Ministry of Agriculture, Food and Fisheries

Emerging Virus Diseases of Greenhouse Vegetables

March 2021

There have been several new viral diseases reported on greenhouse vegetable crops worldwide, and some of them are of great concern to greenhouse vegetable production in British Columbia (B.C.). Information given below focuses only on a few potential new diseases caused by viruses that have been reported on greenhouse vegetable crops in North and Central America, and, therefore, these diseases are very likely to be introduced into Canada. The purpose of this factsheet is to bring awareness to the greenhouse vegetable growers and to engage them in active surveillance and biosecurity measures to prevent the Introduction, establishment and spread of such damaging viral diseases.

Early detection of diseases caused by viruses is critical to prevent or minimize the spread of the pathogens and potential crop losses in greenhouses. If a new viral-like symptom(s) or a potential virus-vector is suspected in a greenhouse, then, it is critical to confirm the presence of it by following a proper identification process through a recognized plant diagnostic laboratory. Viruses are too small to be seen and identified with a light microscope. Therefore, specialized techniques such as ELISA (enzyme-linked-immunosorbent-assay) and RT-PCR (reverse transcriptase polymerase chain reaction) are required for confirming the viruses. Once the identity of the pathogen is confirmed, specific control strategies must be implemented immediately.

Tomato Brown Rugose Fruit Virus (Potyvirus)

Virus Description and Distribution

Tomato brown rugose fruit virus (*ToBRFV*) is in the genus Tobamovirus, similar to *Tobacco mosaic virus* (*TMV*) and *Tomato mosaic virus* (*ToMV*). It is known to infect tomato and pepper (perhaps, other solanaceous plants), particularly those grown under environmentally controlled greenhouses or screenhouses. *ToBRFV* appears to be more damaging to tomato than pepper. *ToBRFV* was first detected in Israel (2014) and Jordan (2015), subsequently in the Europe (Germany, Italy, Netherlands, UK, Turkey, Greece) and then in China, Mexico and the USA. In the Europe and USA, *ToBRFV* is treated as a regulated quarantine pest, and in the USA, and claimed to be eradicated upon positive findings. In Mexico, *ToBRFV* has been treated as a regulated non-quarantine pest and believed to be present in the major tomato producing areas.

In Canada, the virus was first suspected to be present in a tomato greenhouse in Ontario in 2019 and, subsequently, in a greenhouse in Alberta and Ontario in 2020. As per the Canadian Food Inspection Agency (CFIA), the reported incidences were investigated and found to be eradicated. Based on the Pest Risk Assessment conducted by the CFIA, no regulatory action has been taken on *ToBRFV* by the CFIA.

Symptoms

ToBRFV causes more damage to tomato crop than other tobamoviruses like *TMV* or *ToMV*. Symptoms are expressed on leaves, calyx and fruit during the developmental stages of a plant. Leaves show early symptoms of discolouration, mosaic and shoestring or fern-like appearance (Figure 1 A & B), that could mimic the symptoms caused by *TMV* or *ToMV*. Calyx attached to green fruit shows distinct browning of the veins and drying out of the

tips of the calyx (Figure I C). Symptoms on fruit appear as the characteristic brown wrinkled (rugose) patches on green fruit (Figure I D & F), and blotching, crinkling, and yellow to brown necrotic areas further develop on the skin of mature fruit (Figure I F). Fruit become misshaped and may result in complete fruit abortion.

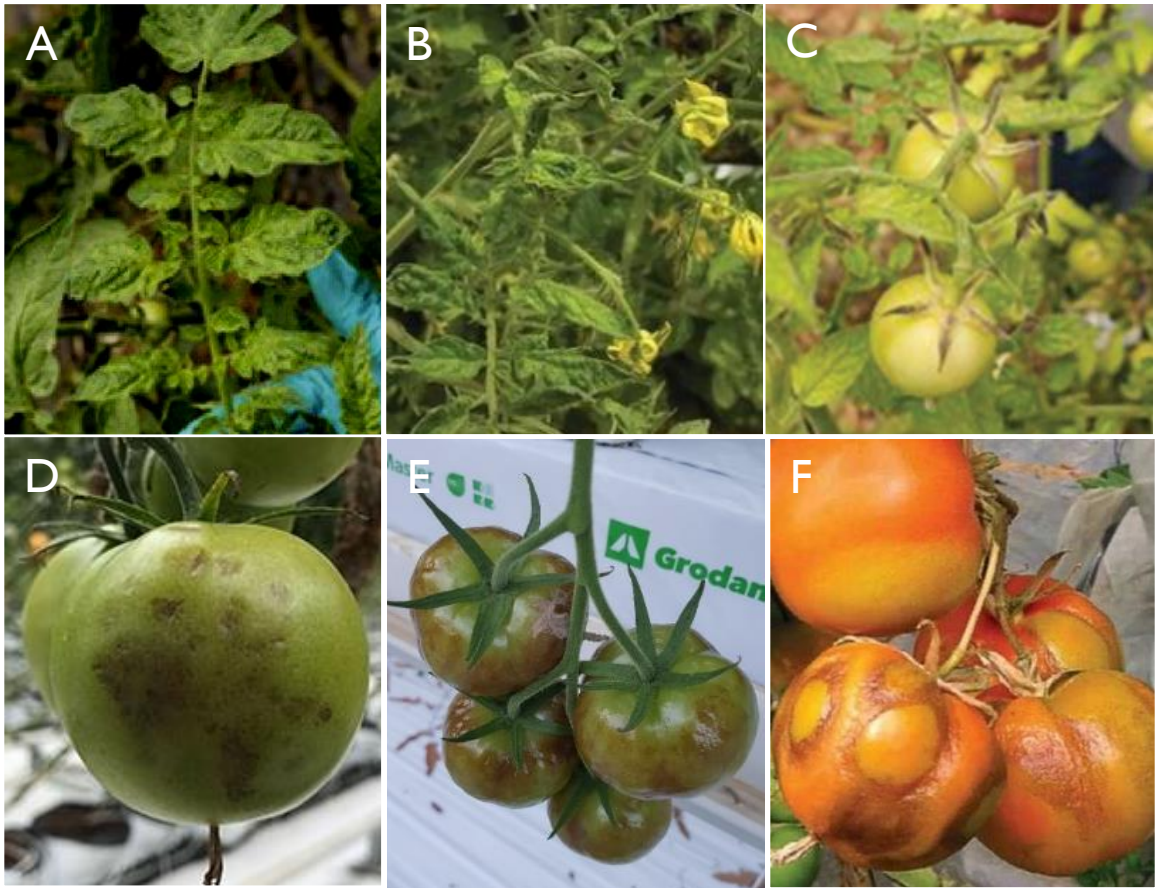

Figure 1. Symptoms on leaves (A & B), calyx (C), and green (D & E) and ripe (F) fruit infected with *Tomato brown rugose fruit virus.* Photo Credit: Florida Department of Agriculture (A, B, E & F), American Seed Trade Association (C), and EPPO Quarantine Alert - courtesy by Diana Godinez (D).

Spread

ToBRFV is mechanically transmitted and no insect-vector is involved in the transmission of the virus. It is seed-borne and, therefore, both seeds and transplants are the major pathways for the introduction and spread of the disease. Fruit from infect plants circulated for consumption can also be a source of spread of the virus if they have been taken into crop production facilities. Tobamoviruses are highly infectious and are considered highly stable and able to survive for months on plant debris, plant growth media, tools and workers' clothing.

Tomato varieties that carry the genes, Tm1, Tm 2 & Tm 2^2, that are generally resistant to *TMV* and *ToMV* found to be highly susceptible to *ToBRFV*, except var. 'Roma'. Whereas, popper varieties with the resistant gene L seem to provide some protect against *ToBRFV*.

Columbian Datura Virus (Potyvirus)

Virus Description and Distribution

Columbian datura virus (CDV), a member of the family Potyvirus, is known to infect plants in the family Solanaceae, and many ornamentals (*Brugmansia, Juanulloa, Petunia, Pepino* etc.). Initially, CDV was detected in *Datura* species imported from Columbia to the United States in 1968. Since then, the virus has been reported from Australia, Germany, Hungary, Japan, Netherlands, Poland and the United States. In 2003 and 2004, CDV was detected in several States on ornamental plants (*Spiranthes* orchids, *Brugmansia* spp. etc.). In Canada, CDV was first detected on *Brugmansia* spp. from B.C. in 2007. CDV is on the US Regulated Plant Pest list but not on the Canadian Regulated Plant Pest List. It appears that CDV is more widespread than originally thought. Economically important Solanaceous crops, including field- and greenhouse-grown tomato and field potato can be at risk. It is important that growers pay close attention to the disease and engage in periodic monitoring for symptoms on greenhouse tomato.

Symptoms

Infected tomato plants can remain asymptomatic, but the symptoms are expressed when plants are stressed. Symptoms are most seen on activity growing plants. Although the typical symptoms on greenhouse tomato are not well characterized the symptoms may mimic the symptoms expressed on other solanaceous plants such as *Brugmansia* spp. (Figure 1). The commonly observed symptoms on greenhouse tomato in the Netherlands are reduction in leaf size, chlorotic flecking (mosaic) and mottling on leaves, shrivelling of leaves, vein-banding, stunting of plants and discolouration of flowers.

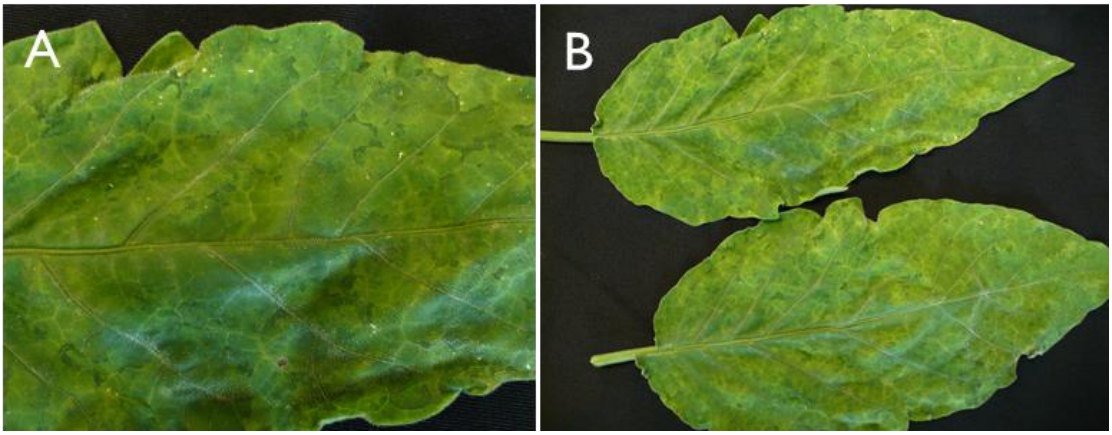

Figure 1. Typical symptoms on *Brugmansia* sp. infected with Columbian datura virus showing vein-banding, chlorotic (A), and mottling of leaves (B).

Tomato Infectious Chlorosis Virus (Closterovirus)

Virus Description and Distribution

Tomato infectious chlorosis virus (TICV) is a member of genus Crinivirus (family Closterovirus). It was first reported in 1993 on field tomatoes and then in greenhouse tomatoes in California and North Carolina, USA. Subsequently, the virus was detected on greenhouse tomatoes in Europe (Italy, Spain, Greece and France) and Asia (Indonesia, Japan and Taiwan). It has been shown to have a moderately wide host range (26 plant species in 8 plant families), including vegetables such as tomato, potato, lettuce and artichoke, ornamentals such as petunia, and several weeds.

Symptoms

Symptoms can be confused with nutritional disorders, poor growing conditions, natural senescence, or pesticide toxicity. Initial symptoms appear as interveinal yellowing with green veins mostly on mature lower leaves (Figure 2), while the rest of the plant tends to appear "normal". As the disease progresses, the similar symptoms can be observed on young upper leaves. Subsequently, the symptomatic leaves become pale-white, necrotic, dry and curled. Infected leaves (especially older ones) may also turn red. Early infection can also affect the fruit set, colour and quality, resulting in substantial yield loss. Similar symptoms can also be expressed by tomato plants infected with Tomato chlorosis virus, ToCV.

Spread

TICV is transmitted in a semi-persistent manner by the greenhouse whitefly, *Trialeurodes vaporariorum* (Figure 7). Therefore, the movement of virus in the host plant is restricted to phloem tissue only. TICV is not known to be transmitted by other whiteflies (*Trialeurodes* spp. and *Bemisia* spp.). The virus is not seed-borne or transmitted mechanically.

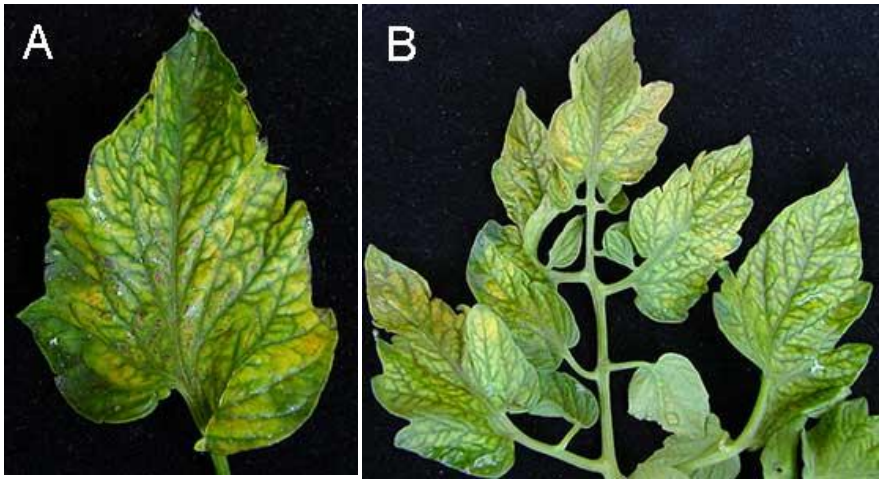

Figure 2. Tomato plant infected with Tomato infectious chlorosis virus showing interveinal chlorosis and mild necrosis on leaflet (A) and leaf (B). Photo credit: W. M. Wintermantel, USDA-ARS, Salinas, CA, USA.

Tomato Chlorosis Virus (Closterovirus)

Description and Distribution

Tomato chlorosis virus (ToCV) is also a member of genus Crinivirus (family Closterovirus) which is closely related to *Tomato infectious chlorosis virus* (TICV). ToCV causes symptoms on tomatoes that are very similar to the symptoms caused by TICV and, thus, cannot be distinguished. However, ToCV and TICV can be differentiated based on the symptoms expressed on the indicator plants, *Nicotiana benthamiana* and *N. clevelandii*. The major difference between ToCV and TICV is that ToCV is transmitted by the greenhouse whitefly (*Trialeurodes vaporariorum*), the banded-wing whitefly (*T. abutilonea*) and silverleaf whiteflies (*Bemisia* spp.), biotypes A (*B. tabaci*) and B (*B. argentifolii*), while TICV is transmitted solely by the greenhouse whitefly. Like TICV, ToCV is also transmitted in a semi-persistent manner by whiteflies and its movement in host plants is restricted to phloem tissue. ToCV has been shown to have a moderately wide host range (24 plant species in 7 plant families), including tomato and sweet pepper, as well as some weeds.

Although ToCV first appeared in 1989 in greenhouse-grown tomatoes in Florida, USA, and, later, in Colorado and Louisiana, it wasn't confirmed as ToCV until 1996. Subsequently, ToCV has been reported on greenhouse-

grown tomatoes in many countries of the Caribbean, East Asia, Southern Africa, Europe and the Mediterranean. In 2003, sweet pepper was identified as a natural host for ToCV in Spain.

Symptoms

Tomato plant infected with ToCV expresses symptoms similar to those expressed by TICV (Figure 3). Therefore, it is difficult to diagnose plants infected with these viruses based on the symptoms. It is also possible that a single tomato plant can also be co-infected with both ToCV and TICV. It is, therefore, critical to submit suspected plant samples to a recognized plant pest diagnostic laboratory for accurate identification.

Spread

TICV is transmitted in a semi-persistent manner by the greenhouse whitefly (*T. vaporariorum*), (Figure 7), the banded-wing whitefly (*T. abutilonea*) and silverleaf whiteflies (*Bemisia* spp.); biotypes A (*B. tabaci*) and B (*B. argentifolii*), (Figure 6). The movement of virus in the host plant is restricted to phloem tissue. Studies have shown that persistence and efficacy of transmission of ToCV is variable depending on the type of virus-vector involved. Although all ToCV vectors are capable of transmission, the banded-wing whitefly and silverleaf whitefly-biotype B are highly efficient vectors of ToCV. The virus is not seed-borne or transmitted mechanically.

Figure 3. Tomato plant infected with *Tomato chlorosis virus* showing interveinal chlorosis on leaflet (A), and mild necrosis on leaves (B). Photo credit: W. M. Wintermantel, USDA-ARS, Salinas, CA, USA.

Tomato Yellow Leaf Curl Virus (Bigeminivirus)

Virus Description and Distribution

Tomato yellow leaf curl virus (TYLCV) is known to infect many vegetable crops including tomato, pepper and bean as well as many ornamental plants such as poinsettia. TYLCV can cause severe economic losses to tomato production, where yield losses of up to 100% in greenhouse tomato production have been reported in Southern Europe and the Middle East. TYLCV spreads systemically in the host plant and is limited to phloem tissue.

TYLCV has been a major threat to tomato production in Israel since 1930. It was introduced into the Dominican Republic, Cuba, and Jamaica in the early 1990s'. Since then, TYLCV has been reported from Africa, Asia, Australia, Caribbean, Europe and North and Central America. In North America, TYLCV is known to occur in Florida, Georgia, Louisiana, and has recently been detected in California and Arizona.

Symptoms

Visible symptoms can be seen on tomato plants 2-3 weeks after initial infection by TYLCV. Symptoms can vary slightly depending on the tomato cultivar and amount of virus infection (Figure 4). Generally, infected plants have smaller-than-normal leaves that are cupped upward, thick and rubbery with chlorotic margins (Figure 4). Young infected plants become severely stunted. Infected plants drop up to 90% of their flowers resulting in major yield losses.

Spread

TYLCV is transmitted by adult silverleaf whiteflies, *Bemisia argentifolii* (Figure 5), previously known as *Bemisia tabaci* biotype B, (Figure 6). The silverleaf whitefly is a different species than the common greenhouse whitefly which does not transmit TYLCV. Silverleaf whiteflies are rarely seen in British Columbia. They are small, phloem-feeding insects which pick up the virus while feeding on infected host plants. Since TYLCV has a broad host range, it can be spread by silverleaf whiteflies that feed on other infected host plants, including cultivated and wild plants. Not all host plants infected with TYLCV show visible symptoms, however the virus can be acquired by silverleaf whiteflies from symptomless infected plants and transmitted to tomato. The virus can also be transmitted through cuttings taken from infected plants or it can be introduced into a greenhouse with virus-infected transplants. TYLCV cannot be transmitted mechanically or by workers and is not transmitted by seeds. Even if TYLCV shows up in British Columbia, it may not become established due to the unlikely survival of silverleaf whiteflies in winter months. On the other hand, there is evidence to suggest that TYLCV can be persistent and can overwinter in infected plants and plant materials.

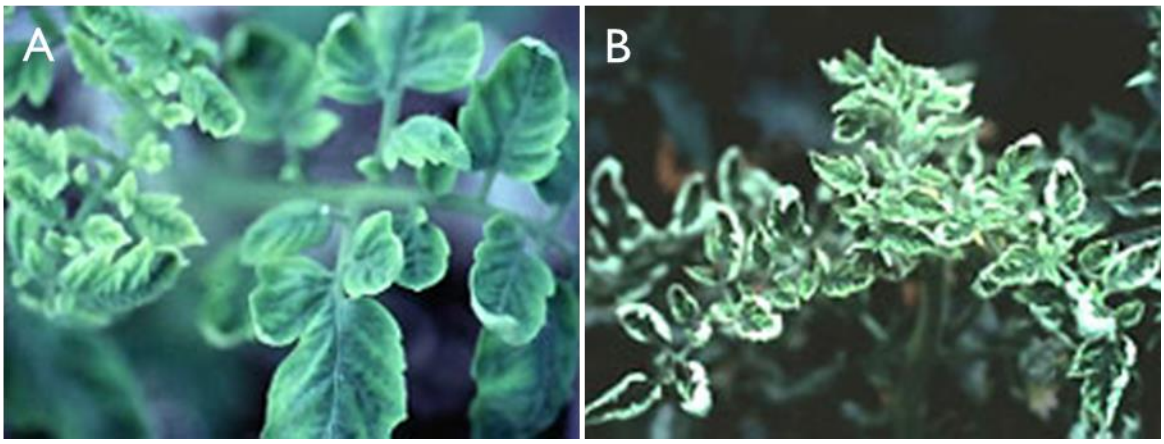

Figure 4: Symptoms on tomato leaves, mild (A) and severe (B) of a tomato plant infected with *Tomato yellow leaf curl virus*. Photo credit: T. Schubert, Florida Department of Agriculture.

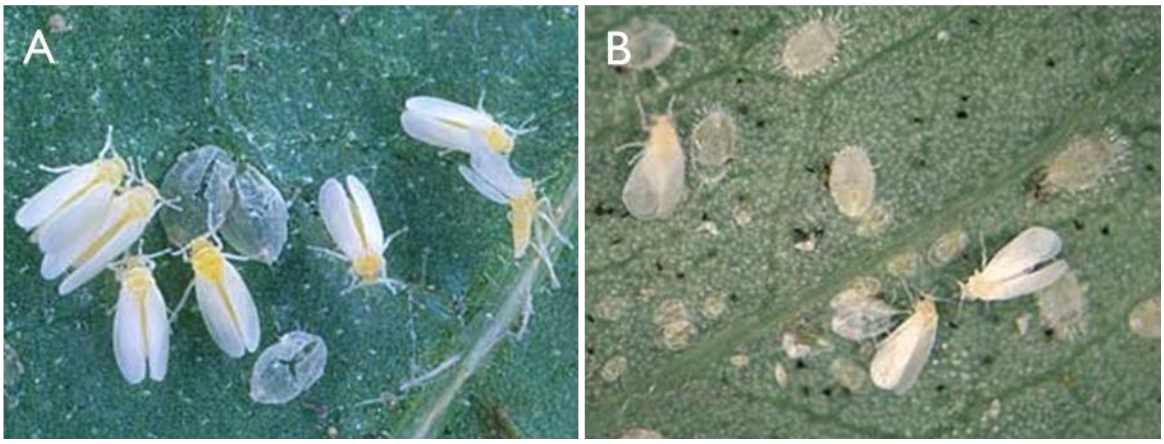

Figure 5: Adult Silverleaf whiteflies, *Bemisia argentifolii*, feeding on the underside of a leaf; wings are usually folded vertically along the body while feeding and nymphs do not have filaments or fringe around their body (A), and Greenhouse whitefly, *Trialeurodes vaporariorum,* feeding on the underside of a leaf; wings tend to lie parallel to the body and nymphs have filaments around their body (B). Photo credit: Whitney Cranshaw, Colorado State University, www.forestryimages.org. Photo credit: Scott Bauer, USDA Agricultural Research Service, www.forestryimages.org

General Virus Control Measures

Virus diseases are very difficult to control once they become established. The possible presence of a potential virus on other host plants (including weeds) in the absence of a host crop, and the ability of virus-vectors (the greenhouse whitefly, the banded-whitefly and silverleaf whiteflies) to feed and reproduce on crop plant make it difficult to control the disease successfully. It is highly recommended that a collective management approach, i.e. a combining of cultural practices, biosecurity measures, greenhouse sanitation and disinfection practices, and insect-vector control strategies, should be adopted to reduce the impact of virus diseases on a crop. For information on disinfectants and sanitation products and their use in crop production facilities, please refer the Ministry's factsheet on "Disinfection and Sanitation Practices".

- Use virus-free transplants that come from certified transplant nurseries
- Use tomato cultivars, if any, that are resistant to TICV, ToCV, TYLCV and CDV
- Monitor for whitefly and aphid populations throughout the tomato growing season (spring to fall) and, if present, apply appropriate insecticides that are registered in British Columbia for greenhouse tomato. Protection of young tomato plants from aphid- and whitefly-feeding is essential to reduce potential yield losses.
- If whiteflies are detected in B.C. greenhouses, use reflective or coloured (yellow) mulches that may reduce the whitefly populations feeding on tomato leaves.
- Use trap plants, preferably cucurbits that are preferred by whiteflies, to reduce infection rate on tomato.
- Maintain periodic scouting for virus symptoms, particularly on young tomato plants, and remove and deep-bury or incinerate the infected or suspected tomato plants.
- Maintain healthy growth of tomato plants to minimize virus damage.

Since viruses have a broad host range, including many weeds that are symptomless, maintain a rigorous weed control program in and around the greenhouse during the growing season and winter months.

TICV, ToCV, TYLCV and CDV are not yet detected on greenhouse tomato in B.C. and it is very difficult to eradicate once established. Therefore, preventing the introduction and establishment of these viruses is very important. Submit any suspected virus-infected plant samples or plants showing virus-like symptoms and any suspected virus-vectors (e.g. whiteflies and aphids) to the Ministry of Agriculture, Food and Fisheries - Plant Health Laboratory or to a recognized plant pest diagnostic laboratory for proper diagnosis and confirmation.

To prevent the introduction and spread of potential diseases of greenhouse vegetable crops, please refer the factsheets on "On-Farm and Greenhouse Sanitation and Disinfection Practices" and "Biosecurity Guidelines".

For Further Information

Tomato brown rugose fruit virus – Canadian Food Inspection Agency (2019): https://inspection.canada.ca/plant-health/plant-pests-invasive-species/plant-diseases/tobrfv/eng/1560266450577/1560266450826

Tomato brown rugose fruit virus – CABI Datasheet (2020): https://www.cabi.org/isc/datasheet/88757522

Tomato brown rugose fruit virus – EPPO Bulletin (2020): https://onlinelibrary.wiley.com/doi/full/10.1111/epp.12711

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