Protect your nursery from virus diseases

What are viruses?

Viruses are minute, non-cellular pathogens which multiply within the cells of their hosts; they can only be seen using an electron microscope. Virus infections are usually to the detriment of their host and results in the development of disease symptoms. Viruses are obligate parasites and cannot multiply outside of a host cell nor be cultured on any growth media.

How do plant viruses spread?

Viruses are immobile and rely on other organisms for dispersal. Most plant viruses are transmitted from plant to plant by a living organism called a vector or carrier. Plant viruses can be spread in the following ways:

- Sap sucking insects, particularly aphids, whiteflies, thrips and mealy bugs.
- Other insects including leafhoppers and leaf chewing beetles.
- Certain mites can transmit viruses including eriophyid mites and flat mites, e.g. *Brevipalpus californicus* transmits *Orchid fleck virus*.
- Nematodes (e.g. dagger nematodes transmits *Grapevine fan leaf virus*).
- Fungi (e.g. *Olpidium virulentus* transmits *Mirafiori lettuce virus* which causes lettuce big vein disease).

Fig. 1. *Hardenbergia mosaic virus* (HarMV) causing mottle and deformed leaves in *Hardenbergia comptoniana* (left) and virus symptoms on *Chamaedorea seifrizii.*

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- Infected vegetative propagating material. Plant viruses usually cause systemic infection and any plant part used for propagation will carry the virus e.g. budwood, cuttings, bulbs, corms.
- Infected or contaminated seeds (e.g. *Lettuce mosaic virus*; *Tomato mosaic virus*).
- Infected pollen (e.g. *Prunus necrotic ringspot virus* in *Prunus* species).
- Contact between plants (e.g. *Tomato mosaic virus*, *Cymbidium mosaic virus*).
- Some viruses are mechanically transmitted, others are not.

Insect transmission

Transmission of viruses by an insect is a specific biological process. A particular virus is transmitted by one vector type only, e.g. an aphid, a whitefly or a thrips. If a virus has an insect vector, it is transmitted by only one insect group. In other words, if aphids transmit the virus, it will not be transmitted by whiteflies, thrips or any other insect.

As mentioned above, the most important insect vectors of plant viruses are aphids, whiteflies, thrips and leafhoppers. All have piercing-sucking mouthparts that include a needle-like stylet which allow the insects to access and feed on the contents of plant cells.

Two broad categories of insect transmission are recognised: non-persistent and persistent. The terms relate to the length of time an insect takes to acquire and to transmit a virus and the length of time the insect remains capable of transmitting the virus. Non-persistent transmission is very rapid while persistent transmission takes at least several hours.

In non-persistent transmission, an insect feeding time of less than one minute is enough for the virus to be acquired from an infected plant or transmitted to another plant (Fig.3). The virus particles are usually only retained on the insect's mouthparts for a few hours, after which the insect needs to feed again on an infected plant to obtain more virus if further transmission is to occur. Many important viruses are transmitted in this way, including *Cucumber mosaic virus* and *Turnip mosaic virus*.

In persistent transmission, the insect needs to feed on an infected plant for several hours to acquire the virus, which then must circulate through the insect's body to the salivary glands before transmission can occur. Thus there is a latent period, or lag time during which transmission cannot occur, while the virus particles travel through the insect's body. When the latent period is completed the insect can then transmit the virus for many weeks or the rest of its life without needing to obtain more virus particles from an infected plant. This form of transmission is also known as circulative transmission because of

Key Facts

- Almost every plant species can be infected with one or more viruses and can be associated with major economic loss.
- Virus symptoms are extremely varied and are often mistaken for disorders caused by nutritional or environmental conditions or fungal or bacterial pathogens.
- Common symptoms include mosaics, mottles, streaks, ringspots, necrotic spots and deformed or stunted abnormal growth.
- Infected plants cannot be cured; management of viruses must focus on preventing infection.
- Remove all plants that are known to have a virus.
- All plant viruses can be spread by propagation, e.g. cuttings, bulbs and budwood. Some viruses are transmitted by seed.
- Some viruses can be spread mechanically, for example with secateurs, or even by touching infected plants followed by healthy plants.
- Many viruses are spread by sucking insects; aphids, whiteflies and thrips are the most common vectors.
- Management of weeds and other hosts around the nursery is critical; many viruses can survive in weeds without symptoms and these reservoirs allow infection of the crop.
- Grow resistant varieties whenever possible.
- If you suspect that a plant is being affected by a plant virus, submit a sample to a diagnostic service as accurate identification often determines control measures.

Fig. 2. *Capsicum chlorosis virus* causing ringspot symptoms on *Hoya* sp.

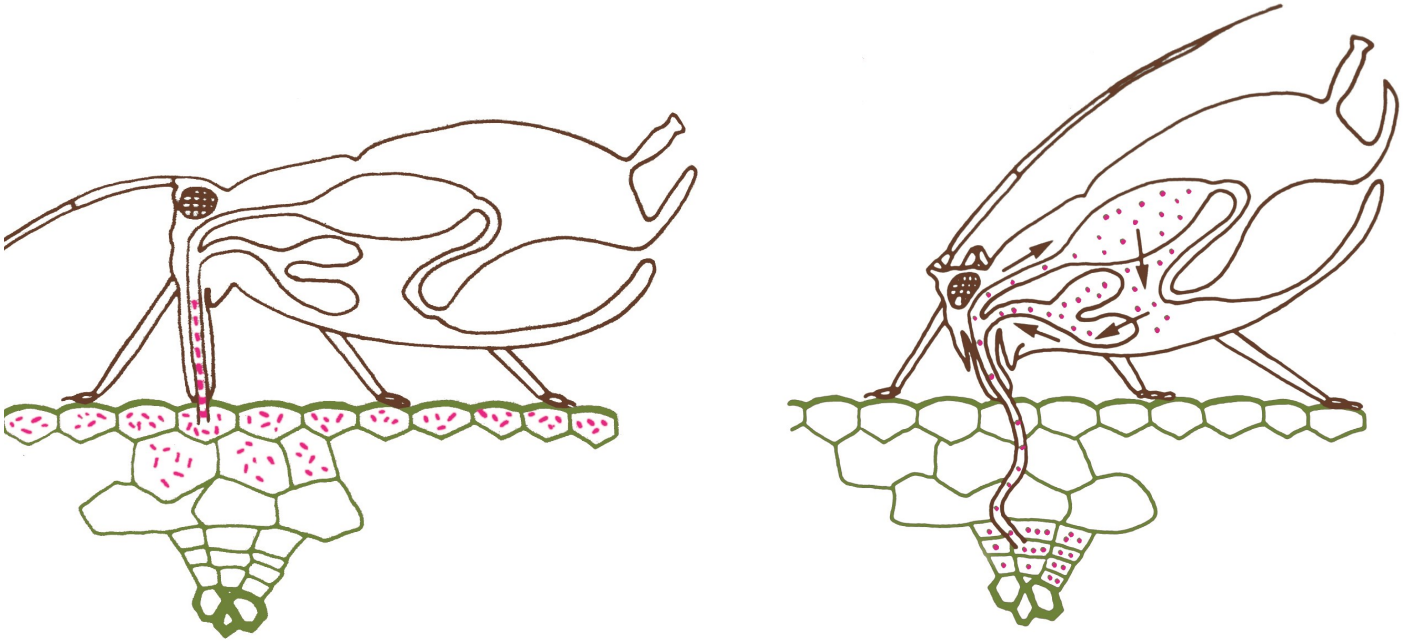

Fig. 3. Non-persistent transmission (left) of viruses occurs quickly. Feeding from tissues near the surface of leaves is sufficient to obtain the virus. Persistent transmission (right) occurs over a longer period of time; the insect needs to feed for several hours, often in food-conducting tissues of the plant to obtain the virus.

the circular pathway the viruses take through the insect's body. Viruses transmitted in this way include *Potato leaf roll* and *Tomato yellow leaf curl viruses*.

Host plants and symptoms

A virus has specific host plants in which it can survive and cannot infect all plant species with which it may have contact. Several virus species have very wide host ranges, for example, *Tomato spotted wilt virus* and *Cucumber mosaic virus* (Fig. 5). Conversely, *Papaya ringspot virus*-type W infects only members of the cucurbit family. Plant viruses are generally named after the first host in which they were found and this may not give a true indication of the importance of the virus to that host.

Plants develop a wide of range of symptoms following virus infection (see all pictures). These include mosaic and mottle patterns on leaves, roughly circular ringspots on leaves and fruit, patterns of discolouration on flowers called colour break and chlorosis or yellowing of leaves. Other symptoms include tissue death or necrosis, leaf rolling, deformed leaves and stunting.

Fig. 4. Orchids can host a large number of viruses, each of which have slightly different symptoms. *Orchid fleck virus* on *Cymbidium* (left) and *Oncidium* (left insert) and *Odontoglossum ringspot virus* on *Cattleya* (right) and *Cymbidium* (right insert)

Fig. 5. *Tomato spotted wilt virus* on tomato (top left) and capsicum (top right). Flower break caused by *Cymbidium mosaic virus* on *Dendrobium* (middle left). Rhabdovirus on violet (middle right). *Cucumber mosaic virus* on *Petunia* sp. (bottom left and insert) and celery (bottom right).

Not all of these symptoms are always the result of virus infection and may be caused by nutritional issues, growing conditions or other pathogens, particularly phytoplasmas.

Virus symptoms can be very confusing. The same virus can produce very different symptoms on different host plants or on different plant parts of the same plant species. In addition, different viruses can produce very different symptoms on one plant species. If you suspect that a plant is being affected by a plant virus, submit a sample to a diagnostic service as accurate identification often determines control measures. Once you know what virus or viruses are affecting the crop, it may be possible to purchase field based ImmunoStrip or Pocket Diagnostic tests for specific viruses, e.g. CMV, TSWV, TMV, ZYMV and others. These are available through NGIQ or Agdia. These can be quite economical when purchased for a specific purpose.

How do viruses survive?

With very few exceptions, viruses cannot survive outside living host plants or insects. Viruses survive adverse conditions and intervals between crop cycles in alternative annual and perennial weed hosts, volunteer crop plants, abandoned crops, infected seeds and vegetative plant parts. Persistently transmitted viruses may also survive in the insect vector. The exception to this rule is Tobacco mosaic virus (TMV) which is a serious pathogen in production nurseries.

TMV – The 'big bad wolf' of plant viruses

TMV has an extremely wide host range (Table 1), is present throughout the world and is spread between plants very easily. Common symptoms include distorted new growth, stunting, leaf curling, chlorotic foliage (mosaic and mottle) and necrotic leaf spots (Fig. 6). Dark green areas of mottled foliage may appear thicker and somewhat raised giving a blister-like appearance. Infected plants often have reduced fruit set and may sometimes have blemishes or distorted fruit. Plants may be 'dwarfed' and flowers may also be discoloured. Different host plant species display different symptoms (Fig. 6) which can mask the overall problem and allow the problem to spread. It can even be present in weeds without symptoms and be spread to nursery stock. Furthermore, symptoms can be influenced by abiotic conditions, including temperature, light, nutritional factors and water stress.

TMV is not spread by insects but can be spread simply by touching infected leaves followed by handling healthy plants. Infected leaves rubbing against healthy plants can also spread the disease. TMV can be spread on clothes, contaminated implements, e.g. cutting knives, secateurs etc. TMV survives in dead plant material, including decomposing plant matter and in cigarettes. As such,

Fig. 6. Symptoms caused by *Tomato mosaic virus* on tomato (top), *Tobacco mosaic virus* on *Calibrachoa* (middle - B. Watt University of Maine, Bugwood.org) and *Odontoglossum* spp. (bottom - Dept of Plant Pathology Archive, N Carolina State University, Bugwood.org).

Fig. 7. *Tomato yellow leaf curl virus* on tomato (top left); *Turnip mosaic virus* on *Lobellia* sp. (middle left - A. Phibbs); *Alfalfa mosaic virus* on *Pachysandra terminalis* (bottom left - A. Phibbs, WI Dept of Agricutlure, Trade and Consumer Protection, Bugwood.org); infected (with CMV) and healthy statice (top right); symptoms in rose consistent with infection by *Rose spring dwarf virus* (bottom right).

strict hygiene measures should be put in place to eliminate spread of the virus from employees after cigarette breaks (refer to decontamination section). TMV has been shown to survive for up to 4 months on equipment that is not exposed to UV radiation and can infect healthy plants if they contact the contaminated equipment.

Management of TMV must be treated very seriously. If TMV is detected in nursery stock it is recommended to test all mother stock plants of all potentially infected hosts for presence of the virus. Any plant testing positive for the disease should be discarded immediately. This can be achieved using a diagnostic laboratory or field based kits available through NGIQ and Agdia. Be sure to do all testing in a hygienic manner so as not to spread the disease to healthy plants (refer to decontamination section below). *Tomato mosaic virus* (ToMV) (Fig. 6) is a very closely related virus, also with a wide host range and identical management strategies. However, ToMV is not spread through cigarettes.

The entire growing area should be decontaminated following an infestation of TMV including benches, shadehouse and polytunnels and any area which has come in contact with infected plants. Any employee that has touched cigarettes, cigarette packets or lighters should wash their hands in milk-powder or another appropriate product before commencing work.

Virus disease management

Plants cannot be cured once infected by a virus. Instead, disease control aims to prevent or delay the infection of plants. No single method is likely to provide good control and integrating multiple measures will generally be more successful. The methods used to manage virus diseases can be grouped under the following headings:-

Exclusion/avoidance

- Quarantine (international, state and regional).
- Plant virus-free seed.
- Grow crops in regions where the disease seldom occurs or during periods when the virus or its vector are at a low level.
- Grow crops in insect-proof protected structure.

Reduction in virus inoculum levels

- Control weeds and other hosts of viruses and insect vectors in and around crops
- Destroy old crops promptly
- Physical separation of new crops from maturing crops and avoiding overlapping crops.

Fig. 8. *Begonia* (top) and *Spathiphyllum* (bottom) infected with *Impatiens necrotic spot virus* which was eradicated from Australia after early detection in a nursery.

Protection of the host

- Grow virus resistant or tolerant varieties
- Using highly reflective mulches and oil sprays to deter insect vector feeding
- Barrier crops and bare land to reduce vector activity
- Strategic use of insecticides can protect plants from the virus insect vectors
- Insecticides are more effective against persistently transmitted viruses because insects are killed before they have time to acquire and transmit

Vectors of non-persistent viruses will eventually be killed after feeding on plants sprayed with systemic insecticide. However, because these viruses may be transmitted within seconds, many plants may become infected before the insect dies or moves out of the crop. In fact, some insecticides agitate the insects and encourage movement and feeding of greater numbers of plants, with a resulting increase in transmission rates.

Decontamination of hands and equipment

There are a range of methods to decontaminate tools, work areas, hands and other equipment, which is particularly important for viruses that are transmitted mechanically. Trisodium orthophosphate or 0.6% sodium hypochlorite can be very effective at eliminating viruses on secateurs and other small equipment. Sodium hypochlorite should be rinsed off using clean water after 5 -10 minutes to reduce corrosion. Milk powder (20% (wt./ vol) of non-fat milk powder), is effective against TMV and other Tobamaviruses. Milk powder has the advantage of being non-toxic on skin for cleaning hands and is not corrosive, unlike bleach and some other products, and binds Tobamovirus particles almost instantly. However care must be taken owing to intolerances and allergies. Appropriate safety procedures should be put in place for all of these products.

Fig. 9. Symptoms of *Frangipani mosaic virus* on Frangipani and *Papaya ringspot virus* on cucurbits leaves (bottom) and fruit (insert).

It is recommended to have more than one pair of secateurs and to leave at least one pair in the decontaminant while using another. The exact length of time will depend on the product and the concentration. As with TMV, decontaminate the working area thoroughly with an appropriate product.

Virus biosecurity threats

There are many virus species which are not recorded in Australia which would cause substantial economic loss if introduced. If the virus is detected at an early stage it is possible to eradicate it from Australia. This has been demonstrated by biosecurity organisations eradicating such viruses as *Impatiens necrotic spot virus* eradicated from NSW.

It is therefore very important to identify unusual symptoms observed by sending samples to a diagnostic laboratory, particularly when importing plants. If you see anything unusual, contact your local agricultural department or call the Exotic Plant Health Hotline on 1800 084 881.

Further reading

Sastry, K.S. and Zitter, T.A. 2014. Management of virus and viroid diseases of crops in the tropics. In: *Plant Virus and Viroid Diseases in the Tropics*. Springer. Pg. 149-480. Available at http://goo.gl/TXv7kR (this is a shortened URL).

Table 1. Some important viruses that can affect nursery crops, their means of spread and overview of plant species they can infect. This is not a comprehensive list.

Virus (virus group)	Means of spread	Important crop hosts
Alfalfa mosaic virus (Alfamovirus)	Seed, propagation, mechanical, aphids (non-persistent)	Very wide host range including *Solanum* sp., *Nicotiana* sp., Capsicum, cucurbits, hibiscus, tomato, *Petunia* sp., beans, peas, *Vinca* sp., *Zinnia* sp.
Bean yellow mosaic virus (Potyvirus)	Aphids (non-persistent)	Beans, peas, gladiolus, lisianthus, *Nicotiana* sp. *Freesia* sp., clover, vetch
Beet western yellows virus (Polerovirus)	Aphids (persistent)	Brassicas, lettuce, legumes, brassica weed species
Cucumber mosaic virus (Cucumovirus)	Seed, vegetative propagation, aphids (non-persistent)	Infects over 150 plant species including chrysanthemum, salvia, geranium, gladiolus, heliotrope, hyacinth, larkspur, lily, marigold, morning glory, nasturtium, periwinkle, petunia, phlox, snapdragon, tulip, and zinnia. Vegetables infected include cucurbits, tomato, spinach, celery, peppers, water cress, beet, sweet potato, turnip, beans, onion, eggplant, potato, carrot, parsley, milkweed and various weed species.
Cymbidium mosaic virus (Potexvirus)	Propagation, mechanical including contact between plants, Australian cockroach may sometimes spread this virus.	Main hosts are orchids including *Cymbidium* sp. *Cattleya* sp., *Phalaenopsis* sp., *Vanda* sp., *Epidendrum* sp, *Laelia* sp., *Laeliocaltleya* sp. *Oncedium* sp., *Zygopetalum* sp.
Dahlia mosaic virus (Caulimovirus)	Propagation, mechanical, aphids (non-persistent)	*Dahlia* sp., *Ageratum* sp., *Zinnia* sp., *Amaranthus* sp., *Nicotiana* sp., *Gladiolus* sp.
Hippeastrum mosaic virus (Potyvirus)	Propagation, aphids (non-persistent)	*Hippeastrum* spp., *Eucharis* sp., *Nicotiana* sp., *Petunia* sp.
Poinsettia mosaic virus (Tymovirus)	Mechanical and propagation.	*Euphorbia* (poinsettia) sp., *Nicotiana* sp., *Datura* sp.
Prunus necrotic ringspot virus (Ilarvirus)	Seed, propagation, mechanical, pollen	*Prunus* sp., rose, *Vinca* sp., *Zinnia* sp., *Petunia* sp., *Helianthus* sp.
Tobacco mosaic virus (Tobamovirus)	Seed, propagation, mechanical including contact between plants	Very wide host range including chrysanthemum, *Datura* sp., delphinium, wisteria, tomato, capsicum, *Nicotiaana* sp., *Petunia* sp. plants, orchids, *Calibrachoa*, cyclamen, gerbera, helianthus, impatiens, lisianthus and penstemon, and many other solanaceous plants.
Tomato spotted wilt virus (Tospovirus)	Thrips (persistent) propagative)	Very wide host range including ornamental, vegetable and weed species, e.g. *Aster* sp, *Amaranthus* sp., *Petunia* sp., *Primula* spp. chrysanthemum, cyclamen, gerbera, hydrangea, geranium, tomato, capsicum, cucumber, celery, beans, lettuce, *Solanum* sp., *Verbena* sp. and many others.
Turnip mosaic virus (Potyvirus)	Propagation, aphids (non-persistent)	Wide host range including, *Datura* sp., *Nicotiana* sp., *Physalis* sp., anemone, nasturtium, petunia, statice, wallflower, zinnia, brassicas

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