GUIDE TO IDENTIFICATION AND MANAGEMENT OF

# MAJOR VIRUS DISEASES AFFECTING AUSTRALIAN FIELD VEGETABLE CROPS

Hort Innovation
Strategic levy investment

VEGETABLE FUND

Queensland Government

2022

GUIDE TO IDENTIFICATION AND MANAGEMENT OF

# MAJOR VIRUS DISEASES AFFECTING AUSTRALIAN FIELD VEGETABLE CROPS

First published May 2022


AUTHORS

**Cherie Gambley, Paul Campbell, Denis Persley, Flavia Bonora, Kara Pendavingh, Luke Halling, Lara Senior, and Peter Nimmo**
Department of Agriculture and Fisheries, Queensland

**Len Tesoriero and Toni Chapman**
Department of Primary Industries, NSW

**Cliff Kinoti, Fiona Constable, and Bianca Rodrigues Jardim**
Agriculture Victoria

**Craig Webster and Monica Kehoe**
Department of Primary Industries and Regional Development, Western Australia

**Samantha Bond**
Department of Industry, Tourism and Trade, Northern Territory

**Calum Wilson**
University of Tasmania

**Anthony Rice**
Granite Belt Integrated Pest Management

**Marco Amaya**
Rocky Ponds Produce

**John Fletcher**
Private Consultant

**Chris Themsen**
Agreco Australia Pty Ltd

REVIEWER/EDITOR
**Nick Macleod**
Department of Agriculture and Fisheries, Queensland

DESIGNED BY
**Annette Vandermaat**
Graphic Design by AV

FUNDING

Hort Innovation Project VG16086 'Area wide management of diseases: viruses and bacteria' This project has been funded by Hort Innovation using vegetable industry levies and contributions from the Australian Government with co-investment from the Queensland Department of Agriculture and Fisheries; Victorian Department of Economic Development, Jobs, Transport and Resources; The Northern Territory Department of Primary Industry and Resources; the Western Australia Department of Primary Industries and Regional Development and the University of Tasmania. It is supported by a second project led by the New South Wales Department of Primary Industries and similarly funded by Hort Innovation using vegetable industry levies and contributions from the Australian Government and NSW DPI.



Hort Innovation Strategic levy investment | VEGETABLE FUND

This project has been funded by Hort Innovation using the vegetable research and development levy and funds from the Australian Government. For more information on the fund and strategic levy investment visit horticulture.com.au

TABLE OF
# CONTENTS

GUIDE

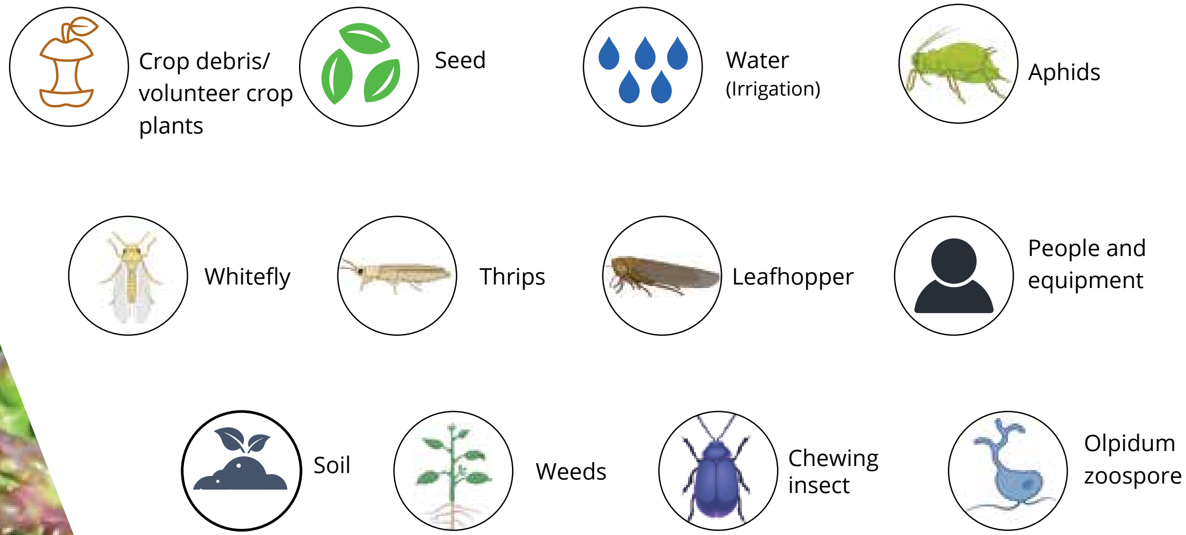
# INTRODUCTION

Virus diseases cause significant impacts to vegetable production nationally. Disease outbreaks are sporadic and influenced substantially by the behaviour of the insects that spread them. Insect behaviour is influenced strongly by weather conditions, both directly through effects on their multiplication rate and through availability of alternative plant hosts. Some of the viral diseases are not spread by insects. Spread of these viruses is influenced by hygiene and crop production practices. This guide provides information on the most common viral diseases in Australian vegetables, how to identify them and what management is available for their control. Viral diseases can affect all production systems from open field to high-tech protected cropping.

This disease guide covers viruses already present in Australia. There are many exotic viruses present overseas which could enter Australia. It is important to be aware of these viruses and send samples for diagnoses if you suspect a new disease has arrived.

# HOW TO
# USE THIS GUIDE

This guide is divided into different sections. The first section outlines basic viral disease identification and general disease management. The next section has specific details on the major viral diseases affecting Australian vegetable crops, including what they look like and additional control methods for management if known. The major production areas for each jurisdiction with the common crops grown and the viral diseases likely to be found in that area, are provided in the last section. Further resources are provided in the appendices.



# VIRUS DISEASE **IDENTIFICATION**

## HOW DO I KNOW IF I HAVE A VIRUS DISEASE IN MY VEGETABLE CROP?

Viruses are minute pathogens which invade and multiply within their hosts. These infections may or may not trigger disease symptoms. A virus has a core of nucleic acid (DNA or RNA) which contains the genetic information essential for infection and multiplication. This core is surrounded by a protein coat which both protects the nucleic acid and assists in multiplication and spread of the virus. Viruses need living host plants to complete their life cycle and for survival; very few survive for long periods in soil or crop residues. However, there are some exceptions (e.g. cucumber green mottle mosaic virus). The symptoms of virus diseases vary and are influenced by temperature, host variety, stage of growth and crop nutrition. They are usually distinct from symptoms caused by fungi or bacteria; however, they can be confused with herbicide damage, mite feeding damage or nutritional disorders. For example, if veins remain green while areas between turn yellow (especially on older leaves) it is more likely a nutritional disorder.

The symptoms of many virus diseases are similar, and it is possible for a plant to be infected by more than one virus or more than one pathogen. The best advice is to have samples checked by a diagnostic laboratory. This is an essential first step in deciding on future actions.

**COMMON VIRUS SYMPTOMS INCLUDE:**

**Mosaic or mottling patterns on leaves**

**Concentric ring patterns or lines on leaves or fruit**

**Yellow blotches on leaves**

**Fruit can be distorted, have spots and streaks**

## THE FOLLOWING GENERAL OBSERVATIONS IN THE FIELD MAY INDICATE A VIRUS DISEASE

- Diseased plants are often along crop edge rows
- Recent influx of virus-spreading insects (aphids, whitefly, thrips, leafhoppers)
- Fungicide, bactericides, or fertilisers are not effective
- Symptoms are mostly seen on new growth
- Plants do not grow out of symptoms

While these observations are useful for guiding disease identification, it is still important to confirm the cause with more formal diagnostics through a qualified laboratory. Many diseases and nutritional conditions can look similar even to a trained eye and will require sample testing to accurately identify.

For a list of common diseases in each major Australian growing district refer to page 44.

**Death of leaves and shoots and plant wilting**

**Stunting and distorting of apical growth of plants**

# WHERE CAN I SEND SAMPLES FOR DIAGNOSTIC TESTING?

A range of diagnostic services are available in Australia for accurate identification of disease agents. Sending samples to your state or territory diagnostic service is recommended. These services are listed in Appendix 1 (page 60) with information on how to collect and package samples (Appendix 2 page 61).

There are field diagnostics available from Agdia Inc. for some viruses. The Australian distributor for these is the TASAG ELISA and Pathogen Testing Service, Department of Natural Resources and Environment Tasmania (https://nre.tas.gov.au/biosecurity-tasmania/plant-biosecurity/plant-diagnostic-services/tasag-elisa-testing).

Recommended assays include those for *cucumber green mottle mosaic virus* (CGMMV), *cucumber mosaic virus* (CMV), *Impatiens necrotic spot virus* (INSV), *Iris yellow spot virus* (IYSV), *melon necrotic spot virus* (MNSV), *pepper mild mottle virus* (PMMoV), *potato virus Y* (PYV), potyvirus group (only some viruses, check the validation information), *tobacco mosaic virus* (TMV), *tomato spotted wilt virus* (TSWV) and *zucchini yellow mosaic virus* (ZYMV).

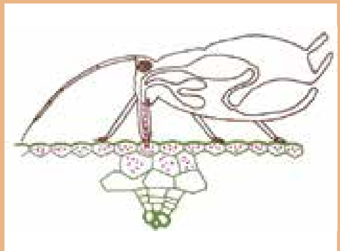
Some kits have local specificities, for example, the ZYMV dipstick does not detect a Kununurra strain of the virus. Check with your local diagnostic service before your first order of a kit to be sure it is suitable for your needs.

## WHICH VIRUS IS IT AND HOW DOES IT SPREAD?

There are six major groups of viruses that affect vegetable crops, based on the mode of spread. For viruses spread by insects, this happens during insect feeding of plant sap. Disease caused by phytoplasma are also included in this guide as their spread is also by insects. Almost all the insect spread diseases are initiated from external sources of the virus or phytoplasma, typically weeds and/or volunteer crop plants. Weather influences the longevity of these external sources and in turn, the likelihood of disease outbreaks. Appendix 3 details two case studies showing how weather influences virus disease outbreaks.

Almost all these diseases can occur in all growing districts, however, some are more commonly found in certain districts. For a list of common disease in each major Australian growing district refer to page 44.

- Non-persistent virus transmission (spread): the virus is only in the insects' mouthparts (stylet). Virus spread occurs within minutes and can only occur for a few hours
- Persistent virus transmission (spread): the virus must circulate through the insects' body from the mouthparts through the gut and into the salivary glands before the insect can spread the virus to a new plant. Some viruses also need to replicate within the insect before it can be spread. Virus spread occurs within hours and can continue the lifespan of the insect.
- Semi-persistent virus transmission (spread): the virus moves from the mouthparts into the foregut before the insect can spread the virus to a new plant. Virus spread occurs within a couple of hours and can continue for a few weeks.



***NON-PERSISTENT VIRUS SPREAD***

***PERSISTENT VIRUS SPREAD***



# 01 VIRUSES SPREAD BY THRIPS

In Australia, the viruses spread by thrips affecting vegetable crops are almost all orthotospoviruses. The exception is *tobacco streak virus* (TSV) which can infect French beans and potentially affect other vegetables, though it rarely causes major problems.

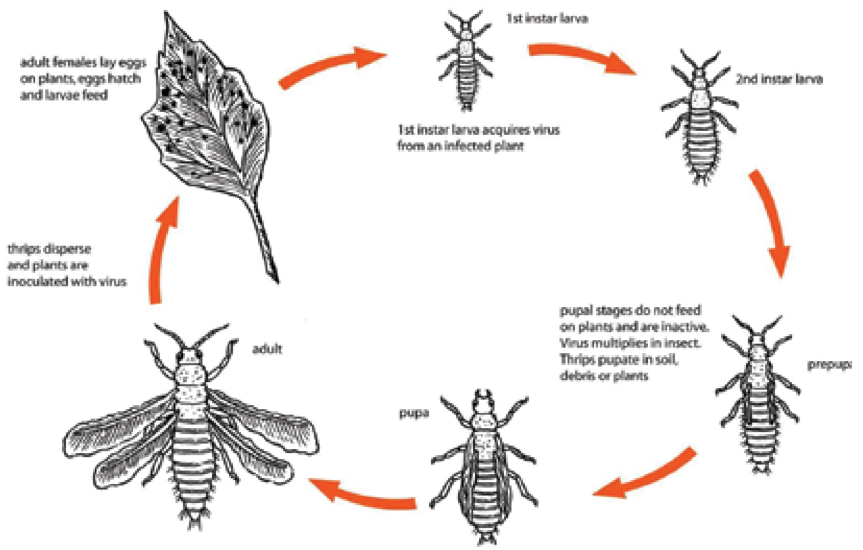
The orthotospoviruses affecting Australian crops include *tomato spotted wilt virus* (TSWV), *capsicum chlorosis virus* (CaCV), *Impatiens necrotic spot virus* (INSV) and *Iris yellow spot virus* (IYSV). Except for TSWV, these viruses have limited host ranges with only a few vegetable crops affected. For CaCV, this is tomato, capsicum, and chilli; for INSV this is lettuce and for IYSV this is allium crops. TSWV affects many vegetable crops.

There are four major thrips species that spread these viruses and not all thrips spread all viruses.

| Thrips | Common name | TSWV | INSV | CaCV | IYSV |
|---|---|---|---|---|---|
| *Frankliniella occidentalis* | Western flower thrips | + | + | - | - |
| *Frankliniella shultzei* | Tomato thrips | + | + | + | - |
| *Thrips tabaci* | Onion thrips | + | + | - | + |
| *Thrips palmi* | Melon thrips | - | - | + | - |

The viruses are persistently spread by the thrips. This means it takes at least 30 min for the thrips to pick up the virus through feeding and then about 4-10 days for it to circulate through the insects' body to the salivary glands before it can spread it to a healthy plant. The thrips must pick up the virus in a juvenile stage to be able to transmit the virus as an adult. Once a thrips becomes infected it can spread the virus for the rest of its life. Adult thrips have wings and can thus spread the virus rapidly in and between crops.

**Life cycle and transmission of orthotospovirus by thrips**




## 02 VIRUSES SPREAD NON-PERSISTENTLY BY APHIDS

There are many non-persistently aphid spread viruses that affect Australian vegetable crops. This includes at least 12 potyviruses, and *cucumber mosaic virus* (CMV), *cauliflower mosaic virus* (CaMV) and *alfalfa mosaic virus* (AMV). Non-persistent transmission means the viruses are spread very rapidly. The viruses are in the aphids' mouthparts and do not circulate through the insect like persistently transmitted viruses do. This means it takes only minutes of feeding for an aphid to pick up the virus from an infected plant and transfer it to a healthy plant. The viruses remain on the mouthparts, for only a few hours. They are also easily cleaned off if the insect feeds on a non-virus plant host. If either of these things happen, the aphid needs to feed on another infected plant to re-acquire the virus for further spread to occur.

CaMV affects brassica crops although impacts are generally low. Disease is more severe at temperatures <18°C and yields of turnip and Chinese cabbage are more affected than broccoli and cauliflower. AMV has a wide host range affecting many crops but usually at low disease incidence.

Of these viruses, ZYMV, LMV and PsbMV are also spread in seed. This is usually at a very low rate (about 1% of seed) and this rate depends on the virus-crop combination. Volunteer plants from previously infected crops are a very high risk as a virus source for newly planted crops.

The major aphid species that spread these viruses includes *Myzus persicae* (green peach aphid; GPA), *Brevicoryne brassicae* (cabbage aphid), *Lipaphis pseudobrassicae* (turnip aphid), *Aphis gossypii* (melon/cotton aphid) and *Aphis craccivora* (cowpea aphid). Most aphid species can spread all these viruses, however some such as GPA are more efficient. Aphid monitoring via sticky traps gives a much better idea of aphid numbers than direct observations of plants. This is because most aphids which fly over crops can spread virus, however only a small percentage of them will colonize crops.

Potyviruses are a major group of non-persistently transmitted viruses that affect vegetables.

| Potyvirus | Carrots, Celery | Brassicas | Cucurbits | Lettuce | Legumes | Solanaceae |
|---|---|---|---|---|---|---|
| Watermelon mosaic virus (WMV) | | | + | | | |
| Papaya ringspot virus (PRSV) | | | + | | | |
| Zucchini yellow mosaic virus (ZYMV) | | | + | | | |
| Turnip mosaic virus (TuMV) | | + | | + | | |
| Lettuce mosaic virus (LMV) | | | | + | | |
| Carrot virus Y (CarYV) | + | | | | | |
| Celery mosaic virus (CeMV) | + | | | | | |
| Potato virus Y (PVY) | | | | | | + |
| Pea seedborne mosaic virus (PSbMV) | | | | | + | |

## 03 VIRUSES SPREAD PERSISTENTLY BY APHIDS

Persistently aphid spread viruses also affect Australian vegetable crops. These include Poleroviruses and the Rhabdovirus, *lettuce necrotic yellow virus* (LNYV). Persistently transmitted viruses are spread more slowly than non-persistently transmitted viruses. This is because once the insect has picked up the virus it needs to circulate through the insects' body to the salivary gland before it can be deposited into a new plant. This takes several hours to complete. For some virus-insect combinations the virus must also multiply within the insect. Once the virus is in the aphids' salivary glands the insect can spread the virus for many weeks or the rest of its life, unlike the previously described non-persistently spread viruses.

LNYV affects lettuce crops and is spread by *Hyperomyzus lactucae* (sowthistle aphid). The Poleroviruses affect a range of crops. *Turnip yellows virus* (TuYV) affects brassicas, lettuce, and legume crops and *potato leafroll virus* (PLRV) affects Solanaceae crops (tomato, chilli, capsicum. *Beet western yellows virus* (BWYV) was recently found in capsicum and chilli crops in Queensland, however impacts from BWYV are largely unknown. The Poleroviruses are spread by *Myzus persicae* (green peach aphid), *Brevicoryne brassicae* (cabbage aphid), *Lipaphis pseudobrassicae* (turnip aphid) and *Macrosiphum euphorbiae* (potato aphid). Not all aphid species spread all of these poleroviruses.

## 04 VIRUSES SPREAD BY WHITEFLY

In Australia, there are very few viruses spread by whitefly. Most are spread by *Bemisia argentifolli* (silverleaf whitefly, SLW; aka Biotype *B. tabaci*). These include *tomato yellow leaf curl virus* (TYLCV), *tomato leaf curl virus* (ToLCV) and *tomato torrado virus* (ToTV) which all affect tomato and *cowpea mild mottle virus* (CPMMV) which affects legumes, particularly French bean. Greenhouse whitefly (*Trialeurordes vaporariorum*) also transmits ToTV plus *beet pseudoyellows virus* (BPYV) which affects cucurbits, particularly greenhouse cucumbers. Of these viruses, CPMMV and ToTV are spread by seed. Seed transmission of CPMMV is specific for different virus strain-crop legume host combinations.

## 05 PHYTOPLASMAS SPREAD BY LEAFHOPPERS

Phytoplasmas are bacterial pathogens that affect vegetable crops but are very different to other bacteria. They are obligate pathogens which means they do not survive outside their plant or insect hosts. Their mode of infection and spread is like plant viruses. Phytoplasma are spread from one plant to the next by phloem-feeding insects such as leafhoppers. These include the common brown leafhopper (*Orosius argentatus* and *O. orientalis*), Canberrian brown leafhopper (*O. canberrensis*), and spotted leafhopper (*Austroagallia torrida*). Phytoplasmas can affect most vegetable crops, however they are very sporadic in their incidence. They are not seedborne.

| Insect | Species Name | Common Name | What it spreads |
|---|---|---|---|
| Aphid | *Aphis craccivora* | cowpea aphid | potyviruses |
| | *Brevicoryne brassicae* | cabbage aphid | potyviruses, poleroviruses |
| | *Hyperomyzus lactucae* | sowthistle aphid | LNYV |
| | *Lipaphis pseudobrassicae* | turnip aphid | potyviruses, poleroviruses |
| | *Macrosiphum euphorbiae* | potato aphid | poleroviruses |
| | *Myzus persicae* | Green peach aphid | potyviruses, poleroviruses |
| Leafhopper | *Austroagallia torrida* | spotted leafhopper | Phytoplasma |
| | *Orosius argentatus* | common brown leafhopper | Phytoplasma |
| | *Orosius canberrensis* | Canberrian brown leafhopper | Phytoplasma |
| | *Orosius orientalis* | common brown leafhopper | Phytoplasma |
| Thrips | *Frankliniella occidentalis* | Western flower thrips | TSWV, INSV |
| | *Frankliniella shultzei* | Tomato thrips | TSWV, INSV and CaCV |
| | *Microcephalothrips abdominalis* | composite thrips | CaCV |
| | *Thrips palmi* | Melon thrips | CaCV |
| | *Thrips tabaci* | Onion thrips | TSWV, INSV, IYSV |
| Whitefly | *Bemisia argentifolli* | silverleaf whitefly | TYLCV, ToLCV, ToTV and CPMMV |
| | *Trialeurordes vaporariorum* | greenhouse whitefly | BPYV and ToTV |

## 06 VIRUSES SPREAD BY SOIL-BORNE FUNGI

In Australia, there are four viruses known to be spread by soil-borne fungi. These are *lettuce big-vein associated virus* (LBVaV), *mirafiori lettuce big-vein virus* (MLBVV), *melon necrotic spot virus* (MNSV) and *ranunculus white mottle virus* (RWMV). LBVaV and MiLV are spread by *Olpidium virulentus* and are associated with big-vein disease in lettuce. MNSV is spread by *O. bornovanus* and infects cucurbit crops in Australia. RWMV is spread by an unidentified *Olpidium* spp., has very limited distribution, and found in capsicum and chilli crops in South Australia. Spread of these viruses is via movement of motile *Olpidium* zoospores in nutrient solutions, water or in the soil medium between plant root systems and infection is via roots. *Olpidium* spp. produce resting spores that are stable in soil for many years. Of these viruses, only MNSV is seed transmitted.

## 07 MECHANICALLY SPREAD VIRUSES

Several plant viruses are mechanically spread. This means they move in sap which can contaminate equipment or people and infect via plant wounds. These viruses include tobamoviruses, potexviruses and potyviruses. In Australia, this includes the three potyviruses affecting cucurbits, *watermelon mosaic virus* (WMV), *papaya ringspot virus* (PRSV) and *zucchini yellow mosaic virus* (ZYMV) and the tobamoviruses, *cucumber green mottle mosaic virus* (CGMMV) which affects mainly cucumbers and melons and *tomato mosaic virus* (ToMV), *tobacco mosaic virus* (TMV) and *pepper mild mottle virus* (PMMoV) which all affect Solanaceae crops (tomato, capsicum, chilli, eggplant). The potexvirus, *potato virus X* (PVX) affects potato and capsicum.

Insects can also mechanically spread the viruses on their body parts, such as legs, and transfer these through physical contact from an infected plant to another plant. Some insects, such as bees, ants, and thrips, can also pick up virus infected pollen, which can then be spread. Bees are known to mechanically spread CGMMV with pollen, and the virus can remain viable in beehives for several months. Of these viruses, CGMMV, PVX, ToMV, TMV, PMMoV, and ZYMV are seed transmitted.

# WHAT SHOULD I DO?

**Disease management should start before planting and include sourcing clean planting material and management of external virus sources. Source certified seed from reputable seed company representatives and consider disinfestation strategies such as hot water treatment to further reduce risk.**

Appendix 4 has a list of recommended seed disinfection treatments. If disease outbreaks occur restrict access in that area, contain where possible and implement strict hygiene measures for staff and equipment movements. Manage younger and unaffected crops first before moving into older or diseased crops to reduce risk of disease spread.

Most virus diseases affecting vegetables are spread by insects, thus management of external virus sources is critical, and should be routine. Weed and volunteer crop plants should be destroyed where possible prior to first plantings. Where it is not possible to destroy these plants, monitor for presence of insect vectors and take appropriate action to reduce adult populations (as per the Australian Pesticides and Veterinary Medicines Authority (APVMA) guidelines). Consider using barrier plants as additional protection to intercept any infective adult insects. Barrier plants can also be used as a refuge to build biological control populations of predatory insects and mites.

Knowledge of which virus vector species is present is important as the levels of insecticide resistance varies between these species. There may also be biological control agents that are specific to a particular insect species. Diagnostic confirmation of the insects each season is important as changes can occur with introduction of new species that may displace previous species. Insect identifications are available through the diagnostic services listed in Appendix 1.

## FOR FIELD CROPS WHERE POSSIBLE

- Check seedlings are free from insect pests and diseases prior to planting
- Rotate with non-crop hosts or non-susceptible hosts
- Ensure weeds and insects are well controlled in and around crops
- Manage younger and unaffected crops first before moving into older or diseased crops to reduce risk of spread
- Plant new crops upwind of older crops
- Ensure equipment is decontaminated prior to use to prevent the spread of viruses in sap
- Dispose or bury crop trash soon after harvest to minimise risk of virus harbouring viruses
- Monitor crops regularly for nutrition and crop health for early detection and management of diseases
- Ensure the plants receive sufficient calcium and not excess nitrogen for optimal plant health – suboptimal nutrition weakens plant defence responses
- UV reflective mulches, oil sprays, barrier plants and bare land help to deter insects which spread viruses

## FOR PROTECTED CROPS WHERE POSSIBLE

- Cleaning and disinfecting greenhouse, benches, and equipment before planting
- Disinfect tools, particularly those used for cutting or pruning
- Maintain greenhouse, equipment, and staff hygiene
- Check seedlings are free from insect pests and diseases prior to planting
- Monitor crops regularly for potential insect vectors, nutrition and crop health for early detection and management of diseases
- Regular EC/pH/nutrient monitoring for optimal crop growth and ensure recirculating solutions are pathogen free
- Monitor insects and start control of insects when flights of insects start
- Maintain a clean and weed free buffer zone around growing areas
- Dispose of crop debris away from growing areas
- Use reputable planting media

## TREATMENT OPTIONS

Generally preventative strategies are the only option for viral disease management. Once infected, it is too late to save the plant. Removal of early infected plants at low disease incidence can be useful to reduce in-field spread.

No products are registered for use in vegetable production including chemical and biological agents for management of virus diseases. Products are registered for management of insect pests, and general insect control is recommended. Use of insecticides can often increase disease caused by non-persistently spread viruses. There are a few specific exceptions where anti-feeding chemistries can reduce spread of persistently spread viruses, and these are noted in the following sections. Please refer to the 'Australian Pesticides and Veterinary Medicines Authority (APVMA) website for a list of registered products.

## IS DISEASE MONITORING USEFUL?

**Yes**, disease and insect monitoring are useful. It allows for early intervention if needed and with time it builds knowledge about the triggers leading to disease outbreaks. Regular monitoring with good record keeping provides a baseline on when and where diseases occurred and what management actions did or did not work. For example, regular appearance of disease in a section of a certain block indicates presence of the virus in the environment nearby and can focus weed management to that area.

Regular diagnostic testing of disease outbreaks and insect samples value adds to the monitoring data. Symptoms can be similar for different diseases, thus getting diagnostic tests done allows the monitoring data to be linked to a specific virus and disease. Similarly, some insects can look alike but might spread different viruses. For example, western flower thrips and tomato thrips are nearly identical but only tomato thrips spreads CaCV. Onion thrips are very similar in appearance to plague thrips but only onion thrips spread TSWV and INSV.

For recommendations on insect monitoring, refer to Appendix 4.

# BIG BUD DISEASE: PHYTOPLASMA

**Phytoplasma are phloem-limited bacteria that affect a wide range of crops including vegetables. The phytoplasma subgroup 16SrII-D phytoplasmas, or '*Candidatus* Phytoplasma australasia' is thought to be the major species affecting vegetable crops in Australia, although other species do occur. The phytoplasma causes the diseases 'tomato big bud' and 'little leaf phytoplasma'. This phytoplasma can affect a broad range of crops including vegetables such as bean, bitter gourd, capsicum, carrot, celery, cowpea, eggplant, lettuce, mungbean, potato, pumpkin, ridged gourd, snakebean, sweetpotato tomato, and zucchini. Weeds that host phytoplasma and insect vectors play important roles in the disease cycle.**

## WHAT DOES IT LOOK LIKE?

Phytoplasma cause a variety of symptoms in their plant hosts and affect the development of the floral parts, leaves, roots, and branches. Some typical floral symptoms include the conversion of flowers into leafy tissue (phyllody), the greening of petals (virescence), and aborted fruit development. Other typical symptoms include little leaf syndrome, leaf yellowing, witches'-broom, stunting, distortion and aerial roots or tubers. Disease symptoms can sometimes be confused with physiological conditions, herbicide damage or off-type characteristics.

## WHERE DOES IT COME FROM AND HOW DOES IT SPREAD?

Phytoplasma are mainly spread from one plant to the next by phloem-feeding insects such as leafhoppers. These include the common brown leafhopper (*Orosius argentatus* and *O. orientalis*), Canberrian brown leafhopper (*O. canberrensis*), and spotted leafhopper (*Austroagallia torrida*). Some planthoppers and psyllids can also spread the bacteria. Phytoplasma spread is persistent as the bacteria needs to multiply within the insect after it picks it up from an infected plant. It then must circulate within the insect to the salivary gland before it can be deposited into a new plant. This takes several hours, after which the leafhopper can spread the bacteria for the remainder of its life. Phytoplasmas come into vegetable crops from environmental hosts such as weeds and native plants that may not always show any symptoms of phytoplasma infection.

## DISEASE MANAGEMENT

There are limited management strategies available to control the spread of phytoplasma diseases. Removal of infected plants and alternative weed hosts can limit phytoplasma spread to new crops by insect vectors. Use of insecticides may reduce leafhopper movement within a crop, but it is the influx of new leafhoppers from surrounding vegetation that result in most new infections. Netting can be effective in excluding phytoplasma vectors from areas surrounding crops and weeds, although this is mostly not practical. Risk of introduction and spread of phytoplasma is low in protected cropping when crops are completely enclosed but can still occur.

There are no known management strategies for phytoplasma management. Regular monitoring of disease in crops may provide some information on seasonality to better predict disease outbreaks. Further work is needed before management strategies can be recommended.

# BRASSICA DISEASE:
# VIRUSES SPREAD BY APHIDS

**Three viruses commonly affect Brassica crops in Australia: *turnip mosaic virus* (TuMV), *turnip yellows virus* (TuYV), and *cauliflower mosaic virus* (CaMV). All Brassica crops can be affected including broccoli, cabbage, cauliflower, leafy brassicas such a choi sum, bok choy and gai lan. TuMV and TuYV commonly occur together in the one plant.**

## WHAT DOES IT LOOK LIKE?

All these viruses cause symptoms of mosaic, mottling, and yellow ringspots to develop on leaves. These symptoms can be a strong yellow/green contrast or a contrast in green colouring only. Leaves may be twisted and distorted. Black streaks and flecks can develop on leaves and stems which can be confused with fungal or bacterial symptoms. Plants may also be stunted and have reddening of lower leaves. Drum cabbage and Chinese cabbage develop internal dead or necrotic areas which are only seen when the plant is cut. More than one of these symptoms can be present on the plant and not all leaves will have the same symptoms. Leaf distortion symptoms can be confused with herbicide or insect feeding damage. Some symptoms can be confused with nutritional disorders. Plants may be infected by more than one virus and symptoms caused by different viruses are often similar.

## WHERE DOES IT COME FROM AND HOW DOES IT SPREAD?

Primary spread of these viruses into crops is via aphids, their insect vector, from external virus sources in the environment. External sources for virus spread are weeds and volunteer crop plants growing alongside production blocks on headlands, in riparian areas or along roadsides that are a host for both the virus and the aphids.

These sources are very important for primary spread of viruses into first plantings of crops. Once in commercial crops, these crops can become external virus sources for new plantings. This explains why diseases tend to increase through the season.

Major weed hosts for these viruses are various cruciferous weeds such as wild turnip, wild radish, Indian mustard, and shepherd's purse (*Capsella bursa-pastoris*). Canola crops may also be a source of these viruses. TuMV and TuYV also infect lettuce (*Lactuca serriola*) and some related weeds such as prickly lettuce and sowthistle (*Sonchus oleraceus*).

Viruses are spread by aphids move from surrounding virus infected plants. The aphids may simply visit, feed or probe then move on to another host within the crop. For example, a cabbage aphid moving from an infected wild turnip colony to feed on cabbage will introduce the virus into that crop. Aphids may also colonise, feed, and reproduce before moving within the crop or elsewhere. Spread of TuYV by aphids is 'persistent' which means the insect has picked up the virus it needs to circulate through the insect's body to the salivary gland before it can be deposited into a new plant. This takes several hours to complete. Non-persistent transmission of CaMV and TuMV occurs after aphids feed for a few minutes and the virus attaches to aphid mouthparts from which they can be quickly transferred into a new plant during further feeding. Aphids may be windblown, fly or walk within a crop, spreading virus as they feed while moving *all these viruses cause mosaic, mottling and yellow ringspots to develop on the leaves*

from plant to plant. When colonies mature and aphids fly further, they spread viruses over longer distances. Mechanical transmission of TuMV and CaMV may occur with movement of equipment or people through the crop. Green peach aphid (*Myzus persicae*), cabbage aphid (*Brevicoryne brassicae*), turnip aphid (*Lipaphis pseudobrassicae*) are the key aphid vectors. Brassica crops, including cover or biofumigant crops can also be bridging hosts for subsequent brassica crops.

## DISEASE MANAGEMENT

In addition to general disease management recommendations (refer pages 15-17) the critical management point for viruses spread by aphids in brassica crops is to prevent primary introduction. This will be from weeds, volunteer plants or older affected crops. To reduce this risk, remove these plants from nearby or treat them to reduce insect numbers. This should be done routinely.

Alternatively, using barrier non-virus host plants or fallow areas between and around crops will reduce spread of the non-persistently transmitted TuMV and CaMV. Barrier plants are effective to both intercept aphids to reduce numbers entering crops and to cleanse aphid mouthparts of the viruses if they are a non-host for the virus (e.g sorghum, millet, corn).

Aphids entering crops after feeding on the barrier plants will no longer spread TuMV and CaMV. The barrier plants can also be used to multiply and maintain biological control agents to assist in controlling aphid populations.

If virus is detected in crops, additional actions are:

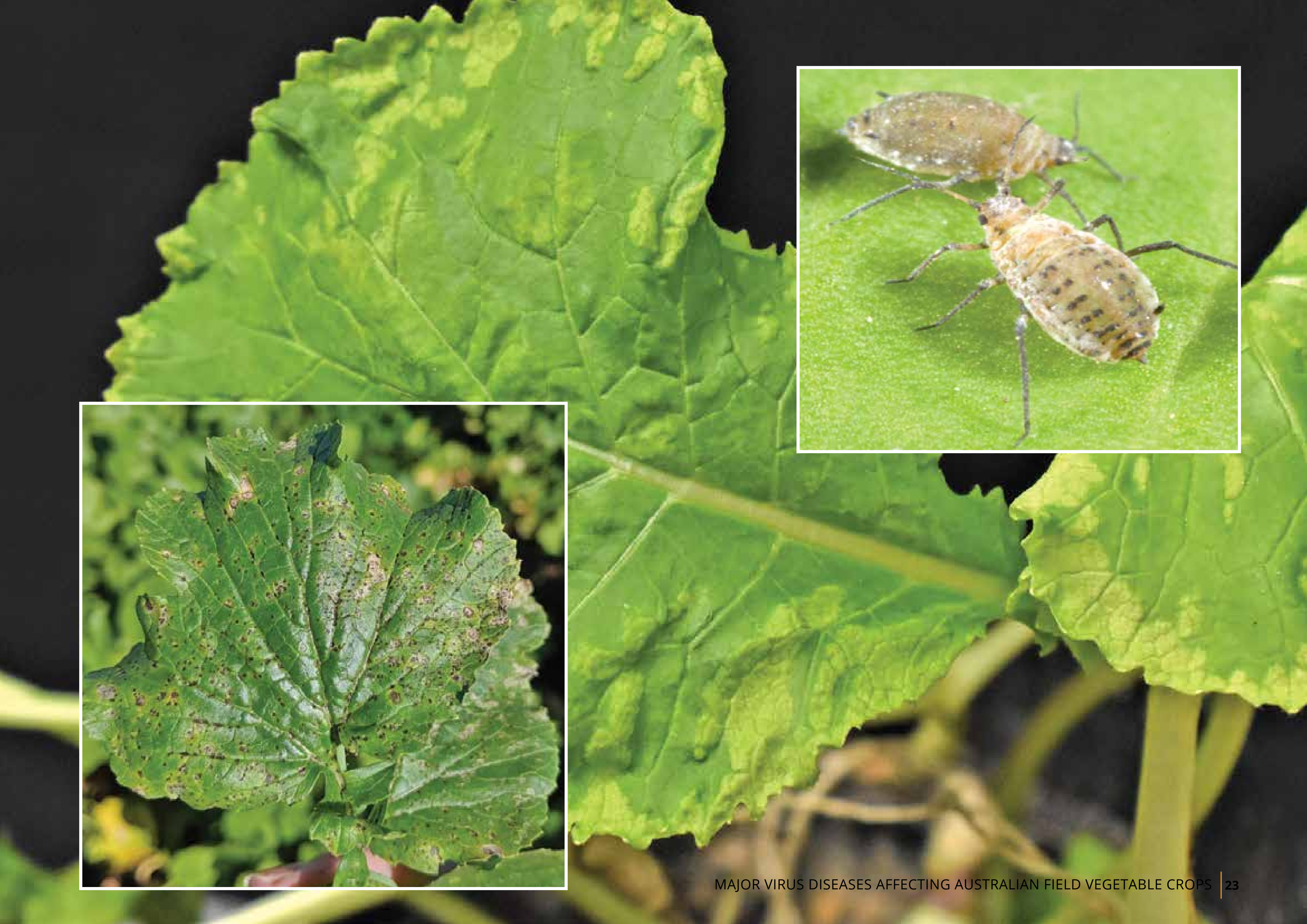
- Diagnostic testing of symptomatic plants to confirm it is TuMV, TuYV and/or CaMV that requires management
- Roguing of infected plants, plus at least two additional plants either side which are not showing symptoms – recommended for virus incidences of <1%
- Normal insecticides applications within crops to control aphid populations and prevent colonisation
- Biological control agents, insecticides, pest oil or some combination of these products applied to external sources could also be useful to control aphid populations multiplying on those plants (seek advice from APVMA on registration for non-crop usage of products)

Some anti-feeding insecticides may slow secondary spread of TuYV but will not be effective against TuMV or CaMV.

Given secondary spread contributes little to virus disease outbreaks and these products have a very limited target range they are not recommended for use specifically as a virus disease control strategy.

Usage should be limited to control insect populations as part of a routine spray program.

# BRASSICA DISEASE:
# **VIRUSES SPREAD BY APHIDS**



# CUCUMBER DISEASE:
# CUCUMBER GREEN MOTTLE MOSAIC VIRUS

***Cucumber green mottle mosaic virus* (CGMMV) is a highly contagious tobamovirus which affects a range of cucurbit species. It is spread very easily through contact and although it has no specific insect vector, physical spread can occur with insects. Note this virus is considered a regulated pest in some areas. Please consult with your local biosecurity agency on regulation requirements if CGMMV is detected on your property.**

## WHAT DOES IT LOOK LIKE?

CGMMV causes yellowing and mosaic on newest leaves of infected cucurbits but the severity of this depends on the crop. Cucumber are most affected and other species like pumpkin, zucchini or watermelon show milder reactions. Symptoms on leaves cannot be reliably distinguished from the cucurbit potyviruses so testing is required to confirm its presence. Fruit do not show many exterior symptoms but necrotic lesions on the peduncles of watermelon can occur. The inside of watermelon fruit is often spongy with a meat like texture and are unmarketable. Cucumbers can be soft with a reduced post-harvest storage life. Other crops often do not show noticeable fruit symptoms.

## WHERE DOES IT COME FROM AND HOW DOES IT SPREAD?

Primary spread is through seed, including volunteers from previous seasons or weeds. From these plants virus spread by contact is rapid, including by pollinators such as bees. The virus is also spread in sap on tools, equipment, hands, clothing etc. CGMMV can remain viable on these surfaces for days. Secateurs used to harvest fruit of an infected plant can spread the virus to ten healthy plants. Any plant debris (including dried plant material) is highly infectious including between seasons. Cucumber beetles and potentially other chewing insects which fly can spread the virus.

## DISEASE MANAGEMENT

In addition to general disease management recommendations (refer pages 15-17) the critical management point for CGMMV is to prevent primary introduction so ensure seed is sourced from a reputable company and has tested virus free. In cucumber the disease is well managed by use of resistant cultivars. The virus resistance results in milder symptoms and harvestable fruit.

These plants are still easily infected, and the disease is still very easily spread to other crops. No commercially available resistance to CGMMV is available in other cucurbit crops. To reduce risk of transfer from volunteer crop plants or weeds, remove these plants from nearby or prevent movement of people and equipment from these areas into crops. This should be done routinely. Infected material to be disposed of by deep burial or burning.

If virus is detected in crops, additional actions are:

- Diagnostic testing of symptomatic plants to confirm it is CGMMV that requires management
- Disposable gloves should be worn when handling infected plants and disposed of
- Roguing of infected plants, plus at least two additional plants either side which are not showing symptoms – recommended for virus incidences of <1%
- Remove the infected material without contacting remaining plants and dispose of either by deep burial or burning.
- Normal insecticides applications to control chewing insects can assist in reducing spread
- Equipment can be disinfected by a variety of commercially available chemicals such as sodium hypochlorite, Virkon or quaternary ammonium chloride compounds
- At least 30 seconds is needed to disinfect tools so switching tools between blocks/rows etc. can be effective to reduce spread

# CUCURBIT MOSAIC DISEASE:
# POTYVIRUSES SPREAD BY APHIDS

**There are three potyviruses in Australia which cause disease in cucumber, pumpkin, zucchini, and gourds. These viruses also infect melons and watermelons. The three viruses are *Papaya ringspot virus* (PRSV), *Watermelon mosaic virus* (WMV) and *Zucchini yellow mosaic virus* (ZYMV) and are all known to occur in all growing regions but typically PRSV affects crops in Queensland, WMV affects crops in NSW and ZYMV affects crops in Western Australia. Symptoms are very similar between the three viruses but depend on the crop and variety infected. Of these three viruses only ZYMV is known to be seedborne. These viruses are often indistinguishable from other important viruses (such as CGMMV) in cucurbits so diagnostic testing to confirm identify is important as management needs to be adjusted accordingly.**

## WHAT DOES IT LOOK LIKE?

All these viruses cause young leaves to become deformed having a blistered appearance or a stretched – shoestring appearance. The colour also turns to a mosaic with areas of light (yellow) and dark on the leaves. Fruit develops a warty or lumpy appearance and are reduced in size often with a mosaic colouring. Some cucurbits develop vein yellowing where the small veins of the leaves turn a clear/yellow colour. The symptoms are most easily confused with other viruses such as *cucumber green mottle mosaic virus* (CGMMV) or occasionally *cucumber mosaic virus* (CMV).

Symptoms of these viruses may also be confused with nutrient deficiencies, however these normally occur on lower leaves with shoot tips remaining healthy, while for viruses the young shoots are affected, and the lower leaves appear healthy (but are infected). Feeding damage by mites (especially broad mites) can resemble symptoms of viruses, but these can usually be seen with a hand lens on the undersides of leaves and in sheltered parts of the plant. Broad mite egg cases are white with spines projecting out. Genetic factors sometimes cause plants to be distorted in shape or colouring – which often resemble virus symptoms. These will be apparent in seedlings, but roguing plants is often prudent.

## WHERE DOES IT COME FROM AND HOW DOES IT SPREAD?

Primary spread of these viruses into crops is via aphids, their insect vector, from external virus sources in the environment. External sources for virus spread are weeds and volunteer crop plants growing alongside production blocks on headlands, in riparian areas or along roadsides that are a host for both the virus and the aphids. These sources are very important for primary spread of viruses into first plantings of crops. Once in commercial crops, these crops can become external virus sources for new plantings. This explains why diseases tend to increase through the season.

Major weed hosts for these viruses are cucurbits such as Mukia (*Cucumis maderaspatanus*), Afghan melon (*Citrullus lanatus*), and prickly paddy melon (*Cucumis myriocarpus*). Often symptoms on these weeds are mild or absent so they should be removed when close to the crop, even if no symptoms are seen.



## DISEASE MANAGEMENT

The critical management point for control of potyviruses in commercial crops is firstly to prevent primary introduction into the crop, which is from weeds, older affected crops, infected seedlings, or volunteer plants from the previous crop. Refer to the general disease management recommendations (pages 15-17). To reduce risk of transfer from external sources, remove these plants from nearby or treat them to reduce insect numbers. This should be done routinely.

Alternatively, using barrier non-virus host plants or fallow areas between and around crops will reduce spread of the viruses. Barrier plants are effective to both intercept aphids to reduce numbers entering crops and to cleanse aphid mouthparts of the viruses if they are a non-host for the virus (e.g sorghum, millet, corn). Aphids entering crops after feeding on the barrier plants will no longer spread the viruses. The barrier plants can also be used to multiply and maintain biological control agents to assist in controlling aphid populations.

Crop resistance is available in pumpkin, cucumber and particularly zucchini. It is generally partial resistance so some plants may still develop disease, but economic impacts are largely reduced, particularly in high disease pressure situations. Virus levels in resistant zucchini is greatly reduced which decreases spread by aphids to other non-resistant crops for which resistant varieties are not available. The level of resistance to each of the three viruses (PRSV, WMV and ZYMV) does vary so it is important to determine which varieties will work best in each region.

If virus is detected in crops, additional actions are:

- Diagnostic testing of symptomatic plants to confirm it is a potyvirus that requires management
- Roguing of infected plants, plus at least two additional plants either side which are not showing symptoms – recommended for virus incidences of <1%
- Reduce physical damage of plants where possible as the viruses are spread in sap between plants
- Regularly clean harvest knives to reduce risk of transfer in sap
- Normal insecticides applications within crops to control aphid populations and prevent colonisation
- Mineral oil foliar sprays can help reduce spread of virus in crops as they disrupt the aphid feeding – apply additional sprays as needed to protect new plant growth
- Biological control agents, insecticides, pest oil or some combination of these products applied to external sources could also be useful to control aphid populations multiplying on those plants (seek advice from APVMA on registration for non-crop usage of products).

# CUCUMBER YELLOWS DISEASE:
# BEET PSEUDOYELLOWS VIRUS

**Cucumber yellows disease caused by Beet pseudoyellows virus (BPYV) is found in most protected cropping cucumber districts, particularly on the east coast. The disease was confused with nutritional disorders for many years. Significant disease outbreaks, sometimes up to 100% of plants, occurred in the early-mid 2000s.This was from the Sydney basin, NSW and Virginia, SA production areas. The virus was subsequently found in mid and far north coast NSW and in Bundaberg, Queensland.**

## WHAT DOES IT LOOK LIKE?

By contrast with many other virus diseases, symptoms are more obvious on older leaves. Leaves develop a yellowing pattern between the veins and leaf margins curl downward and dead areas may develop between the veins. As younger leaves age, these symptoms become obvious on them. Fruit set is reduced, and severely affected plants are stunted. The symptoms are most confused with nutritional disorders. A key difference is the block-like pattern of the yellowing with BPYV infection, where leaves are more uniformly yellow with nutritional disorders.

## WHERE DOES IT COME FROM AND HOW DOES IT SPREAD?

The known natural or field host plants of BPYV is quite wide and includes lettuce, beet, endive, and common weeds including prickly lettuce (*Latuca serriola*), nettleleaf goosefoot (*Chenopdium murale*), dandelion (*Taraxacum officinale*), mallow (*Malva parviflora*) and shepherd's purse (*Capsella bura-pastoris*).

BPYV is semi-persistently spread by greenhouse whitefly (*Trialeurodes vaporariorum*). This means the whitefly needs to feed for at least 30 mins on an infected plant to pick up the virus. The virus is retained in the foregut and salivary glands of the insect and does not circulate within the insect like persistently transmitted viruses. The whitefly spreads the virus into new plants during subsequent feedings, which can continue for several days before the insect needs to feed again on an infected plant to re-acquire the virus. The virus in not seedborne and not spread by contact.

## DISEASE MANAGEMENT

In addition to general disease management recommendations (refer pages 15-17) the critical management point for BPYV in cucumber crops is to prevent primary introduction. This will be from weeds or older affected crops. To reduce this risk, ensure greenhouse structures have minimal entry points for insects and use sticky tape or traps to reduce numbers inside the structure. Removal of external plants hosting the virus and/or whitefly from nearby or treat them to reduce insect numbers is also of benefit. This should be routinely done and does not require monitoring.

If virus is detected in crops, additional actions are:

- Diagnostic testing of symptomatic plants to confirm it is BPYV that requires management
- Normal insecticides applications within crops to control whitefly populations and prevent colonisation

# FRENCH BEAN DISEASE:
# COWPEA MILD MOTTLE VIRUS (CPMMV)

***Cowpea mild mottle virus*** **(CPMMV) was found in Australia in 2016 where it caused extensive losses in south-east Queensland. The virus is found in all bean production areas in Queensland, but impacts are mostly low. Impacts have mostly occurred in one area and only in autumn crops. High disease correlates with high levels of silverleaf whitefly (SLW) the specific vector of the virus. This happens when dry weather in late summer increases SLW on other crops. The SLW then move into legume weed hosts in riparian areas when these crops are destroyed and then into newly planted autumn bean crops. Refer to Appendix 3 for more detail on weather influences on CPMMV outbreaks.**

## WHAT DOES IT LOOK LIKE?

Infected plants develop mosaic and mottling on leaves which vary in severity depending on the variety and age at infection. Pods on infected plants become curled, distorted, and look greasy, particularly when plants are infected during the first 3-4 weeks of growth. More than one of these symptoms can be present on the plant and not all plants will have the same symptoms. The symptoms can be confused with legume infecting potyviruses, however these are rarely detected. Pod distortion symptoms can be confused with insect feeding damage and leaf symptoms can be confused with some nutritional disorders.

## WHERE DOES IT COME FROM AND HOW DOES IT SPREAD?

The known natural or field host plants of CPMMV in Queensland are bean, soybean, cowpea, mung bean, siratro (*Macroptilium atropurpureum*), glycine (*Neonotonia wightii*) and phasey bean (*Macroptilium lathyroides*). CPMMV is non-persistently spread by SLW (*Bemisia argentifolii*, aka MEAMI or Biotype B of *B. tabaci*). Feeds of only about 10 min will spread the virus and this can continue for up to 2 h, after which the whitefly can no longer spread the virus. CPMMV is spread to bean crops from infected weed hosts, particularly siratro or glycine. Beans are not a preferred host of SLW, so secondary spread of CPMMV is very limited. Spread of some strains of CPMMV through seed is reported overseas but not known with Australian isolates.

## DISEASE MANAGEMENT

In addition to general disease management recommendations (refer pages 15-17) the critical management point for CPMMV in bean crops is to prevent primary introduction. This will be from weeds or older affected crops. To reduce this risk, remove these plants from nearby or treat them to reduce insect numbers. This should be done routinely.

Several commercial bean varieties are tolerant to the virus. When infected, plants develop very mild symptoms and pods develop normally. These varieties are tolerant, not highly resistant, and varying levels of yield decrease may still occur. The very low cull of pods in the packing shed is a key advantage. Growing virus tolerant varieties combined with knowledge of likely SLW populations throughout the production period provide the tools to minimise the economic impact of the virus.

Another strategy is to plant an area of other crops, such as pumpkin, which is a preferred host for SLW. This would reduce movement of SLW into bean crops and as pumpkin is not a host of CPMMV it would have a positive impact in reducing virus spread into bean crops.

If virus is detected in crops, additional actions are:

- Diagnostic testing of symptomatic plants to confirm it is CPMMV that requires management
- Normal insecticides applications within crops to control SLW populations and prevent colonisation

# LETTUCE DISEASE:
# VIRUSES SPREAD BY APHIDS

**There are four main lettuce viruses spread by aphids, *turnip mosaic virus* (TuMV), *turnip yellows virus* (TuYV), *lettuce mosaic virus* (LMV) and *lettuce necrotic yellows virus* (LNYV). TuMV and LMV are potyviruses, TuYV is a polerovirus and LNYV is a rhabdovirus. LNYV also infects other crop species in Australia including, garlic, chickpea, lupin, safflower, lucerne, and peanut. The major aphid species which spread these viruses to lettuce crops include green peach aphid (GPA; *Myzus persicae*), cabbage aphid (*Brevicoryne brassicae*), sowthistle aphid (*Hyperomyzus lactucae*) and turnip aphid (*Lipaphis pseudobrassicae*). Not all these aphid species spread all three viruses. LNYV is only spread by sowthistle aphid. LMV occurs sporadically in Australia and is seed transmitted. Clean seed schemes have markedly reduced the impact of this virus.**

## WHAT DOES IT LOOK LIKE?

TuMV causes bubbly, distorted leaves with necrotic spots leading to large necrotic patches. TuYV causes interveinal yellowing that can lead to necrotic patches. TuMV and TuYV can be found as mixed infections in single plants, often with more severe symptoms. Young lettuce infected with LNYV may show leaf chlorosis and stunting. Infections of older plants, start with browning of leaf veins followed by partial death of the inner leaves. Infected plants are yellow and stunted, often with twisted and lopsided leaves. In advanced stages, the outer leaves wilt severely, giving the plant a flattened, stunted appearance. Mature lettuce heads often show internal necrosis symptoms and cannot be marketed. Plants infected by LMV are stunted and deformed, often with mosaic or mottling symptoms on leaves. The older, outer leaves may be twisted and deformed. Plants may be infected by more than one virus and symptoms caused by different viruses are often similar. More than one of these symptoms can be present on the plant and not all leaves will have the same symptoms. Leaf distortion symptoms can be confused with herbicide or insect feeding damage. Some symptoms can be confused with some nutritional disorders

## WHERE DOES IT COME FROM AND HOW DOES IT SPREAD?

The main source of TuMV, LNYV and TuYV are weeds near the crop. The major source of LMV is virus-infected seed. A wide range of weed hosts exist for TuMV and TuYV including turnip weed (*Rapistrum rugosum*), bittercress (*Cardamine hirsuta*), sowthistle (*Sonchus oleraceus*) and shepherd's purse (*Capsella bursa-pastoris*), which may or may not show symptoms of the disease. For LNYV, the major weed and vector host is sowthistle and minor hosts include the native sowthistle (*S. hydrophilus*), prickly sowthistle, (*S. asper*), dune thistle (*S. megalocarpus*), prickly lettuce (*Lactuca serriola*), and false sow-thistle, (*Reichardia tingitana*). The sowthistle aphid is often found in large numbers on the flower stalks of sowthistle. It is also found on Hawksbeard (*Crepis capillaris*) and chicory (*Cichorum intybus*). The sowthistle aphid does not breed on lettuce but can spread LNYV within a lettuce crop as it moves through looking for a favourable weed host. TuYV and TuMV also infect brassicas. Brassica crops, including cover or biofumigant crops can also be sources of virus for spread into lettuce.

TuMV and LMV are spread non-persistently by a wide range of aphid species, but most common are the green peach and cabbage aphids. Non-persistent virus spread is very quick, aphids only need to feed for less than a minute to pick up the virus and a similar feeding time to deposit the virus into another plant. Once the virus is deposited into another plant the aphid is unable to spread the virus further unless it feeds again on an infected plant.

TuYV and LNYV are also spread by aphids, but in a persistent manner. Persistent virus spread takes much longer than non-persistent virus spread. For persistent virus spread, an aphid needs to feed for several hours to pick up the virus after which the virus circulates within the aphid's body to the salivary glands. This can take up to 12 hours. Once in the salivary gland it can be deposited into another plant. The aphid can then continue to spread the virus for weeks, or the rest of its life. For LNYV, the virus also propagates within the sowthistle aphid and is infective throughout its life and may pass the virus to offspring.

## DISEASE MANAGEMENT

In addition to general disease management recommendations (refer pages 15-17) the critical management point for viruses spread by aphids in lettuce crops is to prevent primary introduction. This will be from weeds or older affected crops. To reduce this risk, remove these plants from nearby or treat them to reduce insect numbers. This should be done routinely.

Alternatively, using barrier non-virus host plants or fallow areas between and around crops will reduce spread of the non-persistently transmitted TuMV. Barrier plants are effective to both intercept aphids to reduce numbers entering crops and to cleanse aphid mouthparts of the viruses if they are a non-host for the virus (e.g sorghum, millet, corn).

Aphids entering crops after feeding on the barrier plants will no longer spread TuMV. The barrier plants can also be used to multiply and maintain biological control agents to assist in controlling aphid populations.

If virus is detected in crops, additional actions are:

- Diagnostic testing of symptomatic plants to confirm which virus or viruses requires management
- Roguing of infected plants, plus at least two additional plants either side which are not showing symptoms – recommended for virus incidences of <1%
- Normal insecticides applications within crops to control aphid populations and prevent colonisation
- Mineral oil foliar sprays can help reduce spread of virus in crops as they disrupt the aphid feeding – apply additional sprays as needed to protect new plant growth
- Biological control agents, insecticides, pest oil or some combination of these products applied to external sources could also be useful to control aphid populations multiplying on those plants (seek advice from APVMA on registration for non-crop usage of products)

Some anti-feeding insecticides may slow secondary spread of TuYV but will not be effective against TuMV, LMV or LNYV. Given secondary spread contributes little to virus disease outbreaks and these products have a very limited target range they are not recommended for use specifically as a virus disease control strategy. Usage should be limited to control insect populations as part of a routine spray program.

# LETTUCE DISEASE:
# VIRUSES SPREAD BY THRIPS

***Tomato spotted wilt virus* (TSWV) is one of the most wide-spread and damaging viruses affecting vegetable crops in Australia. The virus affects lettuce in almost all growing districts.** *Impatiens necrotic spot virus* **(INSV) is reported in several Australian states affecting ornamental crops, however distribution in lettuce crops in Australia is limited to NSW. For INSV, the major insect vector is *Frankliniella occidentalis* (Western flower thrips, WFT), and for TSWV, the key thrips are WFT, *Frankliniella shultzei* (tomato thrips), *Thrips palmi* (melon thrips) and *Thrips tabaci* (onion thrips).**

## WHAT DOES IT LOOK LIKE?

Disease symptoms from TSWV and INSV infection in lettuce are similar but can vary depending on the variety, time of infection and other growing conditions. General TSWV and INSV symptoms in lettuce include yellowing and wilting of leaves, distortion of the central leaves, and a distinct brown russeting and necrotic spotting of the leaves. Heart formation is often incomplete, and plants may twist to one side. Seedlings can be infected with the virus and not show symptoms until the plant is mature. INSV in open-leaf lettuce varieties commonly does not move into the new growth so symptoms are confined to outer leaves. More than one of these symptoms can be present on the plant and not all leaves will have the same symptoms. Leaf distortion symptoms can be confused with herbicide or broad mite infestations. Some symptoms can be confused with some nutritional disorders.

## WHERE DOES IT COME FROM AND HOW DOES IT SPREAD?

Primary spread of TSWV and INSV into crops is via thrips, their insect vector, from external virus sources in the environment and this is the most important factor influencing disease outbreaks. Secondary spread within crops can occur but is low by comparison to primary spread from external sources. External sources for virus spread are weeds and volunteer crop plants growing near production blocks, in riparian areas or along headlands and roadsides. Infected crops can become external virus sources for new plantings if thrips populations are not well managed. A list of weed hosts for TSWV by district is provided in Appendix 6.

The viruses are not seedborne but primary spread into seedlings at nurseries is possible. Check the general health status of seedlings prior to planting and discard any unhealthy or thrips infested seedlings. The viruses are not spread on equipment or people during crop maintenance and harvest.

Both viruses are persistently spread by thrips and only if the thrips picks up the virus in their larval or juvenile stage (i.e they must hatch from eggs on an infected plant). The juveniles pick up virus during feeding on an infected plant, then the virus circulates through the insect body to the salivary glands. Once in the salivary gland subsequent feeding by the thrips spreads the virus to another plant. The virus cannot circulate within an adult thrips body thus adults feeding on infected plants cannot pick up and spread the viruses. A guide to this time is an initial feeding of 30 minutes to pick up the virus, 5 days for circulation then another feeding on a healthy plant of 5-10 minutes to introduce the virus into that plant. The thrips pupae do not feed on plants thus do not spread virus and are also not controlled by systemic insecticides. Only adult thrips have wings, so these can spread the virus rapidly between crops and are the primary way in which the virus enters crops.

Different thrips species spread viruses with different efficiencies, so knowledge of local

thrips and virus populations is key. Thrips are very small and difficult to identify without specialist training and equipment. Samples can be sent to diagnostic labs for testing (Appendix 1).

## DISEASE MANAGEMENT

In addition to general disease management recommendations (refer pages 15-17) the critical management point for TSWV and INSV in commercial crops is to prevent primary introduction. This will be from weeds or older affected crops. To reduce this risk, remove these plants from nearby or treat them to reduce insect numbers. This should be done routinely. If virus is detected in crops, additional actions are:

- Diagnostic testing of symptomatic plants to confirm it is TSWV and/or INSV that requires management
- Identification of thrips to confirm there is a virus vector present and which species
- Roguing of symptomatic plants – recommended for virus incidences of <1%
- Normal insecticides applications within crops to control thrips populations and prevent colonisation
- Thrips pupae are dormant and do not feed on plants, and so they are not killed by systemic insecticides. Successive sprays often needed to eliminate newly emerged adult thrips. This should be done in crops only if larval stages are detected.
- Biological control agents, insecticides, pest oil or some combination of these products applied to external sources could also be useful to control aphid populations multiplying on those plants (seek advice from APVMA on registration for non-crop usage of products)

# SOLANACEAE DISEASE:
# VIRUSES SPREAD BY THRIPS

**There are two viruses spread by thrips that affect tomato, capsicum, chilli, eggplant, and potato crops. *Tomato spotted wilt virus* (TSWV) is widespread in Australia whereas *capsicum chlorosis virus* (CaCV) is mainly found around Bundaberg and the dry tropics in Queensland. For TSWV, the key thrips are *Frankliniella occidentalis* (Western flower thrips; WFT), *Frankliniella shultzei* (tomato thrips), *Thrips palmi* (melon thrips) and *Thrips tabaci* (onion thrips). and for CaCV, the key thrips are tomato thrips, *Microcephalothrips abdominalis* and melon thrips. Disease outbreaks are heavily influenced by presence of external virus and thrips sources. The abundance of these alternative plants is in turn influenced by weather, particularly rainfall. Appendix 3 details a case study on the influence of rainfall on CaCV outbreaks in the dry tropics to explain these types of interactions.**

## WHAT DOES IT LOOK LIKE?

TSWV and CaCV infections look very similar and dual infections are possible. Infected fruits are often distorted, have ringspots, chlorotic blotches and necrotic areas or some combination of these symptoms. Infected leaves of capsicum and chilli can show chlorotic blotches, ringspots, line patterns, mottling and yellowing of leaf margins. In tomato, chlorotic spots, blotches, and mottling are common and concentric rings and lines rarely seen on the leaves. More than one of these symptoms can be present on the plant and not all leaves will have the same symptoms. Leaves can also be distorted, and plants stunted if infected early. Leaf distortion symptoms can be confused with herbicide or broad mite infestations. Fruit distortion and necrotic tissue can be confused with thrips feeding damage and some nutritional disorders.

## WHERE DOES IT COME FROM AND HOW DOES IT SPREAD?

Primary spread of TSWV and CaCV into crops is via thrips, their insect vector, from external virus sources in the environment and this is the most important factor influencing disease outbreaks. Secondary spread within crops can occur but is low by comparison to primary spread from external sources. External sources for virus spread are weeds and volunteer crop plants growing near production blocks, in riparian areas or along roadsides and that are a host for both the virus and the thrips. Infected crops can become external virus sources for new plantings if thrips populations are not well managed. A list of weed hosts for TSWV by district is provided in Appendix 6. For CaCV the major weed hosts are billy goat weed (*Ageratum conyzoides*) in Bundaberg and *Praxelis clematidea* in the dry tropics.

The viruses are not seedborne but primary spread into seedlings at nurseries is possible. Check the general health status of seedlings prior to planting and discard any unhealthy or thrips infested seedlings. The viruses are not spread on equipment or people during crop maintenance and harvest.

Both viruses are persistently spread by thrips and only if the thrips picks up the virus in their larval or juvenile stage (i.e they must hatch on an infected plant). The juveniles pick up virus during feeding on an infected plant, then the virus circulates through the insect body to the salivary glands. Once in the salivary gland subsequent feeding by the thrips spreads the virus to another plant. The virus cannot circulate within an adult thrips body thus adults feeding on infected plants cannot pick up and spread the viruses. A guide to this time is an initial feeding of 30 minutes to pick up the virus, 5 days for *primary spread of CaCV and TSWV into crops is via thrips, their insect vector, from external virus sources in the environment*

circulation then another feeding on a healthy plant of 5-10 minutes to introduce the virus into that plant. The thrips larvae do not feed on plants thus do not spread virus and are also not controlled by systemic insecticides. Only adult thrips have wings, so these can spread the virus rapidly between crops and are the primary way in which the virus enters crops.

Different thrips species spread viruses with different efficiencies, so knowledge of local thrips and virus populations is key. Thrips are very small and difficult to identify without specialist training and equipment. Samples can be sent to diagnostic labs for testing (Appendix 1).

## DISEASE MANAGEMENT

In addition to general disease management recommendations (refer pages 15-17) consider resistant or tolerant varieties. Commercially available TSWV tomato varieties are generally robust, however, the TSWV resistance gene in capsicums can be overcome by resistance-breaking strains of the virus. There are no CaCV resistant crop varieties currently available. Chilli and eggplant do not have resistance to either virus.

The critical management point for TSWV and CaCV in crops is to prevent primary introduction. This will be from weeds or older affected crops. To reduce this risk, remove these plants from nearby or treat them to reduce insect numbers. This should be done routinely. If virus is detected in crops, additional actions are:

- Diagnostic testing of symptomatic plants to confirm it is TSWV and/or CaCV that requires management
- Identification of thrips to confirm there is a virus vector present and which species
- Roguing of symptomatic plants – recommended for virus incidences of <1%
- Normal insecticides applications within crops to control thrips populations and prevent colonisation
- Thrips pupae (the dormant life stage between larvae and adults) do not feed on plants, and so they are not killed by systemic insecticides. Successive sprays often needed to eliminate newly emerged adult thrips. This should be done in crops only if larval stages are detected.
- Biological control agents, insecticides, pest oil or some combination of these products applied to external sources could also be useful to control aphid populations multiplying on those plants (seek advice from APVMA on registration for non-crop usage of products)

# SOLANACEAE DISEASE: **VIRUSES SPREAD BY THRIPS**

# SWEET CORN MOSAIC DISEASE: JOHNSON GRASS MOSAIC VIRUS (JGMV)

**The potyvirus *Johnson grass mosaic virus* (JGMV) causes mosaic symptoms in susceptible sweet corn hybrids. The virus also infects maize, sorghum, forage sorghum, millets, and some annual grasses.**

**Although scattered JGMV infected plants occur in crops the virus is seldom a problem as most hybrids now have at least moderate resistance to the virus. This reduces the chances of serious disease outbreaks.**

## WHAT DOES IT LOOK LIKE?

Light green and dark green patches develop on young leaves, giving them a mosaic or mottled pattern. These patches are usually seen as broken lines between the leaf veins. Plant growth is reduced, and plants appear yellow compared with healthy neighbours. Cob formation and development is affected, particularly when plants are infected at an early stage of development.

## WHERE DOES IT COME FROM AND HOW DOES IT SPREAD?

JGMV is spread non-persistently by many species of aphids. Virus spread only needs very short feeding times (<1 min). Johnson grass (*Sorghum halepense*) is the major primary source of the virus. This weed occurs commonly along roadsides and in weedy areas in southern and central Queensland. Once the virus is established in a crop of a susceptible host aphids can rapidly spread JGMV.

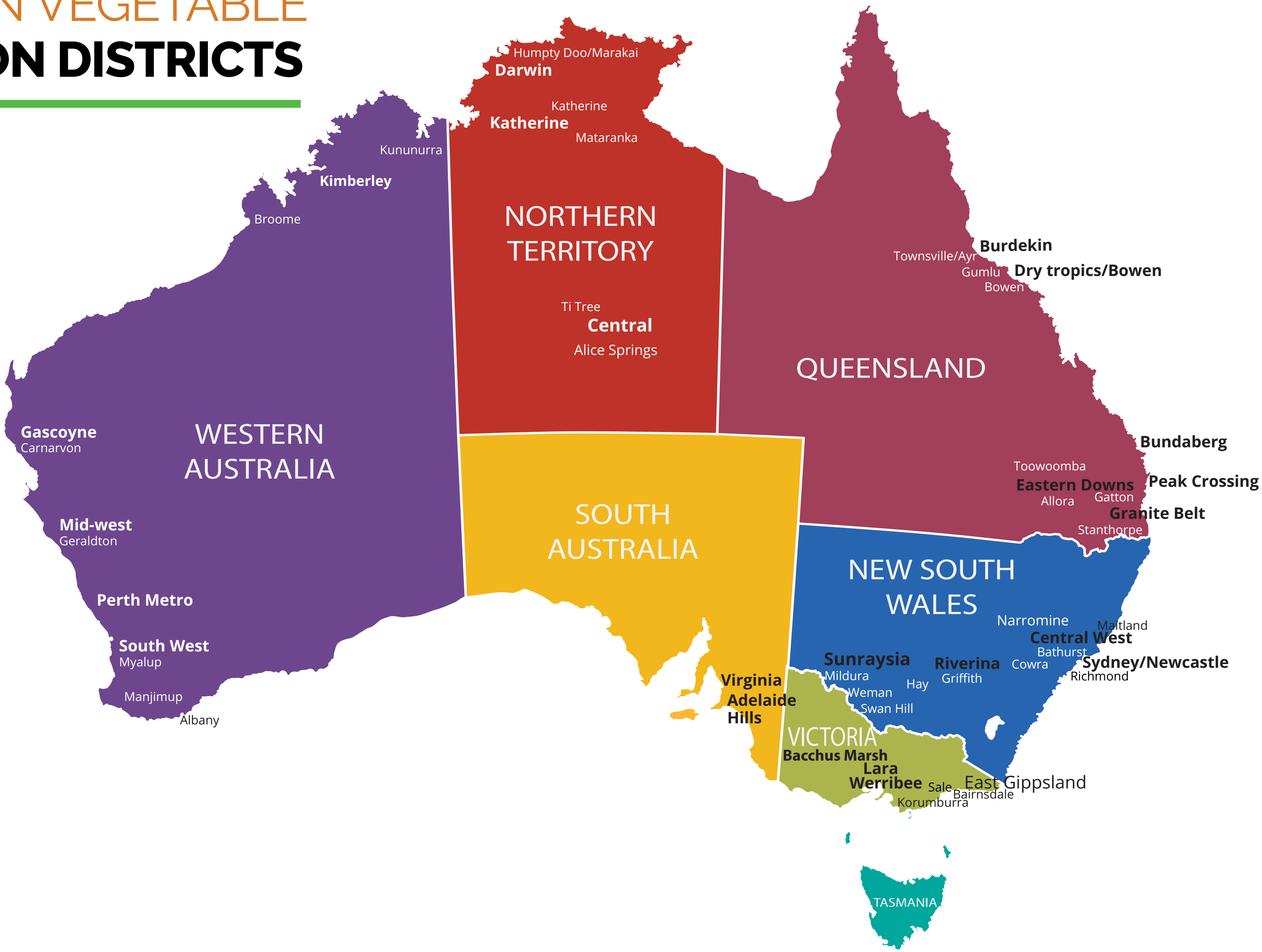
## DISEASE MANAGEMENT

Most sweet corn and maize hybrids have at least a moderate level of resistance to JGMV. This resistance has markedly reduced the impact of JGMV in sweet corn and is the primary disease management option. Virus resistant hybrids has been developed both in Australia and in the USA where hybrids bred for resistance to a related virus, Maize dwarf mosaic virus (MDMV) are also usually resistant to JGMV in Australia.

It is still important to follow general disease management recommendations (refer pages 15-17) to limit spread of other diseases and to reduce risk of new strains of JGMV emerging which could overcome crop resistance genes.

# AUSTRALIAN VEGETABLE **PRODUCTION DISTRICTS**

The following table provides key details for each major Australian vegetable production district. These details include the most commonly occurring viral disease found in each district and information on where the viruses come from and how they spread. The presence and importance of viral diseases can change over time and regular monitoring and diagnostics are recommended to ensure disease management remains appropriate.



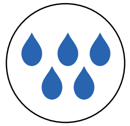
## LIST OF VIRUS ACRONYMS

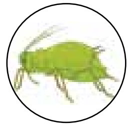
| | | | |
|---|---|---|---|
| AMV | alfalfa mosaic virus | PeVYV | pepper vein yellows virus |
| BBWV | broad bean wilt virus | PMMoV | pepper mild mottle virus |
| BCMV | bean common mosaic virus | PRSV | papaya ringspot virus |
| BPYV | beet pseudo yellows virus | PSbMV | pea seedborne mosaic virus |
| BYMV | bean yellow mosaic virus | PSTVd | potato spindle-tuber viroid |
| CaCV | capsicum chlorosis virus | PVY | potato virus y |
| CaMV | cauliflower mosaic virus | RWMV | ranunculus white mottle virus |
| CarYV | carrot virus y | SCRLV | subterranean clover red leaf virus |
| CeMV | celery mosaic virus | SDV | satsuma dwarf virus |
| CGMMV | cucumber green mottle mosaic virus | SPFMV | sweet potato feathery mottle virus |
| ClYVV | clover yellow vein virus | SPLCV | sweet potato leaf curl virus |
| CMoV | carrot mottle virus | SqMV | squash mosaic virus |
| CMV | cucumber mosaic virus | TBB | tomato big bud |
| CPMMV | cowpea mild mottle virus | TMGMV | tobacco mild green mottle virus |
| CRLV | carrot red leaf virus | ToLCV | tomato leaf curl virus |
| INSV | impatiens necrotic spot virus | ToTV | tomato torrado virus |
| JGMV | johnsongrass mosaic virus | TSWV | tomato spotted wilt virus |
| LBVaV | lettuce big-vein associated virus | TuMV | turnip mosaic virus |
| LBVD | lettuce big-vein disease | TuYV | turnip yellows virus |
| LMV | lettuce mosaic virus | TYDV | tobacco yellow dwarf virus |
| LNYV | lettuce necrotic yellow virus | TYLCV | tomato yellow leaf curl virus |
| MLBVV | mirafiori lettuce big-vein virus | WMV | watermelon mosaic virus |
| MNSV | melon necrotic spot virus | ZYMV | zucchini yellow mosaic virus |
| PBMYV | phasey bean mild yellow virus | PeVYV | pepper vein yellow virus |
| PEMV | pea enation mosaic virus | | |

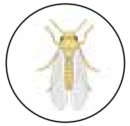
## ICONS AND MEANING

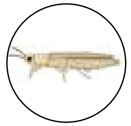

Crop debris/ volunteer crop plants

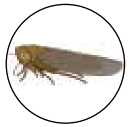

Seed


Water (Irrigation)


Aphids

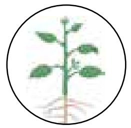

Whitefly

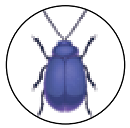

Thrips


Leafhopper


People and equipment


Soil


Weeds


Chewing insect


Olpidium zoospore

***Credit: insect icons BioRender.com***

## Queensland: Dry Tropics and Burdekin: Bowen, Gumlu & Ayr

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Capsicum, chilli | CaCV | | | P |
| | TSWV | | | P |
| French bean | CPMMV | | | NP |
| Melon | PRSV | | | NP |
| | WMV | | | NP |
| Pumpkin | PRSV | | | NP |
| | WMV | | | NP |
| Tomato | CaCV | | | P |
| | TSWV | | | P |
| | TYLCV | | | P |
| Zucchini | PRSV | | | NP |
| | WMV | | | NP |

## Queensland: Bundaberg

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Capsicum, chilli | CaCV | | | P |
| | PVY | | | NP |
| | TSWV | | | P |

## Queensland: Bundaberg

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Cucumber | BPYV | | | SP |
| | CGMMV | | | M |
| | PRSV | | | NP |
| French bean | CPMMV | | | NP |
| Melon | PRSV | | | NP |
| | WMV | | | NP |
| Pumpkin | PRSV | | | NP |
| | WMV | | | NP |
| Squash | PRSV | | | NP |
| | WMV | | | NP |
| Tomato | CaCV | | | P |
| | PVY | | | NP |
| | TSWV | | | P |
| | TYLCV | | | P |
| Zucchini | PRSV | | | NP |
| | WMV | | | NP |

## Queensland: Lockyer Valley, Gatton

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Brassicas | AMV | | | NP |
| | CaMV | | | NP |
| | TSWV | | | P |
| | TuMV | | | NP |
| | TuYV | | | P |
| Capsicum, chilli | TBB* | | | P |
| | TSWV | | | P |
| French bean | CPMMV | | | NP |
| Lettuce | AMV | | | NP |
| | LBVD | | | P |
| | LMV | | | NP |
| | LNYV | | | P |
| | TSWV | | | P |
| | TuMV | | | NP |
| | TuYV | | | P |
| Pumpkin | PRSV | | | NP |
| | WMV | | | NP |

## Queensland: Lockyer Valley, Gatton

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Tomato | TSWV | | | P |
| | TYLCV | | | P |
| Sweet corn | JGMV | | | NP |
| Zucchini | PRSV | | | NP |
| | WMV | | | NP |

## Queensland: Eastern Downs

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Brassicas | AMV | | | NP |
| | CaMV | | | NP |
| | TuMV | | | NP |
| | TuYV | | | P |
| Capsicum, chilli | TBB* | | | P |
| | TSWV | | | P |
| Celery | CeMV | | | NP |

*TBB* = tomato big bud phytoplasma, not a virus but spread like a virus*

## Queensland: Eastern Downs

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Lettuce | AMV | | | NP |
| | LBVD | | | P |
| | LNYV | | | P |
| | TSWV | | | P |
| | TuMV | | | NP |
| | TuYV | | | P |
| Sweet corn | JGMV | | | NP |

## Queensland: Fassifern Valley and Peaks Crossing

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Brassicas | AMV | | | NP |
| | CaMV | | | NP |
| | TuMV | | | NP |
| | TuYV | | | P |
| French bean | CPMMV | | | NP |
| Lettuce | AMV | | | NP |
| | CaMV | | | NP |
| | TuMV | | | NP |
| | TuYV | | | P |

## Queensland: Fassifern Valley and Peaks Crossing

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Pumpkin | PRSV | | | NP |
| | WMV | | | NP |
| Sweet corn | JGMV | | | NP |

## Queensland: Granite Belt

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Capsicum, chilli | TBB* | | | P |
| | TSWV | | | P |
| Celery | CeMV | | | NP |
| Parsley | AMV | | | NP |
| Tomato | TBB* | | | P |
| | TSWV | | | P |
| Zucchini | PRSV | | | NP |
| | WMV | | | NP |

*TBB* = tomato big bud phytoplasma, not a virus but spread like a virus*

## New South Wales: Sydney to Mid-North Coast (Sydney Basin, Newcastle, Maitland, Gosford, Peats Ridge, Coffs Harbour)

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Brassicas | CaMV | | | NP |
| | TuMV | | | NP |
| | TuYV | | | P |

## New South Wales: Sydney to Mid-North Coast (Sydney Basin, Newcastle, Maitland, Gosford, Peats Ridge, Coffs Harbour)

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Broad bean | CMV | | | NP |
| Capsicum | TSWV | | | P |
| Cucumber | BPYV | | | SP |
| | CGMMV | | | M |
| | CMV | | | NP |
| French bean | CMV | | | NP |
| Lettuce | TSWV | | | P |
| Pumpkin | WMV | | | NP |
| Rockmelon | CGMMV | | | M |
| | WMV | | | NP |
| Squash | PRSV | | | NP |
| | WMV | | | NP |
| Tomato | TSWV | | | P |
| Watermelon | CGMMV | | | M |
| | WMV | | | NP |
| Zucchini | CMV | | | NP |
| | PRSV | | | NP |
| | WMV | | | NP |

## New South Wales: Central West (Bathurst, Cowra and Narromine)

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Brassicas | CaMV | | | NP |
| | TuMV | | | NP |
| | TuYV | | | P |
| Pumpkin | WMV | | | NP |
| Squash | WMV | | | NP |
| Watermelon | WMV | | | NP |
| Zucchini | WMV | | | NP |

## New South Wales: Riverina (Griffith and Hay)

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Cucumber | CGMMV | | | M |
| Pumpkin | WMV | | | NP |
| Rockmelons | CGMMV | | | M |
| | MNSV | | | P |
| | WMV | | | NP |
| Squash | WMV | | | NP |
| Watermelon | CGMMV | | | M |
| | MNSV | | | P |
| Zucchini | WMV | | | NP |

## Victoria: Melbourne, Bacchus Marsh, Werribee, Cranbourne and Clyde

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Brassicas | CaMV | | | NP |
| | TSWV | | | P |
| | TuMV | | | NP |
| | TuYV | | | P |
| Carrot | CarVY | | | NP |
| | CeMV | | | NP |
| | TSWV | | | P |
| Celeriac | CarVY | | | NP |
| | CeMV | | | NP |
| | TSWV | | | P |
| Celery | CarVY | | | NP |
| | CeMV | | | NP |
| | TSWV | | | P |
| Coriander | CMV | | | NP |
| | TSWV | | | P |

## Victoria: Melbourne, Bacchus Marsh, Werribee, Cranbourne and Clyde

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Endive | CMV | | | NP |
| | LBVaV | | | P |
| | LMV | | | NP |
| | LNYV | | | P |
| | MLBVV | | | P |
| | TSWV | | | P |
| | TuMV | | | NP |
| Lettuce | CMV | | | NP |
| | LBVaV | | | P |
| | LMV | | | NP |
| | LNYV | | | P |
| | MLBVV | | | P |
| | TSWV | | | P |
| | TuMV | | | NP |
| Parsley | CarVY | | | NP |
| | CeMV | | | NP |
| | TSWV | | | P |

## Victoria: Melbourne, Bacchus Marsh, Werribee, Cranbourne and Clyde

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Radicchio | CMV | | | NP |
| | LBVaV | | | P |
| | LMV | | | NP |
| | LNYV | | | P |
| | MLBVV | | | P |
| | TSWV | | | P |
| | TuMV | | | NP |
| Spinach | CMV | | | NP |
| | TSWV | | | P |

## Victoria: Mildura, Swan Hill

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Brassicas | AMV | | | NP |
| | CaMV | | | NP |
| | TSWV | | | P |
| | TuMV | | | NP |
| | TuYV | | | P |
| Capsicum | RWMV | | | P |
| | TSWV | | | P |

## Victoria: Mildura, Swan Hill

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Chilli | AMV | | | NP |
| | RWMV | | | P |
| | TSWV | | | P |
| Eggplant | TBB* | | | P |
| | TSWV | | | P |
| Lettuce | CMV | | | NP |
| | LBVaV | | | P |
| | LMV | | | NP |
| | LNYV | | | P |
| | MLBVV | | | P |
| | TSWV | | | P |
| | TuMV | | | NP |
| Pumpkin | CMV | | | NP |
| | WMV | | | NP |
| | ZYMV | | | NP |

*TBB* = tomato big bud phytoplasma, not a virus but spread like a virus*

## Victoria: Mildura, Swan Hill

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Tomato | TBB* | | | P |
| | TSWV | | | P |
| | TYLCV | | | P |
| Zucchini | CMV | | | NP |
| | WMV | | | NP |
| | ZYMV | | | NP |

*TBB* = tomato big bud phytoplasma, not a virus but spread like a virus*

## Victoria: Eastern Gippsland

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Brassicas | AMV | | | NP |
| | CMV | | | NP |
| | TSWV | | | P |
| | TuMV | | | NP |
| | TuYV | | | P |

## Victoria: Eastern Gippsland

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Endive | AMV | | | NP |
| | CMV | | | NP |
| | LBVaV | | | P |
| | LMV | | | NP |
| | LNYV | | | P |
| | MLBVV | | | P |
| | TSWV | | | NP |
| | TuMV | | | NP |
| Lettuce | AMV | | | NP |
| | CMV | | | NP |
| | LBVaV | | | P |
| | LMV | | | NP |
| | MLBVV | | | P |
| | LNYV | | | P |
| | TSWV | | | NP |
| | TuMV | | | NP |

| Victoria: Eastern Gippsland | | | | |
|---|---|---|---|---|
| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
| Peas | AMV | | | NP |
| | BYMV | | | NP |
| | CMV | | | NP |
| | TuYV | | | P |
| Beans | BYMV | | | NP |
| | TuYV | | | P |
| | TYDV | | | P |
| Radicchio | AMV | | | NP |
| | CMV | | | NP |
| | LBVaV | | | P |
| | LMV | | | NP |
| | LNYV | | | P |
| | MLBVV | | | P |
| | TSWV | | | NP |
| | TuMV | | | NP |
| Sweet corn | JGMV | | | NP |

| South Australia: Virginia | | | | |
|---|---|---|---|---|
| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
| Brassicas | AMV | | | NP |
| | CaMV | | | NP |
| | TSWV | | | P |
| | TuMV | | | NP |
| | TuYV | | | P |
| Capsicum | RWMV | | | P |
| | TMGMV | | | M |
| | TSWV | | | P |
| Chilli | AMV | | | NP |
| | RWMV | | | P |
| | TSWV | | | P |
| Cucumber | BPYV | | | SP |

## South Australia: Virginia

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Lettuce | CMV | | | NP |
| | LBVaV | | | P |
| | LMV | | | NP |
| | LNYV | | | P |
| | MLBVV | | | P |
| | TSWV | | | P |
| | TuMV | | | NP |
| Tomato | TBB* | | | P |
| | ToTV | | | P |
| | TSWV | | | P |
| Zucchini | CMV | | | NP |
| | PRSV | | | NP |
| | WMV | | | NP |
| | ZYMV | | | NP |

*TBB* = tomato big bud phytoplasma, not a virus but spread like a virus*

## Tasmania

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Brassicas | CaMV | | | NP |
| | TuMV | | | NP |
| | TuYV | | | P |
| Broad bean | BBWV | | | NP |
| | BCMV | | | NP |
| | BYMV | | | NP |
| | ClYVV | | | NP |
| | SCRLV | | | P |
| | SCSV | | | P |
| | SDV | | | P |
| | TuYV | | | P |
| Carrot | CMoV | | | P |
| | CRLV | | | P |
| | CarVY | | | NP |

## Tasmania

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| French bean | BBWV | | | NP |
| | BCMV | | | NP |
| | BYMV | | | NP |
| | ClYVV | | | NP |
| | SCRLV | | | P |
| | SCSV | | | P |
| | SDV | | | P |
| | TuYV | | | P |
| Lettuce | BPYV | | | SP |
| | LBVaV | | | P |
| | LMV | | | NP |
| | LNYV | | | P |
| | MLBVV | | | P |
| | TSWV | | | P |
| | TuYV | | | P |

## Tasmania

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Peas | AMV | | | NP |
| | CMV | | | NP |
| | PBMYV | | | P |
| | PEMV | | | P |
| | PSbMV | | | NP |
| | SCRLV | | | P |
| | SCSV | | | P |
| | SDV | | | P |
| | TSWV | | | P |
| | TuYV | | | P |

## Western Australia: Gascoyne: Carnarvon

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Capsicum, chilli | CMV | | | NP |
| | PMMoV | | | M |
| | PVY | | | NP |
| | PSTVd | | | M |
| | TBB* | | | P |
| | TSWV | | | P |
| Cucumber | CGMMV | | | M |
| | TBB* | | | P |
| | ZYMV | | | NP |
| Eggplant | TBB* | | | P |
| | TSWV | | | P |
| Melon | CGMMV | | | M |
| | TBB* | | | P |
| | ZYMV | | | NP |

## Western Australia: Gascoyne: Carnarvon

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Pumpkin | CGMMV | | | M |
| | TBB* | | | P |
| | ZYMV | | | NP |
| Tomato | CMV | | | NP |
| | PSTVd | | | |
| | TBB* | | | P |
| | TSWV | | | P |
| Zucchini | ZYMV | | | NP |

*TBB* = tomato big bud phytoplasma, not a virus but spread like a virus*

## Western Australia: Perth Metro: Wanneroo, Gingin, Carabooda

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Capsicum | CMV | | | NP |
| | TSWV | | | P |
| Carrot | CarVY | | | NP |
| Lettuce | LBVV | | | P |
| | TSWV | | | P |
| Tomato | TSWV | | | P |
| Zucchini | ZYMV | | | NP |

## Western Australia: South West: Myalup, Manjimup, Albany

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Brassicas | CaMV | | | NP |
| | TuMV | | | NP |
| | TuYV | | | P |
| Carrot | CarVY | | | NP |
| Tomato | TSWV | | | P |

## Western Australia: Kimberly: Kununurra, Broome

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Beans | BCMV | | | NP |
| Melon | CGMMV | | | M |
| | SqMV | | | NP |
| | TBB* | | | P |
| | ZYMV | | | NP |
| Pumpkin | CGMMV | | | M |
| | Luteovirus | | | P |
| | PRSV | | | NP |
| | SqMV | | | NP |
| | TBB* | | | P |
| | ZYMV | | | NP |

*TBB* = tomato big bud phytoplasma, not a virus but spread like a virus*

## Western Australia: Mid-West: Geraldton

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Capsicum | CMV | | | NP |
| | TSWV | | | P |
| Cucumber | CGMMV | | | M |
| | ZYMV | | | NP |
| Eggplant | TSWV | | | P |
| Melon | CGMMV | | | M |
| | ZYMV | | | NP |
| Tomato | TSWV | | | P |

## Northern Territory: Darwin Region

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Asian melons[1] | Phytoplasma | | | P |
| | PRSV | | | NP |
| | ZYMV | | | NP |
| Capsicum, chilli | PeVYV | | | P |
| Cucumber | PRSV | | | NP |
| | ZYMV | | | NP |

[1] *including bitter melon, long melon, snake gourd, luffa, sinqua etc.*

## Northern Territory: Darwin Region

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Pumpkin | PRSV | | | NP |
| | ZYMV | | | NP |
| Eggplant | Phytoplasma | | | P |
| Peanut | Phytoplasma | | | P |
| Snake bean | CMV | | | NP |
| | Phytoplasma | | | P |
| Sweetpotato | SPFMV | | | NP |
| | SPLCV | | | P |
| | Phytoplasma | | | P |
| Tomato | ToLCV | | | P |
| Watermelon | CGMMV | | | M |
| | PRSV | | | NP |
| | ZYMV | | | NP |

## Northern Territory: Katherine Region

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Cucumber | PRSV | | | NP |
| | ZYMV | | | NP |
| Eggplant | Phytoplasma | | | P |
| Pumpkin | PRSV | | | NP |
| | ZYMV | | | NP |
| Snake bean | Phytoplasma | | | P |
| | CMV | | | NP |
| Tomato | ToLCV | | | P |
| Watermelon | PRSV | | | NP |
| | CGMMV | | | M |

## Northern Territory: Central Region

| Commodity | Viruses | Where does it come from? | How does it spread? | What is the mode of vector spread? |
|---|---|---|---|---|
| Pumpkin | PRSV | | | NP |
| | ZYMV | | | NP |
| Watermelon | CGMMV | | | M |
| Zucchini | ZYMV | | | NP |


power
besgrow
gropac

# APPENDIX 1
# DIAGNOSTIC SERVICES

| Institute | Laboratory | Weblink |
| --- | --- | --- |
| DAF, Queensland | Grow Help Australia | https://www.business.qld.gov.au/industries/farms-fishing-forestry/agriculture/agribusiness/grow-help-australia/service |
| DJPR, Victoria | Crop Health Services | https://agriculture.vic.gov.au/support-and-resources/services/diagnostic-services |
| DPRIR, Northern Territory | Berrimah Agricultural Lab | https://industry.nt.gov.au/contacts/laboratories |
| DPIRD, Western Australia | DPIRD Diagnostic Laboratory Services | https://www.agric.wa.gov.au/bacteria/ddls-plant-pathology-services |
| DPI, NSW | Elizabeth Macarthur Agricultural Institute | https://www.dpi.nsw.gov.au/about-us/science-and-research/centres/emai |
| DPIPWE, Tasmania | Plant Diagnostic Service | https://nre.tas.gov.au/biosecurity-tasmania/plant-biosecurity/plant-diagnostic-services |

# APPENDIX 2
# SAMPLE COLLECTION AND PACKAGING

When attempting to identify viral diseases, correctly sampling the tissue, and packing the sample is important When deciding what part of the plant needs to be sent, it is helpful to include more tissue than not enough. If there are only symptoms on fruit, it can be helpful to include leaf tissue as well. As a preference, collect fresh, new growth displaying symptoms.

Cut off a sprig / branch of about a hand-span in size and wrap in one layer of paper towel and keep inside a plastic bag. The paper helps to minimise the sweating that occurs when samples are in plastic.

Keep samples cool, in a fridge. Do not freeze. Samples kept below room temp will be fine for many hours, but high temperatures (back seat of car in sun) will cause rapid degradation.

Your diagnostic lab will have information requirements, but as a minimum, you should have contact information, location, suspect symptoms, distribution and incidence of affected plants and any unusual weeds or crops nearby.

# APPENDIX 3
# WEATHER, INSECTS, AND DISEASE

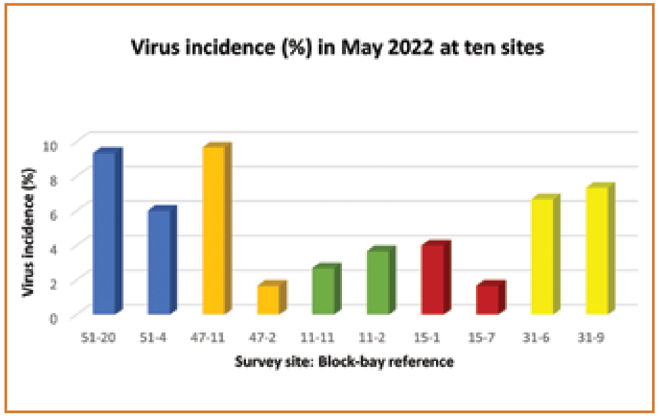
Evaluating weather and monitoring data together provides valuable insight into potential for virus disease outbreaks. The timing and amount of rainfall affects weed longevity which impacts survival of viruses and their insect vectors. Overlap of weeds with early season crops can trigger major disease outbreaks. Rainfall also affects the insects, particularly whiteflies and can reduce virus spread. The effect of weather on disease outbreaks is specific to each virus-insect-weed combination and is very complex. It is also very site specific, driven mostly by weed diversity, abundance, and ability to host the virus and/or vector. Local knowledge of these factors is very useful to assist with virus disease management.

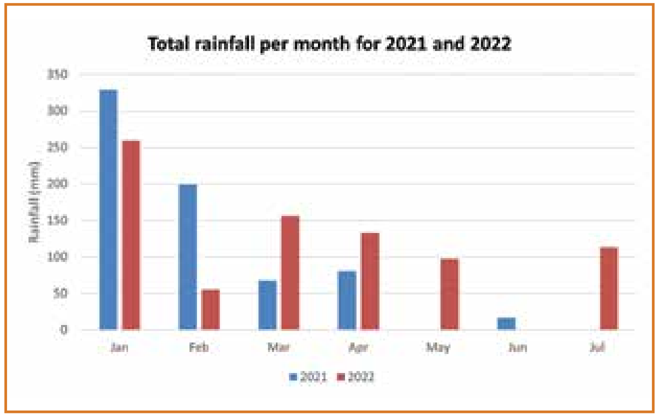
## CASE STUDY: CAPSICUM CHLOROSIS VIRUS (CACV) IN CAPSICUM IN GUMLU, QUEENSLAND

CaCV and tomato thrips were monitored from early season in 2022 in capsicum blocks across the Gumlu production district. Virus infections appeared in April, about six weeks from first crop plantings. The highest recorded incidence of CaCV in the area was 48% with other blocks ranging from 2-10%. Virus incidence and thrips numbers were also estimated across 10 sites within a single property, over a one-month period (April-May). Virus incidence varied within the property and even within the blocks. During the study month virus incidence increased about 2-fold or less at most sites.

Adult thrips numbers within the crops were very low and juvenile stages almost never detected. Adult and juvenile thrips were detected on weeds growing near crops during the season. Combined these results indicate virus disease was from influx of thrips from external virus sources and within crop spread was negligible. The observed variation in virus incidence across the property was mostly due to the relative closeness of a crop to weeds harbouring thrips and CaCV.

During 2022 rainfall extended into the normally dry autumn and winter. This enabled continued weed presence. By contrast, the 2021 season had negligible virus disease and a normal dry season. The routine insecticide programs used on the property was sufficient to maintain very low thrips populations within crops. Spikes in adult numbers were observed and linked to flights from external sources. For example, a big spike in some crops was seen in June and was linked to drying of the weeds.



Key points:

- Most virus infections are from external sources, thus extra insecticide applications within crop are not beneficial
- Disease outbreaks are seasonal and linked with overlap of weeds with crop production windows
- Weed presence is linked to weather

## CASE STUDY: COWPEA MILD MOTTLE VIRUS (CPMMV) IN FRENCH BEAN IN FASSIFERN, QUEENSLAND

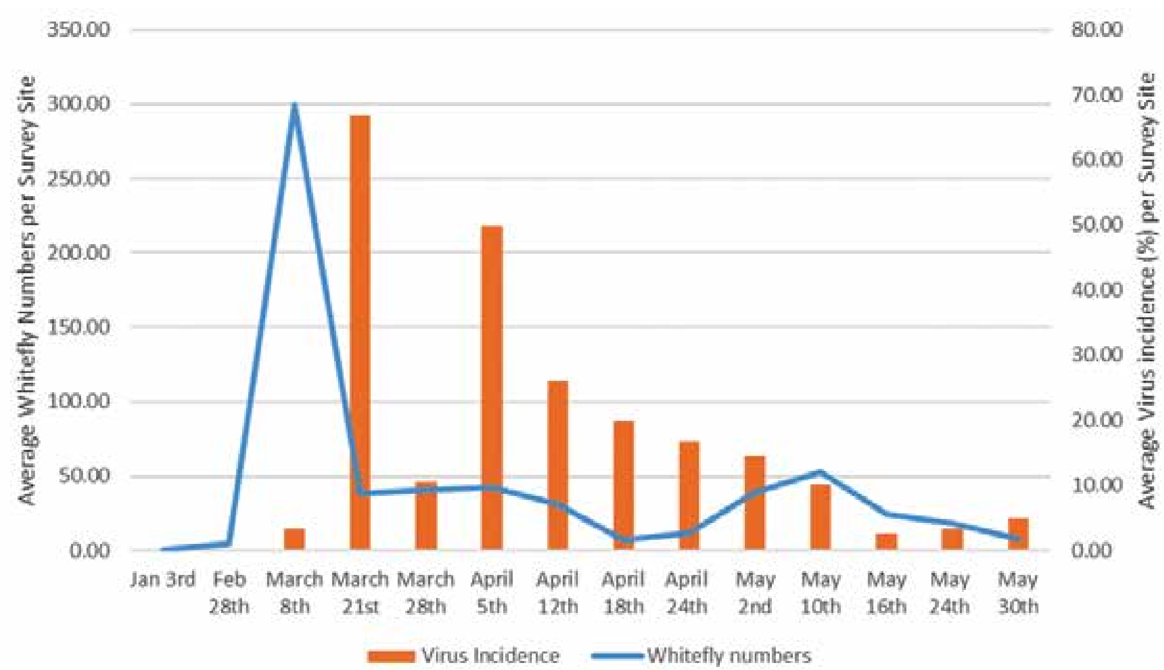
Surveys of French bean crops for CPMMV and its insect vector silverleaf whitefly (SLW) were done in the Fassifern Valley from November 2016 until June 2019. In this district, pumpkin crops can support high levels of SLW which then move into riparian areas during harvest at the end of summer. Legume weeds in these riparian areas are an external source of CPMMV. The subsequently planted autumn French bean crops are at risk of CPMMV from infective SLW leaving weeds and entering the crops as these riparian areas dry off.

Virus incidence in 2019 spiked to almost 70% in mid-March, about two weeks after a major spike in SLW. The SLW levels crashed after a large rainfall event in early March and this in turn reduced virus incidence. Virus incidences, however remained higher than normal due to the very high starting point in March. Secondary spread within crop was minimal as French bean is not a preferred host of SLW.

Key points:

- Large starting populations of SLW causes significant CPMMV incidence early
- High virus incidences continue if disease pressure is high early, even with low SLW
- Rainfall is a very good knockdown for SLW – wet seasons will be low for CPMMV

**Comparison of CPMMV incidence and SLW numbers in French bean crops (2019)**



# APPENDIX 4
# IS SEED DISINFESTATION TREATMENT USEFUL?

The disinfestation treatment of seed to reduce risk of introduction of pathogens into commercial crops is a feasible option for some vegetable crops. Some viruses affecting vegetable crops are seedborne and linkages with field disease outbreaks are reported, with serious implications in some instances.

Ongoing high-volume international trade in seed, together with the high seed-transmissibility of some of these viruses, also increases the risk of co-importation of new races or species into Australia. Seed disinfestation helps mitigate both local disease outbreaks each season and introduction of new diseases. General seed disinfestation treatments such as hot water has the added benefit of eliminating other plant pathogens including many bacteria and fungi (see following below).

Incubation of seed in hot water is a very common, highly effective, method for seed disinfestation and should be done close to sowing as storage after treatment affects germination rates. The method used will depend on the plant species as seed size influences efficacy of the treatment.

A general treatment at 50 - 53 °C for 10-30 min has good effect but at 40 °C there is no significant reduction of seedborne pathogens, even with longer incubation times.

Hot water treatment is recommended for small-seeded crops such as capsicum, eggplant, tomato, cucumber, carrot, spinach, lettuce, celery, cabbage, turnip, and brassicas but may not be practical for large-seeded crops such as peas, beans, sweet corn, beetroot, and some cucurbits.

An exception to the temperature recommendation is for brassica seed, where a combination of lower temperature and cupric acetate was shown to be effective for seed disinfestation to eliminate black rot (*Xanthomonas campestris* pv. *campestris*). This method involves incubating seed in a pre-warmed 0.2% (w/v) cupric acetate with 0.1% (v/v) glacial acetic acid and 0.02% (v/v) Triton X-100 solution at 40 °C for 20 min with gentle shaking. Seed are treated at a rate of 40 g seed to 400 ml of treatment solution. Seed are rinsed twice in water and then dried.

## WHEN SHOULD HOT-WATER TREATMENT BE USED

When deciding if heat treatment of seed is needed consider the following questions?

1. What disease are you trying to control and is seed contamination a significant risk?
2. Was the seed produced in a way that was likely to minimise the potential for it to become contaminated?
3. Was the seed tested by the supplier?
4. Has the seed already been heat or otherwise treated?

The table of common diseases (see pages 44-58) lists which viruses are seedborne. To assist with answering the remaining questions talk to your local seed company and nursery supplier. Also consider if the seed is coated with fungicide or insecticide as these coatings will be removed during the process. If you need this protection, hot water treatment might not be feasible, or you may need to reapply the products.

If you haven't tried hot water treatment before, it is recommended to start with small batches of seed to optimise the method, checking germination rates as you go, before doing large batches. Also, hot water treated seed will not store for very long so only treat in batches which are to be sown within 48 h of treatment.

**Seed disinfestation protocols for different vegetable crops recommended by the University of Massachusetts Amherst (UMass 2015). For other vegetable crops, disinfestation methods will need to be developed and validated.**

| Crop | Temperature (°C) | Time (min) | Diseases and pathogens removed from seed |
|---|---|---|---|
| Brassicas | 50 | 20-25 | bacterial leaf spots (*Pseudomonas syringae* pv. *maculicola* and *Xanthomonas campestris* pv. *raphani*), black leg (aka phoma stem canker, *Phoma lingam*), alternaria disease (black spot, gray leaf spot and pod spot, *Alternaria brassicicola* and *A. japonica*) and ***Alfalfa mosaic virus***. |
| Capsicum | 52 | 30 | BLS (*Xanthomonas* species complex), anthracnose (*Colletotrichum* spp.), ***Cucumber mosaic virus***, ***Pepper mild mosaic virus***, ***Tobacco and Tomato mosaic virus*** |
| Carrot | 50 | 20 | alternaria leaf blight (*Alternaria dauci*), bacterial leaf blight (*Xanthomonas campestris* pv. *carotae*), cercospora leaf spot (*Cercospora carotae*), crater rot (*Athelia arachnoidea* aka *Rhizoctonia carotae*) and southern foliar blight (*A. rolfsii* aka *Sclerotium rolfsii*). |
| Celery/ Celeriac | 48 | 30 | bacterial leaf spot (*Pseudomonas syringae* pv. *apii*), cercospora leaf spot (*Cercospora apii*), septoria leaf spot (aka late blight, *Septoria apiicola*), phoma crown and root rot (*Phoma apiicola*) |
| Eggplant | 50 | 25 | anthracnose, early blight, phomopsis, verticillium wilt |
| Lettuce | 48 | 30 | anthracnose (*Microdochium panattonianum*), bacterial leaf spot (*Xanthomonas campestris* pv. *vitians*), l***ettuce mosaic virus***, septoria leaf spot (*Septoria lactucae* and *S. birgitae*), verticillium wilt (*Verticillium dahliae*) |
| Onion | 50 | 20 | purple blotch (*Alternaria porri*), stemphylium leaf blight (*Stemphylium vesicarium*), basal rot (*Fusarium culmorum*, *F. oxysporum* f.sp. *cepae* and *F. proliferatum*), botrytis blight (*Botrytis squamosa*), smudge (*Colletotrichum circinans*), black mould (*Aspergillus niger*), downy mildew *Peronospora desctructor*), bacterial blight (*Pseudomonas syringae* pv. *porri*) |
| Parsley | 50 | 30 | bacterial leaf spot (*Pseudomonas syringae* pv. *apii*), alternaria leaf blight (*Alternaria petroselini*, *A. selini* and *A. smyrnii*), black rot, cercospora leaf spot (*Cercospora apii*), and septoria leaf spot (aka late blight, *Septoria apiicola*), |
| Spinach | 50 | 25 | anthracnose (*Collectotrichum dematium* f.sp *spinaciae*), cladosporium leaf spot (*Cladosporium variabile*), ***cucumber mosaic virus***, downy mildew (*Peronospora farinosa* f.sp *spinaciae*), fusarium wilt (*Fusarium oxysporum* f.sp. *spinaciae*), stemphylium leaf spot (*Stemphylium botryosum*), and verticillium wilt (*Verticillium dahliae*) |
| Tomato | 50 | 25 | BLS (*Xanthomonas* species complex), *alfalfa mosaic virus*, anthracnose (*Colletotrichum* spp.), bacterial canker (*Clavibacter michiganensis* subsp. *michiganensis*), bacterial speck (*Pseudomonas syringae* pv. *tomato*), bacterial wilt (*Ralstonia solanacearum*), ***cucumber mosaic virus***, early blight (*Alternaria solani*), fusarium wilt (*Fusarium oxysporum* fsp. *lycopersici*), leaf mold (*Passalora fulva*), septoria leaf spot (*Septoria lycopersici*), ***tomato mosaic virus*** and verticillium wilt (*Verticillium albo-atrum* and *Verticillium dahliae*). |

# APPENDIX 5
# DISEASE AND INSECT MONITORING

**Monitoring viruses and the insects which spread them can aid in predicting disease risks and therefore disease management options. Long term observation covering seasons over several years is very useful to generate base-line data on seasonality of insect movements and similarly, virus disease incidences. Monitoring virus incidence can also help in identifying the sources of virus spread, such as weeds or volunteer crop plants. This subsequently provides opportunity to reduce the risk of primary spread through management of those external sources.**

## DISEASE MONITORING

For diseases with insect vectors, monitoring is best done near crop edges, particularly close to weedy areas or older crops where the primary spread into crops will originate. This improves the chance of disease detection and usually gives the worst-case scenario for disease incidence. A typical survey rate for detection is to inspect 30 m of crop from the edge of the row and to observe about 10 rows. For disease incidence estimates, inspect blocks of 50 plants in these rows, to a total of 300 plants (e.g 6 blocks of 50 plants spread over 10 rows). For diseases that are seedborne and have no specific insect vector, the same protocol will work. Primary spread of seedborne viruses into crops is random thus there is no area within a crop that will improve chances of detection.

## INSECT MONITORING

Plant inspections and sticky traps are both useful for evaluating insect population levels within crops. A suggested method is to inspect a set number of plants in the crop with a bias towards the outside areas of the crop, especially the edge facing the prevailing wind. This is because the insects are most likely to enter those edge rows first. Number of plants to examine depends on crop type, age, and the monitoring time and resources that are available.

If using sticky traps, a bias on the outside of crops is again more likely to provide early detection of insect infestations than in the middle of crops. Traps should be inspected at least weekly to reveal changes in pest numbers; obviously the more frequent the inspection, the quicker you can respond.

The relative numbers of adults and juveniles within a crop is important. The presence of adults only indicates a recent flight from external sources and thus the potential for introduction of virus. If this occurs, plant disease symptoms are likely to be seen within the next 7-14 days. Presence of juveniles within the crop indicates the insects are colonising the crop. The presence of juveniles in combination with virus-infected plants will trigger secondary spread within the crop.

## APHID MONITORING

Yellow sticky traps are attractive to aphids so their placement at upwind edge rows is likely to reveal dispersal of aphids to the crop. Aphids generally reside in colonies on new flush and the underside of leaves (older infestations may be found deeper in canopy where spray coverage

is difficult) so inspection or sampling should focus here. Count the number of colonies seen visually on a set number of plants. Predators and parasitoids can also be recorded and may indicate whether control options will benefit aphid management or potentially hinder biocontrol effectiveness. Common predators include ladybeetle adults and larvae, hover/syrphid fly larvae and lacewings. Parasites include wasps which are more likely to be observed indirectly via bloated and discoloured, mummified aphid bodies, often with an exit hole once the wasp has emerged.

## WHITEFLY MONITORING

The best way to inspect plants is to count adult whitefly on the back of one leaf per plant. For an accurate estimation of the adult population, inspect 150 plants. To monitor colonising whitefly, inspect a younger leaf for eggs and young nymphs and an older leaf for older nymphs and pupae using a hand lens. Inspection of 10 plants with no detection of these earlier life-stages indicates a low likelihood of colonisation.

To evaluate parasitism rates by the SLW parasitoid, *Eretmocerus hayati,* collect leaves with older nymphs/pupae and inspect them using a stereomicroscope. Parasitised specimens display asymmetrical internal bodies and then become darker and shinier externally. A hole in an empty puparium indicates that a parasitoid has emerged rather than a whitefly. Incubation of leaves in a moist container at room temperature will allow the parasitoids inside the nymphs to develop and can be easier to see.

## THRIPS MONITORING

The most immediate way to inspect plants for thrips is by beating. Flowering parts or new growth are tapped with a stick/pvc tube onto a sturdy white surface such as a plastic serving platter so that tiny insects can be distinguished and counted. Magnification such as a 10x hand lens or jewellers loupe glasses will help in recognising thrips and their life stage (ie the more mobile, flying adults vs the crawling larvae).

Plant inspections can be a collection of a set number of flowers, for example 50 flowers from a tomato or capsicum crop, which can later be dissected and evaluated under magnification. This method is more likely than beating to reveal larvae which are often found deep inside the flowers. For non-flowering crops such as lettuce, inspection would involve in-field observations of plants by looking into leaf whorls.

Sticky traps are a simple method of monitoring over days to weeks. Once again, a bias to the edge of crops is more likely to enable early detection of thrips infestations than in the middle of crops. If interested mostly in thrips, and bycatch is problematic/overwhelming, blue traps will still attract thrips but less of some other insects than yellow traps.

## LEAFHOPPER MONITORING

Leafhoppers are difficult to monitor and to identify to species. Leafhoppers are cryptic and active fliers so inspection of plants needs to either minimise disturbance to observe them, or their presence can be detected by gently running your hand through the canopy and observing hoppers dispersing. They are more likely to be seen on new flush. Beating plant material is likely to result in specimens hopping or flying away before being counted, unless a sticky tray is used (a detergent solution frequently sprayed onto a beating tray may hold them longer). A plant can be quickly sampled using an insect sweep net or a leaf blower with a vacuum setting and the addition of a mesh net on the inlet. Samples can then be collected for analysis. Yellow sticky traps are attractive to leafhoppers so they can also be used for monitoring.

# APPENDIX 6
# WEED HOSTS OF TOMATO SPOTTED WILT VIRUS IN MAJOR AUSTRALIAN PRODUCTION DISTRICTS

The relative risk of each weed species is shown based on its abundance and longevity in the environment from no risk (light orange) to high risk (dark orange).

## QUEENSLAND DISTRICTS

| Plant species | Common name | Dry Topics | Bundaberg | Lockyer Valley | Eastern Downs | Granite belt |
|---|---|---|---|---|---|---|
| *Acanthospermum hispidum* | starburr | | | | | |
| *Amaranthus retroflexus* | amaranth | | | | | |
| *Arctotheca calendula* | capeweed | | | | | |
| *Aster sp.* | Aster | | | | | |
| *Bidens pilosa* | Spanish needle, cobblers pegs, farmers friends | | | | | |
| *Brassica rapa* | wild turnip | | | | | |
| *Capsella bursa-pastorius* | shepherd's purse | | | | | |
| *Chenopodium album* | fat-hen | | | | | |
| *Chenopodium murale* | nettleleaf goose-foot, sowbane | | | | | |
| *Cichorium intybus* | chicory/blue daisy | | | | | |
| *Cirsium sp.* | thistle | | | | | |
| *Conyza bonariensis* | fleabane | | | | | |
| *Conyza canadensis (syn. Erigeron canadensis)* | horseweed/Canadian fleabane | | | | | |
| *Datura stramonium* | thornapple, jimsonweed, devils snare | | | | | |
| *Galinsoga parviflora* | Galinsoga | | | | | |
| *Hibiscus trionum* | bladder ketmia | | | | | |
| *Lactuca serriola* | prickly lettuce/milk thistle | | | | | |
| *Malva parviflora* | cheese weed, marshmallow | | | | | |
| *Nicandra physalodes* | apple of peru | | | | | |

| Plant species | Common name | Dry Topics | Bundaberg | Lockyer Valley | Eastern Downs | Granite belt |
|---|---|---|---|---|---|---|
| *Physalis spp.* | wild gooseberry | | | | | |
| *Picris sp. (syn. Helminthotheca sp.)* | ox-tongue | | | | | |
| *Portulaca oleraceae* | common purslane, pigweed | | | | | |
| *Rumex sp.* | dock, sorrel | | | | | |
| *Senecio vulgaris* | groundsel | | | | | |
| *Silybum marianum* | milk thistle | | | | | |
| *Solanum nigrum* | blackberry nightshade | | | | | |
| *Sonchus asper* | spiny sow thistle | | | | | |
| *Sonchus oleraceus* | common sow thistle | | | | | |
| *Sonchus sp.* | sow thistle | | | | | |
| *Stachytarpheta jamaicensis* | Jamaican snakeweed | | | | | |
| *Stachys arvensis* | stagger weed | | | | | |
| *Stellaria media* | chickweed | | | | | |
| *Tagetes sp.* | marigold | | | | | |
| *Tagetes minuta* | stinking roger | | | | | |
| *Trifolium sp.* | white clover | | | | | |
| *Verbena litoralis* | verbena, vervain | | | | | |
| *Verbena officinalis* | common verbena, holy herb | | | | | |

## VICTORIAN DISTRICTS

| Plant species | Common name | Bacchus Marsh | Werribee | Mildura | East Gippsland | Clyde Cranbourne |
|---|---|---|---|---|---|---|
| *Arctotheca calendula* | capeweed | | | | | |
| *Amaranthus retroflexus* | amaranth | | | | | |
| *Brassica rapa* | wild turnip | | | | | |
| *Capsella bursa-pastoris* | shepherd’s purse | | | | | |
| *Chenopodium album* | fathen, | | | | | |
| *Cirsium arvense* | Californian thistle | | | | | |
| *Conzya bonariensis* | fleabane | | | | | |
| *Datura ferox* | fierce thornapple | | | | | |
| *Datura stromonium* | thorn apple | | | | | |
| *Geranium sp.* | geranium | | | | | |
| *Heliotropium europaeum* | common heliotrope | | | | | |

| Plant species | Common name | Bacchus Marsh | Werribee | Mildura | East Gippsland | Clyde Cranbourne |
|---|---|---|---|---|---|---|
| *Lactuca serriola* | prickly lettuce | | | | | |
| *Malva spp.* | mallow | | | | | |
| *Marrubium vulgare* | horehound, | | | | | |
| *Medicago polymorpha* | burr medick | | | | | |
| *Mesmebryanthemum crystallinum* | common ice plant | | | | | |
| *Physalis hederifolia* | prairie ground cherry | | | | | |
| *Polygonum aviculare* | wireweed | | | | | |
| *Portulaca oleracea* | purslane | | | | | |
| *Rumex sp.* | dock, sorrel | | | | | |
| *Senecio vulgaris* | groundsel | | | | | |
| *Solanum aviculare* | kangaroo apple | | | | | |
| *Solanum elaeagnifolium* | | | | | | |
| *Solanum nigrum* | black nightshade | | | | | |
| *Sonchus oleraceus* | sow thistle | | | | | |
| *Stellaria media* | chickweed | | | | | |
| *Tribulus terrestris* | caltrop | | | | | |
| *Trifolium sp.* | white clover | | | | | |
| *Verbena officinalis* | common verbena | | | | | |

## NEW SOUTH WALES DISTRICTS

| Plant species | Common name | Sydeny Basin | Riverina |
|---|---|---|---|
| *Arctotheca calendula* | capeweed | | |
| *Bidens pilosa* | cobbler's peg | | |
| *Cirsium arvense* | Californian thistle | | |
| *Sonchus oleraceus* | sow thistle | | |
| *Verbena bonariensis* | purple top | | |

## WESTERN AUSTRALIAN DISTRICTS

| Plant species | Common name | Kimberly | Carnarvon | Mid-West | Perth Metro | South-West |
|---|---|---|---|---|---|---|
| *Acanthospermum hispidum* | starburr | | | | | |
| *Amaranthus retroflexus* | amaranth | | | | | |
| *Apium graveolens* | wild celery | | | | | |
| *Arctotheca calendula* | capeweed | | | | | |
| *Bidens pilosa* | cobblers pegs | | | | | |
| *Brassica rapa* | wild turnip | | | | | |
| *Capsella bursa-pastoris* | shepherd's purse | | | | | |
| *Carduus sp.* | thistle | | | | | |
| *Chenopodium album* | rat hen | | | | | |
| *Chenopodium murale* | nettleleaf goose-foot, sowbane | | | | | |
| *Cirsium sp.* | thistle | | | | | |
| *Conyza sp.* | fleabane | | | | | |
| *Datura stramonium* | thornapple, jimsonweed, devils snare | | | | | |
| *Galinsoga parviflora* | potato weed | | | | | |
| *Gladiolus sp.* | Gladioli | | | | | |
| *Lactuca serriola* | prickly lettuce/milk thistle | | | | | |
| *Malva parviflora* | cheese weed, marshmallow | | | | | |
| *Medicago polymorpha* | burr medick | | | | | |
| *Nicandra physalodes* | apple of peru | | | | | |
| *Physalis angulata* | wild gooseberry | | | | | |
| *Physalis peruviana* | cape gooseberry | | | | | |
| *Picris sp. (syn. Helminthotheca sp.)* | Ox-tongue | | | | | |
| *Polygonum aviculare* | knotweed, wireweed | | | | | |
| *Portulaca oleraceae* | common purslane, pigweed | | | | | |
| *Rumex sp.* | dock, sorrel | | | | | |
| *Senecio vulgaris* | groundsel | | | | | |
| *Silybum marianum* | milk thistle, variegated thistle | | | | | |
| *Solanum nigrum* | blackberry nightshade | | | | | |
| *Sonchus asper* | rough sowthistle | | | | | |
| *Sonchus oleraceus* | common sow thistle | | | | | |
| *Stellaria media* | chickweed | | | | | |
| *Trifolium sp.* | white clover | | | | | |
| *Tropaeolum majus* | garden nasturtium | | | | | |

# FURTHER RESOURCES

## PUBLICATIONS AVAILABLE THROUGH HORT INNOVATION

(https://www.horticulture.com.au/)

- Area-wide management of insect-vectored viral and bacterial diseases: VG16086, 2018
- Prioritised list of viral and bacterial diseases of vegetables: VG16086, 2018
- Viruses infecting Brassicas: VG16086, 2020
- Virus diseases of lettuce in Australia: VG16086, 2020
- Lettuce necrotic yellows disease in the Lockyer Valley: VG16086, 2020
- Lettuce necrotic yellows disease in temperate cropping areas of Australia: VG16086, 2020
- Cucumber mosaic virus (CMV ) in vegetable crops: VG16086, 2020
- Virus diseases of cucurbits in Australia: VG16086, 2020
- Managing virus diseases on zucchini: VG16086, 2020
- Aphids spreading virus in brassicas and lettuce in the Lockyer Valley: VG16086, 2021

## PUBLICATIONS AVAILABLE THROUGH THE DEPARTMENT OF AGRICULTURE AND FISHERIES, QUEENSLAND

- Aphid-transmitted viruses in vegetable crops: Integrated virus disease management, 2011 (https://www.daf.qld.gov.au/__data/assets/pdf_file/0005/68090/Managment-of-aphid.pdf )
- Plant viruses spread by thrips Integrated virus disease management, 2011 (https://www.daf.qld.gov.au/__data/assets/pdf_file/0007/58777/Thrip-viruses-veg-crops.pdf)
- Viruses in vegetable crops in Australia Integrated virus disease management, 2011 (https://www.daf.qld.gov.au/__data/assets/pdf_file/0005/58802/Viruses-in-vegies.pdf )
- Tobamoviruses—tobacco mosaic virus, tomato mosaic virus and pepper mild mottle virus: Integrated virus disease management, 2011 (https://www.daf.qld.gov.au/__data/assets/pdf_file/0017/71063/Tobamoviruses.pdf )

## PUBLICATIONS AVAILABLE THROUGH AUSVEG

Thrips and tospoviruses: A management Guide (https://ausveg.com.au/app/data/technical-insights/docs/TL151.pdf )

Whitefly-transmitted viruses in vegetable crops Integrated virus disease management, 2011 (https://ausveg.com.au/app/data/technical-insights/docs/TL189.pdf )

## PUBLICATIONS AVAILABLE THROUGH AMERICAN PHYTOPATHOLOGY SOCIETY (APS) PRESS ST PAUL MN

www.apsnet.org

- Compendium brassica diseases. First edition 2007
- Compendium of cucurbit diseases and pests. Second edition 2017
- Compendium of lettuce diseases and pests. Second edition 2017
- Compendium of tomato diseases and pests. Second edition 2014
- Vegetable diseases-a colour handbook by Steven T. Koike, Peter Gladders, and Albert O. Paulus, 2007

Diseases of vegetable crops in Australia CSIRO Publishing 2010.

# GLOSSARY OF TERMS

| | |
|---|---|
| Brassica | Member of the plant family Brassicaceae. The major vegetable brassicas are cabbage, cauliflower, broccoli, Chinese cabbage and mustards. |
| Chlorosis | Partial or complete absence of normal green colour from plant parts. |
| Cucurbit | Member of the plant family Cucurbitaceae. The major vegetable cucurbits are cucumber, melons, watermelons, squash, and pumpkin. |
| Epidemic | A widespread and severe outbreak of an infectious disease. |
| Infection | The process in which an organism enters, invades, and establishes a parasitic relationship with a host plant. |
| Inoculum | Pathogen able to infect a host plant. Examples include virus particles, bacterial cells, and fungal spores. |
| Larva/larvae | The juvenile or immature stage in the life cycle of certain insects |
| Mosaic | Patchy variation of normal green colour of leaves; often associated with virus infection. |
| Mottle | An irregular pattern of light and dark green areas of leaves. Often associated with virus infection and may be used interchangeably with mosaic. |
| Necrosis/necrotic | The death of plant tissue, usually accompanied by a darkening or blackening of the affected area. |

| | |
|---|---|
| Non-persistent transmission | Virus spread on insect mouthparts, fast spread for a short time period |
| Pathogen | A parasite able to cause disease in a host. The major plant pathogens are fungi, bacteria, nematodes, and viruses. |
| Persistent transmission | Virus spread from salivary glands after circulation of virus within insect body, slow spread for long time periods |
| Resistance | Ability of a host to prevent or reduce the development of a disease |
| Riparian | The interface between land and a waterway e.g. creek or river. |
| Rogue | Removal of diseased plants with the aim of reducing disease spread. |
| Seedborne | Carried in or on the seed A seedborne pathogen is spread by seed if germination results in an infected seedling. |
| Semi-persistent transmission | Virus spread from foregut after transfer of virus from mouthparts, relatively fast spread for moderate time periods |
| Strain | A distinct form of an organism differing from others of the same species biologically or physically. |
| Stylet | The stiff, slender, hollow mouthpart used by certain insects (e.g.aphids, thrips) to suck sap and cell contents. |