Tospoviruses (Family *Bunyaviridae*, Genus *Tospovirus*)[1]

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Introduction

Viruses in the genus *Tospovirus* cause significant worldwide crop losses. The genus name is derived from the name of its first member, *Tomato spotted wilt virus* (TSWV). Initially observed in Australia in 1915, the spotted wilt disease of tomato was later shown to be of viral origin. The causal agent was designated TSWV, and considered to be the sole member of the tomato spotted wilt group of plant viruses until the early 1990s. At this time, the identification and characterization of several similar viruses, including *Impatiens necrotic spot virus* (INSV), led to the creation of the plant-infecting *Tospovirus* genus within the Bunyaviridae family, a large group of predominantly animal-infecting viruses. More than a dozen tospoviruses have since been identified and characterized and previously unknown species of the genus continue to be described on a regular basis. Five tospoviruses, TSWV, INSV *Iris, yellow spot virus* (IYSV), a hybrid of Groundnut ringspot virus (GRSV), and Tomato chlorotic spot virus ITCSV), and TCSV are known to occur in the US.

Biology and Transmission

Among plant viruses, tospoviruses have a unique particle morphology, and genome organization and expression strategies. The pleomorphic virus particles are 80-120 nm in size and have surface projections composed of two viral glycoproteins. The genome consists of three negative- or ambisense single-stranded RNAs with partially complementary terminal sequences that allow the RNA to adopt a pseudocircular or panhandle conformation. Each genomic RNA is encapsidated by multiple copies of the viral nucleocapsid protein to form ribonucleoprotein structures also known as nucleocapsids. The nucleocapsids are enclosed in a host-derived membrane bilayer along with an estimated 10-20 copies of the viral RNA-dependent RNA polymerase to form the complete virus particle.

Tospoviruses are transmitted from plant to plant by several species of thrips, which are minute insects found in a variety of habitats around the world. Three thrips species, *Frankliniella occidentalis* (Western flower thrips), *F. fusca* (tobacco thrips) and *Thrips tabaci* (onion thrips) are the major vectors of the tospoviruses currently present in the US. These and a few other thrips species may be more or less important as vectors on a regional basis within the US or in other parts of the world. As with many insect vector/virus associations, the thrips/tospovirus relationship is very specific, with only a few of the many known thrips species being able to acquire and transmit tospoviruses. In the case of TSWV, thrips can only transmit the virus if it is acquired during their larval stages. Once acquired, both larval and adult thrips are able to transmit the virus. Seed transmission is not known to occur.

Host Range

The host range of tospoviruses varies greatly with the virus species. TSWV has one of the widest host ranges of any plant virus, infecting more than 800 plant species, both dicots and monocots, in more than 80 plant families. The

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Solanaceae and Asteraceae families contain the largest numbers of TSWV-susceptible plant species. Major crops susceptible to TSWV infection are tomato, pepper, lettuce, potato, papaya, peanut, tobacco, and chrysanthemum. TSWV also replicates in its thrips vector. In contrast, IYSV has a relatively restricted host range and is commonly found only in monocots such as onion, chive and leek. INSV has a more intermediate host range but is most commonly found infecting annual and perennial ornamental crops. Many tospovirus species also infect weeds, host plants that are important to the epidemiology of the diseases caused by these viruses.

Symptoms and Disease Development

Leaf symptoms caused by most tospoviruses consist of necrotic (brown) and/or chlorotic (yellow) rings or ring patterns on many hosts (Figures 1, 4, 5, 6 and 8). Necrotic and/or chlorotic lesions may also form on stems. Wilting and/or purpling of leaves and stems can occur. Young leaves of TSWV-infected tomatoes frequently turn bronze and later develop numerous small, dark brown lesions (Figure 1). TSWV-infected tomato plants may develop a one-sided growth habit, leaves may be severely distorted, or the entire plant maybe be stunted with drooping leaves suggestive of a vascular wilt. Growing tips may also die. Plants infected early in the season may produce no fruit, whereas plants infected after fruit set has occurred may produce fruits with chlorotic or necrotic ringspots. Green fruit have slightly raised areas with faint concentric rings (Figure 2); on ripe fruit, these turn into obvious rings which become red and white or red and yellow (Figure 3). The chlorotic lesions are difficult to observe at the 'breaker' stage of picking but are highly visible at full color. Similar undesirable fruit color may be observed with TSWV infection of peppers. TSWV-like symptoms are also observed in tomatoes and peppers infected with the GRSV-TCSV hybrid or TCSV. INSV infection induces chlorotic or necrotic ringspots on leaves and stems (Figure 6). IYSV infection leads to chlorotic (sometimes with a distinct diamond shape) or necrotic lesions on the seed stalk and bulb leaves of onion, chive, and leek (Figure 7).

Identification of Tospoviruses

Viruses in general and tospoviruses in particular can cause very similar symptoms. Thus, symptoms alone are not sufficient for identification of the causal virus. Tospoviruses can be diagnosed with serological (antibody-based) or molecular tests using commercially available reagents at a pathogen diagnostic laboratory. It is important to consider

Figure 1. TSWV symptoms on tomato leaves.
Credits: Tim Momol, University of Florida, Gainesville , Florida

Figure 2. TSWV symptoms on immature fruit.
Credits: Scott Adkins, USDA ARS, Ft. Pierce, FL

that a single tospovirus species may vary greatly between different locations around the world. Thus, strains from different areas may differ in their reactions to antibodies against viral structural proteins. Light microscopy of viral inclusion bodies is also useful for diagnosis of diseases caused by tospoviruses.

Distribution

TSWV has caused serious losses in tomatoes and peppers in Australia for many years and is still a serious problem. More recently, TSWV has become economically important in North America (especially in the southeastern US), South America and Europe. INSV may be found wherever ornamentals (especially greenhouse-grown) are produced in North America and Europe, and more recently in Asia. IYSV is currently found in the US onion and onion seed production areas but has also been identified in South

Figure 3. TSWV symptoms on mature fruit.
Credits: Hank Dankers, University of Florida, Quincy, Florida

Figure 4. TSWV symptoms on hosta leaves.
Credits: Scott Adkins, USDA ARS, Ft. Pierce, FL

America, the Middle East, Europe and Australia. The GRSV-TCSV hybrid was first identified in southern Florida in late 2009, and TCSV was found in this same region in 2012.

Recently another tospovirus, Capsicum chlorosis virus (CaCV), was identified in Australia where it has displaced TSWV in pepper and tomato in some areas. CaCV has also been detected in Southeast Asia. Symptoms induced by CaCV in pepper and tomato are similar to those induced by TSWV in these crops although there are distinct features, notably on young pepper leaves and pepper fruit (Figures 8 and 9). In South America, Asia and Africa, other tospoviruses infecting peanuts and tomatoes (such as *Peanut bud necrosis virus*) and cucurbits (such as *Watermelon silver mottle virus* and *Zucchini lethal chlorosis virus*) cause severe

Figure 5. TSWV symptoms on blackberry lily leaf.
Credits: Scott Adkins, USDA ARS, Ft. Pierce, FL

Figure 6. INSV symptoms on prayer plant leaf.
Credits: Scott Adkins, USDA ARS, Ft. Pierce, FL

economic losses. Distribution of these tospovirus species is currently restricted to other regions of the world but could expand via the global plant trade as tospoviruses and their vectors can be spread by the transport of infected plant material.

Figure 7. IYSV symptoms on onion leaf.
Credits: Ron Gitaitis, University of Georgia

Figure 8. CaCV symptoms on chili pepper leaves.
Credits: Pissawan Chiemsombat, Kasetsart University

Management Strategies

Once a plant is infected, no chemical treatments can cure it of a virus. Thus, avoidance is a common management strategy, for instance, exclusion of thrips from vegetable transplant production areas to reduce infection by TSWV. TSWV is extremely difficult to manage because of the wide and overlapping host ranges for this virus and its vectors

Figure 9. CaCV symptoms on bell pepper leaves.
Credits: Murray Sharman and Denis Persley, Department of Primary Industries, Queensland, Australia

and its presence in perennial weeds and ornamentals. TSWV overwinters in a relatively few abundant winter annual weeds, and dispersal of infectious thrips from these sources to susceptible crops and weeds occurs over a brief period in the spring. Use of this information in concert with variety selection and crop planting date is being used to minimize infections. An integrated management approach has been successfully implemented in several crops and locations. Insecticides have been used to reduce thrips larval development and thus limit secondary virus spread. The use of UV reflective mulches, acibenzolar-S-methyl (Actigard), and insecticides has provided excellent management of TSWV in commercial tomato fields in southeastern U.S.

Resistant tomato and pepper cultivars with single dominant gene resistance are currently being used to reduce losses to TSWV. However, symptoms are frequently more evident on fruit (immature and ripening) than on foliage thus limiting the commercial usefulness of these cultivars. Transgenic resistance has been developed, generally with the nucleocapsid gene, and demonstrated. Unfortunately, resistance breaking isolates of TSWV have been identified that can overcome both conventional and transgenic resistance.

Additional Resources

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