Chapter 3: Viral Diseases

Viral Diseases and Their Impact on Crop Production

Viral diseases are caused by infectious pathogens known as viruses, which invade plant cells and disrupt their normal functions. These diseases spread rapidly through vectors like insects, nematodes, or contaminated tools, leading to significant losses in agricultural productivity.

Key Impacts on Crop Production:

1. **Reduced Yield:** Viral infections often stunt plant growth, deform leaves, fruits, or roots, and reduce photosynthesis, leading to lower crop yields.
2. **Quality Deterioration:** Infected crops may develop discoloration, spots, or malformations, making them unmarketable or reducing their nutritional value.
3. **Increased Vulnerability:** Weakened plants become more susceptible to secondary infections by fungi or bacteria, compounding losses.
4. **Economic Losses:** Farmers face financial setbacks due to reduced harvests, higher production costs (e.g., pesticides), and loss of export markets.

Examples of Viral Plant Diseases:

- **Tobacco Mosaic Virus (TMV):** Causes mosaic patterns on leaves, reducing photosynthesis.
- **Tomato Yellow Leaf Curl Virus (TYLCV):** Leads to leaf curling and stunted growth in tomatoes.
- **Cucumber Mosaic Virus (CMV):** Affects cucurbits, causing yellowing and distortion.

Prevention and Control:

- Use certified virus-free seeds and planting materials.
- Control insect vectors (e.g., aphids, whiteflies) with biological or chemical methods.
- Practice crop rotation and remove infected plants promptly.

Develop and deploy resistant crop varieties through breeding or biotechnology.

Impact on Crop Production

- **Economic Losses:** Viral diseases cause over $30 billion in global agricultural losses yearly, causing up to 100% yield reduction in severely affected fields.
- **Reduced Quality and Quantity:** Viruses such as the Banana Bunchy Top Virus (BBTV) and Tomato Yellow Leaf Curl Virus (TYLCV) cause plant stunting, necrotic spots, leaf curling, and fruit deformation, rendering crops unmarketable.
- **Reduced Food Security:** Widespread infections (e.g., Cassava Mosaic Disease) can destroy staple crops in regions like Africa, directly causing food shortages.
- **Reduced Nutritional Value:** Infected plants often show nutrient deficiency symptoms and diminished growth.

Major Viral Threats to Crops

- **Cassava Mosaic Virus (CMV):** Widespread in Africa, it is transmitted by whiteflies and can lead to 90% yield losses.
- **Maize Streak Virus (MSV):** Causes severe yellow streaking in maize, reducing yield.
- **Tomato Yellow Leaf Curl Virus (TYLCV):** Causes leaves to curl and turn yellow, resulting in small or no fruit.
- **Banana Bunchy Top Virus (BBTV):** Causes severe stunting, upright, brittle leaves, and stops fruit production.
- **Bean Common Mosaic Virus (BCMV):** Affects legumes, causing mosaic, leaf curling, and stunted growth.

Transmission and Spread

- **Insect Vectors:** Aphids, whiteflies, and scale insects are the primary vectors transmitting viruses.
- **Seed and Propagule Transmission:** Infected seeds and planting materials (e.g., cuttings, tubers) carry the virus.
- **Mechanical Transmission:** Contaminated tools and handling can spread viruses.

Management and Mitigation Strategies

- **Integrated Pest Management (IPM):** Controlling vectors using biological controls like lady beetles or lacewings and chemical agents.
- **Resistant Varieties:** Developing and planting virus-resistant or tolerant varieties.
- **Sanitation:** Removing and destroying infected plants to prevent the spread.
- **Diagnostics:** Using tools like PCR tests for early detection and identification of the virus.

An Introduction To Plant Viruses

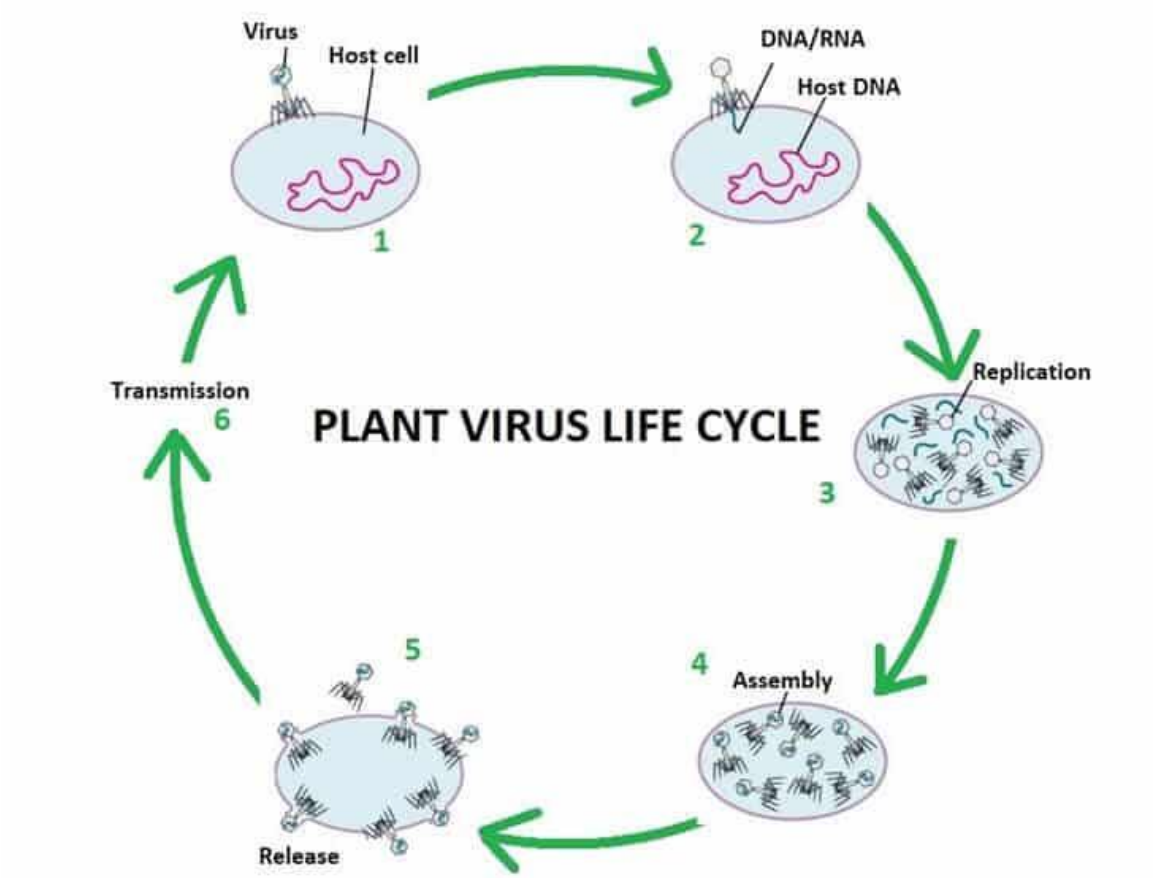
Plant viruses are viruses that affect plants. Like all other viruses, plant viruses are obligate intracellular parasites that do not have the molecular machinery to replicate without a host.

Plant viruses are pathogenic to higher plants. They can cause a dramatic decrease in yield, quality, and shelf life, and even plant death. Plant viruses are made up of a strand of nucleic acid (DNA or RNA) surrounded by a protein sheath. Technically, they are not living, as they are not cell-based and cannot move or replicate on their own. There is no cure for plant viruses; they must be managed with cultural practices and virus-resistant plant stocks.

Plant viruses under a microscope. Most plant viruses are rod-shaped. Photo: University of Florida

Plant viruses can cause major crop losses and greatly reduce the quality and storage of products (vegetables/ornamentals and grains). Viruses can remain dormant and express when plants are unhealthy or stressed. They can join with other pathogens and plant viruses to form disease complexes that can decimate crops. They mutate very fast, and new strains emerge all the time.

Life Cycle of Plant Viruses



1. **Attachment** – the virus attaches itself to the outside of a plant cell.
2. **Penetration** – the protein pushes the nucleic acid strand into the plant cell
3. **Replication** – the viruses' nucleic acid uses the plant cell DNA to make many new nucleic acid strands and protein sheathes
4. **Assembly** – the nucleic acid and protein assembly into millions of new virus copies
5. **Release** – the viruses leave the cell – at this stage, the cell is normally dead and bursts, releasing the viruses
6. **Transmission** – the viruses move using a vector to new cells to infect.

Symptoms of Viral Diseases In Plants

The symptoms of viral diseases in plants are important for virus identification and are often used to name the virus. The symptoms will change according to the plant virus strain / mixed virus infections, the host plant species, the nutritional status of the plant, the age of the plant, the stage of the infection, and the physiological growing conditions. Plant virus symptoms can be confused with bacterial and fungal diseases, nematode infections, plant nutrient deficiencies, abiotic stresses, and herbicide injuries.

It is generally very difficult to identify a virus from symptoms alone. Viruses are sub-microscopic, and plant samples should be sent to the laboratory for confirmation.

Viruses can be present but not expressed in healthy plants, weeds, cuttings, and seedlings. Symptoms can appear when the plants are stressed and in hotter weather. Multiple viruses can be present in one plant, and/or be present with bacterial or fungal infections that can form disease complexes that can be catastrophic, with 100% plant loss.

Plant virus symptoms include, but are not limited to the following:-

- Mosaic or mottled leaf patterns
- leaf yellowing
- chlorosis
- vein clearing
- green vein banding
- yellow vein banding
- leaf rolling
- leaf curling
- leaf shoe-stringing
- leaf blistering
- witches' brooms
- bunchy tops
- leaf tip necrosis
- veinal necrosis
- ringspots
- plant stunting
- wilting, tumours/galls
- colour streaking in flowers, leaves, or fruits
- plant death

Importance of Identifying Plant Viruses

By identifying the viruses infecting your plants, you can look closely at the life cycle / the method of transmission/vector/host plants, and the level of damage that they can cause. Then you can make an informed, fact-driven, scientifically based strategy to control it.

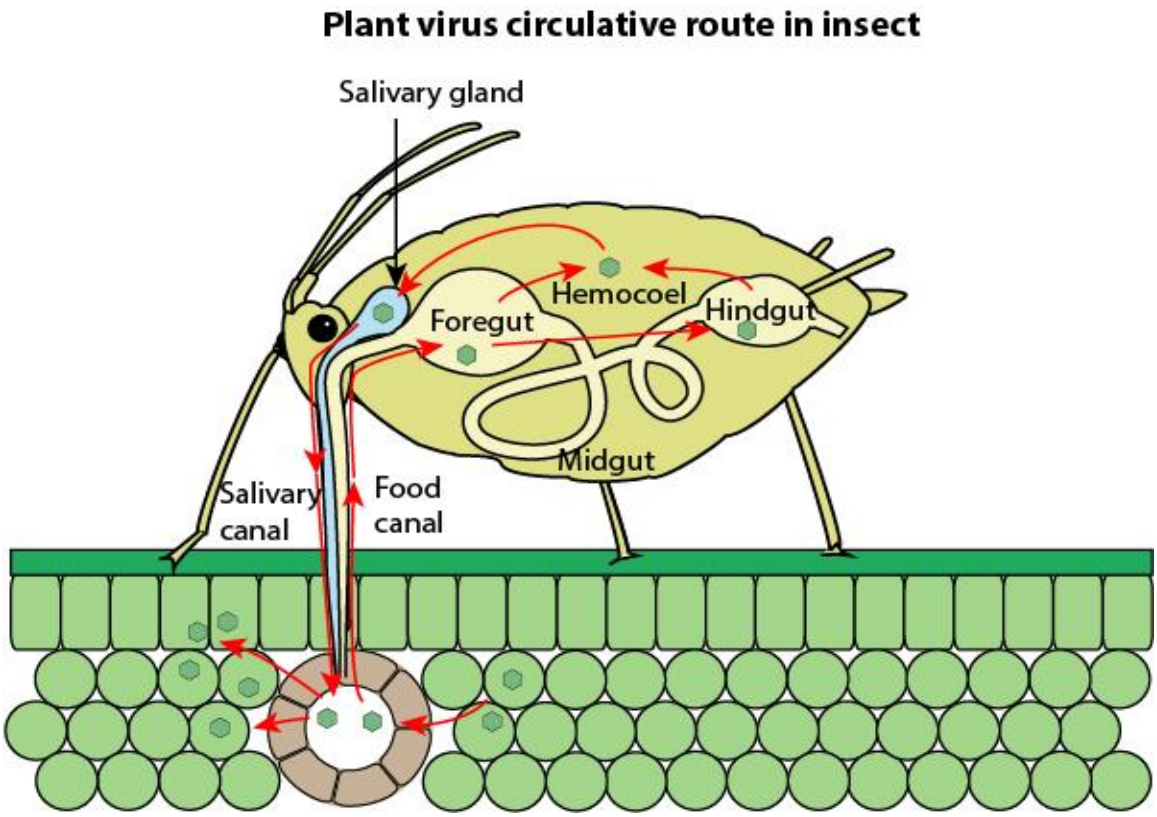
Propagation is a common form of virus transmission – it is important to screen plants, cuttings, seeds, and starter material for viruses to ensure that the material is clean and virus-free at the onset of any project, especially projects in new areas.

Potato seed can be screened for viruses and bacteria before planting – this allows the farmer to make an informed decision to use farm-saved seed or buy in new seed. This also applies to other seeds, for e.g. wheat, soybean & tomato seed. Sometimes, if you are aware you have a virus in your crop, a special seed treatment can clean the seed.

Transmission Of Plant Viruses

Viruses are technically non-living and cannot move around by themselves. They require a transmission method and often a vector. By removing the vector or understanding the transmission mechanism, you can put hygiene protocols in place to control the spread of plant viruses.

Viruses can be transmitted in the plant sap via direct mechanical transmission. If your hands or tools get plant sap on them and you then touch a clean plant, you can move the virus around. Some viruses do not last long outside a plant (semi-stable), while some viruses, like Tobacco mosaic virus (TMV) and Tomato mosaic virus (ToMV) are very robust and stable and remain infective for 2 years after drying.



Most plant viruses depend on insect vectors for their survival, transmission, and spread. Image: ViralZone

Plant virus vectors are generally insects that carry and move the virus around on their mouth parts or salivary glands. The viruses can be transmitted by insects persistently – the insect acquires the inoculum and can transmit the virus indefinitely until the insect dies. Insects can transmit the virus non-persistently – the virus moves just to one plant, or semi-persistently – where the inoculum can remain infective for several hours.

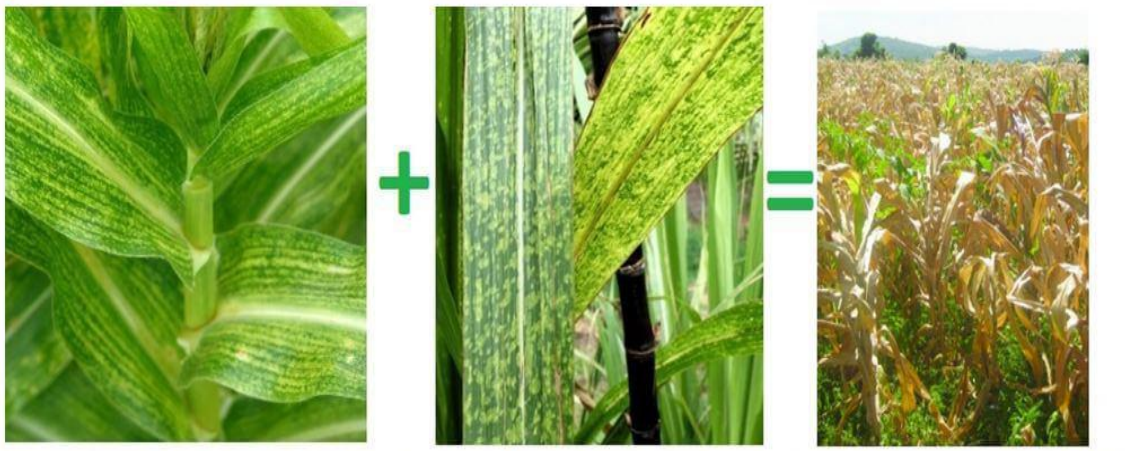
Plant viruses generally cannot survive on their own and tend to live and perpetuate in host plants. These are neighbouring plants, commercial crops, volunteer plants or weeds that breed the virus up and act as reservoirs for new inoculum. Very often, the host plants will show no symptoms. It is important to identify the potential reservoirs and remove the plants to stop the virus cycle from continuing from one planting to another.

Viral Diseases In Plants

The following section contains information on viruses that we can screen for in our CropNuts Pathology laboratory. Viruses are tested using ELISA.

Maize Lethal Necrotic Disease

This is caused by the maize chlorotic mottle virus (MCMV) combining with a potyvirus, in Kenya, this is the sugarcane mosaic virus (SCMV), to create a virus disease complex in the plants that is potentially fatal. The SCMV was first identified in Kenya in the 1930's and is widespread, not causing much damage as our germplasm is quite resistant to it. MCMV was first noticed in Kenya in 2012 and caused up to 100% yield loss in the areas that were affected.



Maize Clorotic Mottle Virus (MCMV) + Sugarcane Mosaic Virus (SCMV) = Maize lethal necrotic disease (MLND)

Transmission from place to place is via seed, in the seed coating, and inter-plant transfer is via several insect vectors. Testing seed plants, rogueing (removing and burning) symptomatic plants, special seed cleaning treatments and planting resistant varieties go a long way to reduce spread and damage.

Tobacco Mosaic Virus (TMV)

This was the first plant virus to be discovered. It was isolated from Tobacco plants in the 1800's. It has a wide host range of over 350 plant species. It can cause serious economic losses in tomatoes and peppers. The virus multiplies in living plant tissue but is very resilient and survives in a dormant state in dead plant tissue, retaining its infectiveness. It can also survive outside plant tissue in plant sap that has dried on tools and hands.

The most important method of transmission is mechanical transmission (direct, not via a vector or seed), on workers' hands, tools, and clothing. It survives in dry sap, so if you touch an infected plant, then touch a door handle, the next person to touch the door handle can pick up the virus. Chewing insects (e.g., caterpillars and grasshoppers) can occasionally spread the virus, but are not considered important in the spread. Vegetative propagation perpetuates TMV and other viruses. TMV is found in all parts of infected plants. Infected stock plants should be discarded. Cuttings can be infected but show no symptoms. TMV can be moved around in tobacco products.

TMV Symptoms include stunting, mosaic patterns on leaves, malformation of leaves and growing points, and yellow streaking or spotting. Like most viruses, TMV cannot be diagnosed from symptoms alone. Plant material should be sent to our lab for confirmation.

Tomato Mosaic Virus (ToMV)

ToMV is a closely related strain of TMV, it infects tomatoes most commonly, but can also cause problems in pepper, potatoes, apples and numerous weeds, including amaranth and lamb's quarter.

ToMV and TMV in tomatoes can look very similar, leaf mosaic and fruit rotting and discolouration. In order to confirm - lab tests must be done

TMV ToMV Biology and Disease Cycle

The virus is initially seed-borne and can move large distances in seed. Only a few infected seedlings are required for the viruses to spread rapidly in a field. The viruses then spread from plant to plant via mechanical transmission. Both viruses are stable to drying, so hygiene protocols should be particularly rigorous if these viruses have been found.

ToMV and TMV can exist for two years in dry soil, one month in moist soil, and over 22 months in infected roots left in the soil. The viruses also stay infective in dried plant material and soil, and can be blown around by the wind. So, it is very important to remove plants, roots, and all, and burn and bury them away from the field or greenhouse.

The viruses can persist in greenhouse structures for a long time.

TMV ToMV Plant Virus Cultural Control

There are no effective chemical controls against viruses.

- Start clean and stay clean – use certified disease-free seed or treat your own seed (soak seed in a 10% solution of trisodium phosphate (TSP) for at least 15 minutes).
- Buy seedlings from reputable sources, check their hygiene protocols. Inspect plants before purchase and choose only clean-looking seedlings.
- Use a minimum two-year rotation and avoid fields that have tomato/potato roots or volunteer crops in them, as the virus can stay for a long time in root debris.
- The viruses can persist in greenhouse structures for a long time. Disinfect all equipment – ties / wires / stakes / benches / troughs / planting pots /greenhouse posts / plastic between growing seasons. Steam treat soil/media or replace.
- Avoid touching plants as much as possible. Avoid pruning young plants. Wash in soap, then disinfect hands and tools thoroughly before starting work and between plants. Rubber gloves can protect hands. A 1-minute dip in skimmed milk (20% solution) to inactivate the virus, or use 3% TSP. Wash greenhouse PPE every day.
- Remove and burn, deep bury all seedlings/plants that show symptoms (mottling/ mosaic etc).
- Always work in healthy houses/areas first.
- The virus can also come from infected soil particles and water
- TMV can survive in tobacco products – keep these away from your growing area / hands, and pockets.
- Plant ToMV or TMV-resistant varieties / or graft on resistant rootstock.

omato Spotted Wilt Virus (TSWV)

Tomato Spotted Wilt Virus (TSWV) can cause serious crop losses in many economically important crops including vegetables, ornamentals and field crops. It has an unusually large host range (>35 plant families, >174 plant species including monocots and dicots). It is transmitted by thrips in a persistent manner. Many local weeds act as a reservoir.

Early accurate detection of the virus in infected plants and controlling thrips are critical measures in its control. The virus can be present on the seed coat, but not in the embryo. Seeds can be disinfected. However, seeds are not considered important for disease spread.

Crops that can be affected by TSWV

This table contains a partial list of common crops that can be affected by TSWV. The list continues to grow as new crops are identified or the virus mutates into new strains

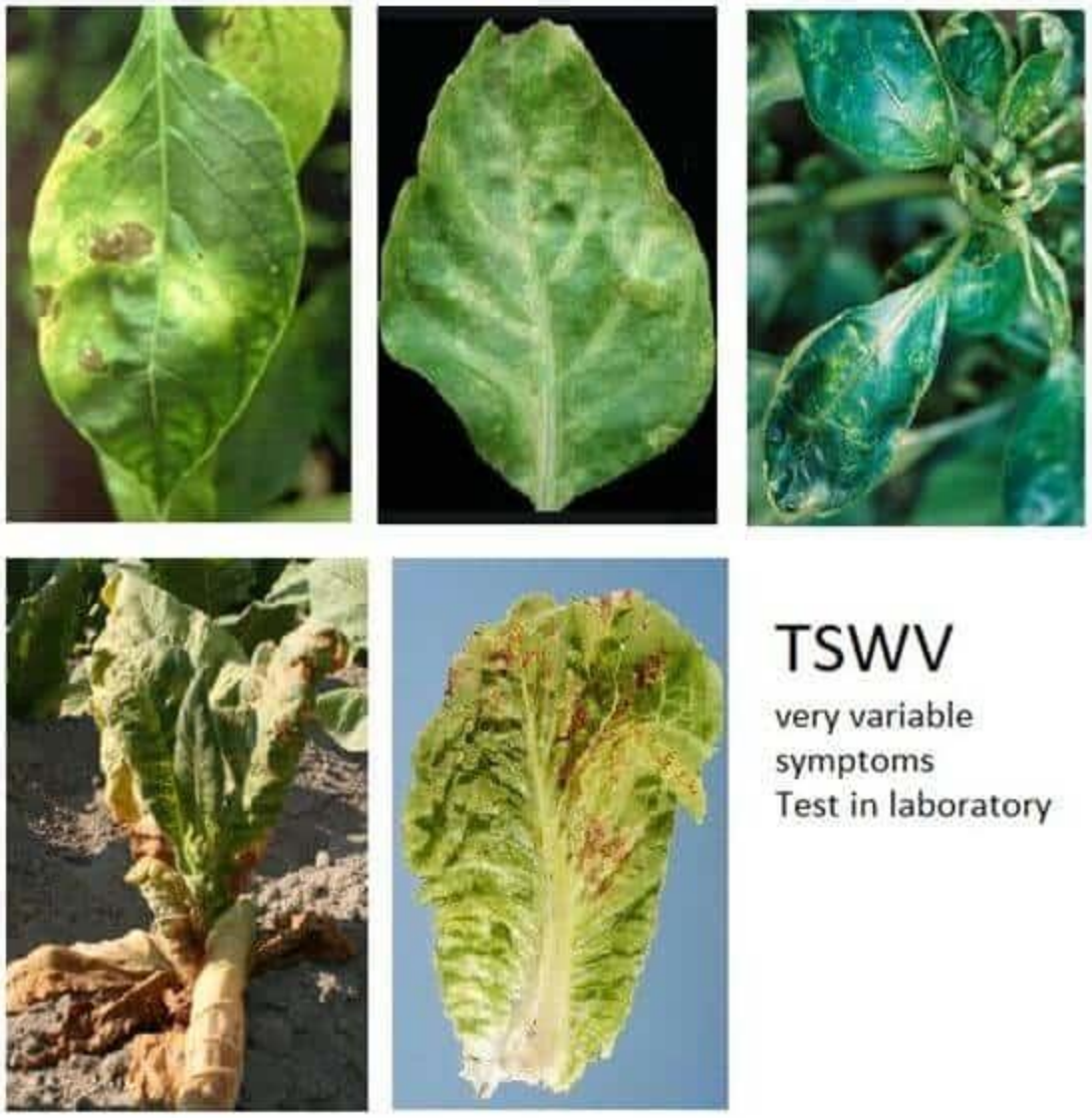
Field Crops	Tobacco, Peanut, cowpea, beans

Vegetable Crops	Tomato, pepper, potato, eggplant, lettuce, endive, celery, spinach, cucumber, cauliflower
Ornamentals / cut flowers	Chrysanthemum, Gypsophila, Aster, Snapdragon, Zinnia, Cyclamen, Begonia, Cosmos, Dahlia, Calendula, Primrose, Calla Lily, Gerbera, Amaryllis, Gladiolus, Peony, Delphinium, Ranunculi, Hydrangea, Geranium, Stock, Anemone, Salvia, Verbena, Phlox, Morning glory, Poppy, Ageratum, Impatiens, Coleus, Lobelia, Tiger Lily, Lupine, Marigold, Evening Primrose, nasturtium, Limonium

TSWV Symptoms

Symptoms of TSWV can be very host specific. Common manifestations are:

- brown or yellow ringspots or other line patterns
- black streaks on petioles or stems
- necrotic leaf spots
- tip dieback



Weeds that harbour TSWV

Weed hosts are important reservoirs for TSWV and other viruses. TSWV has been picked up in the following weed families:-

- Amaranthaceae (spiny amaranth)
- Caryophyllaceae (chickweed)
- Chenopodiaceae (lamb's quarter)
- Compositae (burdock, sow thistle)
- Convolvulaceae (ipomoea, blue morning glory)
- Cruciferae (shepherd's purse)

- Leguminosae (crotalaria, smooth rattle pod)
- Plumbaginaceae (statice)
- Malvaceae (mallow)
- Portulacaceae (purslane)
- Solanaceae (black nightshade)
- Tropaeolaceae (nasturtium)
- Verbenaceae (verbena)

Virus Vector Relationship in TSWV

This is most important in understanding how the virus spreads. It can be spread by all thrips species in a persistent way. The virus is acquired by the larval stage, feeding on an infected plant. After a latent incubation period of 3-10 days, depending on the thrip species, the adult thrips become infective and can spread the TSWV virus from plant to plant for the remainder of their adult lives. They cannot pass the virus to their progeny.

A large pool of infected plants and overlapping thrips life cycles can lead to continuous virus spread here in Kenya. The thrips' rapid development time (quicker in hot weather) and reproduction rate can allow an undetected infestation to become a major problem very quickly. Although not strong fliers, thrips can catch a lift on wind currents and clothing. Effective chemical control can be hindered by insecticide resistance buildup.

TSWV Methods of Control

Remove infected plants, control thrips, screen new plants, disinfect seed coatings, scout clean fields first and infected fields at the end of the day. Do not wear yellow or blue clothing. Protect greenhouses with thrip net. Screen in-coming plants for TSWV. Plant TSWV resistant varieties.

Infection in seedlings / young plants can cause the worst losses. Do not mix plant generations in one greenhouse. Do not mix ornamentals or infected cuttings in the same propagation house as seedlings/tissue culture plantlets. Rigorous control of thrips in propagation units is required (zero tolerance). Zero tolerance of weeds in greenhouses or fields. Screen mother plant stock and replace if infected.

Cucumber Mosaic Virus (CMV)

Cucumber mosaic virus (CMV) is a Bromovirus with a worldwide distribution and very wide host range (>1200 plants – reputed to be the widest host range in the world). It is transmitted in seeds, parasitic weeds (like dodder), and is moved from plant to plant via aphids and mechanically (it is semi-stable). It can be harboured in many weeds. The transmission by aphids is non-persistent – they take about 5 minutes to acquire the virus, and after about 2 minutes, the inoculum load decreases, and after 2 hours, it is finished.

While it was first discovered in cucumbers, it infects many vegetable and ornamental plants. (squash, peppers, beans, tomatoes, carrots, celery, spinach, eggplant, and many ornamentals).

Symptoms include stunting, yellowing, leaf mottling, mosaics, shoe-stringing, leaf, flower, and fruit distortion. It can cause up 20% loss in vegetable crops and 100% losses in ornamentals (by affected leaf and flower quality).

There are no chemical controls, and treating aphids with insecticides does not kill the virus. Buy clean certified seed and plants. Screen and discard infected mother stock. Remove all weeds. Wash and disinfect hands and tools. Move from healthy crops to infected crops. Select CMV-resistant varieties.

Alfalfa Mosaic Virus (AMV)

Other names include Alfalfa yellow spot, Lucerne mosaic virus, potato calico virus, tomato necrotic tip curl virus. AMV is an *alfamovirus* spread by aphids. The primary source of inoculum is infected seed or pollen. AMV can cause important yield losses, reduced cold / dry weather survival, and increased susceptibility to other pathogens. It can reduce the mineral content of fodder crops . AMV has a wide host range including some important crops (*peas, lentils, potatoes, tomatoes, tobacco, wheat, lucerne*).

Symptoms include wilting, stunting, dwarfing, mosaics, ringspots, mottles and necrosis, depending on the strain, crop, crop stage and environmental conditions. Signs of infection can persist or disappear. Potato leaves can display a very distinctive calico mottling in potatoes, and cause misshapen, cracked tubers.

Distinctive calico mottling in potatoes - caused by AMV Leaves stand out in the field. They can develop a shiny sheen. (*photo credit University of Utah*)

AMV Transmission and Control

lanting infected seeds/tubers in a field followed by an aphid infestation causes high levels of infection. Plant clean seed / tubers. Control aphid populations. AMV persists in fields in weeds, infected seed pieces and volunteer plants.

The virus is transmitted by aphids in a non-persistent way. The aphid feeds on an infected plant, acquires the virus and spreads it to only a few plants before it is all deposited.

Do not plant susceptible crops within a mile of infected lucerne / clover / wheat fields. The highest risk of infection comes when these crops dry up and aphids move into new crops looking for moisture. Planting potatoes and Lucerne on one pivot is not recommended. Controlling aphids with insecticide does not control the virus.

Potato Virus Y

Potato virus Y (PVY) is a potyvirus, there are three strains. (PVYO, PVYN, PVYNTN). It affects solanaceous crops (potato, tomato, pepper, tobacco, nightshade, many weeds). It can cause 50-80% losses in highly infected potato fields and reduce tuber quality and result in post-harvest tuber death.

Symptoms vary according to the strain. PVYO causes mosaic on the leaves. PVYN causes necrotic sports of the leaves and tubers. PVYNTN causes necrotic spots on the leaves and necrotic rings on the tubers, which extend into the flesh.

Mottling (top left), necrotic lesions (bottom left) and necrotic ringspots in the tubers are signs of PVY. Symptoms vary according to virus strain, crop variety, crop stage. Confirm in lab.

PVY is most frequently introduced into fields on infected tubers. It is then spread by aphids and farm equipment/tools/hands. The virus is transmitted by aphids in a non-persistent way; they can only transmit the virus to one plant. The virus persists in fields in tubers/volunteer plants / solanaceous weeds.

Remove weeds and volunteer plants. Insecticides do not affect the control of the spread of the virus.

Citrus Tristeza Virus (CTV)

Citrus Tristeza (CTV) is a Closterovirus that affects citrus. Tristeza is means sad in Spanish. It has killed over 80 million trees worldwide. It is widespread in Kenya. Symptoms are highly variable and depend on the host tree / virulence and

environmental conditions. The most common are quick and slow decline, seedling yellows, and stem pitting. Decline can be from several months to several years.

Citrus Tristeza Virus (CTV) is spread by aphids and grafting stock, brown citrus aphids are very good at spreading the virus. It causes many different symptoms - including rapid decline and tree death.

It is transmitted via rootstock and grafting material to fields, and by aphids in a semi-persistent manner inside the nursery. Screen mother stock. Screen new orchards. Control aphids in young plants. Use CTV-tolerant rootstocks.

If you'd want to test your plant samples, please send samples of your mother stock for screening at our CropNuts pathology lab. Till next time,
Kindest regards,
Ruth

About Ruth

Ruth Vaughan is the Technical Director at Crop Nutrition Laboratory Services Ltd. (CROPNUTS). Ruth is also a contributing author to Kenya's leading horticulture magazines , such as the HortFresh Journal, HortiNews , and Floriculture. Ruth is a great

believer in soil health, organic matter, biochar, and carbon sequestration as a way to alleviate climate change and increase food security. Loves visiting farmers and seeing all the different farming methods