Virus Transmission and Grafting Practices

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Fire blight and scab are two major diseases of concern to apple production and orchard profitability in New York. Less familiar to the apple industry but worrisome in their own right are viruses. Several viruses have been identified in domestic apple (*Malus x domestica* Brokh.). These viruses occur in all the apple-growing regions of the world, where they can cause severe diseases, not only in apple, but also in other fruit crops. Some of these diseases were described as early as the 1910s in New York apple orchards, although it is only a few decades later that their viral nature was elucidated. Of major concern to orchard profitability in New York are *Apple chlorotic leaf spot virus* (ACLSV), *Apple stem pitting virus* (ASPV), and *Apple stem grooving virus* (ASGV). These three viruses are common and generally latent; they do not cause acute symptoms on most commercial cultivars. However, when present in susceptible cultivars and/or susceptible rootstocks, particularly in mixed infection, their effect is often economically devastating. Other viruses, such as *Apple mosaic virus* (ApMV) and *Tomato ringspot virus* (ToRSV), can also affect apple production in New York, and *Cherry rasp leaf virus* (CLRV) and *Tobacco ringspot virus* (TRSV) are potential threats.

"Viruses can have a devastating effect on apple growth and productivity. All viruses of apple are transmitted through propagation, grafting, and top working. The critical importance of sourcing propagation material from trees that test negative for viruses cannot be overemphasized."

Viruses in apple: Impact and symptoms

Viruses affect tree growth and reduce budding success, causing substantial losses to nursery and orchard operations. They also can reduce the productive lifespan of apple trees in orchards. The impact of viruses is usually more severe when the trees are infected at an early development stage. Most viruses are predominantly latent; they survive in their host without causing symptoms. Because of their latency, this type of virus is reliably identified in apple tissue only by laboratory tests. The lower tree vigor due to virus infection often increases susceptibility to pests or adverse environmental factors, resulting in higher economic damage. As a consequence, the cost of orchard maintenance increases due to more frequent tree replacements or block removals.

ACLSV is one of the most widely distributed viruses of fruit trees, including in New York. It is present in cultivated, ornamental and wild species of the Rosaceae; e.g., apple, pear, quince, apricot, peach, plum, cherry, etc. This virus is believed to be the major contributing factor to apple top working disease. It can cause a decline of grafted trees, generally 1–2 years after top grafting is done with virus infected scion budwood (Figure 1). Although infected trees show no obvious disease symptoms, their performance can be reduced. For example, a reduction in yield of 10–30% has been reported for ACLSV in combination with other latent viruses. ACLSV causes no observable symptoms in most commercial apple cultivars, although in some susceptible cultivars, foliar symptoms can include chlorotic leaf spots and line patterns, premature leaf drop, stunting, terminal dieback, inner bark necrosis, and local bark necrosis surrounding the inoculum buds. ACLSV is often found in mixed infection with other latent viruses such as ASPV and/or ASGV.

Figure 1. Decline of Red Delicious/G.935 trees infected with *Apple chlorotic leaf spot virus* and *Apple stem pitting virus* (left side of the post) compared with vigorous, healthy trees (right side of the post) in a nursery in fall 2015. Note the stunted growth, browning of the leaves, reduced terminal growth or terminal dieback on virus–infected trees. Photo: D. I. Breth and E. M. Tee.

ASPV is frequently found in apple in New York. No symptom is associated with infection on most scion/rootstock combinations, although infection can result in the development of pits in the wood cylinder (Figure 2). In susceptible cultivars, extensive pitting can impair functions of the vascular tissue. Production can be reduced, particularly when ASPV is co-infecting with other latent viruses such as ACLSV.

ASGV is common in apple. On *Malus x domestica*, Hewes Virginia, commonly known as Virginia crab, this virus causes depressions in the wood cylinder. In other scion/rootstock combinations, the graft union can be swollen and exhibit a necrotic line. With symptoms progressing over time, the necrosis of the graft union terminal makes the scion exhibit poor growth, and leaves can become pale and drop prematurely. Wood symptoms can be more pronounced when ASGV is co-infecting with ACLSV and/or ASPV.

Figure 2. Pitting in the wood cylinder of a declining Red Delicious/G.935 tree infected with *Apple chlorotic leaf spot virus and Apple stem pitting virus.* Photo: D. I. Breth and E. M. Tee.

ApMV is one of the oldest known apple viruses. Infected trees develop pale to bright cream spots on spring leaves as they expand. These foliar spots may become necrotic as the season progresses, coalescing into shot holes. Severely affected leaves drop prematurely. Most commercial cultivars are affected, but the severity of symptoms varies; Golden Delicious and Jonathan are severely affected, whereas Mclntosh is only mildly affected. Except in severe cases, infected trees can still produce a crop, with yield reductions varying from no reduction to 50% reduction. The occurrence of ApMV is very scarce in apple in New York.

ToRSV causes apple union necrosis. The disease can be prevalent in Delicious on MM.106 rootstock. The first symptom is pitting at the graft union. Removal of the bark at the union exhibits a brown line of necrotic tissue. In more advanced stages of the disease, trees may break off at the union. Infected trees generally have thinner canopies and the leaves become pale green. Fruit productivity progressively declines and trees may die 4–5 years after the initial symptoms are observed. The disease is especially severe in trees that become infected in the first two years after planting. Trees that are well established in a planting site and become infected at a later development stage with ToRSV may remain productive for many years, although vigor is reduced.

CLRV causes flat apple disease. Infected trees exhibit a general reduction in productivity that can be associated with smaller upward-rolled leaves and smaller fruit. Symptoms are more pronounced on the fruit of Delicious and related cultivars. CLRV is present in western North America but not shown to occur yet in New York. Therefore, extreme vigilance is recommended when trees, liners or scion buds are sourced from a non-reputable operation in western states, to avoid the introduction of CLRV to New York.

TRSV is the causal agent of union incompatibility in apple trees in Canada. This virus has yet to be reported in apple in the United States; however, it is present in other fruit crops such as blueberry and grapevine in New York. Therefore, vigilance is recommended for the selection of planting sites where TRSV is known to occur.

Conditions for virus infection

All viruses of apple are transmitted through propagation, grafting and top working. ACLSV, ASGV, ASPV and ApMV have no known insect vectors and are not seed transmitted. Therefore, their dissemination results from either a careless selection of scion buds from infected trees or of infected rootstock liners that are used for grafting or top working. In other words, these viruses are transmitted when a virus-infected scion bud is grafted onto, for example, a healthy rootstock (Figure 1) or an already virus-infected rootstock. Consequently, viruses translocate from the infected scion bud to the healthy rootstock (Figure 1) or vice-versa from an infected rootstock onto a healthy scion, resulting in infected, declining trees. As discussed above, virus-infected trees are often symptomless, but they can sometimes manifest symptoms. Viral symptoms vary greatly from very discrete to severe, depending on the susceptibility of the cultivar and rootstock, cultivar/rootstock combination, virus strain, virus combination, and environmental conditions. It is important to keep in mind that diagnostic symptoms can be deceiving because they can be confused with herbicide damage, chemical thinners, mineral deficiencies, or other diseases. Only laboratory tests can reliably identify the presence of viruses in apple.

As discussed above, the absence of obvious symptoms of the three latent viruses (ACLSV, ASGV and ASPV) on most trees increases the risk of their unintentional distribution through grafting and top working. If trees are not tested and shown to be clean (e.g., test negative for viruses), grafting and top working will contribute to the dissemination of latent viruses and their transfer across long distances through the exchange of uncontrolled propagation and planting material. The importance of a thorough testing of propagation material, i.e., rootstock liners and buds, cannot be overstressed. This is critical for the production of healthy trees. In addition, there is no cure for a virus-infected apple tree in the orchard or in the nursery, and there is no direct way to combat a virus besides removing infected trees, emphazising the need to carefully select clean buds and liners for the establishment of healthy orchards.

ToRSV has a broad host range, including fruit, vegetable, and ornamental crops, as well as weeds such as dandelion and chickweed, in addition to apple. This virus is transmitted by the dagger nematodes *Xiphinema americanum* and *X. rivesi*. Spread of ToRSV is relatively slow in apple orchards; however, the movement of soil can accelerate its dissemination, because nematodes that carry the virus can be transferred throughout the orchard or from orchard to orchard. Trees established on sites previously planted to ToRSV-infected trees can become infected. A careful selection of the planting site and its management are critical to manage ToRSV in New York orchards. TRSV can infect fruit, field, and ornamental crops, as well as weeds such as broadleaf plantain, in addition to apple. This virus is transmitted by the dagger nematode *Xiphinema americanum*. TRSV occurs on blueberry and grapevine in New York. A careful selection of the planting site is critical to avoid dealing with TRSV in New York orchards.

CLRV infects sweet cherry, peach and several weeds such as dandelion and broadleaf plantain, in addition to apple. CLRV is transmitted by the dagger nematode *Xiphinema americanum*. Spread of CLRV is slow and trees grown on sites previously planted to CLRV-infected trees can become infected. This virus is of limited concern to apple growers in New York because it is only known to occur in western States.

Diagnosis

It is critical to identify clean trees for nursery operations and top working in order to avoid the dissemination of viruses. The fact that latent viruses do not cause obvious symptoms on most trees highlights the need to perform diagnostics in apple tissue using laboratory techniques. Lab tests include serological assays, such as double antibody sandwich enzyme-linked immunosorbent assay, and molecular assays, based on reverse transcription polymerase chain reaction. These tests can be used to detect all the viruses in apple tissue.

Management Recommendations

The only way to manage apple viruses and secure a healthy and high quality crop is to ensure that the planting material originates from virus-tested, clean trees. If a tree is healthy, with a clean rootstock and a clean scion, that tree will remain healthy in an orchard situation, although a slow spread of viruses can occur through natural root grafts or by dagger nematode feeding if an infected tree is present in the orchard. It is the use of propagation material of poor health status or the uncontrolled exchange of infected propagation material that is a source of virus dissemination. If growers and propagators select buds and liners based exclusively on visual observation and perceived satisfactory tree performance, the risk of collecting buds and liners that are infected with one of the latent viruses is relatively high. Taking such a risk means that apple growers will deal with production uncertainties due to virus-infected trees.

Preventive measures based on the selection of clean, virus-tested (negative) scions and rootstocks are essential for establishing healthy orchards and for the management of apple viruses. Prior to the establishment of a new orchard or replanting, it is recommended to collect soil samples and test them for the presence of dagger nematodes. If nematode-transmitting dagger nematodes are detected, it is important to limit the movement of soil, aggressively control weeds, and select tolerant/resistant cultivars and rootstocks. Trees derived from clean, virus-tested stocks (liners and buds) should be selected to replant or establish new orchards and ensure a healthy and high quality crop.

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