidence of eggs or larvae (refer to Section 5.2.3) take a sample (refer to Section 7.2) to be formally diagnosed
Check for a problem that have occurred regularly in the past, until you are certain it is not present
Record on the 'Crop Monitoring Record' sheet the presence or absence of the pest
Routinely inspect growing areas and remove alternate hosts and reservoirs of the pest, including weeds, crop residues and old plants that will not be marketed

Additional information is provided by the IPPC (1995) in Requirements for the Establishment of Pest Free Areas. This standard describes the requirements for the establishment and use of pest free areas as a risk management option for phytosanitary certification of plants and plant products. Establishment and maintenance of a PFA can vary according to the biology of the pest, pest survival potential, means of dispersal, availability of host plants, restrictions on movement of produce, as well as PFA characteristics (size, degree of isolation and ecological conditions).

Table 12. *Summary of monitoring processes for field production areas as described in BioSecure HACCP Guidelines. Further specific guidelines may be provided by a CCEPP*

Wear protective clothing when handling suspect samples
Pay particular attention to areas on the windward side, the sides bordering ditches, canals or other uncultivated areas and growing block centres
Place a flag or other marker at the entrance to the block or sampling area at the beginning of each inspection
Vary the entrance point in the sampling area (1 m to 3 m) for each subsequent sampling so that the same plants are not inspected each time
Walk at random through the area in a zigzag pattern
The scout should follow the same general pattern at each sampling
Make an effort to select those plants that appear less healthy for visual inspection
Take at least 10 minutes to inspect 10-20 plants or plug trays per 100 m^2 of production area
Inspect the tops and bottoms or leaves, looking for any direct evidence of insects
Inspect the entire plant if it has less than six leaves, or from larger plants select six leaves from all parts of the plant (upper, lower, middle) and examine them individually
Inspect the length of all stems and branches for insects and symptoms
During individual plant inspection, strike the foliage over a white sheet of paper, or a plastic or paper plate to dislodge small insects for easier viewing
If any plants show suspect symptoms or evidence of eggs or larvae take a sample (refer to Section 7.2) to be formally diagnosed
Check for a problem that have occurred regularly in the past, until you are certain it is not present
Record on the 'Crop Monitoring Record' sheet the presence or absence of the pest
Routinely inspect growing areas and remove alternate hosts and reservoirs of the pest, including weeds, crop residues and old plants that will not be marketed

7.3 Availability of control methods

7.3.1 General procedures for control

Control of thrips transmitted viruses is likely to be largely reliant on control measures for the thrips vectors however measures can also be taken to minimise the spread of virus-infected nursery stock. Specific control measures will be determined by a CCEPP however general procedures include:

- Keep traffic out of affected areas and minimise movement in adjacent areas
- Adopt best-practice property hygiene procedures to retard the spread of the pest between fields and adjacent properties
- After surveys are completed, and permission has been obtained from the Chief Plant Health Manager or OCPPO, destruction of the infested plant material is an effective control
- On-going surveillance of infected areas to ensure the virus is eradicated
- Do not use any material from infected plants for propagation

For general management (i.e. not eradication), controlling thrips populations before they reach large numbers in crops is very important and requires close monitoring of thrips populations early in the

season. If the adults occur in large numbers it becomes difficult to control the nymphal stages. Adults move between successive crops, so management approaches must be employed in all crops within the area.

To reduce early season populations, best management practices require consideration of several management approaches including the use of pest-free seedlings, weed management, chemical control and cleaning up of crop residue.

It should be recognised that it will be extremely difficult for effective eradication of thrips populations and this will in turn limit the ability to eliminate all transmission of a thrips transmitted virus.

7.3.2 Pest free (clean) seedlings

Seedlings are potentially a major means of spreading thrips and thrips transmitted viruses into new plantings. Young plants are more susceptible to damage from thrips, so early infestations need to be avoided. Clean seedlings can be the first line of protection against the development of damaging populations.

Growers should check their suppliers to determine how the seedlings are grown and what measures are being used to protect against thrips infestation. Inspect transplants carefully upon arrival for thrips eggs, nymphs and adults.

7.3.3 Weed management

The availability of a continuous source of hosts, whether they are crops, weeds or abandoned crops, can be a major contributing factor to a severe thrips problem. Even a small area of a favoured host can maintain a significant thrips population.

Minimising thrips hosts is important in reducing the base population at the start of the cropping season. A smaller base population then will delay the time it takes for thrips numbers to reach significant levels, reducing the number of sprays needed to control thrips populations.

Common weed species that carry high numbers of thrips include amaranth, cape weed, pigweed, mallows, blue heliotrope, fat hen, purple top, shepherd's purse, nightshades, scotch thistle and sow thistle. Control these weed species in farming areas and seedling nurseries to minimise a build-up in thrips populations.

7.3.4 Chemical control

Chemical control of viruses is not an option, but chemicals may be effective in trying to eliminate thrips vectors in an eradication campaign, or in the management of the thrips vectors should eradication be deemed unfeasible. In the event of an incursion of an exotic thrips transmitted virus, several chemicals are currently registered for the control of thrips in Australia. As the major vectors of thrips transmitted viruses (*F. occidentalis, F. schultzei, T. tabaci, T. palmi*) are present in Australia, chemicals are available for their control.

For long term management, the use of chemical recommendations currently available for the control of thrips in production systems is recommended until further research is undertaken. For example, the use of seedling drenches to prevent infection in nursery seedlings prior to transplanting has shown promise for minimising the impact and spread of TSWV by the thrips vectors (Persley *et al.* 2006).

Insecticide applications that target Western flower thrips can reduce populations and reduce the within-crop transmission of tospoviruses e.g. TSWV (NSW DPI 2007). As Western flower thrips is effective at developing resistance to chemicals used for their control, it is important to strictly adhere to the recommended resistance strategy (Herron *et al*. 2007). Often the first sign that Western flower thrips are present in a crop is the failure of the insecticide to control other thrips species.

In the event of an incursion of a thrips transmitted virus, several chemicals as listed on Infopest, are currently registered for the control of thrips in Australia (Table 13).

All insecticides listed above are registered for use in Australia against other insect pests by the Australian Pesticides & Veterinary Medicines Authority (APVMA, PO Box E240, Kingston, ACT 2604; ph. 02 6272 5158; **www.apvma.gov.au**). If thrips transmitted viruses were detected in Australia, an additional permit may be required to enable the use of these chemicals for its management and/or destruction. Additional permits would be required from the Civil Aviation Safety Authority (CASA, phone 131 757, **www.casa.gov.au**) if it was intended the pesticide be aerially applied.

7.3.5 Integrated pest management (IPM)

IPM is a strategy that uses a range of management tools with a goal of using the least ecologically disruptive techniques to manage pests to within economically acceptable levels.

If eradication is not feasible, IPM appears to offer the best option for controlling thrips infestations without causing contamination of the environment in the long term. Beneficial insects are used alongside chemicals that offer a high level of selectivity, such as insect growth regulators. If crops or cultivars of a crop that offer resistance to the virus become available, these should also be incorporated into an IPM system.

If Western flower thrips numbers are high enough to be causing physical damage at vulnerable stages or a virus is present, then insecticide sprays may be needed. Always use recommended rates, adhere to the resistance management strategy and apply sprays to maximise spray coverage.

Table 13. *Registered chemicals and chemical use permits for the control of thrips in crops (from Infopest 2011)*

Chemical group	Active ingredient	APVMA Permit	Use
	abamectin 18 g L^{-1}	10491	Melon thrips in ornamentals
	acephate 750-970 g kg^{-1}	12378	Western flower thrips in ornamentals, tomatoes and peppers
	aldicarb 150 g kg^{-1}	11105	Garlic seed production crops
	alpha-cypermethrin 100 g L^{-1}	9355	Thrips in silverbeet and spinach
	chlorfenapyr 360 g L^{-1}	11508	Western flower thrips in spring onions and shallots
	chlorpyrifos 500 g kg^{-1}	10700	Bananas
	diazinon 800 g L^{-1}	11119	Onion thrips in onions
		10882	Thrips in spring onions and shallots
	Imidacloprid 200 g L^{-1}	10497	Thrips in Brassica leafy vegetables
	lambda-cypermethrin 250 g L^{-1}	10714	Onion thrips in bulb onions
	maldison 500 g L^{-1}	8762	Onion thrips in spring onions, shallots and leek
	methamidophos 580 g L^{-1}	10416	Western flower thrips in lettuce
	methidathion 400 g L^{-1}	10265	Thrips in ornamentals, peppers, tomatoes and eggplant
	methomyl 225 g L^{-1}	6914	Western flower thrips in shallots and spring onions
	Methyl bromide	12389	Post-harvest fumigation
		11092	Post-harvest fumigation
		10699	Post-harvest fumigation
		10695	Post-harvest fumigation
		10145	Fruit and fruiting vegetables
	phorate100 g kg^{-1}	9895	Thrips in leeks
	spinosad	10596	Western flower thrips in spring onion and shallots

Chemical group	Active ingredient	APVMA Permit	Use
		5815	Melon thrips in eggplant
	spirotetramat 240 g L^{-1}	11839	Sorghum and maize seed crops
	tau-fluvalinate 240 g L^{-1}	11821	Stone fruit

7.3.6 Clean-up crop residues

For control of thrips, movement of adults from older crops and crop residues is the main source of local infestation for younger crops. Post-harvest destruction of heavily infested crops often causes mass migration of thrips into adjacent crops. Therefore it is important to control thrips before they move into young crops.

Clean-up strategies for thrips infested crops/crop residues:

- For moderate thrips infestations, use an insecticide effective against adults
- Use high spray volumes for better coverage as defined on the label
- Re-entry/withholding periods still apply. Entry into crops should be avoided and produce should not be taken from the fields for consumption. Crop residues should not be fed to livestock
- Residues should be deep-buried or contained (sealed plastic bags) and disposed of via incineration

Clean-up of virus-infected plant material could include:

- Spraying of host material (including newly emerging plants) with herbicide to kill the plants *in situ,* followed by disposal of plant material by deep burial
- Break down of larger volumes of plant material under black plastic prior to deep burial (methodology to be confirmed by a CCEPP)
- Burning of plant material providing
    - Material is sufficiently dry to burn
    - Thrips populations have been controlled/eliminated to ensure they are not distributed in rising thermals or surrounding areas by burning
- Decontamination of all items in contact with decomposing plant material with a 1% a.i. sodium hypochlorite solution or by deep burial
- Keeping infested area free of hosts for a minimum of 12 months (or a period to be determined by a CCEPP)

7.3.7 Cultural Control

In an eradication campaign, preventing the movement of infected plant material and viruliferous thrips vectors is crucial. Destruction of all host crops (including weeds) in the control zone may be required. For PFBV, where the virus is predominantly spread through vegetative propagation, destruction of all Pelargonium propagation material in the control zone may be required because many plants will be symptomless.

If the exotic virus cannot be eradicated, then management should focus on the use of virus-free planting material and the use of screens (mesh size < 135 µm) to prevent entry of thrips into glasshouses and placing new plants in separate glasshouse compartments.

Crops are most susceptible to tospoviruses as seedlings; hence, raising seedlings away from production areas and preferably in thrips-proof netting (Jones 2005) will be beneficial. Controlling weed hosts of thrips vectors can also aid in preventing a large build-up of vectors. In the case of

PFBV, hygiene practices such as the use of sterilised/clean equipment and maintaining clean irrigation water will be essential for minimising the impact of the virus.

7.3.8 Host-Plant Resistance

In the case of tospoviruses, host plant resistance may provide some benefits but is unlikely to be the sole method of control. Experience with TSWV suggests that while some breeding programs around the world are actively pursuing resistant cultivars of some crops, there is a limited amount of resistant germplasm among many major hosts and the resistant genes are not particularly durable (summarised in Persley *et al.* 2006).

However, transgenic approaches to breeding resistance may prove useful: Yeh *et al*. (2005) recently showed broad spectrum resistance to tospoviruses in transgenic tobacco carrying the conserved region of the L protein of WSMoV. Similarly, expression of the PFBV coat protein in geranium confers some resistance to the carmovirus PFBV (Berthomé *et al.* 2000).

7.3.9 Biological control

Natural enemies have been investigated and biological control programs using predatory mites and other beneficial insects have been developed. They have been shown to be effective if environmental thrips pressure is not too great.

The predators *Typhlodromips montdorensis* and *Neoseiulus cucumeris* have controlled thrips in protected environments and are effective when applied early in the growing season at the first sign of thrips (**http://www.sardi.sa.gov.au/pestsdiseases/horticulture/horticultural_pests/integrated_pest_management/resources/greenhouse_pests/western_flower_thrips**).

Entomopathogenic (insect infecting) fungi have also been shown to be effective against thrips and some other sap sucking insects.

7.3.10 Managing viruses

The two key points in managing the spread of thrips transmitted viruses are to:

- Prevent the movement of infected host plants, seedlings and thrips-infected plants
- Control thrips on-farm, in surrounding vegetation and in seedling nurseries using good farm management and farm hygiene practices
- For viruses that are spread mechanically, minimise handling during the growing season to reduce the mechanical spread (eg, TEV (AVRDC 2005))
- Use virus free nursery stock

7.4 Phytosanitary Measures

A number of thrips transmitted viruses have been added to the EPPO A1 or A2 quarantine lists (EPPO 2010 a and b), including INSV and CSNV.

8 Course of action

Additional information is provided by the IPPC (1998b) in Guidelines for Pest Eradication Programmes. This standard describes the components of a pest eradication programme which can lead to the establishment or re-establishment of pest absence in an area. A pest eradication programme may be developed as an emergency measure to prevent establishment and/or spread of a pest following its recent entry (re-establish a pest free area) or a measure to eliminate an established pest (establish a pest free area). The eradication process involves three main activities: surveillance, containment, and treatment and/or control measures.

8.1 Destruction strategy

8.1.1 Destruction protocols

- General protocols:
    - No plant material should be removed from the infested area unless part of the disposal procedure
    - Disposable equipment, infested plant material or growing media/soil should be disposed of by autoclaving, high temperature incineration or deep burial
    - Any equipment removed from the site for disposal should be double-bagged
    - Machinery used in destruction processes need to be thoroughly washed, preferably using a detergent or farm degreaser

8.1.2 Decontamination protocols

Machinery, equipment and vehicles in contact with infested plant material or growing media/soil, or present within the Quarantine Area, should be washed to remove plant material and growing media/soil using high pressure water or scrubbing with products such as a degreaser or a bleach solution (1% available chlorine) in a designated wash down area. When using high pressure water, care should be taken not to spread plant material. High pressure water should be used in wash down areas which meet the following guidelines:

- Located away from crops or sensitive vegetation
- Readily accessible with clear signage
- Access to fresh water and power
- Mud free, including entry and exit points (e.g. gravel, concrete or rubber matting)
- Gently sloped to drain effluent away
- Effluent must not enter water courses or water bodies
- Allow adequate space to move larger vehicles
- Away from hazards such as power lines
- Waste water, growing media/soil or plant residues should be contained (see Appendix 18 of PLANTPLAN [Plant Health Australia 2010])

- Disposable overalls and rubber boots should be worn when handling infested plant material or growing media/soil in the field. Boots, clothes and shoes in contact with infested plant material or growing media/soil should be disinfected at the site or double-bagged to remove for cleaning
- Skin and hair in contact with infested plant material or growing media/soil should be washed

Procedures for the sterilisation of plant containers and growing media are provided within the BioSecure HACCP Guidelines, however, in the event of a thrips transmitted virus incursion, additional or modified procedures may be required for the destruction of the pest. Any sterilisation procedure must be approved for use in the endorsed Response Plan.

8.1.3 Priorities

- Confirm the presence of the pest
- Limit movement or people and prevent movement of vehicles and equipment through affected areas
- Stop the movement of any plant material that may be infested with the pest
- Determine the strategy for the eradication/decontamination of the pest and infested host material
- Determine the extent of infestation through survey and plant material trace back and trace forward which would be assessed on a case by case basis and included within the response plan

8.1.4 Plants, by-products and waste processing

- Any growing media/soil or infected plant material removed from the infected site should be destroyed by (enclosed) high temperature incineration, autoclaving or deep burial
- As some thrips transmitted viruses are easily spread and can be mechanically transmitted in sap, plant debris from the destruction zone must be carefully handled and transported
- Infected areas (and areas infested with the vectors) or production nursery property should remain free of susceptible host plants until the area has been shown to be free from the virus

8.1.5 Disposal issues

- Particular care must be taken to minimise the transfer of infected plant material from the area
- Host material including leaf litter should be collected and incinerated or double bagged and deep buried in an approved site

8.2 Containment strategies

For some exotic pest incursions where eradication is considered impractical, containment of the pest may be attempted to prevent or slow its spread and to limit its impact on other parts of the state or country. Containment is currently being considered for inclusion within the Emergency Plant Pest

Response Deed (EPPRD). The decision on whether to eradicate or contain the pest will be made by the National Management Group, based on scientific and economic advice. Emergency interim containment measures are possible under EPPRD arrangements to gather information to determine if eradication is technically feasible.

8.3 Quarantine and movement controls

Consult PLANTPLAN (Plant Health Australia 2010) for administrative details and procedures.

8.3.1 Quarantine priorities

- Plant material and growing media/soil at the site of infestation to be subject to movement restrictions
- Machinery, equipment, vehicles and disposable equipment in contact with infested plant material or growing media/soil, or present in close proximity to the site of infestation to be subject to movement restrictions

8.3.2 Movement controls

Movement controls need to be put in place to minimise the potential for transport of the pest, and this will apply to all plant material, growing media and other items within the quarantined area.

Movement of people, vehicles, equipment and plant material, from and to affected properties or areas, must be controlled to ensure that the pest is not moved off-property. Movement controls can be achieved through the following; however specific measures must be endorsed in the Response Plan:

- Signage to indicate quarantine area and restricted movement into and within these zones
- Fenced, barricaded or locked entry to quarantine areas
- Movement of equipment, machinery, plant material or growing media/soil by permit only. Therefore, all non-essential operations in the area or on the property should cease
- Where no dwellings are located within these areas, strong movement controls should be enforced
- Where dwellings and places of business are included within the Restricted and Control Areas movement restrictions are more difficult to enforce, however limitation of contact with infested plants should be enforced
- If a production nursery is situated within the Restricted Area, all trading in host and no-host material must cease and no material should be removed from the site without permission, due to the high likelihood of pest spread. Movement restrictions would be imposed on both host and non-host material
- Residents should be advised on measures to minimise the inadvertent transport of thrips vectors from the infected area to unaffected areas
- Clothing and footwear worn at the infested site should either be double-bagged prior to removal for decontamination or should not leave the site until thoroughly disinfected, washed and cleaned

- Plant material or plant products must not be removed from the site unless part of an approved disposal procedure
- All machinery and equipment should be thoroughly cleaned down with a high pressure cleaner (see Section 8.1.2) or scrubbing with products such as a farm degreaser or a 1% bleach (available chlorine) solution, prior to leaving the affected area. Machinery should be inspected for the presence of insects and if found, treatment with insecticide may be required. The clean down procedure should be carried out on a hard surface, preferably a designated wash-down area, to avoid mud being re-collected from the affected site onto the machine. When using high pressure water, care should be taken to contain all plant material and mud dislodged during the cleaning process

8.4 Zoning

The size of each quarantine area will be determined by a number of factors, including the location of the incursion, biology of the pest, climatic conditions and the proximity of the infested property to other infested properties. This will be determined by the National Management Group during the production of the Response Plan. Further information on quarantine zones in an Emergency Plant Pest (EPP) incursion can be found in Appendix 10 of PLANTPLAN (Plant Health Australia, 2010). These zones are outlined below and in Figure 8.

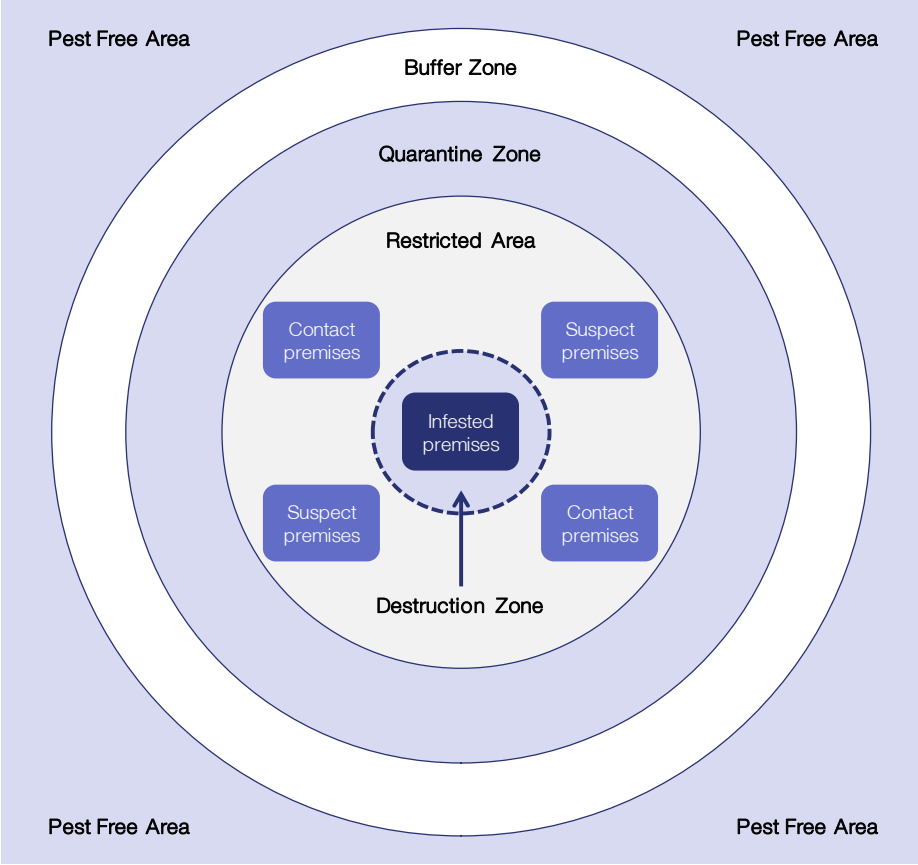


Figure 8. *Schematic diagram of quarantine zones used during an EPP incursion (not drawn to scale)*

8.4.1 Destruction Zone

The size of the destruction zone (i.e. zone in which the pest and all host material is destroyed) will depend on the ability of the pest to spread, distribution of the pest (as determined by delimiting surveys), time of season (and part of the pest life cycle being targeted) and factors which may contribute to the pest spreading.

All host plants should be destroyed after the level of infestation has been established. The delimiting survey will determine whether or not neighbouring plants are infested and need to be destroyed. Non-host plant material within this zone may be destroyed, based on recommendations in the Response Plan. The Destruction Zone may be defined as contiguous areas associated with the same management practices as, or in contact with, the infested area (i.e. the entire production nursery, property or area if spread could have occurred prior to the infection being identified).

Particular care needs to be taken to ensure that plant material (including non-hosts) is not moved into surrounding areas.

8.4.2 Quarantine Zone

The Quarantine Zone is defined as the area where voluntary or compulsory restraints are in place for the affected property or properties. These restraints may include restrictions or movement control for removal of plants, people, growing media/soil or contaminated equipment from an infected property.

8.4.3 Buffer Zone

A Buffer Zone may or may not be required depending on the incident. It is defined as the area in which the pest does not occur but where movement controls or restrictions for removal of plants, people, soil or equipment from this area are still deemed necessary. The Buffer Zone may enclose an infested area (and is therefore part of the Control Area) or may be adjacent to an infested area.

8.4.4 Restricted Area

The Restricted Area is defined as the zone immediately around the infected premises and suspected infected premises. The Restricted Area is established following initial surveys that confirm the presence of the pest. The Restricted Area will be subject to intense surveillance and movement control with movement out of the Restricted Area to be prohibited and movement into the Restricted Area to occur by permit only. Multiple Restricted Areas may be required within a Control Area.

8.4.5 Control Area

The Control Area is defined as all areas affected within the incursion. The Control Area comprises the Restricted Area, all infected premises and all suspected infected premises and will be defined as the minimum area necessary to prevent spread of the pest from the Quarantine Zone. The Control Area will also be used to regulate movement of all susceptible plant species to allow trace back, trace forward and epidemiological studies to be completed.

8.5 Decontamination and farm clean up

Decontaminant practices are aimed at eliminating the pathogen thus preventing its spread to other areas.

8.5.1 Decontamination procedures

General guidelines for decontamination and clean up:

- Refer to PLANTPLAN (Plant Health Australia 2010) for further information
- Keep traffic out of affected area and minimise it in adjacent areas
- Adopt best-practice property hygiene procedures to retard the spread of the pest between growing areas/fields and adjacent properties
- Machinery, equipment, vehicles in contact with infested plant material or growing media/soil present within the Quarantine Zone, should be washed to remove growing media/soil and plant material using high pressure water or scrubbing with products such as a degreaser or a bleach solution in a designated wash down area as described in Section 8.1.2
- Only recommended materials are to be used when conducting decontamination procedures, and should be applied according to the product label
- Infected or vector-infested plant material should be disposed of by autoclaving, high temperature (enclosed) incineration or deep burial

8.5.2 General safety precautions

For any chemicals used in the decontamination, follow all safety procedures listed within each MSDS.

8.6 Surveillance and tracing

8.6.1 Surveillance

Detection and delimiting surveys are required to delimit the extent of the outbreak, ensuring areas free of the pest retain market access and appropriate quarantine zones are established.

Initial surveillance priorities include the following:

- Surveying all host growing properties and businesses in the pest quarantine area
- Surveying all properties and businesses identified in trace-forward or trace-back analysis as being at risk
- Surveying all host growing properties and businesses that are reliant on trade with interstate or international markets which may be sensitive to pathogen presence
- Surveying production nurseries selling at risk host plants
- Surveying other host growing properties and backyards

8.6.2 Survey regions

Establish survey regions around the surveillance priorities identified above. These regions will be generated based on the zoning requirements (see Section 8.4), and prioritised based on their potential likelihood to currently have or receive an incursion of this pest. Surveillance activities within these regions will either allow for the area to be declared pest free and maintain market access requirements or establish the impact and spread of the incursion to allow for effective control and containment measures to be carried out. Detailed information regarding surveys for thrips transmitted viruses have been outlined elsewhere in this plan (refer to Section 7.2).

Steps outlined in Table 14 form a basis for a survey plan. Although categorised in stages, some stages may be undertaken concurrently based on available skill sets, resources and priorities.

Table 14. *Phases to be covered in a survey plan*

Phase 1	Identify properties that fall within the buffer zone around the infested premise Complete preliminary surveillance to determine ownership, property details, production dynamics and tracings information (this may be an ongoing action)
Phase 2	Preliminary survey of host crops in properties in buffer zone establishing points of pest detection
Phase 3	Surveillance of an intensive nature, to support control and containment activities around points of pest detection
Phase 4	Surveillance of contact premises. A contact premise is a property containing susceptible host plants, which are known to have been in direct or indirect contact with an infested premises or infected plants. Contact premises may be determined through tracking movement of materials from the property that may provide a viable pathway for spread of the disease. Pathways to be considered are: • Movement of plant material and growing media/soil from controlled and restricted areas • Items of equipment and machinery which have been shared between properties including bins, containers, irrigation lines, vehicles and equipment • The producer and retailer of infected material if this is suspected to be the source of the outbreak • Labour and other personnel that have moved from infected, contact and suspect premises to unaffected properties (other growers, tradesmen, visitors, salesmen, crop scouts, harvesters and possibly beekeepers) • Storm and rain events and the direction of prevailing winds that result in air-borne dispersal of the pathogen during these weather events
Phase 5	Surveillance of production and greenlife retailers, including garden centres, hardware outlets and supermarkets, as well as gardens and public land where plants known to be hosts of pathogen are being grown
Phase 6	Agreed area freedom maintenance, post control and containment

8.6.3 Post-eradication surveillance

The period of pest freedom sufficient to indicate that eradication of the pest has been achieved will be determined by a number of factors, including growth conditions, the previous level of infection, the control measures applied and the pest biology.

Specific methods to confirm eradication of thrips transmitted viruses may include:

- Monitoring of sentinel plants. In the case of CSNV, it may be necessary to use *Datura stramonium* as an indicator plant to differentiate symptoms of CSNV from other viruses (such

as TSWV, which is widespread in Australia), because only CSNV causes stem necrosis after mechanical inoculation (Verhoeven *et al.* 1996).

- Sentinel plants are to be grown in containers or small plots at the affected site. Plants are to be grown *in situ* under quarantine conditions and monitored for symptoms of infection
- If symptoms are detected, samples are to be collected and stored and plants destroyed
- Surveys comprising host plant sampling for the virus should be undertaken for a minimum of three years after eradication has been achieved (or as endorsed by a CCEPP)
- Alternate non-host crops should be grown on the site and any self-sown plants sprayed out with a selective herbicide

9 Technical debrief and analysis for stand down

Refer to PLANTPLAN (Plant Health Australia 2010) for further details

The emergency response is considered to be ended when either:

- Eradication has been deemed successful by the lead agency, with agreement by the Consultative Committee on Emergency Plant Pests and the Domestic Quarantine and Market Access Working Group
- Eradication has been deemed impractical and procedures for long-term management of the disease risk have been implemented

A final report should be completed by the lead agency and the handling of the incident reviewed.

Eradication will be deemed impractical if, at any stage, the results of the delimiting surveys lead to a decision to move to containment/control.

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11 Appendices

11.1 Appendix 1: Standard diagnostic protocols

For a range of specifically designed procedures for the emergency response to a pest incursion refer to Plant Health Australia's PLANTPLAN (**www.planthealthaustralia.com.au/plantplan**).

11.2 Appendix 2: Resources and facilities

Table 15 provides a list of diagnostic facilities for use in professional diagnosis and advisory services in the case of an incursion.

Table 15. *Diagnostic service facilities in Australia*

Facility	State	Details
DPI Victoria – Knoxfield Centre	Vic	621 Burwood Highway Knoxfield VIC 3684 Ph: (03) 9210 9222; Fax: (03) 9800 3521
DPI Victoria – Horsham Centre	Vic	Natimuk Rd Horsham VIC 3400 Ph: (03) 5362 2111; Fax: (03) 5362 2187
DPI New South Wales – Elizabeth Macarthur Agricultural Institute	NSW	Woodbridge Road Menangle NSW 2568 PMB 8 Camden NSW 2570 Ph: (02) 4640 6327; Fax: (02) 4640 6428
DPI New South Wales – Tamworth Agricultural Institute	NSW	4 Marsden Park Road Calala NSW 2340 Ph: (02) 6763 1100; Fax: (02) 6763 1222
DPI New South Wales – Wagga Wagga Agricultural Institute	NSW	PMB Wagga Wagga NSW 2650 Ph: (02) 6938 1999; Fax: (02) 6938 1809
SARDI Plant Research Centre – Waite Main Building, Waite Research Precinct	SA	Hartley Grove Urrbrae SA 5064 Ph: (08) 8303 9400; Fax: (08) 8303 9403
Grow Help Australia	QLD	Entomology Building 80 Meiers Road Indooroopilly QLD 4068 Ph: (07) 3896 9668; Fax: (07) 3896 9446
Department of Agriculture and Food, Western Australia (AGWEST) Plant Laboratories	WA	3 Baron-Hay Court South Perth WA 6151 Ph: (08) 9368 3721; Fax: (08) 9474 2658

11.3 Appendix 3: Market access impacts

Within the AQIS PHYTO database (**www.aqis.gov.au/phyto**) export of some material may require an additional declaration regarding freedom from the virus. Should Thrips transmitted viruses be detected or become established in Australia, some countries may require specific declaration. Latest information can be found within PHYTO, using an Advanced search “Search all text” for the particular virus.