CAPS Datasheets provide pest-specific information to support planning and completing early detection surveys.

Pospiviroid Potato spindle tuber viroid

Scientific Name
Potato spindle tuber viroid

Synonyms:
Potato spindle tuber virus
Tomato bunchy top virus
Potato gothic virus

Common name
Disease
Spindle tuber of potato

Type of Pest
Viroid

Figure 1: *Potato spindle tuber viroid*: reduced size and yield of potato tubers (healthy tubers on right). (Source: European and Mediterranean Plant Protection Organization, Bugwood.org)

Taxonomic Position
Class: Viroids, **Order:** Unassigned, **Family:** Pospiviroidae

Pest Recognition
This section describes characteristics of the organism and symptoms that will help surveyors recognize possible infestations/infections in the field, select survey sites, and collect symptomatic material. For morphological descriptions, see the Identification/Diagnostic resources on the AMPS pest page on the CAPS Resource and Collaboration website.

Pest Description
There are no visible morphological or behavioral characteristics for this organism in the field.

Symptoms
Surveyors should look for visual symptoms of potato spindle tuber viroid (PSTVd) infection in the field. The natural hosts of PSTVd are primarily solanaceous species, including economically important ones such as potato, tomato, and pepper. Symptoms of infection vary depending on the host species and variety, viroid strain, and environmental conditions (Hadidi et al., 2017; Owens and Verhoeven, 2009; Slack, 2001; Zitter, 2014).

Potato: PSTVd infection often stunts plant growth and reduces yield (Fig. 1, 2). Yield reduction is caused by decreases in both tuber number and tuber weight (LeClerg et al., 1944, 1946; Pfannenstiel and Slack, 1980), and yield progressively declines as disease incidence increases (LeClerg et al., 1944).

Tubers can become abnormally elongated and spindly with rougher skin, cracks, or numerous and prominent eyes. Plant emergence from infected tubers is slower, and infected plants may remain upright but look stunted and have small, rough leaves (Slack, 2001). Yield losses may vary depending on viroid strain and incidence.

Figure 2: Typical aerial symptoms of *Potato spindle tuber viroid* on potato cv. Kennebec (center); healthy plants (left and right). (Source: R.P. Singh, Bugwood.org)

Tomato: Infected tomato plants are stunted, with apical leaf proliferation and mottled, rough, discolored, and downturned leaves (Fig. 3). Affected plants may partially recover (Owens and Verhoeven, 2009; Zitter, 2014).

Infection causes fruit stunting and may reduce yields (Kryczyński et al., 1988). Fruits harvested from infected plants are smaller than healthy ones and unevenly colored; seeds collected from infected plants germinate normally and their viability is not affected (Kryczyński et al., 1988).

Pepper: Peppers show only a slight distortion or wavy margin on the leaves near the top of the plants (Lebas et al., 2005). Studies on artificially inoculated peppers in the Netherlands resulted in more severe symptoms, including a reduction in maximum fruit size, but yield losses were not quantified (Verhoeven et al., 2009b).

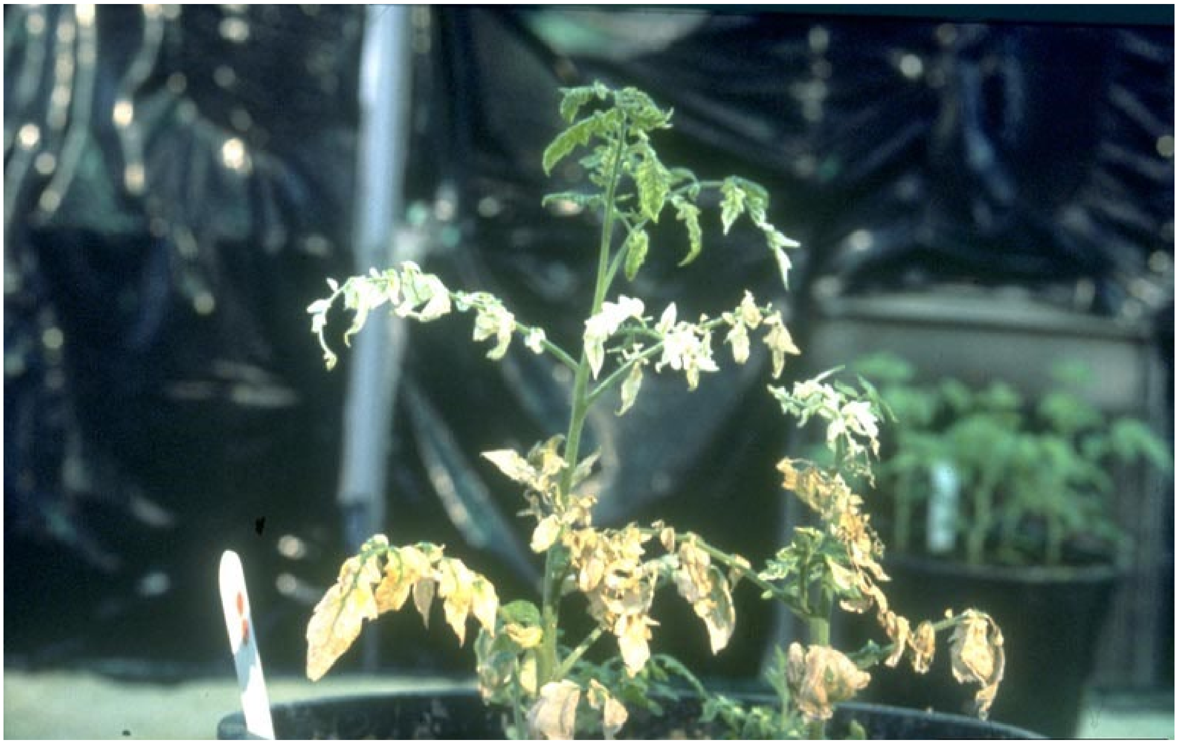

Figure 3: *Potato spindle tuber viroid* symptoms in a pot-grown tomato plant (Source: Central Science Laboratory, Harpenden, British Crown, Bugwood.org)

Easily Mistaken Species

PSTVd cannot be visually distinguished from other plant pathogens or abiotic symptoms. Molecular identification is necessary to confirm the presence of PSTVd. Symptoms can easily be confused with nutrient imbalances, spray damage, or other plant diseases (Mackie et al., 2002).

Numerous viruses are present in the United States and can infect tomato, potato, and/or pepper. Some of these viruses include: pepper mild mottle virus (PMMoV), tobacco mosaic virus (TMV), tomato mosaic virus (ToMV), tomato mottle mosaic virus (ToMMV), tomato spotted wilt virus (TSWV), potato virus Y (PVY), and potato leafroll virus (PLRV) (Jones, 2007; Jones et al., 2014; Pernezny et al., 2003; Stevenson et al., 2001).

Biology and Ecology

Potato spindle tuber viroid is a small, highly structured, covalently closed circular RNA plant pathogen (Sanger et al., 1976). It was the first viroid disease to be recognized and studied (Diener, 2003; Hadidi et al., 2017; Martin, 1922). Viroid infections are systemic, so viroids will be found in all tissues of infected hosts (Hadidi et al., 2003). Infection can result in yield loss and crop quality reduction (Hadidi et al., 2017). Different strains of PSTVd cause symptoms that range from asymptomatic to lethal, depending on the host (Diener, 1979; Singh et al., 1970; Slack, 2001).

PSTVd can be spread through vegetative propagation, contact with contaminated materials, infected seed and pollen, and, under specific conditions, insect vectors

(Hadidi et al., 2003; Hadidi et al., 2017; Owens and Verhoeven, 2009). The literature does not offer conclusive evidence of seed transmission of PSTVd in all hosts. Seed transmission is not well understood but is affected by viroid strain, host cultivar, plant growth stage at the time of infection, and environmental conditions (EUPHRESCO, 2011; Faggioli et al., 2015; Matsushita and Tsuda, 2016). PSTVd can be borne internally in the seed and can contaminate the surface of the seed coat. Surface disinfection of seeds does not prevent seed transmission (EUPHRESCO, 2011; Matsushita et al., 2011).

Known Hosts

PSTVd is known to infect plants in the family Solanaceae, and the most economically important hosts are potato (*Solanum tuberosum*) and tomato (*Lycopersicon esculentum*) (Diener and Raymer, 1967; Puchta et al., 1990; Slack, 2001). In addition, numerous other solanaceous plants are natural hosts of this viroid. The experimental host range of PSTVd is wide and encompasses at least 9 more families.

The host list below includes cultivated and wild plants that 1) are infected or infested by the pest under natural conditions, 2) are frequently described as major, primary, or preferred hosts, and 3) have primary evidence for feeding and damage documented in the literature. Plants are highlighted in bold if they are commercially produced and the pest causes economically significant damage.

Preferred hosts

Solanaceae: *Brugmansia sanguinea*, (red angel's trumpet), *Brugmansia* spp. (angel's trumpet), *Brugmansia suaveolens* (white angel trumpet)*, *Brugmansia* x *candida*, (double white angel's trumpet)*, *Brugmansia* x *flava* (angel's trumpet), *Calibrachoa* spp. (million bells)*, ***Capsicum annuum* (pepper)***, *Cestrum elegans* (purple cestrum), *Cestrum elegans Smithii* (purple cestrum), *Cestrum fasciculatum Newellii* (early jessamine)*, *Cestrum* spp. (jessamine)*, *Datura* spp. (devil's trumpets)*, *Lycianthes rantonnetti* (blue potato bush), ***Lycopersicon esculentum* (tomato)***, *Petunia* x *hybrida* (petunia)*, *Physalis peruviana* (cape gooseberry)*, *Solanum jasminoides* (potato vine), *Solanum muricatum* (sweet cucumber), *Solanum pseudocapsicum* (Jerusalem cherry)*, ***Solanum tuberosum* (potato)***, *Streptosolen jamesonii* (marmalade bush);

Asteraceae: *Argyranthemum frutescens* (paris daisy)*, *Chrysanthemum* spp. (chrysanthemum)*, *Dahlia × hybrid* (dahlia)* (Chitambar, 2015; Di Serio, 2007; Lebas et al., 2005; Lemmetty et al., 2011; Luigi et al., 2011; Matousek et al., 2014; Mertelik et al., 2010; Shamloul et al., 1997; Tsushima et al., 2011; Verhoeven, 2010; Verhoeven et al., 2008; Verhoeven et al., 2010; Verhoeven et al., 2009b).

Reported woody hosts include: **Lauraceae**: *Persea americana* (avocado)* and **Euphorbiaceae**: *Hevea brasiliensis* (rubber) (Kumar et al., 2015; Ramachandran et al., 2000).

* Host with known U.S. distribution.

Pest Importance

PSTVd has caused significant damage to potato crops worldwide for several decades (Hadidi et al., 2017; Martin, 1922). PSTVd remains an important pathogen of potato, tomato, peppers, and an increasing number of ornamental plants. In the United States, PSTVd is no longer observed in potato production thanks to a concerted effort to eradicate it from the production systems (Hadidi et al., 2017). Robust state seed certification programs and requirements to grow commercial potatoes from certified seed have prevented its reintroduction (Frost et al., 2013; Potatoes USA, 2018; Sun et al., 2004). In the United States, PSTVd has also been occasionally reported in greenhouses, where conditions are favorable for spread of the viroid (Chitambar, 2015; Ling et al., 2013; Ling and Sfetcu, 2010).

Potato plants infected with PSTVd show significant reduction in yield. Under experimental conditions, PSTVd can cause yield reduction in potato that range between 17 and 24 percent for plants infected by mild strains and up to 82 percent in plants infected by severe strains (Singh et al., 1971; Verhoeven et al., 2004). In infected tomato plants, yields are reduced between 40 and 45 percent depending on the cultivar (Owens and Verhoeven, 2009; Zitter, 2014). This viroid can also infect pepper and has the potential to become problematic to pepper cultivation (Lebas et al., 2005; Verhoeven et al., 2009b).

PSTVd is listed as a harmful organism in Georgia, Israel, Japan, Mexico, Turkey, and Ukraine (PExD, 2022). There may be trade implications with these countries if this pest becomes established in the United States.

Known Vectors (or associated insects)

PSTVd has been transmitted by insect vectors under experimental conditions. An old study reports aphid transmission (Folsom, 1923), but it has been questioned given the ease of mechanical transmission (Bokx and Piron, 1981), and no reports of natural spread of PSTVd by vectors were found. One report indicates that there are no natural vectors of PSTVd among the aphids (Syller and Marczewski, 2001). Other studies have found that some insects transmitted PSTVd alone while others require the presence of a helper virus like Potato leafroll virus (PLRV) (Querci et al., 1995; Salazar et al., 1995). The aphid *Macrosiphum euphorbiae* was reported to transmit PSTVd under experimental conditions at low rates in a non-persistent manner, and no transmission by *Myzus persicae* or *Aulacorthum solani* was reported (Bokx and Piron, 1981). In a later study, *Myzus persicae* was shown to transmit PSTVd but only when the source plant is infected with both PSTVd and PLRV (Querci et al., 1997; Salazar et al., 1995; Syller et al., 1997). In potatoes with high levels of resistance to PLRV, it was found that PSTVd was present in 23 percent of the aphid inoculated plants, indicating that PLRV can act as a carrier of PSTVd even when PLRV infection does not occur (Syller and Marczewski, 2001). Aphid transmission of PLRV is persistent and non-propagative (Taliansky et al., 2003), and given that PSTVd is enclosed by PLRV (Querci et al., 1997), its transmission can also be characterized as persistent and non-propagative. Transmission of PSTVd did not occur when the source plant was infected with PSTVd only.

The significance of aphid transmission of PSTVd in the field is not known. In epidemiological surveys carried out in China, a strong correlation between PSTVd infection and PLRV infection was observed. Most (but not all) PSTVd infected plants were also infected with PLRV indicating that PLRV can facilitate the spread of PSTVd in the field (Querci et al., 1997).

Known Distribution

PSTVd has been reported as present in the following countries: **Africa**: Egypt, Ghana, Nigeria; **Americas**: Costa Rica, Dominican Republic, Peru; **Asia**: Afghanistan, Bangladesh, China, India, Iran, Israel, Japan; **Europe**: Austria, Azerbaijan, Belgium, Croatia, Czech Republic, Georgia, Germany, Italy, Malta, Montenegro, Poland, Russia, Slovenia, Spain, Turkey, Ukraine, Belarus; **Oceania**: Australia, New Zealand (Arezou et al., 2008; Badilla et al., 1999; Batuman and Gilbertson, 2013; EPPO GD, 2022; Ling et al., 2014; Luigi et al., 2011; Luigi et al., 2016; Mahfouze et al., 2010; Marn and Pleško, 2011; Matousek et al., 2014; Navarro et al., 2009; Owens et al., 1992; Querci et al., 1995; Ryazantsev and Zavriev, 2009; Singh et al., 1993; Tsutsumi et al., 2010; Verhoeven et al., 2009a; Verhoeven et al., 2009b; Visage et al., 2013; Ward et al., 2010).

Status of infestation in the United States (November, 2022)

In 2004, PSTVd was declared eradicated from all seed and food potato production systems in the United States (Frost et al., 2013; Sun et al., 2004). Robust state seed certification programs and requirements to grow commercial potatoes from certified seed have prevented its reintroduction (Frost et al., 2013; Potatoes USA, 2018; Sun et al., 2004). PSTVd has been occasionally reported in greenhouse-grown tomatoes. In April of 2009, PSTVd caused significant yield losses in tomato plants in a commercial greenhouse in California and was also found in neighboring greenhouses the following spring (Ling and Sfetcu, 2010). In the spring of 2012, PSTVd caused severe disease on tomato plants in a research greenhouse in North Carolina (Ling et al., 2013). In 2013, PSTVd was detected on infected Cestrum [*C. fasciculatum* Newellii, *C. elegans* Smithii, and *C. elegans* (Brongn. ex Neumann) Schltdl.] nursery stock that was shipped from California to Illinois under federal permit. In all cases, the infected plants were destroyed and the pathogen was eradicated from the affected greenhouses (Chitambar, 2015; Ling et al., 2013; Ling and Sfetcu, 2010).

Pathway

Pathways of introduction include movement of contaminated or infected seed and pollen (Hammond and Owens, 2006; Lebas et al., 2005; Matsushita and Tsuda, 2016; Singh et al., 1992), vegetative propagation of infected plants, which is particularly important in hosts that have asymptomatic infections (Di Serio, 2007; Hammond and Owens, 2006; Owens and Verhoeven, 2009; Singh et al., 1993), and possibly aphid transmission (Querci et al., 1997; Syller et al., 1997).

Local spread via mechanical transmission occurs through crop handling (Matsushita et al., 2008; Verhoeven et al., 2004), often along rows (Mackie et al., 2002; Matsushita et al., 2008; Verhoeven et al., 2004). Mackie et al. (2015) demonstrated PSTVd-infected tomato sap remained infective up to 24 hours on surfaces, although infectivity decreased as the sap dried.

Use the PPQ databases and/or manuals listed below to determine 1) if host plants or material are allowed to enter the United States from countries where the organism is present and 2) what phytosanitary measures (e.g., inspections, phytosanitary certificates, post entry quarantines, mandatory treatments) are in use. These manuals are updated regularly.

Agricultural Commodity Import Requirements(ACIR) database: ACIR provides a single source to search for and retrieve entry requirements for imported commodities. https://acir.aphis.usda.gov/s/

Plants for Planting Manual: This manual is a resource for regulating imported plants or plant parts for propagation, including buds, bulbs, corms, cuttings, layers, pollen, scions, seeds, tissue, tubers, and like structures. https://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/plants_for_planting.pdf

Treatment Manual: This manual provides information about treatments applied to imported and domestic commodities to limit the movement of agricultural pests into or within the United States. https://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/treatment.pdf

Potential Distribution within the United States

We considered confirmed reports of PSTVd outbreaks in field production areas when determining Plant Hardiness Zones (PHZ) at risk within the United States (Takeuchi et al., 2018). PSTVd was reported in tomato fields in Ghana and the Dominican Republic (Batuman et al., 2019; Ling et al., 2014), indicating that outbreaks in field-grown tomatoes or peppers occur in PHZs 11 to 14. However, PSTVd has been reported in greenhouses (e.g., Chitambar, 2015; Ling et al., 2013; Ling and Sfetcu, 2010), which shows these pests may be found in controlled environments beyond their natural climatic boundaries.

Potato, tomato, and pepper, which are all high value commodities in U.S. agriculture, are all susceptible to PSTVd infection and subsequent yield loss. In 2019, U.S. farmers produced 25 million tons of potatoes (worth $4 billion), 13.4 million tons of fresh tomatoes (worth $963 million), 740,000 tons of processing tomatoes (worth $1.6 billion) 92,064 tons of chili peppers (worth $63 million), and 679,504 tons of bell peppers (worth $557 million), (NASS, 2020).

In 2019, potatoes were produced commercially in more than 20 states, with Idaho and Washington accounting for 58% of total crop production (NASS, 2020). Florida is the top bell pepper producing state, accounting for 42% of the crop value in 2019. The next major pepper producing state, California, accounted for 32% of the crop value. Other major producers include Georgia, Michigan, New Jersey, New York, North Carolina, Ohio, and Pennsylvania (NASS, 2020). For chili peppers, New Mexico was the main producer, accounting for 78% of the crop value. Other producers include California, Arizona, and Texas (NASS, 2020).

California is the top tomato producing state, and it accounted for about 81% of total 2018 U.S. fresh market tomato production (USDA-NASS, 2020). Florida, the other major tomato producing state, accounted for about 8% of the total area harvested of the 2018 U.S. fresh market tomato crop (USDA-NASS, 2020). Other states with significant commercial tomato production include Indiana, Michigan, New Jersey, North Carolina, Ohio, South Carolina, Tennessee, and Virginia (USDA-NASS, 2020).

Survey and Key Diagnostics

Approved Methods for Pest Surveillance:

For the current approved methods and guidance for survey and identification, see Approved Methods for Pest Surveillance (AMPS) pest page on the CAPS Resource and Collaboration website, at https://caps.ceris.purdue.edu/approved-methods.

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Versions

December 2022: Datasheet completed (Version 1)

Reviewer(s)

Tina Gresham, USDA-APHIS-PPQ, Idaho Falls
Dr. Gerhard Steger, Heinrich-Heine-Universität Düsseldorf, Germany