COOPERATIVE RESEARCH CENTRE FOR TROPICAL PLANT PROTECTION

THRIPS AND TOSPOVIRUS

A MANAGEMENT GUIDE

Cooperative Research Centre for Tropical Plant Protection
Queensland Government Department of Primary Industries and Fisheries
HAL Know-how for Horticulture™
AUSVEG
Bowen Crop Monitoring Services Pty Ltd
Crop Tech

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Further Information

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Front Cover Photo: Major crop loss from TSWV in a tomato crop

Back Cover Photo Right: CaCV on Hoya *(wax flower)*

Back Cover Photo Left: CaCV on tomato fruit

Contents

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Summary

Thrips

- *Minute, slender insects less than 2 mm long.*
- *Most thrips feed on flowers and leaves of plants using piercing and sucking mouthparts.*
- *Adults fly and are also easily dispersed by wind.*
- *About 100 thrips species are major pests of crop plants.*
- *Pest species widely dispersed with movement of flowers and horticultural produce.*

Thrips as virus vectors (carriers)

- *All tospoviruses are transmitted by thrips.*
- *Worldwide, about 15 thrips species are known vectors.*
- *Four vector species occur in Australia:*
  - *Western flower thrips*
  - *Tomato thrips*
  - *Melon thrips*
  - *Onion thrips*

Tomato spotted wilt virus

- *Occurs throughout Australia.*
- *Very wide host range among crop, weed and ornamental plants.*
- *Major crop hosts are capsicum, tomato, lettuce, potato, peanut.*
- *Transmitted by all four vector thrips species present in Australia.*

Capsicum chlorosis virus

- *First found in Australia in 1999.*
- *Infects capsicum, tomato, peanut and some weeds, notably Ageratum (billygoat weed).*
- *Transmitted by tomato thrips and melon thrips*

Iris yellow spot virus

- *Found on onion and leek in Australia.*
- *Transmitted by onion thrips.*
- *Serious damage to seed crops through death of flower stalk*

Control

- *Control weed hosts of viruses and thrips*
- *Destroy old crops before planting new crops*
- *Plant healthy transplants*
- *Monitor thrips populations and control insects*
- *Use virus resistant varieties*

Introduction

The aim of this booklet is to provide concise information on the biology of both tospoviruses and their thrips vectors. This information is then related to the range of integrated methods that may be used to reduce the damage from both insect and virus.

Pest species of thrips have become increasingly damaging in fruit, vegetable and ornamental crops throughout the world over the last decade or so. Reasons for this include the incursion of new species into new countries or major production areas, the intensification of crop production and the capacity of thrips to rapidly develop resistance to insecticides.

The ability of several thrips pest species to transmit the tospoviruses or the tomato spotted wilt group of plant viruses has seen a marked increase in the importance of these viruses in world agriculture, to the extent that tospoviruses are now among the most damaging of plant pathogens worldwide.

Australia has not escaped the effects of this formidable thrips– virus combination with, for example, western flower thrips and melon thrips causing serious losses in many crops in recent years and outbreaks of tomato spotted wilt and other tospoviruses causing major crop losses in several States.

Biology of thrips

Adult (bottom right) and larval stages of a thrip

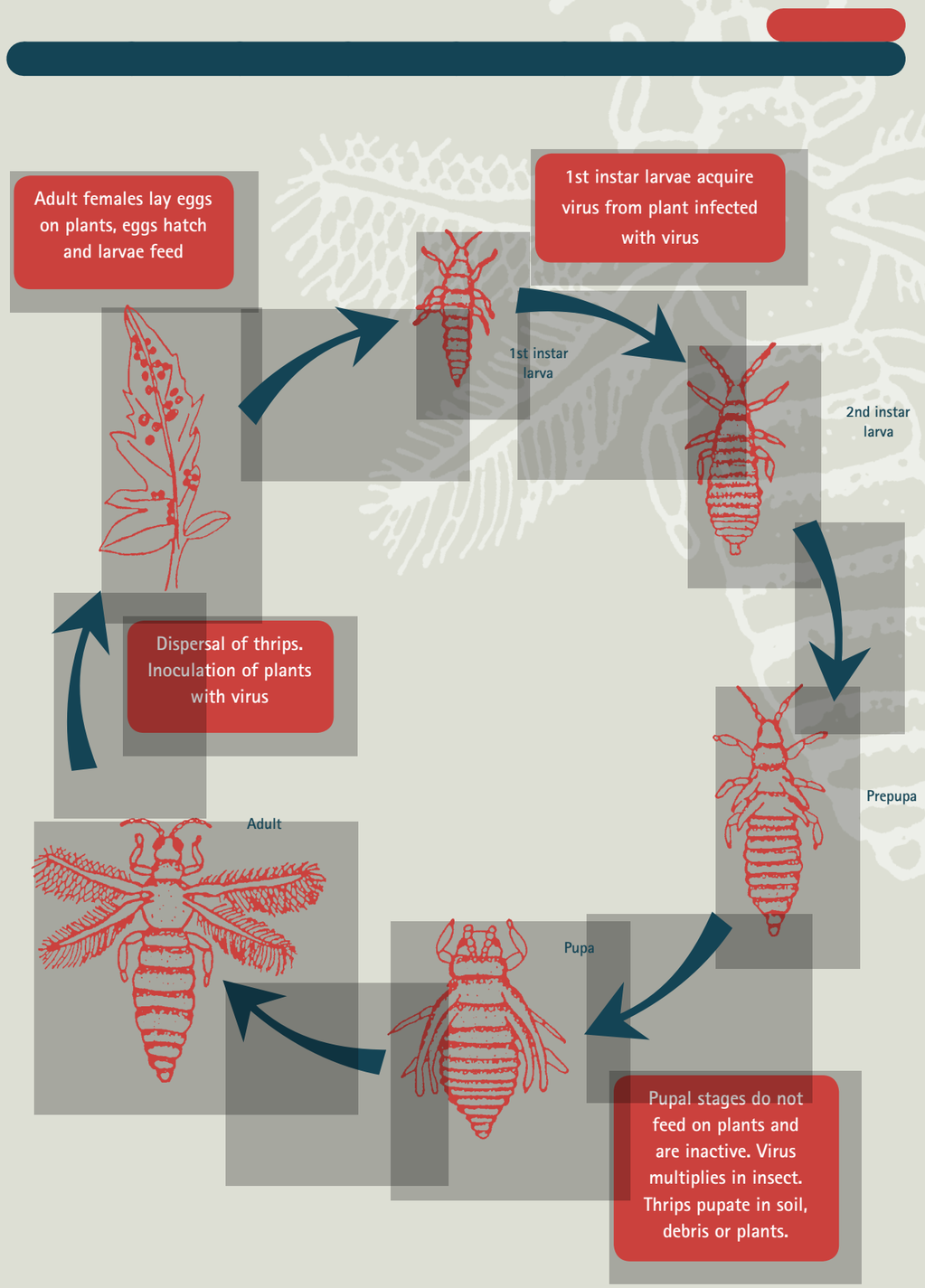
Thrips belong to the insect order Thysanoptera. They are small, slender insects, mostly 0.5 to 2 mm in length. The adults of most species have band-like wings with a wide marginal hair fringe.

There are over 5 000 known species of thrips and they occupy diverse habitats in all climatic zones. Most species feed on fungi or plants. Those that feed on plants use their piercing and sucking mouthparts to pierce plant cells and then suck out the cell contents.

The life cycle of plant feeding thrips is illustrated in Figure1. Adult female thrips lay eggs into leaves or flowers. The eggs hatch into an active, feeding juvenile or larval stage. There are two larval stages, which look like small, wingless adults, followed by two inactive, non-feeding pupal stages found on the ground or on plants. Winged adults then emerge and can live from 28 to 90 days. The length of the life cycle depends on temperature and the quality of the food source. For example, at 30°c the life cycle of western flower thrips will typically be completed in approximately 12 days while at 20°c the cycle extends to about 19 days.

Fewer than 100 thrips species are important pest species of economic plants. Some examples from Australia are provided in Table 1. These insects can cause serious damage to flowers, foliage and fruit when feeding. A small number of these pest species, currently less than 20, also have the ability to transmit viruses in the tospovirus group of plant viruses.

In Australia, the four thrips species which are able to transmit tospoviruses are western flower thrips, tomato thrips, melon thrips and onion thrips. Specific information on each follows.



Western flower thrips (WFT)
(*Frankliniella occidentalis*).

This species has its origin in the western USA and has now spread, largely through international trade, to many countries in both the northern and southern hemispheres. The species was first found in Australia in 1993 and is now present in all Australian States. The thrips damages plants by feeding on flowers and new plant growth including buds and young leaves. It has a wide range of host plants encompassing species used as ornamentals and for cut flowers, fruit crops and vegetables. Important host plants in Australia include carnation, chrysanthemum, gerbera, the vegetable crops capsicum, tomato, beans, lettuce and fruit crops including apple and strawberry.

Table 1

Some important pest thrips in Australia

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.
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.

Tomato thrips
(*Frankliniella schultzei*)

Originates from South America and is now found throughout Africa, Asia, the Caribbean, Australia and Pacific areas. It has a wide range of hosts and generally lives in the flowers of plants. Common host plants include tomato, tobacco, cotton, grain legumes and lettuce.

Melon thrips
(*Thrips palmi*)

First described from Indonesia in 1925 and is now widely distributed throughout South East Asia, Japan, the Caribbean, Australia, the Pacific region and Florida in the USA. It was found in the Northern Territory in 1989 and in Queensland in 1993. Melon thrips have a wide host range, particularly among members of the cucurbit (Cucurbitaceae) and potato (Solanaceae) families.

Important crop hosts include eggplant, potato, capsicum, melons, zucchini and French beans.

Onion thrips
(*Thrips tabaci*)

This species is thought to have originated in the Mediterranean region. The species is widespread in temperate and sub-tropical areas and is favoured by warm, dry weather, particularly where onion, its preferred host, is grown. Onion thrips can be major pests in protected cropping situations.

Onion thrips have a wide host range, including vegetable crops in the families Liliaceae, Cucurbitaceae and Solanaceae. Both adults and larvae feed on leaves causing characteristic white flecking.

All of the four thrips species discussed above also infest weed species as well as their crop hosts. Each species can infest a wide range of weed hosts and these have a considerable influence on the distribution and abundance of the insects. Weeds that are hosts of both the virus and the thrips vector are particularly important as a source of virus for crops. For example, *Ageratum* (billygoat weed) is a host of both tomato thrips and Capsicum chlorosis virus while Snake weed is a host of western flower thrips, tomato thrips and tomato spotted wilt virus. Common weed hosts of thrips are listed in Table 2.

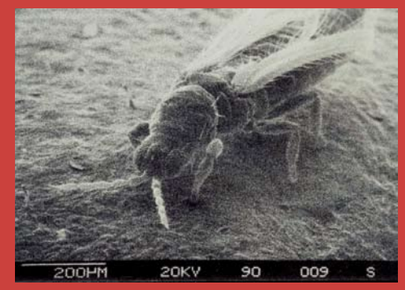
Finding thrips in crops

Adult thrips are usually found in flowers although they may also be present on the undersides of leaves. The numbers and species of thrips present in a crop can be determined by collecting flowers at random, for example 50 flowers/crop and tapping onto a white background to observe the insects. Leaves can also be collected and shaken over a white container to dislodge the insects. Insects can be preserved for later identification by storing in small tubes containing 70% alcohol.

Thrips numbers in crops can also be assessed by yellow sticky traps placed at several locations in a crop. These will also trap non-pest species and considerable experience is necessary to identify the various species that may be present.

Identification of thrips

Accurate identification of thrips species is not easy and requires some experience and training. Identification is bes undertaken by an entomologist or crop protection specialist with experience in thrips identification. Guides to identification of species are listed under 'Further information' on page 1.



A highly magnified electron micrograph of a thrip. The insect uses its mouthparts to pierce and suck the contents of plant cells, transmitting tospoviruses as it does so.

TOMATO


TSWV causing ringspots


TSWV


TSWV - Mature fruit symptoms


TSWV on young growth


CaCV


TSWV


TSWV


CaCV


CaCV


TSWV on leaves

WEEDS


TSWV on Snake weed


TSWV on cobbler's peg


TSWV on sowthistle

CAPSICUM


TSWV - blotchy ripening of fruit


TSWV


TSWV


CaCV on pepper fruit


CaCV on bell capsicum fruit


TSWV


CaCV

LETTUCE


TSWV


CaCV


CaCV

POTATO


TSWV on tuber


TSWV Severe symptoms on a leaf of a susceptible variety

PEANUT


TSWV


TSWV

HOYA


CaCV

ASTER


TSWV

ONION


IYSV

Biology of tospoviruses

Tomato spotted wilt virus (TSWV) was first described from Australia in 1915 and occurs throughout the world. It is the type or reference virus for the Tospovirus group of plant viruses, a genus within the family Bunyaviridae, a large group of predominantly animal-infecting viruses. Until 1990, TSWV was the only virus assigned to the group. However, in the last decade at least 13 new tospoviruses have been described (Table 2). In North and South America and Europe, TSWV and Impatiens necrotic spot virus (INSV) are widespread. In Asia, tospoviruses in serogroup IV or the watermelon silver mottle group cause destructive diseases in a wide range of vegetable and field crops. All tospoviruses are transmitted by thrips. The three tospoviruses found in Australian crops are TSWV, Capsicum chlorosis virus (CaCV) and Iris yellow spot virus (IYSV).

A lettuce crop abandoned due to severe TSWV

Capsicum crop severley affected by CaCV

Iris yellow spot virus (IYSV)

Iris yellow spot virus occurs in the USA, Israel, Japan and Europe and was found in Australia in 2003. Although onion is most severely affected, the virus also infects iris, lisianthus and leek. On onion, IYSV causes eye-like or diamond–shaped spots on the leaves and seed-stalk, which often bends as the spot dries causing the seed stalk to collapse. Plants often develop extensive chlorosis or yellowing. The virus can cause severe losses in onion bulb and seed crops. Transmission of the virus through onion bulbs has not been demonstrated.

Tomato spotted wilt virus (TSWV)

Distribution and importance – Tomato spotted wilt disease was first found in Victoria in 1915 and during the 1920s was regarded as the most serious disease in tomato crops in all southern States. The disease was shown to be caused by a virus in 1930 and named tomato spotted wilt virus. Sporadic serious outbreaks of spotted wilt have occurred ever since in tomato, capsicum, potato, tobacco and other crops. The virus remains one of the most widespread and damaging plant viruses in Australia. The levels of TSWV in crops began to steadily increase in most States in the early 1990s and continued to do so into the 21st century. Several particularly severe epidemics have occurred during recent years in the Perth metropolitan area and the Virginia area north of Adelaide. The crops most frequently and severely affected are capsicum, tomato, lettuce, potato and several flower crops. A major reason for the increased losses from TSWV has been the arrival and wide dispersal of the western flower thrips, a very efficient vector or carrier of TSWV. Although western flower thrips is present in all States and has been implicated in several major epidemics, other thrips species such as tomato thrips and onion thrips have also been involved in TSWV outbreaks in Australia.

Hosts – TSWV has one of the largest range of hosts of any plant virus, infecting over 900 species of weeds, field crops, vegetable and species grown as ornamentals or for flower production. Many hosts are in the potato (Solanaceae), aster (Asteraceae) and legume (Fabaceae) families. Natural hosts of TSWV in Australia are listed in Tables 4 and 5.

Symptoms – TSWV causes a range of symptoms, depending on the plant species affected. Symptoms are influenced by the age of the plants, variety, weather conditions and nutritional state. The range of symptoms found with TSWV infection include ringspots, line patterns, mottling and chlorotic blotches on leaves. Both leaves and fruit are often distorted with dark spots or ring patterns on fruit.

TSWV symptoms on important hosts:

TOMATO: Infected plants develop a bronze or purple discoloration. Leaves curl downwards and are distorted. Numerous small, dark spots develop on leaves and leaf stalks. Affected leaves may wilt and die. Dark streaks often appear on stems near the growing point. Fruit develop distinct chlorotic, concentric thumb prints on the skin. Fruit is often cracked and distorted with brown lines over the surface. Plants are stunted and produce few fruit if infection has occurred when plants are young.

CAPSICUM: Infected plants are usually stunted with leaves showing chlorotic blotching, mottling and chlorotic ring and line patterns. Fruit is distorted, generally reduced in size, and having blotches or dark spots on the skin, giving the fruit a scarred appearance.

LETTUCE: Affected plants develop a leaf mottle followed by chlorosis and necrotic spots and patches on the leaves. Leaves become deformed and plants are stunted with poor head development.

PEANUT: Leaves are small and distorted and develop a green and yellow mosaic pattern, often with chlorotic ringspots. Necrotic spots and streaks may develop on leaves and stems. Internodes are reduced in length and plants have a bunched appearance. Kernels from infected plants are small and misshapen.

POTATO: Symptoms vary with the variety. Shoots on susceptible varieties develop brown blotches and ringspots which may coalesce causing leaf death. Brown streaks may also develop on stems. Dark brown patches of dead tissue can occur within tubers of susceeptible varieties, making them unsuitable for processing or consumption. Less susceptible varieties develop only occasional internal spots and flecks.

Capsicum chlorosis virus
(CaCV)

Distribution and importance – Capsicum chlorosis virus (CaCV) was first identified in Queensland in 1999 from capsicum plants at Bundaberg and has since been found in all capsicum and tomato production areas in Queensland. CaCV has also been found in capsicum at Kununurra in the Ord River area of Western Australia and on the central coast of New South Wales.

CaCV is distinct from TSWV and belongs to the Watermelon silver mottle virus or serogroup IV tospoviruses which are widespread and damaging in Asia. CaCV also occurs in Thailand, Taiwan and China.

CaCV is transmitted by melon thrips and tomato thrips in Queensland and in Thailand by *Ceratothripoides claratris*, a thrips species not found in Australia.

Hosts – The crop hosts of CaCV are capsicum (including chilli types), tomato and peanut. The virus has also been found in the weed species *Ageratum conyzoides* (Billygoat weed), *Sonchus oleraceus* and *Emilia sonchifolia* (Emilia or purple sowthistle). Virus incidence in Ageratum is often high, indicating that this weed may play an important role in the survival and dispersal of CaCV.

The levels of CaCV infection in crops varies between years and districts. In north Queensland, both CaCV and TSWV are prevalent in capsicum crops. In contrast, at Bundaberg, CaCV has been the dominant virus in capsicum crops since 2000 and has become increasingly important in tomato and peanut.

Symptoms – Although the symptoms of CaCV resemble those caused by TSWV, there are several distinct features. In capsicum, chlorosis or yellowing on leaf margins and between the veins develops on young leaves, which often become narrow and curled, with a strap-like appearance. Older leaves become chlorotic with ringspots and line patterns developing. The fruit on infected plants is small, distorted and often marked with dark spots and scarring over the surface.

Infected tomato plants develop chlorotic spots and blotches on leaves which become mottled. Plants become stunted with death of some leaves. Fruit from infected plants develop chlorotic rings and necrotic areas.

Infected peanut plants develop chlorotic spots, blotches and ringspots on leaves. Internodes are reduced in length and new leaves reduced in size. Leaves and terminal growth often develop necrosis (tissue death) and wilt.

Leaves on Hoya plants infected with CaCV display symptoms of ringspots, line patterns, chlorotic blotches and etching of the leaf surface.

CaCV on peanut

Capsicum plant on left showing resistant reaction which limits virus to inoculated leaves. Plant on right is suseptible.

Table 2.
Tospoviruses worldwide

Tospovirus species and acronyms	Geographical distribution	Hosts
Groundnut (peanut) bud necrosis virus (GBNV)	India, South-east Asia	Peanut, other grain legumes and weed species
Groundnut ringspot **virus (GRSV)**	South America, South Africa	Peanut , tomato
Impatiens necrotic spot **virus (INSV)**	USA, West and South Europe, New Zealand, Japan	Ornamentals, peanut, capsicum, potato, weed species
Groundnut (peanut) yellow spot virus (GYSV)	India, Thailand	peanut
Tomato chlorotic spot **vi**rus (TCSV)	South America	Tomato, sweet pepper
Tomato spotted wilt virus (TSWV) *	Worldwide	Many hosts among crop, weed and ornamental species
Watermelon silver mottle virus (WSMoV)	Japan, Taiwan	Watermelon, other cucurbits, tomato
Zucchini lethal chlorosis virus (ZLCV)	Brazil	Zucchini
Capsicum ch**lorosis** virus **(CaCV)** *	Australia, Thailand, Taiwan, China	Capsicum, tomato, peanut, Hoya(waxflower), gloxinia
Chrysanthemum stem necrosis virus (CNSV)	Brazil	Chrysanthemum
Iris yellow spot virus (IYSV) *	Australia, Brazil, Israel, Japan, the Netherlands, USA	Iris, leek, onion
Melon yellow spot virus (MYSV)	Taiwan, Japan, Thailand	Melon
Groundnut (peanut) chlorotic fan-spot **vi**rus	Taiwan	Peanut
Watermelon bud necrosis virus (WBNV)	India	Watermelon
Tomato yellow fruit ring **virus**	Iran	Tomato
Calla lily chlorotic spot **vi**rus (CCSV)	Taiwan	Calla lilies (*Zantedeschia spp.*)

* Occurs in Australia

Table 3

Some important weed hosts of thrips virus vectors

Common sensitive plant	*Mimosa pudica*
Wild radish	*Raphanus raphanistrum*
Green amaranth	*Amaranthus viridis*
Shepherds purse	*Capsella bursa-pastoris*
Common morning glory	*Ipomoea purpurea*
Tridax daisy	*Tridax procumbens*
Billygoat weeds	*Ageratum* sp.
Snake weed	*Stachytarpheta jamaicensis*
Phasey bean	*Macroptilium* sp.
Blue heliotrope	*Heliotropium amplexicaule*
Abutilon	*Abutilon oxycarpum*
Blue butterfly pea	*Clitoria ternatea*
Pig weed	*Trianthema* sp.
Rubbervine	*Crytostegia grandiflora*
Stinking passion vine	*Passiflora foetida*
Thornapples	*Datura* sp.
Wild gooseberries	*Physalis* sp.

Transmission of tospoviruses

All tospoviruses are transmitted by thrips. Tospoviruses are not transmitted by other sap sucking insects such as aphids, leafhoppers or chewing insects, e.g. beetles. The thrips/tospovirus relationship is very specific and less than 20 of the thrips species that feed on plants are carriers or vectors of tospoviruses. Individual tospoviruses are transmitted by only some of these species.

The transmission process is a complex biological system. Transmission can only occur if the viruses are acquired from infected plants by first or early second instar larvae thrips. More mature insects, including adults, may acquire the viruses but the virus cannot complete the life cycle within the insect to allow transmission. The larvae can acquire virus during feeding periods of less than 30 minutes.

Once acquired by immature thrips, the viruses circulate and multiply within the insect and are transmitted to plants as the adult thrips pierce and suck the contents of plant cells. Thrips remain infective for life but do not pass the virus to their offspring through the egg.

About five days are required from the time the virus is acquired by a thrips from an infected plant until it is able to transmit the virus to another plant. This allows time for the virus to move and multiply in the insect gut and salivary glands. Long feeding periods are not required for thrips to transmit viruses with efficient transmission occurring in feeding periods of from 5 to 10 minutes. The transmission cycle is summarised in Figure 1.

Tospoviruses are not spread in seed or on cutting, pruning and cultivation equipment. The viruses are not spread by handling plants and do not survive in soil or decaying crop residues.

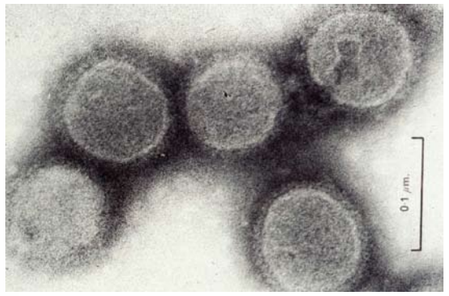
Tospoviruses can be spread in infected plant parts used for plant propagation such as cuttings and bulbs.

Identification of viruses

Plant viruses, including tospoviruses, often cause a similar range of symptoms in plants and virus identification based only on symptoms can be misleading and may result in implementing incorrect control measures. Most important plant hosts of tospoviruses can also be infected by unrelated viruses and dual infection by two or more viruses is possible. For example, tomato plants in Queensland can be infected by up to 10 viruses and the control measures for most of these differ considerably.

When virus infection is suspected, samples should be sent to a plant pathology diagnostic laboratory where a range of tests are available to accurately identify the viruses present. Control strategies can then be recommended based on accurate identification.

When collecting plant samples for virus diagnosis select several samples showing the range of symptoms present. Samples should be placed in plastic bags and kept cool. Before transport to a laboratory, samples should be wrapped in moist paper towelling and placed inside a plastic bag. Send samples to a laboratory by the quickest means to reduce the risk of deterioration. Unlike samples for fungal diagnosis, dried tissue is unsatisfactory for virus diagnostic tests.



Particles of a tospovirus in a plant cell as seen with an electron microscope. Virus particles are exremely small and are measured in millionths of a millimetre.

Control of tospoviruses

Infected plants cannot be cured. Control measures aim to prevent or reduce the levels of disease in crops by removing or avoiding sources of virus infection and minimising spread by thrips.

Crop/farm hygiene. Old infected crops infested by thrips are a major source of virus and should be sprayed for thrips and removed as soon as possible, particularly if young crops are to be planted nearby.

Avoid overlapping sowings of susceptible crops and sequential plantings side by side to minimise virus spread from one crop to the next.

Weeds along headlands, irrigation channels and in fallow land provide host plants for thrips and tospoviruses. Disease levels are often higher in crop rows adjacent to these areas. Weeds that are flowering are particularly attractive to thrips as they feed on pollen. Destroy weeds well before planting, not as crops are planted, as virus infected thrips may migrate from the wilted weeds to the young plants.

Maintaining a clean buffer zone free of weeds at least 25 m between a virus source and a susceptible crop can considerably reduce virus levels.

Control of thrips with insecticide. Reducing thrips populations by use of appropriate insecticides can help reduce virus spread. However, insecticides are often of limited value in tospovirus control as virus spread from non-crop areas is an important source of infection and thrips only require limited feeding times for virus transmission. Significant disease levels can occur when thrips numbers are low, and there is little evidence of direct feeding damage, as small numbers of thrips moving into a crop can result in significant virus transmission. Frequent use of insecticides may also lead to development of insecticide resistance in thrips populations.

Use healthy planting material. Viruses can be introduced in infected seedling plants which then provide a virus source throughout the life of the crop. Seedling production areas should be located well away from production areas, kept weed-free and systematically monitored for pests and diseases with a regular spray schedule in place.

Thrips-proof netting or UV absorbing plastic provides a higher level of protection for seedling production.

Resistant varieties. Varieties of capsicum and tomato resistant to TSWV are available. The resistance operates by the leaf cells around the point of virus inoculation dying and preventing virus movement from the immediate area. Although effective, the resistance is controlled by single dominant genes, (named *Sw-5* in tomato and *Tsw* in capsicum) and is vulnerable to the development of resistance-breaking strains of TSWV. This is most likely to occur when the resistance genes are challenged by high virus pressure thus providing greater opportunity for the selection and establishment of resistance –breaking strains. When resistant varieties are used care should still be taken with crop/farm hygiene and other preventative measures to reduce sources of virus and prolong the useful life of the resistance sources.

Resistant varieties are part of a disease management strategy, not a reason to ignore other vital means of reducing virus reservoirs and spread.

TABLE 4

CROP HOSTS OF TOSPOVIRUSES IN AUSTRALIA

TSWV		CaCV	IYSV
Capsicum Tomato Tobacco Potato Eggplant Duboisia Celery Lettuce Globe artichoke Peanut Pea Broad bean Chickpea Sweet basil	Ornamental and flower crops including: Alstoemeria Aster Calendula Chrysanthemum Gladiolus Cosmos Dahlia Delphinium Statice Zinnia	Capsicum Tomato Peanut	Onion Leek

TABLE 5

SOME WEED HOSTS OF TSWV IN AUSTRALIA

Asteraceae	Capeweed (*Arctotheca calendula*) Cobbler's pegs (*Bidens pilosa*) Fleabane (*Conyza* species) Stinking roger (*Tagetes minuta*) Common groundsel (*Senecio vulgaris*) Sowthistles (*Sonchus* species)
Brassicaceae	Wild turnip (*Brassica rapa*) Shepherd's purse (*Capsella bursa-pastoris*)
Caryophyllaceae	Chickweed (*Stellaria media*)
Chenopodiaceae	Fat hen (*Chenopodium album*)
Fabaceae	Clovers (*Trifolium* species)
Geraniaceae	Musky storksbill (*Erodium moschatum*)
Lamiaceae	Stagger weed (*Stachys arvensis*)
Malvaceae	Mallows (*Malva* species) Bladder ketmia (*Hibiscus trionum*)
Portulaceae	Pigweed or purslane (*Portulaca oleracea*)
Solanaceae	Apple of Peru (*Nicandra physalodes*) Thornapples (*Datura species*) Nightshades (*Solanum species*) Wild gooseberries (*Physalis species*)
Verbenaceae	Jamaican snakeweed (*Stachytarpheta jamaicensis*)