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Are Vectors The Major Transmission of Orthotospoviruses Fitness During Mixed – Infection?

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SUMMARY

The Orthotospovirus (Tospovirus) have become increasingly important worldwide and are among the most important plant virus groups which infect a wide range of economically important crop plants. Due to the spread of the important insect vector (thrips) causes huge economic losses to agriculture worldwide. Like many other viruses, especially those vectored by insects, in order to be effectively and efficiently transmitted from one plant to another, they induce chemical and physical changes in their hosts. Single infection of a named Tospoviruse is common, so also mixed virus infections; in both natural and agricultural ecosystems and often affect host vigor of the plants. Unfortunately, little is known about thrips preferences under mixed-infection conditions. Perhaps, could vector preference responsible for disease prevalence in different crops during mixed infection? Most importantly, viral fitness during host-to-host transmission is considered to be an important component of entire viral fitness; therefore, could the vectoring insects or association of other insects play an important role in mixed infection for Tospoviruses epidemiology?

INTRODUCTION

Thrips-transmitted tospoviruses (genus Tospovirus, family Bunyaviridae) are a major group of plant viruses affecting at least 1,090 host-plant species in 15 monocotyledonous and 69 dicotyledonous families worldwide (Parrella et al. 2003). So far, 20 Tospovirus species have been identified globally along with 14 thrips species in the family Thripidae that can serve as vectors (Hassani-Mehraban, 2010). Though tospoviruses infect insect vectors, as many other bunyaviruses do, members of this genus uniquely infect plant hosts. In 1915 the disease tomato spotted wilt was first identified in Australia (Brittlebank, 1919) and in 1930 it was demonstrated that this disease was caused by a virus, named Tomato spotted wilt virus (TSWV) (Samuel et al., 1930). Until the early 1990s, TSWV remained the only recognized species in the genus Tospovirus (name derived from Tomato spotted wilt virus). As of 2015, 100 years after the first identification of tospovirus disease, the genus Tospovirus is known to include 11 officially recognized distinct virus species with 17 additional described species. Nearly all of these are known to be transmitted by thrips which have very wide plant host ranges and now have worldwide distributions. To date, at least 15 different species of thrips have been reported to vector tospoviruses.

Virus Properties:

Mature tospovirus virions range in size from 80 to 120nm which are composed of a phospholipid membrane with embedded glycoproteins (GN and GC). Three viral genomic RNAs bound to nucleocapsid protein (N) and an RNA-dependent RNA polymerase (RdRp) are found within each virion. Tospovirus genomes are tripartite, single-stranded, and negative-sense or ambisense, with each viral gene transcribed as a separate mRNA for translation of its protein products. In order to replicate in the host cell, each virion must contain an RdRp, which also enables transcription of each viral gene into an orientation that will allow for translation of each viral protein.

Thrips Vectors of Tospoviruses

Thrips are very small insects (generally <1mm in length) that constitute the insect order Thysanoptera. It is estimated that there are more than 6,000 species of thrips. All thrips species that are vectors of tospoviruses are phytophagous insects. The most widespread and efficient vectors of tospoviruses are polyphagous, which increases the chances for virus acquisition and inoculation in diverse plant species. In addition to their role as vectors of tospoviruses, these thrips species are important pests in their own right due to the damage that results from their feeding. Large populations of thrips on young plants can stunt plants and delay crop maturity, and feeding by thrips on developing fruit causes blemishes and reduces marketability.

Molecular Host-Virus Interactions

Plant-Virus Interactions:

After its entrance into the host plant cell, the viral genome is replicated in the cytoplasm by the activity of an RdRp encoded by the L genomic RNA and packaged in the virion. The negative sense RNA genome is transcribed into virus-complementary RNA, which acts as a template for transcription of additional copies of genomic RNAs. Transcription from the negative- sense RNA genome also yields positive-sense subgenomic RNAs from which translation of the viral RdRp, N, and GN/GC occurs. These subgenomic RNAs are capped via cap-snatching of host mRNA 5 caps by activity of the viral RdRp, which shows a preference for cap donors with multiple- base complementarity to the viral sequence. Overall, this process allows the virus to effectively co-opt the host expression machinery to prioritize expression of its own proteins. During infection of plant hosts, viral pathogens, including tospoviruses, must overcome host defenses such as RNA silencing, a highly conserved viral defense mechanism. To overcome the RNA-silencing defense, viruses encode counter defense proteins called RNA-silencing suppressors. Although tospoviruses encode a suppressor of RNA silencing, the tospovirus genome is processed by the RNA-silencing machinery of its plant hosts. Though the development of an infectious clone for any tospovirus species is a desirable goal, generating a full-length, viable RNA L has not been accomplished and remains a challenge for this system.

Insect-Virus Interactions:

The tospovirus transmission cycle begins with acquisition of virus by larval thrips and culminates with dispersal and inoculation to a new plant by adult thrips. The transmission process is modulated by molecular and ecological interactions between the virus, vector, and host plant, and the F. occidentalis –TSWV system is the model for thrips-tospovirus interactions. Virus is ingested by larval thrips, enters and replicates in the midgut epithelial cells, and rapidly spreads in the gut tissues. In F. occidentalis, the gut is connected to the PSGs by the tubular salivary glands, and this tissue may serve as a conduit for virus dissemination in the vector. The extent of PSG infection is a critical determinant of a successful transmission event. The molecular interactions between F. occidentalis and TSWV have been studied in detail and it has been shown that GN and GC are essential for insect transmission but are dispensable in the plant. Mutations in GN and GC can abolish insect transmission but have no apparent effect on virus transmission to plants through mechanical means. GC is likely to be a viral fusion protein analogous to similar proteins in animal-infecting bunyaviruses, whereas GN binds directly to midgut epithelial cells in the insect, serving as a viral attachment protein. An isolate of TSWV that encodes a truncated NSs protein that compromised silencing suppressor activity in plants was also shown to be inefficiently transmitted by thrips, which suggests that the suppressor of RNA-silencing activity of NSs is important in the insect and plant hosts.

Plant-Virus-Vector Interactions:

Tospoviruses have been reported to have an effect on both thrips vector performance and behavior. Whether this effect is positive, negative, or neutral seems to depend on the specific plant-virus vector species combination. Plant infection with tospoviruses can affect the thrips vector through its interaction with the plant as survivorship, fecundity, and host preference. Thrips preference for virus-infected plants may be due to changes in plant volatiles and in host suitability mediated by changes in plant insect defense response modulation or nutritional differences (increased aminoacids). In contrast to F. occidentalis, Frankliniella fusca development time to adult is increased and survival and adult size are reduced when thrips are reared on TSWV-infected plants, and these effects are modulated by biotic and abiotic factors. Moreover, the pathogenic effects of TSWV on F. fusca can be mitigated or exacerbated by the effects of the virus on the suitability of the plant for thrips development.

Integrated Disease Management:

- Management tactics employed early in the growing season can have a significant impact on tomato yield under conditions of high TSWV incidence.

- The insect vector can be controlled through the application of insecticides or the introduction of commercially available thrips predators Amblyseius cucumeris, Hypoaspismiles, and Oriusinsidiosus.
- To more directly manage the virus, planting disease-free seedlings where possible,
- Use of chemical control measures against thrips and foliar insecticides are often relatively ineffective in suppressing tospovirus spread under field conditions.

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