



Outlook on Tospoviruses Affecting Important Crop Plants in Iran

Abstract: Tospoviruses are among the most damaging plant viruses worldwide. Over recent decades, the increasing global trade of plants and plant products, climate changes and types of agricultural practices in different regions have resulted in the spread of both the tospoviruses and their vector's thrips species. This brief review further emphasized the status on the distribution and presence of important Orthotospoviruses affecting major crop plants in different growing regions in Iran. This data may bring more attentions to this important genus of viruses and will help in devising efficient control strategies to curb the tospovirus diseases and the thrips vectors.

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Introduction

Tospoviruses have become increasingly important worldwide since the 1980s due to the spread of the important insect vector *Frankliniella occidentalis* and the discovery of new viruses (Oliver & Whitfield, 2016; Schltthof et al., 2011; Pappu et al., 2009; Winter et al., 2002). A large number of plant families are known to be affected by viruses of the *Tospovirus* genus. These includes both food crops such as (soybean, capsicums, tomatoes, lettuce, peanuts, watermelons, et al) as well as many ornamental species which are important to flower farms (Calla lily, iris, chrysanthemum, impatiens, cineraria, anthurium, et al.). As a result, tospoviruses are now recognized globally as emerging agricultural diseases, classified within the family *Tospoviridae*, genus *Orthotospovirus* and the order Bunyavirales (Abudurexifi et al., 2019; ICTV, 2020; Karavina, 2025; Karthikeyan et al., 2021). All members share a common structure: virus particles quasi-spherical in shape, from 80 to 120 nm in diameter, and surrounded by an envelope of a host-derived membrane in which two glycoproteins, Gn and Gc, are embedded (Karavina, 2025; Zarzynska-Nowak et al., 2022, 2016) (Fig a). Tospoviruses

and their vectors, thrips species in the order *Thysanoptera*, represent a major problem for agricultural and ornamental crops that must be managed to avoid devastating losses. In recent years, the number of recognized species in the genus has increased rapidly, and our knowledge of the molecular interactions of tospoviruses with their host plants and vectors has expanded (Ullman et al., 1977; Karen-Beth et al., 2011; Pappu et al., 2009; Karthikeyan et al., 2021; Mortazavi & Aleosfoor, 2015; Mortazavi et al., 2013).

Background

Genus *Orthotospovirus* currently contains 26 established (Feng et al., 2023; ICTV, Website) and several tentative species. Based on their geographic distribution and nucleocapsid protein sequence homology, members are grouped into American- and Euro/Asian-type orthotospoviruses, respectively. However, the genetic interaction between different species and the possibility, during mixed infections, for trans-complementation of gene functions by orthotospoviruses from different geographic groups remains underexplored. Many of those virus species, from both geographic clades, cause important crop diseases throughout the world or in local regions. *Tomato spotted wilt virus* (TSWV) is the type of member of the orthotospoviruses and belongs to the American clade. Whereas TSWV is the best studied virus in *Orthotospovirus*, most other viruses from both geographic groups are much less studied. (Abadkhah et al., 2018; Abudurexiti et al., 2019; Feng et al., 2023). (EPPO, 2020; Oliver & Whitfield, 2016). Hassani-Mehraban et al., 2019). Tospoviruses are known to be exclusively transmitted by thrips belonging to the family Thripidae and subfamily Thripinae. Of the known 1,710 species of Thripidae only 14 thrips species



are currently reported to transmit tospoviruses (ESFA,2012; Karthikeyan,2021; Mortazavi & Aleosfoor,2015;Mortazavi et al.,2013; Ullman et al.,1997;). Thrips-transmitted tospoviruses cause severe yield losses to several economically important crops in the United States and worldwide. For instance, a single *Tospovirus* (*Tomato spotted wilt virus*) alone caused an estimated \$1.4 billion in losses in the U.S. over 10 years (Ullman et al. 1997; Prins & Goldbach ,1998; Oliver & Whitfield,2016). Global trade and associated movement of plant materials across borders have introduced tospoviruses and their vectors into newer areas. Advances in serological and molecular techniques have also led to identification of new tospoviruses (Zarzynska-Nowak et al.,2022; Seepiban et al.2015; Chao et al. 2025). So far, CSNV, TYRV, INSV, IYSV, GBNV (PBNV) CaCV, MYSV and TSWV has been reported from Iran (Rasoulpour & Izadpanah,2007; Bananej et al.,1998., Golnaraghi et al.,2001,2018; Mehraban et al.,2019; Ghotbi et al.,2005; Shahraeen et al.,2002; Bayat et al.,2017; Salehzadeh et al.,2024; Hassani-Mehraban et al.,2019). However, limited data are available related to the variants, extent of damages of these viruses. Since in recent years, reports of infection of multiple hosts with tospoviruses have increased in different regions of Iran (Table 1). In view of the range of environmental conditions, host availability and sequence variability shown by IYSV, MYSV, CaCV, INSV, TYRV and TSWV, there is a possibility of the abundance of these viruses and their potential vectors, as well as other tospoviruses, in farms. Especially since TYRV was first reported from Iran (Varamin- tomato)(Winter et al.2002), and in the author's opinion, different populations of tospoviruses may exist in Iranian farms, and their detection and identification require a joint and coherent research effort, and scattered reports and research make disease control management difficult.(Gorbani et al.,2008; Golnaraghi et al.,2018; Rasoulpour & Izadpanah,2007;Ghotbi et al.,2005;Ghotbi et al.,2020,2010;Ghotbi & Shahraeen,2010,2022,2023, 2025a,b,c,d).

Tomato spotted wilt virus-TSWV-Orthotospovirus

TSWV causes serious damage to a wide range of economically important crops

worldwide including fruits, vegetables, ornamental, and weed plants as well. TSWV isolates are transmitted by several species of thrips (Thysanoptera, Thripidae) in a persistent and propagative manner, especially the western flowers thrips *Frankliniella occidentalis* (ESFA,2012; Oliver &Whitfield,2016; Mortazavi et al.,2015) (Table 1). Various symptoms including chlorosis, necrosis and ring spots on leaves, fruit, and steams that lead to wilting and death of infected plants are more common in TSWV infection (EPPO,2020; Ghotbi et al.,2005; Ghotbi & Shahraeen,2025c; Amaresan & Kumar,2025). *Tomato spotted wilt virus* has been reported from Iran based on symptoms and electron microscopy in 1996 (Bananej et al., 1996) (Fig.1g, a, d) (Table 1). There are some reports of Orthotospoviruses from different parts of Iran in tomato, potato, soybean, peanuts, allium cepa, melon, lettuce and several ornamental plants based on serological and molecular methods and host plants reactions (Ghotbi & Shahraeen, ,2005,2012; Golnaraghi et al., 2007; Hajiabadi et al., 2012; Pourrahim et al., 2001; Abadkhah,2018; Bayat et al.,2018). Recently, TSWV has been reported from Iran's important export crop, the saffron plant, from the South Khorasan region (Farkhond et al.,2018). Tospoviruses can infect a large number of plant species, including economically important vegetable crops such as bean, cucurbit, lettuce, pepper, potato, soybean, tomato and various ornamental species (Ghotbi & Shahraeen 2025a, b, c and d; Ghobi et al.,2020; EFSA, 2012; EPPO,2020). Recombination analysis based on nucleocapsid gene revealed that the Iranian TSWV isolates have recombination evidence with other isolates (TOS101/TSWV-1423/3906) around the world (Abadikhah et al.,2018). Individual species may have extended host ranges, such as TSWV, which has been reported to infect over 1300 different plant species (EFSA, 2012), whereas others have a more limited host range. Nearly all tospoviruses are known to be transmitted by thrips (order Thysanoptera, family Thripidae) in a persistent and propagative manner (Table 1), Rotenberg et al., 2015). Many of these thrips' species also have wide host ranges and a worldwide distribution. To date, at least 15 different thrips species have been reported to vector tospoviruses (Oliver & Whitfield,2016). Tospoviruses are considered not to be transmitted. A first report of seed



transmission of a tospovirus (*soybean vein necrosis virus*) has recently been published by Groves et al. (2016), but this needs confirmation. Tospoviruses are among the most damaging plant viruses (Pappu et al., 2009; Scholthof et al. 2011). Usually, the impact on tomato crop losses caused by TSWV can reach values that exceed 40%, with over 90% of reduction in quality and marketable tomatoes and worldwide losses that overcome one billion dollars annually. In addition to tomato crops, other important horticultural species with great losses caused by TSWV infection are pepper, lettuce and eggplant (Caruso et al., 2024). *Tomato spotted wilt virus* is included in the OEPP/EPPO A2 pests list recommended for regulation as a quarantine pathogen (EPPO, 2023a)

Tomato yellow ring virus-TYRV-Orthotospovirus

A viral disease that induced bright yellow ring patterns on tomato fruits (Fig. 1a, b) was observed in tomato fields in the Varamin area of Tehran province, Iran in 2002. The causal agent was identified as a distinct tospoviral species and was tentatively named Tomato yellow fruit ring virus (TYFRV) (Winter et al., 2002; Ghotbi et al., 2005). It was also called Tomato fruit yellow ring virus (Winter et al., 2006). Since it was first detected in the Varamin area, it was also called the Tomato Varamin virus (ToVV) (Ghotbi et al., 2005). It has also been reported to be present in Kenya and Poland (Birithia et al., 2012; Zarzynska-Nowak et al., 2016; Gholnaragi et al., 2018). In Poland, the virus was found on tomatoes in one growing season. It has not been detected in subsequent seasons. The virus has a wide host range that includes ornamental plants (such as chrysanthemum, gazania, cineraria, anemone and alstroemeria), potato, soybean, weeds and important food and cash crops from the families Solanaceae and Fabaceae (Bayat et al., 2018; Rasoulpour & Izadpanah, 2007; Pourrahim et al., 2012, 2002b; Shahraeen & Ghotbi, 2003; Golnaraghi et al., 2007a & b). It infects crops grown in open fields and protects environments. TYRV is transmitted principally by the cosmopolitan and highly polyphagous onion thrips (*Thrips tabaci*) and western flower thrips (*Frankliniella occidentalis*) in a persistent and propagative manner. In addition, it can also be transmitted via infected potato tubers and mechanically through infected plant sap. While it

has a limited geographical distribution so far, the presence of its vectors and host plants in many countries across all continents necessitates continuous monitoring to prevent its introduction into new areas where it could potentially rapidly spread out of control and cause severe economic losses (EPPO, 2020; Zarzynska-Nowak et al., 2022). Economic losses caused by TYRV have not yet been quantified, but high disease incidences were reported in soybean and potatoes in Iran (Pourrahim et al., 2012; Golnaraghi et al., 2007; Ghotbi et al., 2005). Farahbakhsh et al. (2016) first reported the occurrence of TYRV on *Anthorium* in Iran, so on *Althea* in Markazi province and *Alstroemeria* in Isfahan and Chaharmahal-o-Bakhtiari provinces, also *Lonicera* and *Ailanthus altissima* and TSWV in *Lonicera* spp. and *Ailanthus altissima* in Isfahan province. Molecular comparison of TYRV isolates from Isfahan, Chaharmahal-o-Bakhtiari and Markazi provinces were also reported (Majidian et al., 2016; Bayat et al., 2018; Beikzadeh, et al., 2011). TYRV occurs in mixed infections with other orthotospoviruses such as *tomato spotted wilt* orthotospovirus (TSWV), *Iris yellow spot* orthotospovirus (IYSV) and *Impatiens necrotic spot* orthotospovirus (INSV). This increases the chances of recombination and reassortment which could give rise to new species and/or more virulent strains of the pathogen (Ghotbi & Shahraeen, 2005; Shahraeen & Ghotbi 2010; Feng et al., 2023; Karthikeyan et al., 2021). The yield and quality losses in some of the greenhouses in Kujawsko-Pomorskie (Poland) were estimated at 70% by growers (Zarzynska-Nowak et al., 2016). TYRV has quasi-spherical particles measuring 80–120 nm in diameter and it is transmitted naturally in a persistent propagative manner by several thrips' species. Similar to other orthotospoviruses, the TYRV genome contains three single-stranded (ss) RNA segments designated as small (S), medium (M) and large (L) RNA. (Zarzynska-Nowak et al., 2016; Hassani-Mehraban et al., 2019; Turina et al., 2012).

Impatiens necrotic spot virus- INSV-Orthotospovirus,

Impatiens necrotic spot virus (INSV) has been present in the Mediterranean for a number of years, but its economic impact in vegetable crops is less than that in ornamental crops

(Turina et al.,2012). *Impatiens necrotic spot virus* (INSV), belonging to genus Orthotospovirus, causes severe damage to greenhouse ornamental plants. INSV reported from almost every ornamental screen house in Iran. INSV general symptoms include necrotic leaf spots, chlorosis and stunting in infected ornamental host plants. A total number of 581 ornamental samples of 58 different plant species with symptoms similar to those of INSV infection were collected in 4 provinces of Iran. The results indicated an average of 20.13 per cent virus incidence. INSV infection was recorded to be 28% in Mahallat, 24.5% in Tehran, 22.1% in Mazandaran and 16.4% in Guilan provinces (Ghotbi & Shahraeen,2023). *Impatiens necrotic spot virus*-INSV- Orthotospovirus is among the most important tospoviruses reported from ornamental plants in the world (Peters, 1998). Infection with viral diseases, not only reduced the quality, but also leads to leaf and flower blistering, dwarf plant, mosaic, marginal leaf chlorosis, leaf entanglement, deformity or lack of flower formation (Shahraeen & Ghotbi, 2003; Shahraeen et al., 2022).INSV is the most important harmful and predominant virus in ornamental plants in Iran and has been reported from various ornamental species in the country (Ghotbi et al., 2005; Shahraeen & Ghotbi,2003; Pourrahim et al., 2012; Bayat & Nazerian,2019).

Iris yellow spot virus-IYSV-orthotospovirus,

An emerging pathogen (IYSV), affecting *Allium* species and ornamental crops, has been identified in over 92 countries and states/provinces worldwide. IYSV was identified in 1981 in Brazil and has spread to many important onion-producing regions of the world, including several U.S. states. IYSV symptoms include straw-colored, dry, tan, spindle- or diamond-shaped lesions on the leaves and scrapes of onion plants and can cause yield loss up to 100% (Diaz-Montano et al.,2011). It is classified within the family Tospoviridae and the genus Orthotospovirus. As a member of the genus Orthotospovirus, it is transmitted by thrips (specifically *Thrips tabaci* and *Frankliniella fusca*) in a circulative and propagative manner. This pathogen leads to significant yield losses in ornamental plants and cultivated alliaceous crops such as onion, garlic, and leeks (Karavina,2025). Bayat et al (2018) by studying

sequence analysis of the obtained fragments from RT-PCR using generic primers of Asian clad 1 and Eurasian clades of tospoviruses and nucleocapsid gene specific primers confirmed the occurrence of TYRV on alstromeria, tobacco, tomato and nasturtium; IYSV on onion and leek and *Capsicum chlorosis virus* (CaCV) on black-eyed Susan (*Rudbeckia* sp.), and *Hippeastrum hybridum* (Bayat et al.,2024) from Markazi province in Iran. During a survey in 2002-2003 in Markazi province of Iran. Ghotbi & Shahraeen (2005) were first reported to have an infection of onion plants with three tospoviruses. Pathological and serological tests (on *Vigna unguiculata* cv. Local, *Chenopodium amaranticolor*, *Datura metel* and *D. stramonium*) confirmed that the causal agents were TSWV (*tomato spotted wilt virus*), TYFRV (*tomato yellow fruit rig virus*) and IYSV (*Iris yellow spot virus*).

Groundnut bud necrosis virus-GBNV-Orthotospovirus

Groundnut (peanut) *bud necrosis virus* (GBNV) is a tospovirus that causes bud necrosis disease in groundnuts and other food crops. It is primarily transmitted by the thrips vector, *Thrips palmi*. GBNV infects a wide range of hosts, including cowpeas, mung beans, soybeans, and potatoes. *Groundnut (peanut) bud necrosis virus* (GBNV) was first reported from Iran by Gholnaraghi et al.,2002c). During the summer of 2001, mosaic, mottle, ring mosaic, stunting, and bud necrosis were observed in peanut fields (*Arachis hypogaea* cv. Guilan) in the Golestan province of Iran. GBNV is a member of the Orthotospovirus genus and has serological relationship with TSWV. Later the virus was reported in Markazi province in ornamental Susan (*Rudbeckia* sp.) (Bayat et al.,2016).

Capsicum chlorosis virus-CaCV-Orthotospovirus,

CaCV infects plant species in the family Solanaceae (i.e. pepper, tomato) and several other species of families, including ornamentals. It may induce severe symptoms on its hosts, mainly on leaves and fruits, which may become unmarketable. The virus is transmitted in a persistent propagative mode by the thrips *Ceratothripoides claratris*, *Frankliniella schultzei*, *Microcephalothrips abdominalis* and *Thrips palmi*. Plants for



planting, parts of plants, fruits and cut flowers of CaCV hosts, and viruliferous thrips were identified as the most relevant pathways for the entry of CaCV into the new region (EPPO,2020,2023a). Should the pests enter and establish in a territory, impact on the production of cultivated hosts is expected. Phytosanitary measures are described to prevent entry and spread of the virus in a new region (EPPO,2020,2023a). CaCV fulfils the criteria that are within the remit of EFSA to assess for it to be regarded as a potential union quarantine pest. Using generic tospovirus primers derived from the nucleocapsid gene of the Asian 1 clade of tospoviruses, incidence of *Capsicum chlorosis virus* on black-eyed Susan plants (*Rudbeckia* sp.) in Markazi province of Iran has been reported (Bayat et al.,2016,2018,2024).

Melon yellow spot virus-MYSV-Orthotospovirus

Melon yellow spot virus (Tospovirus, MYSV) was first identified in 1992 in Japan causing spotted wilt symptoms and a severe chlorosis on melon crops (EPPO, RS 2000/158). It was also found that MYSV is primarily transmitted by *Thrips palmi* (EPPO, A1 List) in a persistent manner. In addition to melons (*Cucumis melo*), diseases caused by MYSV have been observed on cucumbers (*Cucumis sativus*), watermelon (*Citrullus lanatus*) and balsam pear (*Momordica charantia*). MYSV has also been detected in several weed species commonly occurring around cucumber greenhouses. At present, MYSV is considered to be one of the most serious threats to cucumber production in Japan. When infection occurs early in the season, yield losses of 30 to 60% have been observed. In addition to Japan, MYSV has been reported during the last decade on cucurbitaceous crops in Taiwan (2006), Thailand (2008), and China (2009, Hainan and Guangxi Provinces) (EPPO,2020; EPPO,2013). *C. sativus* is a significant vegetable crop that is cultivated year-round in Iran. During a greenhouse survey conducted in the spring of 2024, *Cucumis* (*C. sativus*), plants exhibiting suspected Orthotospovirus infection symptoms, such as severe leaf yellow spots, yellowing, fruit necrosis, and chlorotic ring spots, were collected from Shahinshahr city (Isfahan province, Iran). Using an Orthotospovirus-universal primer pair, Salehzadeh & Afsharifar

(2024) first reported the occurrence of MYSV from Iran. While *Thrips palmi*, also known as melon thrips, is a globally significant pest, it has not been officially reported as established in Iran. It is considered an EPPO A1 quarantine organism, meaning it is a pest of quarantine concern for the European and Mediterranean Plant Protection Organization (EPPO). Although it has been intercepted at borders and has been found in other parts of Asia, Africa, and the Americas, to this date there's no official record of it being present in Iran. (Rajabian et al.,2018; Mirab-balou,2013; EPPO Global data base).

Chrysanthemum stem necrosis virus-CSNV-Orthotospovirus,

In chrysanthemum, CSNV causes symptoms which are similar to those of *Tomato spotted wilt virus* (TSWV). In the Netherlands, they were described as mild or severe necrotic streaks on the stem, wilting of leaves and stems, and chlorotic or necrotic spots and rings on some leaves. However, symptoms of CSNV are more severe and can result in complete necrosis of the stem resulting in wilting of sections of plants (EPPO,2020). Based on the genome structure, CSNV belongs to the genus Orthotospovirus, a typical representative of which is TSWV (Jafarpour et al., 2010). CSNV belongs to the American branch of orthotospoviruses, which differ from the Asian ones in the presence of the amino acid triad (RGD) in the gene encoding the glycoprotein Gc (EPPO,2020). *Chrysanthemum stem necrosis virus* (CSNV) is present in Iran, as confirmed by Jafarpour et al. (2010). The virus causes necrotic zones on chrysanthemum stems, which can lead to plant death. The presence of tospoviruses and CSNV in Iran has been documented in various studies and reports. Further research may focus on the prevalence, impact, and management strategies for CSNV in Iranian chrysanthemum cultivation (Ghotbi et al.,2005; Ghotbi & Shahraeen,2012).

Materials and Methods

Enzyme-linked immunosorbent assay (DAS-ELISA) is widely used in large-scale screening for a tospovirus infection in various types of plants; however, the molecular techniques are more sensitive than the serological ones. Low virus titer can limit sensitivity, producing false negatives when the

virus concentration is under the technique detection threshold (Golnaraghi et al.,2008; BIRTHIA et al.,2012; Bayat et al.,2018; Shahraeen et al.,2001; Ghrbani et al.,2008). Primers were designed for RT-PCR detection of tospoviruses from all recognized clades, i.e. the American, Asian and Eurasian clades, and from the small group of distinct and floating species. Pilot experiments on isolates from twenty different species showed that the designed primer sets successfully detected all species by RT-PCR, as confirmed by nucleotide sequence analysis of the amplicons (Abadikhah et al.,2018; Hassani Mehraban et al.,2016). For the tospoviruses recommended for regulation by EPPO and regulated by a number of EPPO members, commercial antibodies are available. Details of their performance are provided by EPPO (2020).

A protocol for identifying tospovirus and thrips species in an individual thrips sample has been successfully developed. The number of viruliferous thrips in a thrips population is one of the most important factors in the spread of tospovirus disease. To identify viruliferous thrips, both serological and molecular methods have been commonly used. Enzyme-linked immunosorbent assay (ELISA) has been used to identify different tospoviruses in various thrips vectors (Seepiban et al.,2015; Ghotbi et al.,2003; EPPO,2020, Gholnaraghi et al.,2007). Nowak-Zarzyńska et al. (2018) developed and evaluated an mRT-PCR assay for the simultaneous detection and differentiation of TYRV and TSWV. Primers were designed to amplify 666 bp and 328 bp of the nucleocapsid (N) genes of TYRV and TSWV, respectively. mRT-PCR is a rapid, specific and sensitive method for TYRV and TSWV identification which often occur in mixed infection. In recent times, high-throughput sequencing (HTS) has been used to detect orthotospoviruses (Karavina et al., 2020). Unlike RT-PCR, HTS does not require the use of primers. Thus, it provides for unbiased detection of viruses and can recover the whole genome of viruses in a single run. A rapid and sensitive tospovirus (TSWV) detection protocol based on real time reverse transcription loop-mediated isothermal amplification (RT-LAMP) assay has been developed, also using cost-effective and simplified sample preparation procedure. Sensitivity, specificity, accuracy, and in-field application of the real-time RT-LAMP assay were evaluated. The developed real-time RT-LAMP

assay proved to be one thousand and one hundred times more sensitive than end-point RT-PCR and real-time RT-PCR methods, respectively, detecting a total of 9.191×10^1 genome copies as minimum target, and no cross-reactivity were detected with other viruses belonging to tospoviridae and bromoviridae families used as outgroup (Caruso et al.,2024). A universal RT-PCR assay for orthotospoviruses has been developed targeting the RNA-dependent RNA polymerase gene (RdRp) on the L RNA segment by identifying the most conserved protein motifs and taking advantage of the presence of codon usage biases in the tospovirus genus (Chao et al.,2025).

Virus disease managements

Disease management strongly relies on a fast and accurate identification of the causal agent as described (Eppo,2020; Prins & Goldbach,1998; Seepiban et al.,2015) including both serological and molecular methods. During the past three decades, the economic impact of tospoviruses has increased, causing high yield losses in a variety of crops and ornamentals. Owing to the difficulty in combating thrips vectors with insecticides, the best way to limit/prevent tospovirus-induced diseases involve a management strategy that includes virus resistance. More virus-crop combinations need resistance sources to help control the diseases caused by tospoviruses. Given the increasing importance of IYSV, particularly for onion seed production in the United States, some preliminary tests for resistance/tolerance to both onion thrips and IYSV have been carried out and a limited number of selections of potential interest in breeding programs were identified (Pappu et al.,2009; Sofer et al.,1988, Tabassum,2014; Ullman et al.,1997). The most common thrips species in Iran include *Thrips tabaci*, which is a significant pest of crops like onions, garlic, and other vegetables. Other notable species are *Frankliniella occidentalis* (the Western flower thrips), which affects a wide range of flowers and vegetables, and *Thrips angusticeps*, among others. These species are prevalent due to their adaptability to various crops and environmental condition in Iran (Mirab-Balou,2015,2018 and Mortazavi et al,2015,2013). Thrips infestations in Iranian agriculture are typically managed through a combination of integrated pest management



(IPM) strategies, including cultural practices: Biological control, chemical control, and monitoring and early detection. These strategies aim to reduce thrips populations effectively while minimizing environmental impact. Nurseries must also be kept weed-free and systematically monitored for thrips vectors using yellow sticky traps hung vertically above plants (EPPO,2020). Temperature is one of the most important environmental factors that affect plant-pathogen interactions, and it can either increase or decrease disease resistance. This reflects the differential influence of the same temperature variation on different plants. Temperature affects the growth and populations of microorganisms living on plants such as viruses. Several reports have shown that during tospoviruses infection temperature is an important factor that affect the symptom expression as well as viral movement in pathogens such as *Cucumber green mottle mosaic virus* (CGMMV) on cucumber and melon, *Cucumber mosaic virus* (CMV) on melon, *Melon necrotic spot virus* (MNSV) on melon and TSWV on bonnet pepper (*Capsicum chinense*) and peanut (*Arachis hypogaea*) (Soler et al.,1988). Given that one of the main concerns of global warming is its impact on agriculture. The effects of temperature on plant defense against biotic stress need to be considered in future breeding programs for resistance to pathogen ability of some strains of TSWV to overcome host plant resistance (Pappu et al., 2009), influence of climate change on severity, epidemics of tospovirus infections remain as challenges in controlling tospovirus diseases. Hence, a continued vigilance is required to identify and characterize the emerging tospoviruses, to protect crops from severe tospovirus outbreaks. Further, it is also imperative to determine their impact on crop production, understand their epidemiology for effective implementation of control strategies. Thus, a well-coordinated collective plan based on data on infection pressure by virus and the vector population fluctuation during the growing season can represent an effective way of combating tospovirus epidemics. Dependence on any particular control measure may be ineffective; but judicious blending of compatible measures (IDM) is to be adopted on a wide area basis, rather than by individual growers. To ensure that an IDM approach is effective, there is a need to

adopt a harmonious range of control measures applied before planting, during the season and after harvesting to minimize losses and maximize returns. Better understanding of vectors and improved genetic engineering techniques would certainly brighten the prospects of tospovirus disease control in the near future (Karthikeyan et al.,2021; EPPO,2020). Cryotherapy-based methods are recently developed novel biotechnologies for the efficient production of pathogen-free plants. Shoot tip cryotherapy was developed as a novel biotechnology at the beginning of the 21st century to efficiently eradicate plant pathogens (specifically for commercial horticultural crops such as potato and sweet potato, ornamentals and fruit plants such as apple, citrus and grapevine. Combining thermotherapy or cold treatment, or chemotherapy with shoot tip culture, often results in much higher pathogen-free frequencies than shoot tip culture alone, and in some cases can even eradicate pathogens that can infect the AD of shoot tips. Based on these speculations, several cryotherapy-based methods for pathogen eradication have recently been established (Jingwei et al.,2025). There is report of elimination of two important tospoviruses, *tomato spotted wilt* (TSWV) and *impatiens spot necrosis* (INSV), from the ornamental alstroemeria plant using micropropagation (tissue culture) (Ghotbi et al., unpublished).

Social and Economic Impact

The spread of tospoviruses impacts a diverse number of food and ornamental crops, resulting in crop disease epidemics of economic and social significance. Prins and Goldbach (1998) estimated an annual loss of over \$1.0 billion from a single Tospovirus, *Tomato spotted wilt virus* (TSWV) globally. Infection at early stages of crop growth often results in a substantial decrease in plant stand leading to considerable yield losses, but infection at later stages may still cause significant losses in the yield and quality of produce. The economic impact of tospoviruses and of TYRV in Iran where the virus is widespread is not known. However, high infection levels have been recorded on soyabeans (Golnaraghi et al., 2007) and potatoes (Pourrahim et al., 2007). The virus can cause severe necrosis on stems and leaves of ornamentals thereby greatly reducing the quality



of the resultant produce (Beikzadeh et al., 2012). In Poland, yield and quality losses in infected tomatoes were estimated at 70% (Zarzyńska-Nowak et al., 2016). The necrosis and chlorosis induced by TYRV infection reduce the aesthetic value of food crops such as tomatoes and peppers, and ornamentals such as chrysanthemums, petunia and gazania. People will not buy symptomatic produce, leading to a loss of income for farmers. Heavy viral infections can completely kill plants, leading to disruption of livelihoods for farmers and traders of crops and ornamental plants. Tactics employed in tospoviruses management must be based on thorough understanding of epidemiological principles and must fall within integrated disease management (IDM) approaches that include biological, chemical, cultural, host-plant resistance and physical control (Karthikeyan et al., 2021; Prins & Goldbach, 1998). TYRV can be introduced to other areas via infected seedlings. Therefore, seedlings sourced from nurseries should be screened for TYRV before planting or transportation to other areas. (Amaresan & Kumar, 2025; EPPO, 2020; Karavina, 2020).

Discussion

The extent of damage that tospoviruses can inflict to the crop plants and the ability of several species of thrips to transmit these viruses increased our concerns in global agriculture. So far, 26 species of Tospovirus have been identified globally along with 14 species of thrips that

can serve as vectors (Feng et al., 2023; ESFA, 2012; Jones, 2005; Pappu et al., 2009; Ciuffo et al., 2010; Hassani Mehraban et al., 2016). Several species in tospovirus genus cause severe losses in agronomic and horticultural crops and ornamental plants production. *Tomato spotted wilt virus* (TSWV), *Impatiens necrotic spot virus* (INSV) and *Tomato yellow ring virus* (TYRV) are the most important tospoviruses infecting crop plants (Pappu et al., 2009; EPPO, 2020). The majority of tospoviruses cause systemic infection in most of the crop plants they infect and infection at early stages of plant growth causes greatest damage, often resulting in severe stunting of the entire plant which may lead to death. However, other tospoviruses, such as CaCV and IYSV tend to remain localized. The losses caused by tospoviruses arise not only from yield reductions

but also from disfiguring symptoms which affect quality. Fruits from infected plants develop visible surface blemishes and are unsalable (Fig 1), so heavily infected crops are often abandoned. The potato tubers from TSWV infected plants often develop superficial ring symptoms and severe internal necrosis of the flesh which render them unsalable (Pourrahim et al. 2002b, 2001a; Golnaraghi et al. 2007b). Moreover, the fact that thrips are difficult to control has contributed to the spreading of known and unknown tospoviruses into new areas. In Iran, the first record of thrips species was of three species, *Frankliniella intonsa* (Trybom), *Thrips flavus* Schrank and *Thrips tabaci* Lindeman, as pests of summer crops, and after that there were several scattered studies of this group in various parts of Iran (Mierab-Balou, 2013, 2018; Mortazavi et al., 2013). The spread of *Frankliniella occidentalis* is considered the primary driver of the worldwide emergence of tospoviruses, although *Thrips palmi* is the major vector of several important tospoviruses in Asia (Rotenberg et al., 2015). Furthermore, the occurrence of reassortment (exchange of one or more genomic RNAs between virus isolates) and recombination within and between different species might contribute to a further emergence of tospovirus diseases. This is because they can differ with respect to viral properties relevant to management, such as host range, symptomatology, vector transmissibility and the potential to breakdown host resistance (Mandal et al., 2017). As a result, tospoviruses are recognized as emerging diseases threatening food security worldwide (Oliver & Whitfield, 2016; Prins & Goldbach, 1998; Scholthof et al., 2011). Tospovirus study in Iran was intensified since 1998 with the identification of TSWV and TYRV as a new virus species in Iran (Bananej et al., 1998; Ghotbi et al., 2005; Winter et al., 2002) (Table 1). Large scale surveys on tospovirus infections have so far not been made and therefore no estimates can be given about the economic impact of tospoviral diseases in Iran. Moreover, the possible occurrence of other tospovirus species in Iran, and even new ones, cannot be excluded. Population genetics studies should be conducted to find the systematic and random forces of evolution factors on the tospoviruses reported from Iran (Rasoulpour & Izadpanah, 2007; Abadikhah, et al., 2018; Shahraeen & Ghotbi, 2010). Investigations are

required to identify the different and efficient thrips vectors transmitting tospoviruses in Iran. Rapid identification tools are needed, and variants of polymerase chain reaction (PCR) or reverse transcription-PCR (RT-PCR) still have an important role to play, but there are deficiencies in existing assays for both groups of organisms. A universal RT-PCR assay for orthotospoviruses has been developed targeting the RNA-dependent RNA polymerase gene (RdRp) on the L RNA segment by identifying the most conserved protein motifs and taking advantage of the presence of codon usage biases in the virus genus (Chao et al., 2025).

Conclusion

Tospoviruses, particularly those within the Orthotospovirus genus, pose a significant and evolving threat to both agronomic and ornamental crops in Iran. The detection of multiple virus species including TSWV, TYRV, INSV, IYSV, GBNV, CaCV, MYSV, and CSNV across diverse regions and hosts underscores the urgency of systematic monitoring and integrated disease management. Factors such as expanding global trade, changing climate conditions, and the adaptability of thrips vectors have facilitated the rapid emergence and spread of these pathogens. Despite progress in molecular diagnostics and preliminary surveys, comprehensive nationwide studies remain limited. Moving forward, a coordinated approach involving surveillance, vector control, resistance breeding, and novel biotechnologies like cryotherapy and HTS is critical. Such efforts will enhance our ability to mitigate yield losses, protect high-value crops, and strengthen the resilience of Iran's agricultural systems against tospovirus outbreaks.

References

- [1] Abudurexiti A, Adkins S, Alioto D, Alkhovsky SV, Avšič-Županc T, Ballinger MJ, Bente DA, Beer M, Bergeron É, Blair CD, Briese T, Buchmeier MJ, Burt FJ, Calisher CH, Cháng C, Charrel RN, Choi IR, Clegg JCS, de la Torre JC, de Lamballerie X, Deng F, Di Serio F, Digiario M, Drebot MA, Duàn Xàoéi, Ebihara H, ELbeaino T, Ergünay K, Fulhorst CF, Garrison AR, Gão GF, Gonzalez J-PJ, Groschup MH, Günther S, Haenni A-L, Hall RA, Hepojoki J, Hewson R, Hú Z, Hughes HR, Jonson MG, Junglen S, Klempa B, Klingström J, Kòu C, Laenen L, Lambert AJ, Langevin SA, Liu D, Lukashevich IS, et al. (2019). Taxonomy of the order bunyavirales: update 2019. Arch Virol 164:1949–1965. doi: 10.1007/s00705-019-04253-6.
- [2] Abadikhah, M., Koolivand, D & Eini, O. (2018). A new distinct clade for Iranian *tomato spotted wilt virus* isolates based on the polymerase, nucleocapsid, and non-structural genes. Plant Pathol. J. 34(6) :514-531. doi:10.5423/PPJ.OA.04.2018.0062
- [3] Amaresan, K & Kumar, K. (2025). Compendium of Phytopathogenic Microbes in Agro-Ecology. Book: Vol. 2 Viruses and Viroids. Springer Nature link. <https://link.springer.com/book/10.1007/978-3-031-81884-4#page=380>
- [4] BIRTHIA, R., SUBRAMANIAN, S., VILLINGER, J., MUTHOMI, J.W, NARLA, R.D & PAPPU, H.R. (2012). First report of *Tomato yellow ring virus (Tospovirus, Bunyaviridae)* infecting tomato in Kenya. Plant Dis. 96:1384–85.
- [5] Beikzadeh, N., Jafarpour, B., Rouhani, H., Peters, D & Hassani Mehraban, A. (2011). Molecular diagnosis of *Tomato yellow ring virus* (TYRV) On *Alstroemeria* in Khorasan Razavi province, Iran. Iran. Plant Prot. Res. J. Plant Prot., 25, 313–324
- [6] Bananej, K. Shahraeen, N. Ahoonmanesh, A. Lesemann, D.E & Shahreyare, D. (1998). Identification of *tomato spotted wilt virus* from tomato fields in Varamin. Iranian J. Plant Path. Vol: 34, 18-26.
- [7] Bayat, H., Azimi M, H & Bani Hashemian, S.M. (2024). Natural infection of *Hippeastrum hybridum* with *Capsicum chlorosis virus* and *Iris yellow spot virus* in Iran. Iranian Journal of Plant Pathology, vol 59 (1), 49-55. doi:10.22034/IJPP.2024.2016455.434
- [8] Bayat, H., Hassani-Mehraban, A., Safaie, N & Shamsbakhsh, M. (2018). Partial biological and molecular characterization of various tospoviruses from Markazi province. Iranian Journal of Plant Pathology. Vol 53(4), 431-447.
- [9] Bayat, H., Shamsbakhsh, M., Mehraban, A & Safaei, N. (2016). Incidence of *Capsicum chlorosis virus* on black-eyed Susan plants (*Rudbeckia* sp.). Proceedings of 22nd Iranian Plant Protection Congress, 27-30 August 2016. College of Agriculture and Natural Resources, University of Tehran, Karaj, Iran.
- [10] BIRTHIA, R., SUBRAMANIAN, S., VILLINGER, J., MUTHOMI, J. W., NARLA, R.D & PAPPU, H.R. (2012). First Report of *Tomato yellow ring virus (Tospovirus, Bunyaviridae)* Infecting Tomato in Kenya. Plant Disease, Vol. 96, No. 9. <https://doi.org/10.1094/PDIS-05-12-0462-PDN>
- [11] Chao, H.Y., Dietzgen, R. G., Thomas, J. E & Geering, A.D. W. (2025). New molecular diagnostic and surveillance tools for orthotospoviruses and their thrips vectors.



- Phytopathology Research,7:45.
<https://doi.org/10.1186/s42483-025-00336-2>
- [12] Caruso, A. G., Ragona, A., Agrò, G., Bertacca, S., Yahyaoui, E., Galipienso, L., Rubio, L.S. Panno, S and S. Davino, S (2024). Rapid detection of *tomato spotted wilt virus* by real-time RT-LAMP and in-field application. Journal of Plant Pathology. 106:697-712.<https://doi.org/10.1007/s42161-024-01613-3>.
- [13] Diaz-Montano, J., Fuchs, M., Nault, B. A., Fail, J. & Shelton, A.M. (2011) Onion thrips (*Thysanoptera: Thripidae*): a global pest of increasing concern in onion. J. Econ. Entomol. 104, 1–13.
- [14] EPPO. (2020). European and Mediterranean Plant Protection Organization. Tospoviruses (Genus Orthotospovirus), EPPO Bulletin, PM 7/139 (1), 50, 217–240.
- [15] EPPO. (2023a). European and Mediterranean Plant Protection Organization. <https://www.eppo.int>. Accessed 10 October 2023.
- [16] EPPO Global Database. (2013). *Melon yellow spot virus*: an emerging disease of cucurbits in Asia. No. 02 Article: 2013/039.
- [17] ESFA Panel on plant health-PLH (2012). Scientific opinion on the pest categorization of the tospoviruses. EFSA Journal. vol 10 (7),2772. <https://doi.org/10.2903/j.efsa.2012.2772>
- [18] EFSA Panel on Plant Health (PLH) (2020). Scientific opinion. Pest categorization of *Capsicum chlorosis virus*. EFSA Journal 2022;20(6):7337 doi: 10.2903/j.efsa.2022.7337.
- [19] Farkhoond, S., Hosseini S.A., Salari K.H & Amini Fard, M.H. (2018). Detection and phylogenetic analysis of saffron and tomato isolates of *tomato spotted wilt virus* from South Khorasan. Iranian Journal of Plant Protection Science. vol 48, No 2, 217-227. doi: 10.22059/ijpps.2017.229867.100677
- [20] Farahbakhsh, F., Majidian, N & Massah.A. (2016). Detection of tospoviruses infecting ornamental plants in Isfahan and Markazi provinces. Proceedings of 22nd Iranian Plant Protection Congress, 27-30 August 2016. College of Agriculture and Natural Resources, University of Tehran, Karaj, IRAN
- [21] Feng, Mingfeng., Chen, M., Yulong Yuan, Qin Hai Liu, Ruixiang Cheng, Tongqing Yang, Luyao Li, Rong Guo, Yongxin Dong, Jing Chen, Yawen Yang, Yuling Yan, Hongmin Cui, Dong Jing, Jinrui Kang, Shuxian Chen, Jia Li, Min Zhu, Changjun Huang, Zhongkai Zhang, Richard Kormelink & Xiaorong Taoa. (2023). Interspecies/Intergroup Complementation of Orthotospovirus Replication and Movement through Reverse Genetics Systems. Journal of Virology, vol. 93 (4),1-18. doi: 10.1128/jvi.01809-22
- [22] Ghotbi, T & Shahraeen. N. (2025a). *Iris yellow spot virus*. Page 51 in: Compendium of rose diseases and pests, Third Edition. J. Hammond, R. Jordan and D. Mollov, Eds, American Phytopathological Society, St. Paul, MN.
- [23] Ghotbi, T & Shahraeen. N. (2025b). *Impatiens necrotic spot virus*. Pages 51-51 in: Compendium of rose diseases and pests, Third Edition. J. Hammond, R. Jordan, and D. Mollov, Eds, American Phytopathological Society, St. Paul, MN.
- [24] Ghotbi, T & Shahraeen. N. (2025c). *Tomato spotted wilt virus*. Pages 72-73 in: Compendium of rose diseases and pests, Third Edition. J. Hammond, R. Jordan and D. Mollov, Eds, American Phytopathological Society, St. Paul, MN.
- [25] Ghotbi, T & Shahraeen. N. (2025d). *Tomato yellow ring virus*. Pages 73 in: Compendium of rose diseases and pests, Third Edition J. Hammond, R. Jordan and D. Mollov, Eds, American Phytopathological Society, St. Paul, MN.
- [26] Ghotbi, T. & Shahraeen, N. (2023). Molecular and biological detection of *impatiens necrotic spot virus* (INSV) isolate from ornamental plants in Iran. Journal of Horticultural Sciences, 18(2).2023 <https://doi.org/10.24154/jhs.v18i2.1827>
- [27] Ghotbi, T & Shahraeen N. (2022). Diagnosis of important virus diseases of ornamental Anthurium in screen-houses in Tehran province. Int J Med Phar Sci. Vol 12 (5):1-6.
- [28] Ghotbi, T., Shahraeen, N. & Winter. S. (2005). Occurrence of tospoviruses in ornamental and weed species in Markazi and Tehran provinces in Iran. Plant Dis. 89,425-429.
- [29] Ghotbi, T & Shahraeen, N. (2005). Report on the occurrence of three tospoviruses in onions (*Allium cepa*) from Markazi province. Iranian Journal of Plant Pathology. vol 41(1)142-143, Eng. 57-58.
- [30] Ghotbi, T., Gillasian, E. & Shahraeen, N. (2003). Detection of tospoviruses in individual thrips by ELISA from ornamental plants in Tehran and Markazi provinces. Iran J. Appl. Ento. and Phythopath. Vol:70 (2), 138-139.
- [31] Ghotbi, T & Shahraeen. N. (2020). Report of important viruses infecting ornamental Anthurium in Tehran province of Iran. XI International Scientific Agricultural Symposium Agrosympo. October 08-09, 2020, Bosnia and Herzegovina. p 239.
- [32] Ghotbi T., Shahraeen, N., Safarnejad, M., Nazerian, E & Vahid Hosseinnia, S. (2020). Status of two damaging Orthotospovirus TSWV and INSV on lettuce production in Iran. XI International Scientific Agricultural Symposium Agrosympo. October 08-09, 2020, Bosnia and Herzegovina. p 238.

- [33] Ghotbi, T & Shahraeen N. (2010). Report of three ornamental hosts of *Tomato yellow ring tospovirus* (TYRV) from Iran. 19th Iranian Plant Protection Congress, 31 July-3 August-IRIPP, Tehran.
- [34] Ghotbi, T., Shahraeen, N & Vahid Hossein, S. (2010). Two new host of *Impatiens necrotic spot virus* (INSV) from Iran: *Philodendron* spp. and *Pilea cadieri*. 19th Iranian plant protection congress, 31 July-3 August- IRIPP, Tehran. Iran.
- [35] Ghotbi, T & Shahraeen N. (2010). Incidence and distribution of viruses infecting propagated ornamentals in Northern Iran. International Research Journal of Microbiology (IRJM), Vol. 3(11) pp. 373-381.
- [36] Gholnaraghi, A., Shahraeen N. & Nguyen, H.D. (2018). Characterization and genetic structure of a tospovirus causing chlorotic ring spot and chlorosis disease on Peanuts; Comparison with Iranian and Polish population of *Tomato yellow fruit ring virus*. Plant Disease, 102 (8) 1509-1519. (<https://doi.org/10.1094/PDIS-09-17-1350-RE>).
- [37] Golnaraghi, A.R., Pourrahim, R., Farzadfar, Sh. Ohshima Kazusato., Shahraeen, N & Ahoonmanesh, A. (2007a). Incidence and distribution of *tomato fruit ring virus* on soybean in Iran. Plant Pathology Journal. 6 (1) 14-21.
- [38] Golnaraghi, A.R., Pourrahim, R., Farzadfar, S & Ahoonmanesh, A. (2007b) Identification and partial characterization of a tospovirus causing leaf and stem necrosis on potato. Plant Pathol. J. 6, 227-234.
- [39] Golnaraghi, A.R., Pourrahim, R. Shahraeen, N & Farzadfar, Sh. (2002c). First report of *Groundnut bud necrosis virus* from Iran. Plant Disease 86 (5)-561. doi: 10.1094/PDIS.2002.86.5.561B
- [40] Golnaraghi, A.R., Shahraeen, N., Pourrahim, R. & Farzadfar, Sh. (2002a). Comparative host reactions of three *Tomato spotted wilt Tospovirus* isolates from soybean in Iran. Proceeding of the 1st Iranian Congress on Virology, February 19-21, Tehran, Iran, p119.
- [41] Golnaraghi, A.R., Shahraeen, N. & Pourrahim, R. (2000). Detection of *tomato spotted wilt virus* (TSWV), *Bean yellow mosaic virus* (BYMV) and *peanut mottle virus* (PeMotV) from soybean fields in Iran. 14th Iranian Plant Protection Congress, Sept. 2000, Isfahan, Iran.
- [42] Golnaraghi, A.R., Shahraeen, N., Pourrahim, R., Ghorbani, Sh. & Farzadfar, Sh. (2001b). First Report of *Tomato spotted wilt virus* on Soybeans in Iran. Plant Diseases 85 (12) 1290.
- [43] Golnaraghi, A.R., Shahraeen, N., Pourrahim, R., Ghorbani, Sh. & Farzadfar, Sh. (2001a). First report of a *Tospovirus* infection of peanuts in Iran. Plant Disease 85 (12) 1286.
- [44] Ghorbani, S.G.M., Shahraeen, N. & Elahinia, A. (2008). Serodiagnosis of cowpea (*Vigna unguiculata*) viruses in Guilan province, Iran. Iranian Journal of Virology Vol :1 (3) 28-32.
- [45] Groves, C., German, T., Dasgupta, R., Mueller, D & Smith, D.L(2016). Seed transmission of *Soybean vein necrosis virus*: The first tospovirus implicated in seed transmission. PLoS ONE 11(1). doi: 10.1371/journal.pone.0147342.
- [46] Hassani-Mehraban A, Westenberg. M, Verhoeven J.T.J, van de Vossen B.T.L.H, Kormelink R & Roenhorst J.W. (2016) Generic RT-PCR tests for detection and identification of tospoviruses. J Virol Methods. 233:89-96. doi: 10.1016/j.jviromet.03.015.
- [47] Hassani-Mehraban A, Dullemans AM, Verhoeven J.T.J, Roenhorst J.W, Peters D & van der Vlugt R.A.A et al. (2019) *Alstroemeria yellow spot virus* (AYSV): a new orthotospovirus species within a growing Eurasian clade. Archives of Virology **164**, 117-126.
- [48] Jafarpour, B., Sabokkhiz, M.A & Rastegar, M.F. (2010). First report of CSNV in Iran and occurrence of some viral diseases of ornamental plants in Mashhad region, Iran. PETRIA 20 (2), 67-633.
- [49] Jingwei Li, Min-Rui Wang, Zhibo Hamborg, Dag-Ragnar Blystad, Gayle Volk, Jean Carlos Bettoni & QiaoChun Wang. (2025). Cryotherapy-based methods for virus and viroid eradication in horticultural plants. Plant Disease. (May, 2025-accepted) <https://doi.org/10.1094/PDIS-02-25-0384-FE>.
- [50] Karavina, C., Ibaba, J.D. & Gubba, A. (2020) High-throughput sequencing of virus-infected *Cucurbita pepo* samples revealed the presence of Zucchini shoestring virus in Zimbabwe. BMC Res Notes **13**, 53. <https://doi.org/10.1186/s13104-020-4927-3>
- [51] Karavina, C. (2025). Iris Yellow Spot Orthotospovirus. In: Amaresan, N., Kumar, K. (eds) Compendium of Phytopathogenic Microbes in Agro-Ecology, Springer, Cham. https://doi.org/10.1007/978-3-031-81884-4_12.
- [52] Karavina, C. (2022). *Tomato yellow ring orthotospovirus* (*Tomato yellow ring virus*). <https://www.CABI.org/isc/datasheet/119164>.
- [53] Karthikeyan, G., Nagendran, K., Kumari, S., Priyanka, R., Senthilraja, C & Haokip, B.D. (2021). Virus diseases of ornamental plants. Book chapter; tospovirus diseases of ornamental plants: characterization, identification, diagnosis and management. pp 1-21. Springer Nature Link.
- [54] Mandal, B.B., Gawande, S.J., P. Renukadevi, S.K. Holkar, M. Krishnareddy, K.S. Ravi, & Jain, R.K. (2017). The Occurrence, Biology, Serology and Molecular Biology of Tospoviruses in Indian Agriculture. B. Mandal et al. (eds.), A Century of Plant Virology in India, Chapter 20, (pp.445-474). <https://doi.org/10.1007/978-981-10-5672-7-20>



- [55] Majidian, N., Massah, A & Farahbakhsh, F. (2016). Molecular comparison of *Tomato yellow ring virus* on the *Alstroemeria* plants from Isfahan and Chaharmahal-o-Bakhtiari provinces. Proceedings of 22nd Iranian Plant Protection Congress, 27-30 August 2016. College of Agriculture and Natural Resources, University of Tehran, Karaj, IRAN
- [56] Mehraban, A.H. & Shahraeen, N. (2000). Identification of *tomato spotted wilt virus* on *Salvia* in Tehran province. The second Horticulture science congress of Iran. Sept. 2000. Karaj, Iran.
- [57] Mehraban, M. Westenberg, J.T.J., Verhoeven, B. L.H., van de Vossen, R., Kormelink, R & Roenhorst, J.W. (2016). Generic RT-PCR tests for detection and identification of tospoviruses. *Journal of Virological Methods*. Vol 233, 89-96.
- [58] Rajabian Miri, M., Shayanmehr, M. & Mirab-balou, M. (2018) Population fluctuations of thrips (Thysanoptera) and their relationship to the phenology of rice in Babolsar city (Mazandaran Province, Iran). *Journal of Insect Biodiversity and Systematics*, 4 (1), 47–55.
- [59] Mirab-balou, M., Modarres, S. S.N. & Nourollahi, K. (2015). Thrips Pests on Ornamental Plants in Mahallat, Markazi Province, Iran. *Journal of Ornamental Plants*, Volume 5, Number 4: 223-229.
- [60] Mirab-balou, M. (2018). An update checklist of Iranian thrips (INSECTA: THYSANOPTERA). *Far Eastern Entomologist*. No 361, 12-36. <https://doi.org/10.25221/fee.361.2>
- [61] Mortazavi, N & Aleosfoor, M. (2015). Efficiency of *Thrips tabaci* and *Frankliniella occidentalis* populations in transmission of *Tomato yellow ring virus*. *Zoology and Ecology*, 25(3):241-246. doi: 10.1080/21658005.2015.1044165
- [62] Mortazavi, N., Aleosfoor, M & Minaei, K. (2013). Transmission of cineraria isolate of *tomato yellow ring virus* by *Frankliniella occidentalis* and *Thrips tabaci* (Thysanoptera, Thripidae). *Linzer Biologische Beitrage Journal*, 45(2):2011-2018. https://www.zobodat.at/pdf/LBB_0045_2_2011-2018.
- [63] Nowak Zarzynska, A., Jaroszewska, B.H., Korbecka-Glinka, G., Przybys, M & Borodynko-Filas, N. (2018). A multiplex RT-PCR assay for simultaneous detection of *Tomato spotted wilt virus* and *Tomato yellow ring virus* in tomato plants. *Can. J. Plant Pathol.*, 2018 Vol. 40, No. 4, 580–586, <https://doi.org/10.1080/07060661.2018.1503195>
- [64] Nowak Zarzynska-A., Rymelska N., Borodynko N & Hasiow-Jaroszewska B. (2016). The occurrence of *Tomato yellow ring virus* on tomato in Poland. *Plant Dis.* 100:234. 10.1094/PDIS-05-15-0521
- [65] Oliver, J.E. & Whitfield, A.E. (2016) The genus Tospovirus: emerging bunyaviruses that threaten food security. *Annual Review of Virology* 3, 101–124.
- [66] Prins, M & Goldbach, R. (1998). The emerging problem of tospovirus infection and nonconventional methods of control. *Trends in Microbiology*. Volume 6, Issue 1, pages 31-35.
- [67] Pourrahim, R., Farzadfar, Sh., Moini, A.A., Shahraeen, N. & Ahoonmanesh, A. (2001b). First report of *Tomato spotted wilt virus* (TSWV) on potatoes in Iran. *Plant Disease*. 85 (4) 442.
- [68] Pourrahim, R.; Golnaraghi, A.; Farzadfar, S & Ohshima, K. (2012). Partial biological and molecular characterization of *tomato yellow fruit ring virus* isolates from potato. *Plant Pathol. J.* 2012, 28, 390–400.
- [69] Pourrahim, R., Farzadfar, Sh., Golnaraghi, A. R. & Shahraeen, N. (2002b). Incidence of vector and weed reservoir of *Tomato spotted wilt Tospovirus* on seed potato fields. Proceeding of the 15th Iranian Plant Protection Congress, September 5-8, Razi University, Kermanshah, Iran.
- [70] Pappu, H. R., Jones, R. A. C. & Jain, R. K. (2009). Global status of tospovirus epidemics in diverse cropping systems: Successes achieved and challenges ahead. *Virus Research*, 141(2), 219–236.
- [71] Peters, D. (1998). An updated list of plant species susceptible to tospoviruses. Fourth international symposium on tospovirus and Thrips in floral and vegetable crops, 2-6 May, Wageningen, pp. 107-110
- [72] Rasoulpour, R. & Izadpanah, K. (2007). Characterization of cineraria strain of *Tomato yellow ring virus* from Iran. *Australasian Plant Pathology*, 2007, Vol. 36, No. 3, 286-294. doi: 10.1071/AP07023
- [68] Rotenberg, D., L Jacobson, A., Schneeweis, D.J. and, Whitfield, A.E. (2015). Thrips transmission of tospoviruses. *Curr Opin Virol*. Vol. 15, pp80-89. doi 10.1016/j. Coviro.2015.08.003.
- [73] Salehzadeh, M & Afsharifard, A. (2024). The first report of *melon yellow spot virus* Orthotospovirus melolavi occurrence in Iran. *J. Crop Prot.*, 13 (4): 411-416.
- [74] Seepiban, C., Charoenvilai, S., Kumpoosiri, M., Bhunchoth, A., Chatchawankanphanich, O & Gajanandana, O. (2015). Development of a protocol for the identification of tospoviruses and thrips species in individual thrips *Journal of Virological Methods*. Volume 222, pages 206-213. <https://doi.org/10.1016/j.jviromet.2015.06.017>.
- [75] Scholthof, Karen-B. G., Scott, A., Czosnek, Henryk., Palukaitis, P., Jacquot, P., Thomas Hohn., Hohn, B., Saunders, K., Candresse, T., Ahlquist, P., Hemenway, C. & Foster, G. D. (2011). Top 10 plant



- viruses in molecular plant pathology. *Molecular Plant Pathology* (2011) 12(9), 938–954. doi: 10.1111/J.1364-3703. BSPP and Blackwell Publ. Ltd938
- [76] Shahraeen, N., Ghotbi, T & Mehraban, A.H. (2002) Occurrence of *Impatiens necrotic spot virus* in ornamentals in Mahallat and Tehran provinces in Iran. (2002). *Plant Dis.* 86:(6) 694.
- [77] Shahraeen, N & Ghotbi, T. (2010). Investigation on status of *Tomato yellow ring virus* as a new emerging threat to cultivated crops in Iran. 19th Iranian Plant Protection Congress, 31 July-3 August- IRIPP, Tehran.
- [78] Shahraeen, N & Ghotbi, T. (2003). Natural occurrence of different tospoviruses infecting ornamentals and other agricultural crops in Iran. 8th International Congress of Plant Pathology (ICPP), 2-7 February 2003, Christchurch, New Zealand.
- [79] Shahraeen, N., Farzadfar, Sh., Kamran, R. & Naseri, B. (2001). Serology and immunoelectron microscopical studies of three viruses isolated from *Brassica napus* (canola) crop from Iran. First Iranian Congress of Virology, Tehran Feb. 19-21, Iran page 180. (abstract in English).
- [80] Soler, S., Diez M.J & Nuez F. (1988). Effect of temperature regime and growth stage interaction on pattern of virus presence in TSWV resistant accessions of *Capsicum chinense*. *Plant Disease.* 1998;82: 1199-1204. doi: 10.1094/PDIS.82.11.1199.
- [81] Tabassum, A. (2014) Identification of resistant sources to Groundnut bud necrosis disease (GBND) in groundnut (*Arachis hypogaea* L.) genotypes. Master's thesis, Acharya N.G. Ranga Agricultural University.
- [82] Turina, M., Tavella, L & Ciuffo, M. (2012). Tospoviruses in the Mediterranean area. *Advances in Virus Research*, **84**, 403–437.
- [83] Ullman, D.E., Sherwood, J.L. & German, T.L. (1997) Thrips as vectors of plant pathogens. T Lewis (Eds) *Thrips as Crop Pests* CAB International Wallingford, UK 539–565
- [84] Winter, S. Shahraeen, N., Koerbler, M & Lesemann, D.E. (2006). Characterization of Tomato fruit yellow ring virus: a new tospovirus species infecting tomato in Iran. *Plant Pathology.* 55, 287.
- [85] Winter, S., koerbler, M., Shahraeen, N., Katul, L., & Lesemann, D. E. (2002). Characterization of a new tospovirus species infecting tomato in Iran. First Joint Conference of the International Working Groups on Legume and Vegetable Viruses (IWGLVV). August 4-9-2002, Bonn, Germany.
- [86] Zarzynska-Nowak, A., Budzy N. D., Taberska, A., Jędrzejczak, N., Minicka, J., Borodynko-Filas, N & Hasiów-Jaroszewska, B. (2022). Occurrence, genetic variability of *Tomato yellow ring* orthotospovirus population and the development of reverse transcription loop-mediated isothermal amplification assay for its rapid detection. *Viruses* 2022, 14, 1405. <https://doi.org/10.3390/v140714>.
- [87] Zhou, J., Kantartzi, S.K., Wen, R.H., Newman, M, Hajimorad, M.R, et al. (2011). Molecular characterization of a new tospovirus infecting soybean. *Virus Genes* 43:289–95.