



Review Article

Iris yellow spot orthospovirus pathosystem, virus host and vector (*Thrips tabaci*)

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ABSTRACT

Iris yellow spot orthospovirus (IYSV) causes serious problems in the onion (*Allium cepa*) crop and is widely distributed in the producing areas of the country. In Mexico it was reported in 2010 as “yellow spot” on onion and other members of the genus *Allium*. Its main vector is *Thrips tabaci*, which causes direct damage by feeding and by being a vector of other viruses such as *Tomato spotted wilt orthospovirus* and *Impatiens necrotic spot orthospovirus*. Knowledge of the pathosystem of IYSV - *Thrips tabaci* - *Allium cepa* - weeds can contribute to an integrated management and awareness of pesticide use. The versatility of IYSV to infect more than 60 plant species (>20 families), most of which are present in Mexico, coupled with the wide host range of the vector, makes the interaction complex and leads to a better understanding of the diversity of alternate hosts of the vector and/or IYSV. At present, information on weed hosts of IYSV and the vector is limited, but their knowledge will provide a greater understanding of the disease. It is important to have a comprehensive knowledge of the virus, main host, alternate hosts, and vector in the country, in order to channel future research to counteract this problem and minimize losses caused by IYSV in the onion crop mainly.

Keywords: IYSV, *Allium*, weeds, host, *orthospovirus*.

INTRODUCTION

Mexico is rich in a diversity of climatic environment that foster the production of a range of crops of national and international importance. An example, of



this is the planting of onion (*Allium cepa*), which is produced in most states of Mexico. In 2023, a production of 1,528,450 tons was recorded, concentrated in 10 states, with Chihuahua standing out (Panorama agroalimentario, 2023). Despite its importance, it is affected by viral diseases, such as the *Leek yellow stripe virus* (LYSV) (Pérez-Moreno *et al.*, 2004; Velasquez-Valle *et al.*, 2010), the *Tomato spotted wilt orthotospovirus* (TSWV), the *Tobacco etch virus* (TEV), the *Garlic latent common virus* (GLCV) (Velasquez-Valle *et al.*, 2010) and the *Iris yellow spot orthotospovirus* (IYSV) (Velásquez-Valle and Reveles-Hernández; 2011). The latter is of great economic importance in onions worldwide (Jones, 2005; Bag *et al.*, 2009) and in other crops of the *Allium* genus (Bag *et al.*, 2015; Weilner and Bedlan, 2013), with losses in seed production and reductions in bulb size (Bag *et al.*, 2010; Bag *et al.*, 2012b).

IYSV is the most devastating in *Allium* (Brewster, 2008) and is most important for its wide geographic distribution and range of hosts reported in recent years (Smith *et al.*, 2011; Ghotbi *et al.*, 2005; Sampangi and Mohan, 2007). In recent decades, the economic impact of *Orthotospoviruses* has increased, causing economic losses in a diversity of vegetables and ornamental plants (Turina *et al.*, 2016), due to the difficulty of combating insect vectors with insecticides and, implementing different management strategies to limit and prevent the introduction of *Orthotospovirus* into agricultural areas (Turina *et al.*, 2016). Therefore, it is important to know the IYSV in Mexico, its range of hosts that can be reservoirs of the virus and eventual emergence of the disease; in addition to this, the alternate hosts of the virus vector.

Taxonomic and genomic classification of the IYSV. The *Iris yellow spot orthotospovirus* belongs to the *Tospoviridae* family (Order: *Bunyavirales*) and genus *Orthotospovirus* (Adams *et al.*, 2017). Its genome consists of three RNA segments: Small-S (2.9 kb), Medium-M (4.8 kb) and Large-L (8.9 kb) (Cortês *et al.*, 1998). The long RNA contains 8,880 nucleotides, with an Open Reading Frame (ORF) in the complementary viral chain (vc). The RNA codifies for the polymerase RNA protein of the dependent RNA (RdRp) of 331.17 kDa in the negative direction (Figure 1) (Bag *et al.*, 2010). The 5' and 3' termini of the L RNA (vc) contain two untranslated regions with 33 and 226 nucleotides, with both ends having conserved terminal nucleotides (a common characteristic of the genus) (Bag *et al.*, 2010).

MRNA consists of 4,817 nucleotides with two Open Reading Frames (ORF) with ambisense arrangement, separated by an intergenic region (IGR) of 380 nucleotides (Bag *et al.*, 2009). The small ORF contains 935 nucleotides that codifies a protein with 311 amino acids and 34.7 kDa. This ORF codifies in a positive direction for the non-structural movement (NSm). The long ORF contains 3,410 nucleotides and codifies a protein with 1,136 amino acids and 128.84 kDa, where the precursory glycoprotein (Gn/Gc) is found, in a complementary viral direction. Both ORFs

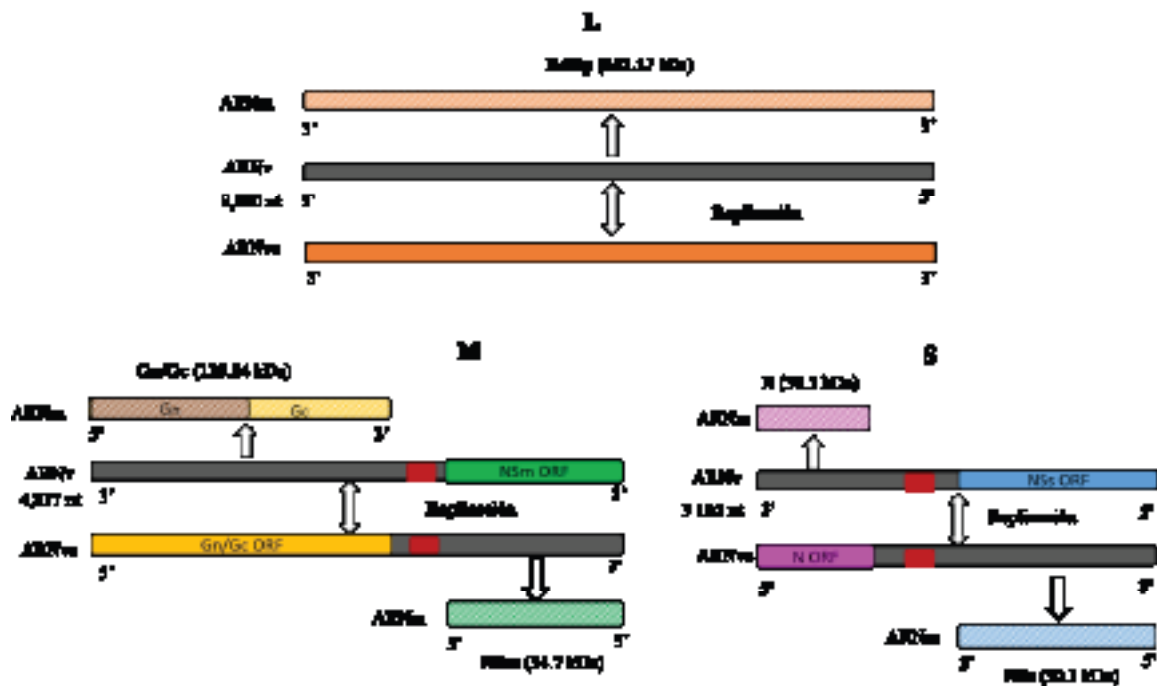


Figure 1. Representation of the segmented organization of the *Iris yellow spot orthospovirus* RNA genome (L, M and S). Modified from Bag *et al.* (2015).

are separated by an intergenic region of 395 nucleotides (Bag *et al.*, 2009). Both S and M RNA are codified in both directions and both contain two ORFs (Granval de Millán and Gracia, 1999). Finally, S RNA consists of 3,105 nucleotides with two ORFs, one ORF with 1,329 nucleotides and codifies non-structural (NSs) protein in the positive direction, and another with 816 nucleotides that codifies the nucleoprotein (N) in the negative direction (Figure 1) (Cortès *et al.*, 1997; Cortès *et al.*, 1998).

Symptoms in onion. In onion, symptoms are usually specific (Weilner and Bedlan, 2013), and consist of elongated or diamond-shaped lesions, chlorotic or light brown to white, and with the presence or absence of a green island in the center of the lesions on the leaves (Figures 2 A-D) and floral stems (Gent *et al.*, 2006). At the onset of infection, symptoms may be confused with lesions caused by thrips or other pathogens (fungi or bacteria) (Weilner and Bedlan, 2013). However, these lesions are observed on the inner part of the leaves near the bulb, where thrips prefer to feed (Figures 2 E-F). When the virus lesions coalesce, the leaves collapse and the photosynthetic area is reduced (Kritzman *et al.*, 2001), affecting bulb formation (Gent *et al.*, 2006) and even causes the death of the plant when the damage is severe

(Weilner and Bedlan 2013). The symptoms are most frequent at an advanced age of the plant, or during the formation of the bulb (Weilner and Bedlan, 2013). The symptoms reported in the onion crop in Mexico are similar to those reported in other countries, chlorotic, yellowish or white, dry and elongated lesions (Figure 2A and 2B) (Ramírez-Rojas *et al.*, 2016), and occasionally, a green island is observed in the center of the lesion (Figure 2 C and D) (Ávila-Alistac *et al.*, 2017).

In other hosts such as *N. benthaminana*, IYSV causes mosaics and deformation of leaves (Ghotbi *et al.*, 2005; Ávila-Alistac *et al.*, 2017; Ornelas-Ocampo *et al.*, 2018). In Mexican husk tomato (*Physalis ixocarpa*), symptoms are related to a yellowing and necrosis of the plant (Ríos-Domínguez *et al.*, 2017). Despite similar symptomatologic reports in Mexico and other countries, the genetic diversity of the



Figure 2. A and B) symptoms associated with the *Iris yellow spot orthospovirus* infection, consisting of pale straw-colored chlorotic lesions with an elongated shape. C and D) pale straw-colored chlorotic lesions with a green island in the center of the lesion E-G) presence of large *T. tabaci* populations (immature and adult) in the onion crop.

IYSV populations may generate a diversity of symptoms (Iftikhar *et al.*, 2014). In Mexico, information on the diversity of IYSV is limited; there is only the report by Ornelas-Ocampo and collaborators (2018), who observe a variability of symptoms in onions infected with IYSV, and classify them as typical and severe symptoms. Nevertheless, there were no genomic differences between the analyzed fragments of the IYSV genome. In spite of this, the probability of variability in onion-producing areas is not ruled out, considering the presence of other *Orthospoviruses* in agricultural areas.

National distribution and alternate IYSV hosts. IYSV is distributed in most of onion-producing areas of the world (Gent *et al.*, 2006). In Mexico, it was reported in 2010, in Delicias, Chihuahua, with severe economic losses in the crop (Velásquez-Valle *et al.*, 2010). It was also reported in Zacatecas in the same year (Velásquez-Valle and Reveles-Hernández, 2011). Later, in 2012, an incidence of 100% was reported in 2,500 ha planted with onion in Morelos (Ramírez-Rojas *et al.*, 2016), and in 2013, in Vista Hermosa and Tanhuato, Michoacán (Ávila-Alistac *et al.*, 2017). These reports were registered for onion, and in Guanajuato alone, its presence was reported in garlic (*Allium sativum*) (Pérez-Moreno *et al.*, 2010), where the presence of the vector (*Thrips tabaci*) was confirmed, along with the virus in the insect (García-Rodríguez *et al.*, 2014).

In addition, IYSV has been detected in tomato husk in Malinalco and Tonicato, State of Mexico (Ríos-Domínguez *et al.*, 2017; Ríos-Domínguez *et al.*, 2018), and tomato (*Solanum lycopersicum*) in Coatepec Harinas, State of Mexico (Ríos-Domínguez *et al.*, 2018). The infection in other hosts different to *Allium* display the ability of the virus to infect other economically important families in the country. Hence, the probability of the virus being distributed in other species is not ruled out.

For example, the IYSV host range was initially limited (Kritzman *et al.*, 2001), although in time, the range of hosts has been diversified in several ornamental plants (Jones, 2005), crops and weeds worldwide (Table 1) (Hsu *et al.*, 2011; Sampangi *et al.*, 2007; Schwartz *et al.*, 2014; Weilner and Bedlan, 2013; Szostek and Schwartz, 2015). The study of the role of the alternate hosts and secondary vectors (Schoonhoven *et al.*, 2005) is crucial to understand the IYSV-Vector-Host-Weed pathosystem to implement assertive strategies for holistic and systemic management. In Zacatecas, Mexico, Velásquez-Valle *et al.* (2013) highlights the importance of *Amaranthus* spp., *Bidens odorata*, *Brassica campestris*, *Chenopodium* spp., *Eruca sativa*, *Malva parviflora*, *Medicago sativa*, *Sisymbrium* spp. and *Sonchus oleraceus* as IYSV hosts. Interestingly, IYSV has been found in at least 20 plant families with a predominance in *Asteraceae*, abundant weeds in the country (Table 1).

Table 1. Range of *Iris yellow spot orthotospovirus* hosts.

Family	Scientific name	Common name	References
Alliaceae	<i>Allium tuberosum</i>	Garlic chives	Gawande <i>et al.</i> , 2014
	<i>A. fistulosum</i>	Green onion	Tabassum <i>et al.</i> , 2016
Amaranthaceae	<i>Amaranthus retroflexus</i>	Redroot pigweed	Gent <i>et al.</i> , 2006; Sampangi <i>et al.</i> , 2007; Schwartz <i>et al.</i> , 2014; BIRTHIA <i>et al.</i> , 2018
	<i>A. hybridus</i>	Smooth pigweed	Karavina y Gubba, 2017
	<i>A. spinosus</i>	Spiny amaranth	Karavina y Gubba, 2017
	<i>Amaranthus</i> spp. ^z	Amaranth	Velásquez-Valle <i>et al.</i> , 2013
	<i>Atriplex micranth</i>	Small-leaved saltbush	Evans <i>et al.</i> , 2009 ^a
Asteraceae	<i>Arctium minus</i>	Common burdock	Hsu <i>et al.</i> , 2011; Smith <i>et al.</i> , 2012
	<i>Tripleurospermum inodorum</i>	Scentless false mayweed	Weilner y Bedlan, 2013
	<i>Artemisia vulgaris</i>	Common mugwort	Weilner y Bedlan, 2013
	<i>Arctium tomentosum</i>	Downy burdock	
	<i>Cichorium intybus</i>	Common chicory	Hsu <i>et al.</i> , 2011; Smith <i>et al.</i> , 2012; Weilner y Bedlan, 2013
	<i>Taraxicum officinale</i>	Dandelion	Hsu <i>et al.</i> , 2011; Smith <i>et al.</i> , 2012; Schwartz <i>et al.</i> , 2014; Szostek y Schwartz, 2015
	<i>Sonchus asper</i>	Prickly sowthistle	Nischwitz <i>et al.</i> , 2007
	<i>Lactuca serriola</i>	Prickly lettuce	Sampangi <i>et al.</i> , 2007; Schwartz <i>et al.</i> , 2014; Szostek y Schwartz, 2015
	<i>S. oleraceus</i> ^t	Annual sowthistle	Schwartz <i>et al.</i> , 2014; Velásquez-Valle <i>et al.</i> , 2013
	<i>Senecio vulgaris</i>	Common groundsel	Schwartz <i>et al.</i> , 2014
	<i>Bidens odorata</i> ^t	Tall beggarticks	Velásquez-Valle <i>et al.</i> , 2013
	<i>Chrysothamnus nauseosus</i>	Rubber rabbitbrush	Schwartz <i>et al.</i> , 2014
	<i>Conyza canadensis</i>	Canadian horseweed	Schwartz <i>et al.</i> , 2014
	<i>Tragopogon dubius</i>	Yellow salsify	Schwartz <i>et al.</i> , 2014; Szostek y Schwartz, 2015
	Amaryllidaceae	<i>Bessera elegans</i>	Coral drops
Brassicaceae	<i>Chorispora tenella</i>	Blue mustard	Schwartz <i>et al.</i> , 2014
	<i>Descurainia sophia</i>	Flixweed	Schwartz <i>et al.</i> , 2014; Szostek y Schwartz, 2015
	<i>Capsella bursapastoris</i>	Shepherd's purse	Weilner y Bedlan, 2013
	<i>Eruca sativa</i> ^t	Arugula	Velásquez-Valle <i>et al.</i> , 2013
	<i>Brassica campestris</i> ^t	Field mustard	Velásquez-Valle <i>et al.</i> , 2013
	<i>Sisymbrium</i> spp. ^z	Hedge mustard	Velásquez-Valle <i>et al.</i> , 2013
	<i>B. kaber</i>	Wild mustard	Schwartz <i>et al.</i> , 2014
Convolvulaceae	<i>Convolvulus arvensis</i>	Field bindweed	Schwartz <i>et al.</i> , 2014; Weilner y Bedlan, 2013
Chenopodiaceae	<i>Kochia scoparia</i>	Kochia	Sampangi <i>et al.</i> , 2007; Schwartz <i>et al.</i> , 2014
	<i>C. album</i>	White goosefoot	Sampangi <i>et al.</i> , 2007; Schwartz <i>et al.</i> , 2014; BIRTHIA <i>et al.</i> , 2018
	<i>Chenopodium</i> spp. ^z	Goosefoot	Velásquez-Valle <i>et al.</i> , 2013
	<i>Salsola iberica</i>	Iberian saltwort	Schwartz <i>et al.</i> , 2014
Euphorbiaceae	<i>Ricinus communis</i>	Castor oil plant	Schwartz <i>et al.</i> , 2014
	<i>Euphorbia dentata</i>	Toothed spurge	Schwartz <i>et al.</i> , 2014
Fabaceae	<i>Medicago sativa</i> ^t	Alfalfa	Velásquez-Valle <i>et al.</i> , 2013

Table 1. Continue...

Family	Scientific name	Common name	References
<i>Geraniaceae</i>	<i>Erodium cicutarium</i>	Redstem filaree	Schwartz <i>et al.</i> , 2014
<i>Polygonaceae</i>	<i>Rumex crispus</i>	Curled dock	Hsu <i>et al.</i> , 2011; Smith <i>et al.</i> , 2012; Weilner y Bedlan, 2013
<i>Portulacaceae</i>	<i>Portulaca oleracea</i>	Purslane	Cosmi <i>et al.</i> , 2003; Schwartz <i>et al.</i> , 2014
<i>Plantaginaceae</i>	<i>Linaria canadensis</i>	Blue toadflax	CABI, 2015
	<i>Plantago lanceolata</i>	Ribwort plantain	Schwartz <i>et al.</i> , 2014
<i>Poaceae</i>	<i>Setaria viridis</i>	Green foxtail	Evans <i>et al.</i> , 2009b
	<i>Aegilops cylindrica</i>	Jointed goatgrass	Schwartz <i>et al.</i> , 2014
	<i>Dactylis glomerata</i>	Orchard grass	Weilner y Bedlan, 2013
	<i>Eleusine indica</i>	Goosegrass	Karavina y Gubba, 2017
	<i>Poa</i> sp.	Bluegrass	Weilner y Bedlan, 2013
<i>Polygonaceae</i>	<i>Polygonum lapathifolium</i>	Pale smartweed	Schwartz <i>et al.</i> , 2014
<i>Malvaceae</i>	<i>Hibiscus trionum</i>	Flower-of-an-hour	Schwartz <i>et al.</i> , 2014
	<i>Malva palviflora</i> ²	Cheeseweed	Velásquez-Valle <i>et al.</i> , 2013
	<i>M. neglecta</i>	Common mallow	Szostek y Schwartz, 2015
<i>Solanaceae</i>	<i>Solanum nigrum</i>	Black nightshade	Schwartz <i>et al.</i> , 2014; BIRTHIA <i>et al.</i> , 2018
	<i>S. sarrachoides</i>	Potato vine	Schwartz <i>et al.</i> , 2014
	<i>Datura stramonium</i>	Jimsonweed	BIRTHIA <i>et al.</i> , 2018
	<i>S. lycopersicum</i> ³	Tomate	Ríos-Domínguez <i>et al.</i> , 2018
	<i>Physalis minima</i>	Pygmy groundcherry	BIRTHIA <i>et al.</i> , 2018
	<i>P. ixocarpa</i> ³	Mexican husk tomato	Ríos-Domínguez <i>et al.</i> , 2017; Ríos-Domínguez <i>et al.</i> , 2018
<i>Zygophyllaceae</i>	<i>Tribulus terrestris</i>	Puncturevine	Sampangi <i>et al.</i> , 2007
<i>Geraniaceae</i>	<i>Pelargonium hortorum</i>	Geranium	Ghotbi <i>et al.</i> , 2005
<i>Cycadaceae</i>	<i>Cycas</i> sp.	Cycad	Ghotbi <i>et al.</i> , 2005
<i>Rosaceae</i>	<i>Rosa</i> sp.	Rose	Ghotbi <i>et al.</i> , 2005
<i>Araceae</i>	<i>Scindapsus</i> sp.	Pothos	Ghotbi <i>et al.</i> , 2005
<i>Gentianaceae</i>	<i>Eustoma russellianum</i>	Lisianthus	Kritzman <i>et al.</i> , 2000
	<i>E. grandiflorum</i>	Lisianthus	Mumford <i>et al.</i> , 2008
	<i>chrysanthemum</i>	Crysanthemum	Rafizadeh <i>et al.</i> , 2013

³Detected by RT-PCR.

²Detected by ELISA.

Forms of transmission and IYSV vectors. To date there is no evidence of the transmission of the virus via seeds (Kritzman *et al.*, 2001) and under controlled conditions, the mechanical transmission in onion plants is lower than 30% (Bag *et al.*, 2015). The main vector is *T. tabaci* (Terebrantia: Thripidae) (Cortês *et al.*, 1998), also known as “onion thrips”, which transmits to the virus in a persistent and propagative manner (Diaz-Montano *et al.*, 2011). It was also shown that *Frankliniella fusca*, under greenhouse conditions, has the ability to transmit the

virus at a low percentage (Srinivasan *et al.*, 2012). Species of *Orthotospovirus* are naturally transmitted by thrips in a persistent manner (Bag *et al.*, 2015); that is, once the virus infects the insect, it will be able to transmit it for the rest of its life.

Onion thrips is an important pest in this crop (Diaz-Montano *et al.*, 2011), and in a large number of economically important plants, such as vegetables and ornamental plants (Schoonhoven *et al.*, 2005; Alford, 1999; Gent *et al.*, 2004). This vector becomes more relevant since it not only transmits IYSV, but also the *Tomato spotted wilt orthotospovirus* (TSWV) (Jenser *et al.*, 2011) and the *Impatiens necrotic spot orthotospovirus* (INSV) (Ghotbi *et al.*, 2005). It is Cosmopolitan and polyphagous pest, which can easily survive in alternate plants as weeds, particularly in the absence of the crop (Schoonhoven *et al.*, 2005). Both INSV and TSWV are found in vegetable crops in Mexico; INSV has been reported in *P. ixocarpa*, *Capsicum* spp. and tomato (Torre-Almaraz *et al.*, 1998; González-Pacheco and Silva-Rosales, 2013; Zuñiga-Romano *et al.*, 2019) and TSWV, in several vegetable and ornamental plant crops in the country, and even in onion crops (Torre-Almaraz *et al.*, 1998; Holguín-Peña and Rueda-Puente, 2007; Morales-Díaz *et al.*, 2008; Velásquez-Valle *et al.*, 2009; Velásquez-Valle *et al.*, 2012).

There is the possibility of *T. tabaci* having the ability of transmitting the three *Orthotospoviruses* in viral mixtures, since there is evidence that two or more viruses can complement to infect their host. Bag *et al.* (2012a) claims this by highlighting that TSWV facilitated the movement of the viral IYSV protein from the area of inoculation to the young *Datura* leaves, becoming a systemic infection. In other words, the double infection of IYSV and TSWV in *Datura* increased the severity of the symptoms in inoculated plants, as well as in young leaves (systemic infection), producing a synergism. It is worth mentioning that the behavior of TSWV and IYSV in *Datura* plants is different: TSWV infects systemically and IYSV is localized (infection limited in inoculated areas). The redistribution and/or the genetic complementation among the genomic segments of the viruses could contribute to greater variability, which is not limiting the infection of two or more *Orthotospoviruses* in nature (Bag *et al.*, 2012a). This reinforces the theory that the vector insect has the ability to transmit viruses individually and in viral mixtures.

Alternate hosts of *Thrips tabaci*. *T. tabaci* host plants include, not only economically important crops, but also a diversity of weeds that, when they die or are eliminated, can favor the dispersion of viruliferous insects to crops of interest (Doederlein and Sites, 1993; Ghotbi *et al.*, 2005). In Mexico, studies have been conducted on the role of weeds of the *Cucurbitaceae* and *Solanaceae* families as potential sources of inoculum for the development of the *Tomato apex necrosis virus* (ToANV), the *Zucchini yellow mosaic virus* (ZYMV), the *Watermelon mosaic virus* (WMV), the *Papaya ring spot virus* (PRSV-W) and the *Cucumber mosaic virus* (CMV) in crops

of agronomic importance (Félix-Gastélum *et al.*, 2023). The information on onion regarding weeds is limited; only in Morelos and Michoacán was there a study of the presence of IYSV in weeds related to the crop (Ramírez-Rojas *et al.*, 2016; Ávila-Alistac *et al.*, 2017). However, only the presence of *T. tabaci* was registered in crops related to the crop, without evaluating the presence of the virus in the insect (Table 2). Nevertheless, the weeds reported in other countries and which tested positive for IYSV are found in Mexico and they interact with the onion crop

Table 2. Alternate *Thrips tabaci* and *Iris yellow spot orthotospovirus* hosts in Mexico and the world.

Species	<i>T. tabaci</i> host in Mexico	National/Global IYSV host	References
Amaranthaceae			
<i>Chenopodium</i> spp	+	+/+	Velásquez-Valle <i>et al.</i> , 2013; Sampangi <i>et al.</i> , 2007; Schwartz <i>et al.</i> , 2014
<i>Amaranthus</i> spp.	+	+/-	Velásquez-Valle <i>et al.</i> , 2013
<i>A. hybridus</i>	+	-/+	Ávila-Alistac <i>et al.</i> , 2017
<i>A. spinosus</i>	+	-/+	Ávila-Alistac <i>et al.</i> , 2017; Karavina y Gubba, 2017
Solanaceae			
<i>Solanum eleagnifolium</i>	+	-/-	Velásquez-Valle <i>et al.</i> , 2013
<i>Solanum tuberosum</i>	+	-/-	Velásquez-Valle <i>et al.</i> , 2013
<i>Capsicum annum</i>	+	-/-	Beltran <i>et al.</i> , 2011; Velásquez-Valle <i>et al.</i> , 2009.
Asteraceae			
<i>Sonchus</i> spp.	+	-/+	Velásquez-Valle <i>et al.</i> , 2013; Nischwitz <i>et al.</i> , 2007
<i>Sonchus oleraceus</i>	+	-/+	Ávila-Alistac <i>et al.</i> , 2017; Schwartz <i>et al.</i> , 2014
<i>Parthenium hysterophorus</i>	+	-/-	Ávila-Alistac <i>et al.</i> , 2017
<i>Tithonia tubiformis</i>	+	-/-	Ávila-Alistac <i>et al.</i> , 2017
<i>Lactuca serriola</i>	+	-/-	Ávila-Alistac <i>et al.</i> , 2017
<i>Bidens odorata</i>	-	+/-	Velásquez-Valle <i>et al.</i> , 2013
Fabaceae			
<i>Phaseolus vulgaris</i>	+	-/-	Velásquez-Valle <i>et al.</i> , 2013
<i>Medicago sativa</i>	-	+/-	Velásquez-Valle <i>et al.</i> , 2013
Brassicaceae			
<i>Brassica</i> spp.	+	-/-	Velásquez-Valle <i>et al.</i> , 2013
<i>Sisymbrium</i> spp.	+	+/-	Velásquez-Valle <i>et al.</i> , 2013
<i>Lepidium virginicum</i>	+	-/-	Ávila-Alistac <i>et al.</i> , 2017
<i>Brassica campestris</i>	-	+/-	Velásquez-Valle <i>et al.</i> , 2013
<i>Eruca sativa</i>	-	+/-	Velásquez-Valle <i>et al.</i> , 2013
Liliaceae			
<i>A. cepa</i>	+	-/-	Magos, 2011; Velásquez-Valle <i>et al.</i> , 2013; Ávila-Alistac <i>et al.</i> , 2017

Table 2. Continue...

Species	<i>T. tabaci</i> host in Mexico	National/Global IYSV host	References
Acanthaceae			
<i>Dicliptera peduncularis</i>	+	-/-	Ávila-Alistac <i>et al.</i> , 2017
Convolvulaceae			
<i>Ipomoea purpurea</i>	+	-/-	Ávila-Alistac <i>et al.</i> , 2017
Euphorbiaceae			
<i>Acalypha ostryifolia</i>	+	-/-	Ávila-Alistac <i>et al.</i> , 2017
<i>Ricinnus comunis</i>	+	-/+	Ávila-Alistac <i>et al.</i> , 2017; Schwartz <i>et al.</i> , 2014
<i>Acalypha arvensis</i>	+	-/-	Ávila-Alistac <i>et al.</i> , 2017
Malvaceae			
<i>Malva parviflora</i>	+	+/-	Velásquez-Valle <i>et al.</i> , 2013; Ávila-Alistac <i>et al.</i> , 2017
<i>Anoda cristata</i>	+	-/-	Ávila-Alistac <i>et al.</i> , 2017
<i>Malvastrum coromandelianum</i>	+	-/-	Ávila-Alistac <i>et al.</i> , 2017
Portulacaceae			
<i>Portulaca oleracea</i>	+	-/+	Ávila-Alistac <i>et al.</i> , 2017; Cosmi <i>et al.</i> , 2003; Schwartz <i>et al.</i> , 2014

+ *T. tabaci* and/or IYSV host.

and are also hosts of the vector (Beltran *et al.*, 2011; Velásquez-Valle *et al.*, 2013; Ávila-Alistac *et al.*, 2017). These weeds have been reported in large populations, as well as *T. tabaci*; e.g., *Portulaca oleracea* has been reported as the host of IYSV (Cosmi *et al.*, 2023; Schwartz *et al.*, 2014), a widely distributed weed in onion-producing areas (Figure 3) (Ávila-Alistac *et al.*, 2017). The frequency of the weeds inside and outside of onion fields are the main cause for the prevalence of *T. tabaci*, potential vectors in productive areas, without the presence of IYSV (Gent *et al.*, 2006; Tanveer *et al.*, 2015). Therefore, the presence of IYSV is not ruled out in weeds found in the country, such as those reported by Velásquez-Valle *et al.* (2013) (Table 2). In Mexico, at least 14 weed species are *T. tabaci* hosts and they have been reported as IYSV hosts in Mexico and areas outside the country (Table 2).

Epidemiology and management of IYSV. IYSV, like the rest of the viruses of the same genus, require the interaction of basic factors to cause an epidemic: the vector, host, alternate host, and virus (Ullman *et al.*, 2002). Alongside these, the weather conditions can condition the epidemic in a particular area (German *et al.*, 1992). These viruses have the capability of using the vector insect to infect new



Figure 3. Weeds interacting inside and outside of the onion (*Allium cepa*) crop. **A)** Parthenium weed (*Parthenium hysterophorus*); **B)** Purslane (*Portulaca oleracea*); **C)** Pineland threes mercury (*Acalypha ostryifolia*); **D)** Mexican sunflower (*Tithonia tubiformis*) on the edge of an onion crop.

hosts, broadening their adaptability when carrying the virus; exerting an influence on its incidence and distribution under different environmental conditions and new hosts (Jones, 2005).

The severity of IYSV in the onion crop is complex and will depend on the population of healthy and infected thrips and on the number of healthy and infected plants, as well as on asymptomatic plants. Once the plant is infected by the virus, there is no treatment to control it, although these plants can become a food source for healthy thrips, and these can infect healthy plants. Additionally, the population density in the field of both thrips and IYSV host plants depend on biotic and abiotic factors, as well as on agronomic management (Figure 4). The impact of IYSV has been observed to depend on the phenological stage in which the first symptoms appear. If the symptoms appear when the bulbs are still developing, the size and quality of the bulbs will be affected (Drost *et al.*, 2019).

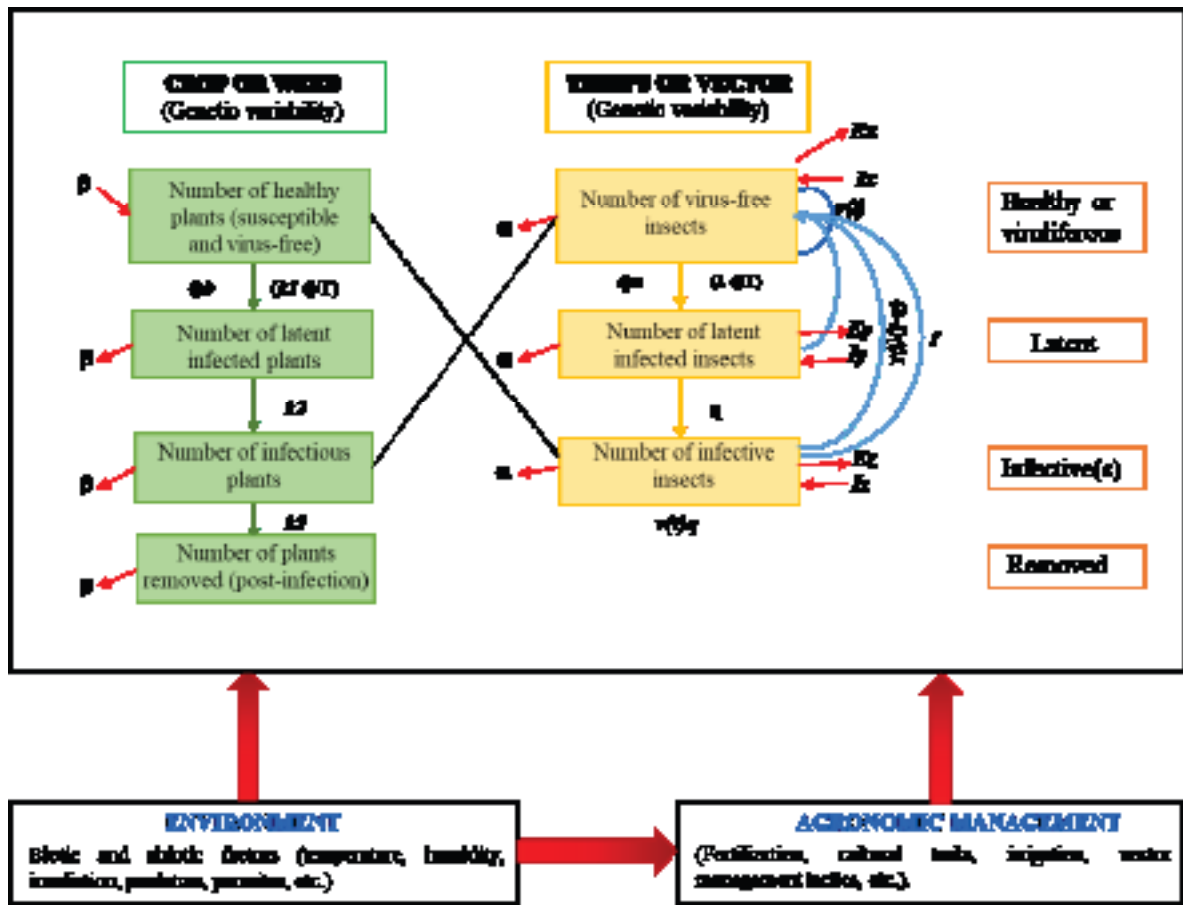


Figure 4. Epidemiological system of a viral pathosystem focused on *Iris yellow spot orthotospovirus* (based on and modified from Madden *et al.*, 2000). Notes used: $v(t)$ = Total fertility rate of the insect population per day within the crop. I' = Virus incubation time within the vector. q = Probability that the offspring of the vector will be viruliferous. β = Plant mortality and recovery rate (replanting). α = Insect mortality and birth rate. ϕb = (Plants visited by insects per day) (Probability that the viruliferous insect inoculates the virus in a plant per visit). $1/k1$ = Time taken for the vector to inoculate the plant. $1/k2$ = Virus latency period in the plant. $1/k3$ = Infectious period of the virus in the plant. ϕT = (Plants visited by insects per day) (Time taken for the insect to sample the plant in one visit). Ex = Rate of emigration of virus-free insects. Ix = Rate of emigration of virus-free insects. Ey = Rate of emigration of latent insects. Ez = Rate of emigration of infective insects. Iy = Rate of emigration of latent insects. Iz = Rate of immigration of infective insects. $1/\lambda$ = Vector acquisition time. ϕa = (Plants visited by insects per day) (Probability that an insect will acquire the virus with a single visit to the infected plant). $1/\eta$ = Time taken for the virus to transition from latent to infective within the vector (latency period). For further information, refer to Madden *et al.* (2000).

On the other hand, the presence of *T. tabaci* in vegetable is an important phytosanitary problem in Mexico (Palomo *et al.*, 2015), since they are virus vectors and due to the direct damage they cause when feeding off the host causing premature wilting, a delay in leaf development and a distortion in vegetative sprouts (Aguilar *et al.*, 2017). In both immature and adult stages, they puncture the cells with their mouth apparatus and draw out the sap (Jones, 2005). Of the six life stages of the insect (egg, two larval instars, prepupa, pupa and adult) (Jones, 2005; Pourian *et al.*, 2009), the larvae of the first and second instar can acquire the virus through feeding, but only the larva from the second instar and adults transmit it (Sastry, 2013; Hull, 2001; Chatzivassiliou *et al.*, 2002). If the insect acquires the virus in an adult stage, it will not be able to transmit it (Jones, 2005; Whitfield *et al.*, 2005). It is imminent that, once the insect acquires the virus, it will reproduce and move efficiently through the midgut and the salivary glands of the thrips, without affecting the development, fertility and mortality of the insect upon virus infection (Inoue *et al.*, 2010). This insect is prolific, recording up to six generations in the crop cycle without being affected by rainfall (Palomo *et al.*, 2015).

Alternate hosts are crucial for the IYSV epidemiology, particularly if *T. tabaci* finishes developing in the hosts (Hsu *et al.*, 2011). Due to this, the management of the alternate hosts are decisive for the comprehensive management of the disease (Schwartz *et al.*, 2014; Wisler and Norris, 2005). This increases the interest in the study of the insect-IYSV-*Allium cepa*-alternate hosts (weeds), since these interactions tend to be complex. Rodríguez *et al.* (2007) emphasize the benefit of broadly understanding this relationship to optimize comprehensive management. These interactions can affect the appearance of new variants of the virus, a range of hosts and/or transmission frequency (Syller, 2012). Likewise, the capability of thrips to develop in other plants favors this type of interaction, since the absence of the main host incentivizes migration to other vegetative parts or the inflorescences of other plants (Milne and Walter, 1998).

In general, all IYSV management strategies have basically focused on precautionary activities that reduce *T. tabaci* populations and avoid the growth of weeds in the crop (Drost *et al.*, 2019). The determination of vector and alternate host patterns of the virus and/or vector could help producers devise integrated management strategies in the crop (Birithia *et al.*, 2018).

However, the vector must not only be controlled chemically, but further research must be carried out to understand its behavior in the country. In Zacatecas, according to their needs, the behavior of the virus has been studied, and the presence of IYSV has been observed in onion seedlings in open field seedbeds, making it impossible for the vector to be present (Velásquez-Valle *et al.*, 2017). This type of problem leads to the belief that the sale of onion seedlings among onion-producing states increases the possibility of virus and vector movement. Faced with the possibility

of a successful sale of their products, onion producers choose to abandon their plots, risking an increase of the virus and thrip populations (Velásquez-Valle *et al.*, 2013). In many cases, management has been crucial to minimize the risks of viral infection of at least avoid severe damage to the crop. Turina *et al.* (2016) point out that, given the difficulty of combating thrips vectors with insecticides, the best way to mitigate or prevent diseases induced by *Orthotospoviruses* implies a strategy of virus-resistant seeds. Studies have been conducted in Mexico on 20 varieties regarding their performance against virus infection in Morelos. These results revealed that the varieties “Blanca Morelos,” “Doña Blanca F1,” “Línea INIFAP 19” and “Chona” have greater yields than the rest of the varieties in the presence of IYSV (Magos, 2011).

CONCLUSIONS

A comprehensive management should be considered that takes into account all factors that influence the IYSV epidemic into account in order to counteract the disease. Since its first report in the country (2010) onion cultivation has been a concern; despite its severity having decreased over time. A similar case occurred with the *Tomato brown rugose fruit virus* (ToBRFV), which was reported to cause severe damages to tomato and peppers in 2018 (Cambrón-Crisantos *et al.*, 2019); but currently, attenuated symptoms and the presence of haplotypes have been reported, which may be having an influence on the symptomatologic intensity on tomato and pepper plants (Ávila-Alistac *et al.*, 2024). Early, accurate and efficient diagnose studies have been conducted on ToBRFV (Zamora-Macorra *et al.*, 2023), as well as studies on the variability of the virus in different tomato and pepper varieties (Ávila-Alistac *et al.*, 2024) and virus management alternatives (Ramos-Villanueva *et al.*, 2023). However, little is known on its range of hosts and factors that influence the epidemiology of the virus. There is a greater knowledge of the host and vector of IYSV, although it is important to inquire with greater interest into this nationwide problem, since it has been reported in Solanaceae, which are of great economic importance in the country, as well as to consider the reemergence of the virus, according to crop management, genetic recombination among species of the same genus and even the influence of climate change, which has a bearing on the *T. tabaci* population dynamics.

Currently, information on weeds as IYSV and vector hosts provides a greater understanding of the disease, similarly to voluntary onion plants. Hence the importance of knowing these aspects, as well as the management carried out by the producers, since it is another crucial factor for the establishment of the vector and IYSV in the different phenological stages of the crop. There is evidently a

complex relationship between IYSV- *T. tabaci* –*Allium cepa*-weeds and other *Orthotospoviruses* transmitted by *T. tabaci*; e.g., studying weeds as a plant trap can be beneficial, due to the feeding preference of *T. tabaci*, even in the presence of the crop. In addition, it should be considered that these weeds are not hosts of the virus, as they would be a problem by hosting the vector and the virus. In summary, knowledge of the virus, alternate hosts, and vector in the country will guide future research to help producers counteract this problem and minimize losses caused by the virus in onion and garlic crops, mainly.

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LITERATURE CITED

- Adams, MJ, Lefkowitz, EJ, King AMQ, Harrach B, Harrison RL, Knowles NJ, Kropinski AM, Krupovic M, Kuhn JH, Mushegian AR, Nibert M, Sabanadzovic S, Sanfacon H, Siddell SG, Simmonds P, Varsani A, Murilo ZF, Gorbalenya AE and Davison AJ. 2017. Changes to taxonomy and the International Code of Virus Classification and Nomenclature ratified by the International Committee on Taxonomy of Viruses. *Virology Division News* 162:2505-2538. <http://dx.doi.org/10.1007/s00705-017-3358-5>
- Aguilar CC, González RA, Pérez RA, Ramírez RSG y Carapia RVE. 2017. Combate químico de *Thrips tabaci* (Thysanoptera: Thripidae) en el cultivo de cebolla en Morelos, México. *Acta Zoológica Mexicana* 33(1): 39-44. <http://www.scielo.org.mx/pdf/azm/v33n1/0065-1737-azm-33-01-00039.pdf>
- Alford DV. 1999. A textbook of Agricultural entomology. Cambridge, UK. Pp. 29-92.
- Ávila-Alistac N, Mora-Aguilera G, Lozoya-Saldaña H, Zamora-Macorra EJ and Hernández-Juárez C. 2024. Genetic variability of two Mexican *Tomato brown rugose fruit virus* isolates and expression of symptoms in tomato and pepper. *Mexican Journal of Phytopathology* 42(2):16 <https://doi.org/10.18781/R.MEX.FIT.2311-2>
- Ávila-Alistac N, Ramírez-Rojas S, Lozoya-Saldaña H, Rebollar-Alviter A y Guzmán-Plazola RA 2017. Hospedantes alternos de *Iris yellow spot virus* y trips en cultivos de cebolla de Morelos y Michoacán, México. *Revista Mexicana de Fitopatología* 35: 242-262. <http://dx.doi.org/10.18781/r.mex.fit.1701-1>
- Bag S, Druffel KL and Pappu HR. 2010. Structure and genome organization of the large RNA of *Iris yellow spot virus* (genus *Tospovirus*, family Bunyaviridae). *Archives of Virology* 155 (2): 275-279. <http://dx.doi.org/10.1007/s00705-009-0568-5>
- Bag S, Druffel KL, Salewsky T and Pappu HR. 2009. Nucleotide sequence and genome organization of the medium RNA of *Iris yellow spot virus* from the United States. *Archives of Virology* 154(4): 715-718. <http://dx.doi.org/10.1007/s00705-009-0349-1>
- Bag S, Mitter N, Eid S and Pappu HR. 2012a. Complementation between two Tospoviruses facilitates the systemic movements of plant virus silencing suppressor in an otherwise restrictive host. *PLoS ONE* 7(10): e44803. <http://dx.doi.org/10.1371/journal.pone.0044803>
- Bag S, Schwartz HF, Cramer CS, Havey MJ and Pappu HR. 2015. *Iris yellow spot virus* (*Tospovirus*: Bunyaviridae): from obscurity to research priority. *Molecular Plant Pathology* 224-237. <http://dx.doi.org/10.1111/mpp.12177>
- Bag S, Schwartz HF and Pappu HR. 2012b. Identification and characterization of biologically distinct isolates of *Iris yellow spot virus* (genus *Tospovirus*, family Bunyaviridae), a serious pathogen of onion. *European Journal of Plant Pathology* 134 (1): 97-104. <http://dx.doi.org/10.1007/s10658-012-0026-1>

- Birithia RK, Subramanian S, Muthomi JW and Narla RD. 2018. Seasonal dynamics and alternate hosts of thrips transmitted *Iris yellow spot virus* in Kenya. *African Crop Science Journal* 26(3): 365-376. <http://dx.doi.org/10.4314/acsj.v26i3.3>
- Brewster J. L. 2008. Onion and other vegetable *Allium*. 2nd edition. Series Crop Protection science in horticulture: 15. CAB International. 204 p.
- CABI, 2015. *Iris yellow spot virus*. Crop Protection Compendium. <http://www.cabi.org/cpc/datasheet/6188>.
- Cortés I, Derks A, Pereira AM, Goldbach R, Peters D and Kormelink R. 1997. *Iris yellow spot virus* (IYSV) S RNA. https://www.ncbi.nlm.nih.gov/nuccore/NC_029800.1
- Cortés I, Livieratos IC, Derks A, Peters D and Kormelink R. 1998. Molecular and serological characterization of *Iris yellow spot virus*, a new and distinct *Tospovirus* species. *Phytopathology* 88(12): 1276-1282. <http://dx.doi.org/10.1094/PHYTO.1998.88.12.1276>
- Cosmi T, Marchesini E, and Martini G. 2003. Presence and spread of *Tospovirus* and thrips vectors in Veneto. *Infomatore Agrario* 59:69-72. <https://www.cabi.org/ISC/abstract/20033086912>
- Chatzivassiliou EK, Peters D and Katis NI. 2002. The efficiency by which *Thrips tabaci* populations transmit *Tomato spotted wilt virus* depends on their host preference and reproductive strategy. *Phytopathology* 92(6): 603-609. <https://doi.org/10.1094/PHYTO.2002.92.6.603>
- Cambrón-Crisantos JM, Rodríguez-Mendoza J, Valencia-Luna JB, Alcasio-Rangel S, García-Ávila CJ, López-Buenfil JA and Ochoa-Martínez DL. 2019. First report of *Tomato brown rugose fruit virus* (ToBRFV) in Michoacan, Mexico. *Revista Mexicana de Fitopatología* 37(1): 185-192. [10.18781/R.MEX.FIT.1810-5](https://doi.org/10.18781/R.MEX.FIT.1810-5)
- Diaz-Montano J, Fuchs M, Nault BA, Fail J and Shelton AM. 2011. Onion Thrips (Thysanoptera: Thripidae): A Global Pest of Increasing Concern in Onion. *Journal of Economic Entomology* 104 (1): 1-13. <http://dx.doi.org/10.1603/EC10269>.
- Doederlein TA and Sites RW. 1993. Host plant preferences of *Frankliniella occidentalis* and *Thrips tabaci* (Thysanoptera: Thripidae) for onions and associated weeds on the Southern High Plains. *Journal of Economic Entomology* 86(6): 1706-1713. <http://dx.doi.org/10.1093/jee/86.6.1706>
- Drost D, Cannon C, Murray M, Alston D. 2019. Utah vegetable production and pest management guide. Chapter 7 Onion production. pp 91-113. EXTENSION. Utha State University.
- Evans CK, Bag S, Frank E, Reeve J, Ransom C, Drost D and Pappu HR. 2009a. Natural infection of *Iris yellow spot virus* in two scale saltbush (*Atriplex micrantha*) growing in Utah. *Plant disease* 93(4): 430. <http://dx.doi.org/10.1094/PDIS-93-4-0430C>
- Evans CK, Bag S, Frank E, Reeve J, Ransom C, Drost D and Pappu HR. 2009b. Green foxtail (*Setaria viridis*), a naturally infected grass host of *Iris yellow spot virus* in Utah. *Plant Disease* 93 (6): 670. <http://dx.doi.org/10.1094/PDIS-93-6-0670C>
- García-Rodríguez OG, Pérez-Moreno L, Navarro-León MJ, Salas-Araiza MD, Martínez-Jaime OA, León-Galván MF y Núñez-Palenius HG. 2014. Virus fitopatógenos en insectos asociados al ajo. *Revista Chapingo Serie Horticultura* 20(2): 147-156. <http://dx.doi.org/10.5154/r.rchsh.2012.10.057>.
- Félix-Gastélum R, Herrera- Rodríguez G, Leyva-Madrigal KY and Mora-Romero GA. 2023. Weeds and ruderal plants as potential sources of inoculum for vegetable diseases in northern Sinaloa. *Mexican Journal of Phytopathology* 41(4): 5. <https://doi.org/10.18781/R.MEX.FIT.2023-4>
- Gent DH, du Toit LJ, Fichtner SF, Mohan SK, Pappu HR and Schwartz HF. 2006. *Iris yellow spot virus*: An emerging threat to onion bulb and seed production. *Plant Disease* 90 (12): 1468-1480. <http://dx.doi.org/10.1094/PD-90-1468>.
- Gent DH, Schwartz HF, and Khosla R. 2004. Distribution and incidence of *Iris yellow spot virus* in Colorado and its relation to onion plant population and yield. *Plant Disease* 88: 446-452. <http://dx.doi.org/10.1094/PDIS.2004.88.5.446>.
- German TL, Ullman DE and Moyer JW. 1992. Tospoviruses: diagnosis, molecular biology, phylogeny and vector relationships. *Annual review of Phytopathology* 30: 315-348. <http://dx.doi.org/10.1146/annurev.py.30.090192.001531>
- González-Pacheco BE, Silva-Rosales L. 2013. First Report of *Impatiens necrotic spot virus* in Mexico in Tomatillo and Pepper Plants. *Plant Disease* 97 (8): 1124. <https://doi.org/10.1094/PDIS-01-13-0092-PDN>.
- Ghotbi T, Shahraeen N and Winter S. 2005. Occurrence of Tospoviruses in ornamental and weed species in Markazi and Tehran provinces in Iran. *Plant Disease* 89: 425-429. <http://dx.doi.org/10.1094/PD-89-0425>
- Granval de Millán N y Gracia O. 1999. El género *Tospovirus* y su importancia en la horticultura. *Avances en Horticultura* 4(1): 1-23.
- Holguín-Peña RJ and Rueda-Puente EO. 2007. Detection of *Tomato spotted wilt virus* in Tomato in the Baja California Peninsula of Mexico. *Plant Disease* 91(12): 1682. <https://doi.org/10.1094/PDIS-91-12-1682B>

- Hull, R. 2001. Transmission 1: By invertebrates, nematodes and fungi. In Hull R. 2001. Matthews' Plant virology. 4th Ed. Pp. 485-531.
- Hsu CL, Hoeping CA, Fuchs M, Smith EA and Nault BA. 2011. Sources of *Iris yellow spot virus* in New York. *Plant Disease* 95: 735-743. <http://dx.doi.org/10.1094/PDIS-05-10-0353>
- Ifikhar, R, Ramesh SV, Bag S, Ashfaq M and Pappu HR. 2014. Global analysis of population structure, spacial and temporal dynamics of genetic diversity, and evolutionary lineages of *Iris yellow spot virus* (Tospovirus: Bunyaviridae). *Gene* 547:111-118. <http://dx.doi.org/10.1016/j.gene.2014.06.036>
- Inoue T, Murai T and Natsuaki T. 2010. An effective system for detecting *Iris yellow spot virus* transmission by *Thrips tabaci*. *Plant Pathology* 59: 422-428. <http://dx.doi.org/10.1111/j.1365-3059.2009.02224.x>
- Jenser G, Almási A, Fail J and Tobiás I. 2011. Differences in the vector efficiency of *Thrips tabaci* in Europe and North America. *Acta Phytopathologica et Entomologica Hungarica* 46(2): 311-317. <http://dx.doi.org/10.1556/APhyt.46.2011.2.15>
- Jones DR. 2005. Plant viruses transmitted by thrips. *European Journal of Plant Pathology*. 113: 119-157. <http://dx.doi.org/10.1007/s10658-005-2334-1>.
- Karavina C and Gubba A. 2017. *Amaranthus* sp. and *Eleusine indica* are natural host of *Iris yellow spot virus* in Zimbabwe. *Plant Disease* 101(1): 262. <http://dx.doi.org/10.1094/PDIS-05-16-0652-PDN>
- Kritzman A, Lampel M, Raccach B and Gera A. 2001. Distribution and transmission of *Iris yellow spot virus*. *Plant Disease* 85:838-842. <http://dx.doi.org/10.1094/PDIS.2001.85.8.838>
- Kritzman A, Beckelman H, Alexandrov S, Cohen J, Lampel M, Zeidan M, Raccach B and Gera A. 2000. Lisianthus leaf necrosis: a new disease of *Lisianthus* caused by *Iris yellow spot virus*. *Plant Disease* 84: 1185-1189. <http://dx.doi.org/10.1094/PDIS.2000.84.11.1185>
- Madden LV, Jeger MJ and van den Bosch F. 2000. A theoretical assessment of the effects of vector-virus transmission mechanism on plant virus disease epidemics. *Phytopathology* 90:576-594.
- Magos GK. 2011. Trips y virus asociados a cebolla (*Allium cepa* L.), su efecto en el rendimiento en Atlacholoaya, Morelos. Tesis de Maestría en Ciencias. Colegio de Postgraduados, Montecillo, México. 67 p.
- Milne M and Walter GH. 1998. Host species and plant parte specificity of the polyphagous onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae), in an Australian cotton-growing area. *Australian Journal of Entomology* 37: 115-119. <https://doi.org/10.1111/j.1440-6055.1998.000017.x>
- Morales-Díaz MV, Alcacio-Rangel S y la Torre-Almaraz R. 2008. *Tomato spotted wilt virus*: agente causal de la marchitez del miguelito (*Zinnia elegans* Jacquin) en el estado de Morelos, México. *Agrociencia* 42:335-347. <http://www.scielo.org.mx/pdf/agro/v42n3/v42n3a8.pdf>
- Mumford, RA, Glover R, Daly M, Nixon T, Harju V and Skelton A. 2008. *Iris yellow spot virus* (IYSV) infecting lisianthus (*Eustoma grandiflorum*) in the UK: first finding and detection by real-time PCR. *Plant Pathology* 57: 768. <http://dx.doi.org/10.1111/j.1365-3059.2008.01856.x>
- Nischwitz C, Gitaitis RD, Mullis SW, Csinos AS, Langston DB, and Sparks AN. 2007. First report of *Iris yellow spot virus* in spiny sowthistle (*Sonchus asper*) in the United States. *Plant Disease* 91:1518. <http://dx.doi.org/10.1094/PDIS-91-11-1518C>
- Ornelas-Ocampo K, Ochoa-Martínez DL, Aranda-Ocampo S, Ramírez-Rojas S, García-Ruiz H. 2018. Variability and symptoms caused by *Iris yellow spot virus* in *Nicotiana benthamiana*. *Revista Mexicana de Fitopatología* 36(1): 131-140. <http://dx.doi.org/10.18781/R.MEX.FIT.1707-2>
- Palomo T LA, Martínez B N, Johansen-Naime R, Napoles RJ, Leon Segura O, et al. 2015. Population Fluctuations of Thrips (Thysanoptera) and Their Relationship to the Phenology of Vegetable Crops in the Central Region of Mexico. *Florida Entomologist* 98(2):430-438. <https://doi.org/10.1653/024.098.0206>
- Pérez-Moreno L, Rico-Jaramillo E, Sánchez-Palé JR, Ascencio-Ibáñez JT, Díaz-Plaza R y Rivera-Bustamante RF. 2004. Identificación de virus fitopatógenos en cultivos hortícolas de importancia económica en el estado de Guanajuato, México. *Revista Mexicana de Fitopatología* 22: 187-197. <https://www.redalyc.org/pdf/612/61222205.pdf>
- Pérez-Moreno L, Navarro-León MJ, Ramírez-Malagón R y Mendoza-Calderón B. 2010. Impacto e identificación de virus fitopatógenos sobre rendimiento y calidad del ajo (*Allium sativum* L), en el estado de Guanajuato, México. *Revista Mexicana de Fitopatología* 28(2): 97-110. <http://www.scielo.org.mx/pdf/rmfi/v28n2/v28n2a3.pdf>

- Pourian HR, Mirab-balou M, Alizadeh M and Orosz S. 2009. Study on biology of onions thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) on cucumber (Var. Sultan) in laboratory conditions. *Journal of Plant Protection Research* 49(4): 390-394. <http://dx.doi.org/10.2478/v10045-009-0061-x>.
- Rafizadeh N, Jafarpour B and Falahati RM. 2013. Detection of *Iris yellow spot virus* (IYSV) in onion and some of ornamental plants by ELISA and RT-PCR methods in Khorasan Razavi Provinces. *Journal of Plant Protection (Agricultura Science and Technology)* 27 (2): 149-158. <https://www.sid.ir/en/journal/ViewPaper.aspx?id=334170>
- Ramírez-Rojas S, Ornelas-Ocampo K, Osuna- Canizalez FJ, Bartolo-Reyes JC, Varela-Loza V, Hernández-Romano J y Ochoa-Martínez DL. 2016. Detection of *Iris yellow spot virus* in onion plants from Tepalcingo, Morelos state, Mexico. *Revista Mexicana de Fitopatología* 34: 308-315. <http://dx.doi.org/10.18781/R.MEX.FIT.1604-1>
- Ríos-Domínguez G Salgado-Siclán ML, Aguilar-Ortigoza C y Aquino-Martínez JG 2017. Detección molecular del *Iris yellow spot virus* (IYSV) en el cultivo de tomate de cascara en Malinalco, estado de México. Vol 35. Suplemento 2017. S69. http://rmf.smf.org.mx/suplemento/docs/Volumen352017/VOLUMEN_35_SUPLEMENTO_2017.pdf
- Ríos-Domínguez, G, Salgado-Siclán ML, Aguilar-Ortigoza C y Aquino-Martínez JG. 2018. Caracterización molecular del género *Orthospovirus* y su vector en solanáceas en el sur del estado de México. *Revista Mexicana de Fitopatología*. Suplemento 36:S106. <http://rmf.smf.org.mx/suplemento/docs/Volumen362018/S362018.pdf>
- Sampangi RK and Mohan SK. 2007. Identification of new alternative weed hosts for *Iris yellow spot virus* in the Pacific Northwest. *Pant Disease*. 91(12): 1683. <http://dx.doi.org/10.1094/PDIS-91-12-1683B>
- Schoonhoven LM, van Loon JJA and Dicke M. 2005. *Insect-Plant biology*. 2nd edition. Oxford University. New York, NY. Pp: 1-24.
- Schwartz HF, Gent DH, Fichtner SM, Otto K, Boateng CO, Szostek S, Cranshaw WS and Mahaffey LA. 2014. *Thrips tabaci* (Thysanoptera: Thripidae) and *Iris yellow spot virus* associated with onion transplants, onion volunteers, and weeds in Colorado. *Southwestern Entomologist* 39(4): 691-704. <https://doi.org/10.3958/059.039.0401>
- SIAP, 2023. Panorama agroalimentario 2023. Servicio de Información Agroalimentaria y Pesquera (SIAP). Edición 2023. 215 p. <https://online.pubhtml5.com/vqdk/rvdl/>
- Smith EA, Ditommaso A, Fuchs M, Shelton AM and Nault BA. 2011. Weed hosts for onion thrips (Thysanoptera: Thripidae) and their potential role in the epidemiology of *Iris yellow spot virus* in an onion ecosystem. *Environmental Entomology* 40(2): 194-203. <https://doi.org/10.1603/EN10246>
- Smith EA, DiTommaso A, Fuchs M, Shelton AM and Nault BA. 2012. Abundance of weed hosts as potential sources of onion and potato viruses in western New York. *Crop Protection* 37: 91-96. <http://dx.doi.org/10.1016/j.cropro.2012.02.007>
- Srinivasan R, Sundaraj S, Pappu HR, Diffie S, Riley DG and Gitaitis RD. 2012. Transmission of *Iris yellow spot virus* by *Frankliniella fusca* and *Thrips tabaci* (Thysanoptera: Thripidae). *Journal of Economic Entomology* 105(1): 40-47. <http://dx.doi.org/10.1603/EC11094>
- Syller J. 2012. Facilitative and antagonistic interactions between plant viruses in mixed infections. *Molecular Plant Pathology* 13(2): 204-216. <http://dx.doi.org/10.1111/j.1364-3703.2011.00734.x>.
- Szostek AS and Schwartz HF. 2015. Overwintering sites of *Iris yellow spot virus* and *Thrips tabaci* (Thysanoptera: Thripidae) in Colorado. *Southwestern Entomologist* 40(2): 273-290. <http://dx.doi.org/10.3958/059.040.0204>
- Tabassum A, Reitz S, Rogers P and Pappu HR. 2016. First report of *Iris yellow spot virus* infecting green onion (*Allium fistulosum*) in the United States. *Plant Disease* 100(12): 2539. <https://doi.org/10.1094/PDIS-05-16-0599-PDN>
- Tanveer A, Khalid A, Ali HH, Mahajan G and Chauhan BS. 2015. Interference and management of *parthenium*: The world's most important invasive weed. *Crop Protection* 68: 49:59. <https://doi.org/10.1016/j.cropro.2014.11.005>
- Torre-Almaraz R de la, Téliz-Ortiz D, Cárdenas-Soriano E, Barrón-Rodríguez B, García-Latorre E, Cárdenas-Alonso M, Rivera-Bustamante R y Valverde RA. 1998. Identification of viral complex in tomatillo (*Physalis ixocarpa* B.) in the Central region of Mexico. *Revista Mexicana de Fitopatología* 16(1):1-11. <https://www.cabdirect.org/cabdirect/abstract/20013020281>
- Turina M, Kormelink R and Resende RO. 2016. Resistance to Tospoviruses in vegetables crops: epidemiological and molecular aspects. *Annual Rev. Phytopathology* 4(54): 347-371. <http://dx.doi.org/10.1146/annurev-phyto-080615-095843>
- Ullman ED, Meideros R, Campbell RL, Whitfield EA, Sherwood LJ and German LT. 2002. Thrips as vectors of Tospoviruses. *In: Plumb T. R. 2002 Advances in Botanical research, incorporating Advances in Plant pathology* 36: 113-140

- Velásquez-Valle R, Mena-Covarrubias J, Amador-Ramírez MD y Reveles-Hernández M. 2009. El virus de la marchitez manchada del jitomate afectando al chile y jitomate en Zacatecas. Instituto Nacional de Investigaciones Forestales, Agrícolas y pecuarias (INIFAP). Litográfica Central, S.A. de C. V. Aguascalientes, Aguascalientes, México. 50 p. <http://www.zacatecas.inifap.gob.mx/publicaciones/virusMarchitezjito.pdf>
- Velásquez-Valle R, Mena-Covarrubias J, Reveles-Hernández M, Amador-Ramírez MD y Schwartz HF. 2010. El virus de la mancha amarilla del iris: una nueva amenaza para el ajo y la cebolla en Aguascalientes y Zacatecas. Folleto Técnico No. 21. Campo Experimental Zacatecas. CIRNOC-INIFAP. 21 p. <http://biblioteca.inifap.gob.mx:8080/jspui/handle/123456789/2669>
- Velásquez-Valle R y Reveles-Hernández M. 2011. Detección del *Iris yellow spot virus* en el cultivo de cebolla en Zacatecas, México. Revista Mexicana de Ciencias Agrícolas 2(6): 971-978. <http://www.scielo.org.mx/pdf/remexca/v2n6/v2n6a13.pdf>.
- Velásquez-Valle R, Reveles-Hernández M y Amador-Ramírez MD. 2012. Distribución viral en plantas de cebolla (*Allium cepa* L.,) asintomáticas. Revista Mexicana de Ciencias Agrícolas 3(7): 1425-1434. <http://www.scielo.org.mx/pdf/remexca/v3n7/v3n7a11.pdf>
- Velásquez-Valle R, Reveles-Torres LR y Amador-Ramírez MD. 2013. Hortalizas y virosis en Zacatecas: un patosistema complejo. Revista Mexicana de Ciencias Agrícolas 4(8): 1267-1277. <http://www.scielo.org.mx/pdf/remexca/v4n8/v4n8a12.pdf>
- Velásquez-Valle R, Reveles-Torres LR, Salas-Muñoz S, Mauricio-Castillo JA y Reveles-Hernández M. 2017 Detección del virus de la mancha amarilla del iris en almácigos de cebolla en Zacatecas, México. Revista Mexicana de Ciencias Agrícolas 8(1): 209-214. <http://www.zacatecas.inifap.gob.mx/publicaciones/IYSV.pdf>
- Weilner S and Bedlan G. 2013. Detection of *Iris yellow spot virus* (IYSV) in selected *Allium* species and overwintering hosts in Austrian onion-producing areas. Journal fur Kulturflanzen 65(2): 60-67. <https://doi.org/10.5073/JfK.2013.02.3>
- Wisler GC and Norris RF. 2005. Interactions between weeds and cultivated plants as related to management of plant pathogens. Weed Science 53(6): 914-917. <https://doi.org/10.1614/WS-04-051R.1>
- Whitfield AE, Ullman DE and German TL. 2005. *Tospovirus*-thrips interactions. Annual Review of Phytopathology 43: 459-489. <http://dx.doi.org/10.1146/annurev.phyto.43.040204.140017>.
- Zamora-Macorra EJ, Aviña-Padilla K, Rosemarie HW and Ochoa-Martínez DL. 2023. Comparison of molecular protocols to detect *Tomato brown rugose fruit virus* in solanaceae hosts. Mexican Journal of Phytopathology 41(4): 2. <https://doi.org/10.18781/R.MEX.FIT.2023-5>
- Zuñiga-Romano MC, Ochoa-Martínez DL, Rojas-Martínez RI and Zamora-Macorra EJ. Identification of begomoviruses in tomato and determination of seed transmission in Atlacomulco, Mexico State. Mexican Journal of Phytopathology 37(2): 279-286. <https://doi.org/10.18781/R.MEX.FIT.1902-2>