

## Progress on management and control of criniviruses in tomato

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### ABSTRACT

Two crinivirus species infect Tomato (*Lycopersicon esculentum*): *Tomato chlorosis virus* (ToCV) and *Tomato infectious chlorosis virus* (TICV). Recent studies demonstrated that transmission efficiency and persistence of ToCV in the vector varies significantly among the 4 vectors capable of transmitting ToCV. *Trialeurodes abutilonea* and *Bemisia tabaci* biotype B are highly efficient vectors of ToCV. *B. tabaci* biotype A and *T. vaporariorum* are less efficient vectors. The complete nucleotide sequence of the bipartite genome of ToCV was sequenced and compared with related crinivirus species. RNA 1 is organized into four open reading frames (ORFs), and encodes proteins involved in replication, and RNA 2 encodes nine ORFs including genes that encode a HSP70 homolog and two proteins involved in encapsidation of viral RNA. Two forms of resistance have been identified that reduce the impact of criniviruses on tomato. Acylsugar production on foliar trichomes reduces vector feeding and can slow the rate of TICV transmission under field conditions. Resistance to TICV infection was recently discovered in a wild species and studies are in progress to determine the efficacy of moving this resistance into cultivated tomato.

### SUMMARY

The genus Crinivirus (family Closteroviridae) contains numerous new species identified within the past several years that are emerging as important pathogens throughout the world. Criniviruses often cause symptoms that are readily mistaken for physiological or nutritional disorders or pesticide phytotoxicity. These symptoms often include interveinal yellowing of leaves, an associated loss of photosynthetic capability, leaf brittleness, reduced plant vigor, yield reductions and early senescence, depending on the host plant affected. Symptoms are typically most apparent on middle to lower parts of plants, while new growth appears normal. Criniviruses remain confined to cells associated with host plant phloem, and symptoms are thought to result from plugging of the phloem with large viral inclusion bodies, which probably interfere with normal vascular transport in infected plants (Wisler and Duffus, 2001).

Two crinivirus species infecting tomato have been identified to date, *Tomato chlorosis virus* (ToCV) and *Tomato infectious chlorosis virus* (TICV). TICV and ToCV cause identical symptoms on tomato, including interveinal chlorosis, leaf brittleness and limited necrotic flecking or leaf bronzing on tomato leaves. Both can cause a decline in plant vigor and reduce fruit yield (Wisler et al. 1998; Wintermantel and Wisler, 2006). Both tomato-infecting criniviruses are transmitted by the greenhouse whitefly, *Trialeurodes vaporariorum*. ToCV, however, is unique in that it is also transmitted by the banded wing whitefly (*T. abutilonea*) and *Bemisia tabaci* biotypes A and B (Duffus et al., 1996; Wisler et al., 1998). Both viruses have now been found in widespread areas of North America and Europe in both field and greenhouse environments, and are being increasingly identified in other subtropical as well as temperate areas of the world where vectors are present. TICV occurs in tomato production fields along the west coast of North America, both in Mexico and California. ToCV is common in the southeastern United States and also has been found in Puerto Rico. Fields in southern California

continue to experience high levels of TICV infection annually, and greenhouse producers have experienced significant economic losses from tomato criniviruses. Enclosed greenhouse production centers can lead to accumulation of high GHWF populations, which in turn facilitate viral spread throughout the facility. This is particularly a problem with organic or reduced chemical production operations, where insecticide use is either decreased or not possible.

### **Host range and transmission of TICV and ToCV**

Recent studies demonstrated that transmission efficiency and persistence of ToCV varies significantly among the different whitefly vectors. *T. abutilonea* and *B. tabaci* biotype B are highly efficient vectors of ToCV. *B. tabaci* biotype A and *T. vaporariorum* are less efficient vectors, but are fully capable of transmission. ToCV persists for up to 5 days in *T. abutilonea*, 2 days in *B. tabaci* biotype B, and only 1 day in *B. tabaci* biotype A and *T. vaporariorum* (Wintermantel and Wisler, 2006). ToCV has a moderately wide host range, infecting 24 host plant species in 7 families (Wintermantel and Wisler, 2006). TICV is known to infect 25 host plant species in 8 families (Duffus et al., 1996).

### **ToCV genome and relationships**

Recent studies determined the complete nucleotide sequence of the bipartite genome of ToCV and compared ToCV with related crinivirus species. RNA 1 is organized into four open reading frames (ORFs), and encodes proteins involved in replication, based on homology to other viral replication factors. RNA 2 is composed of nine ORFs including genes that encode a HSP70 homolog and two proteins involved in encapsidation of viral RNA, referred to as the coat protein and minor coat protein (Wintermantel et al., 2005). These proteins are characteristic of the genus crinivirus. The function of many crinivirus proteins remains to be determined, and ToCV encodes two putative proteins that appear to be unique among known criniviruses (Wintermantel et al., 2005). Analysis of genetic differences with respect to biological function may provide insight into the role crinivirus proteins play in virus infection and transmission.

### **Control of Criniviruses:**

One important control measure to limit spread of criniviruses may be the identification of these viruses in nursery stock and ornamental plants. ToCV and TICV have moderate host ranges, affecting a number of host plants in several different families, many of which include weed species common near tomato fields, as well as ornamentals (Duffus et al., 1996; Wintermantel and Wisler, 2006). Viruses can be introduced to new areas through the distribution of susceptible ornamentals and nursery crops not suspected of harboring viruses. Due to the extensive host ranges of some of these viruses, it would be appropriate to consider testing plant material for crinivirus infection as a means of reducing accidental movement of virus. Once introduced, the viruses may become established in weed populations and moved by vectors. Application of virus testing of nursery material, coupled with effective vector control will reduce spread of these viruses, as well as limit damage to susceptible crops both in greenhouse and field environments.

Currently, the only method available to reduce losses from criniviruses in tomato is insecticide-based control. Imidocloprid based products are most frequently used for whitefly control, and can be applied as a foliar spray, a seed treatment or through drip application. While insecticides effectively reduce whitefly populations, such control methods are inefficient for control of viruses, since whiteflies can transmit a virus before being killed by an insecticide. In

addition, most GHWF-transmitted criniviruses do not produce symptoms until 3 to 4 weeks after infection occurs. Therefore infection can be widespread by the time symptoms are observed and control measures are implemented.

The most effective form of control for any plant virus, if available, is strong stable resistance. Two types of resistance have been identified that reduce the impact of criniviruses on tomato production; resistance to the virus and resistance to the whitefly vector. To date there are no tomato cultivars known to have resistance against TICV or ToCV. In an effort to identify sources of resistance to tomato-infecting criniviruses, we began testing *Lycopersicon* and *Solanum* accessions from the C.M. Rick Tomato Germplasm Center at the University of California-Davis in attempts to identify resistance to TICV. Early in the project we identified apparent resistance in *Lycopersicon pennellii* and *L. hirsutum* that prevented infection by TICV in tests in which whiteflies were given a choice of which plants to feed on in mass feeding experiments. Ultimately it was determined that these plants could be infected by TICV and that resistance was based on a reduced desire of *T. vaporariorum* to feed on these species. Previous research demonstrated that *L. pennellii* and *L. hirsutum* exhibited resistance to insect feeding through production of acylsugars on foliar trichomes (Liedl et al, 1995). Preliminary field trials demonstrated a significant delay in TICV infection in acylsugar producing tomato lines compared with non-acylsugar lines over two years of field testing in southern California coastal production areas. Additional research on the benefits of insect based control as a component of tomato IPM is continuing.

Additional studies examined wild germplasm for true resistance to TICV infection, and recently identified what appears to be true resistance to TICV infection in a wild *Solanum* species. Efforts are in progress to determine the genetics of this resistance and if this resistance can be introgressed into cultivated tomato.

## LITERATURE CITED

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