EPPO DATA SHEETS ON QUARANTINE PESTS[1]

Tomato spotted wilt tospovirus

IDENTITY

Name: Tomato spotted wilt tospovirus
Synonyms: Tomato spotted wilt virus
Pineapple yellow spot virus
Taxonomic position: Viruses: *Bunyaviridae*: *Tospovirus*
Common names: TSWV (acronym)
Spotted wilt, bronze leaf (English)
Maladie bronzée (French)
Bronceado (Spanish)
Bronzefleckenkrankheit (German)
Vira-cabeça (Portuguese)
Notes on taxonomy and nomenclature: this virus with isometric particles is the nominate member of genus *Tospovirus*. Impatiens necrotic spot tospovirus (INSV) (formerly serogroup III of TSWV) and watermelon silver mottle tospovirus, both EPPO quarantine pests, have been distinguished from TSWV (OEPP/EPPO, 1999a, b). Various other viruses not occurring in the EPPO region, e.g. groundnut bud necrosis tospovirus (Reddy *et al*., 1992) and chrysanthemum stem necrosis tospovirus (Duarte *et al*., 1995), have also been recognized in the genus more recently. Adam & Kegler (1994) and Mumford *et al*. (1996) provide recent reviews of the group.
EPPO computer code: TMSWXX
EPPO A2 list: no. 290
EU Annex designation: I/B and II/A2 (this designation, dating back to 1992 and not revised since, could be considered to extend at least to INSV).

HOSTS

TSWV is polyphagous on a great number of mostly herbaceous hosts. *Capsicum annuum*, lettuces (*Lactuca sativa*), tobacco (*Nicotiana tabacum*), tomatoes (*Lycopersicon esculentum*) and various ornamental crops are the main hosts. Groundnuts (*Arachis hypogaea*) are hosts to both TSWV itself (causing groundnut ring mosaic) and another tospovirus, groundnut bud necrosis tospovirus. TSWV has one of the widest host ranges of any plant virus. A list of hosts compiled by Edwarson & Christie (1986) includes 271 species in 34 dicotyledon and seven monocotyledon families. Species of *Asteraceae, Fabaceae* and *Solanaceae* account for over 100 of the recorded hosts. Weeds are hosts as well as cultivated plants (Jorda *et al*., 1995), but Van Os *et al*. (1993) doubt whether they play an important role in epidemiology.

In the EPPO region, the principal vegetable and industrial host crops are artichokes (*Cynara scolymus*), aubergines (*Solanum melongena*), *Capsicum annuum*, chicory (*Cichorium* spp.), cucurbits (including cucumber, melon and watermelon), faba beans (*Vicia faba*), lettuces, potatoes (*Solanum tuberosum*), tobacco and tomatoes. Although legumes such as chickpea (*Cicer arietinum*) and lentil (*Lens culinaris*) have been seriously infected in Brazil, there are no records of TSWV in these hosts in the Mediterranean area. The principal ornamental hosts are *Alstroemeria*, *Anemone*, *Antirrhinum*, *Araceae*, *Aster*, *Begonia*, *Bouvardia*, *Calceolaria*, *Callistephus*, *Celosia*, *Cestrum*, *Columnea*, *Cyclamen*, *Dahlia*, *Dendranthema* x *grandiflorum*, *Eustoma*, *Fatsia japonica*, *Gazania*, *Gerbera*, *Gladiolus*, *Hydrangea*, *Impatiens*, *Iris*, *Kalanchoe*, *Leucanthemum*, *Limonium*, *Pelargonium*, *Ranunculus*, *Saintpaulia*, *Senecio cruentus*, *Sinningia*, *Tagetes*, *Verbena*, *Vinca* and *Zinnia*. Weeds such as *Amaranthus* spp., *Conyza bonariensis*, *Galinsoga* spp., *Polygonum lapathifolium*, *Portulaca oleracea*, *Senecio vulgaris*, *Solanum nigrum*, *Sonchus* spp., *Stellaria media*, *Taraxacum officinale*, etc. may be important reservoirs of TSWV.

GEOGRAPHICAL DISTRIBUTION

EPPO region: Algeria, Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Egypt, France (first reported in 1933, but did not reappear till 1987; mainly in the south – Provence, Languedoc-Roussillon), Germany, Greece (including Kriti), Hungary, Ireland, Israel, Italy (including Sicilia), Libya, Lithuania, Malta, Moldova, Morocco (unconfirmed), Netherlands, Norway (under eradication), Poland, Portugal, Romania, Russia (southern, Far East), Slovakia, Spain (including Islas Canarias), Sweden, Switzerland, Tunisia (unconfirmed), Turkey, UK (Channel Islands, England, Scotland), Ukraine, Yugoslavia. Eradicated in Denmark and Finland.

[1] This data sheet constitutes a revision of the earlier EPPO data sheet which appeared in EPPO/CABI (1997c).

Asia: Afghanistan, Armenia, Azerbaijan, China (Sichuan), Cyprus, Georgia, India (Andhra Pradesh, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Tamil Nadu, Uttar Pradesh), Israel, Japan (Hokkaido, Honshu, Ryukyu Archipelago), Malaysia (peninsular), Nepal, Pakistan, Russia (Far East), Saudi Arabia, Sri Lanka, Taiwan, Thailand, Turkey, Uzbekistan.
Africa: Algeria, Côte d'Ivoire, Egypt, Libya, Madagascar, Mauritius, Morocco (unconfirmed), Niger, Nigeria, Réunion, Senegal, South Africa, Sudan, Tanzania, Tunisia (unconfirmed), Uganda, Zaire, Zimbabwe.
North America: Canada (Alberta, British Columbia, Manitoba, Nova Scotia, Ontario, Québec, Saskatchewan), Mexico, USA (Alabama, Arizona, California, Connecticut, Delaware, Georgia, Hawaii, Idaho, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Hampshire, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Utah, Vermont, Virginia, Washington, Wisconsin, Wyoming).
Central America and Caribbean: Haiti, Jamaica, Martinique (intercepted), Puerto Rico.
South America: Argentina, Bolivia, Brazil (Bahia, Goias, Minas Gerais, Paranà, Pernambuco, São Paulo), Chile, Guyana, Paraguay, Suriname, Uruguay, Venezuela.
Oceania: Australia (New South Wales, Northern Territory, Queensland, South Australia, Tasmania, Victoria, Western Australia), New Zealand, Papua New Guinea.
EU: Present.
Distribution map: See CMI (1978; No. 8), CABI/EPPO (1998; No. 342).

BIOLOGY

TSWV is transmitted and spread in nature by insects of the family *Thripidae* (Thysanoptera). They include *Thrips tabaci*, *T. setosus*, *Frankliniella occidentalis* (EPPO/CABI, 1997a), *F. fusca*, *F. intonsa*, *F. schultzei* and *Scirtothrips dorsalis* (EPPO/CABI, 1997b). The virus is acquired only during larval stages, and virus inoculation can be achieved by shallow feeding on leaf epidermal cells. The shortest reported acquisition period is 15 min for *T. tabaci*, but the efficiency of transmission increases with feeding time. Larvae which acquire the virus early can transmit the virus at the end of the larval stage. The virus is retained when the vector moults and the latent (incubation) period is 3-10 days, depending on the vector species. Vectors are maximally infective 22-30 days after acquisition and often retain the virus for life, but there is no evidence of transovarial transmission. These observations show that TSWV is persistent in its vectors, and virus has been detected serologically in viruliferous thrips (Cho *et al.*, 1988).

In the EPPO region, TSWV was virtually absent for over 40 years after the Second World War. It is possible that its vector *T. tabaci* was present in relatively small numbers. The failure of this vector to spread the virus is not understood. *F. occidentalis*, indigenous to North America, began to spread internationally around 1980 and is now widely reported in the EPPO region (EPPO/CABI, 1997c). The recent epidemic spread of TSWV in protected and outdoor crops in the EPPO region is closely associated with the establishment and rapid infestation of this vector. Moreover, TSWV isolates have been experimentally acquired and transmitted by *F. occidentalis* under controlled conditions (Marchoux, 1990).

DETECTION AND IDENTIFICATION

Symptoms

Symptoms are illustrated by reference to a selection of economically important vegetables, ornamental plants and industrial crops. TSWV can induce a wide variety of symptoms, which may vary on the same host species with the cultivar, age, and nutritional and environmental conditions of the plant. Further strains of TSWV with different biological properties have been isolated.

On tomatoes, plants show bronzing, curling, necrotic streaks and spots on the leaves. Dark-brown streaks also appear on leaf petioles, stems and growing tips. The plants are small and stunted as compared with healthy plants. The ripe fruit shows paler red or yellow areas on the skin. Sometimes, affected plants are killed by severe necrosis. On *Capsicum annuum*, symptoms are mainly stunting and yellowing of the whole plant. Leaves may show chlorotic line patterns or mosaic with necrotic spots. Necrotic streaks appear on stems extending to the terminal shoots. On ripe fruits, yellow spots with concentric rings or necrotic streaks have been observed. On lettuces, infection starts in leaves on one side of the plant, which becomes chlorotic with brown patches. The discoloration extends to the heart leaves and cessation of growth on one side of the plant produces characteristic symptoms.

On chrysanthemums, there is a wide variation among cultivars. Usually black stem streaks and wilt are observed. On *Sinningia* spp., infected leaves show yellow or brown leaf spotting, or brown oak-leaf patterns.

Morphology

TSWV virions are spherical enveloped particles, about 70-110 nm in diameter, which contain at least four different proteins: an internal nucleocapsid protein (N); two membrane glycoproteins (G1 and G2); and a large protein (L). The genome consists of three linear ssRNA molecules which complex with N proteins to form circular nucleocapsids. Reassortment of segments can contribute to diversity, especially with respect to symptom expression on different hosts, serological properties, and adaptability of TSWV to new hosts and new countries.

Detection and inspection methods

TSWV is sap-transmissible to diagnostic species. *Petunia hybrida* is one of the most useful (Allen & Matteoni, 1991) because of the rapidity with which the brown local lesions develop, within 2-4 days under favourable conditions, without systemic virus spread. *Nicotiana tabacum*, *N. glutinosa* and *N. clevelandii* show large local necrotic lesions followed by systemic mosaic and necrosis, sometimes lethal (*N. clevelandii*). *Cucumis sativus* shows chlorotic lesions with necrotic centres 4-5 days after inoculation.

Sap transmission of TSWV is usually efficient if young test plants are used. However, difficulties are sometimes encountered in transmitting the virus from old infected plants, and transmission efficiency can be greatly increased using neutral phosphate buffers containing a reducing agent.

Antisera of good titre are now available. A commonly used serological test is ELISA, both in extracts from infected plants (Gonsalves & Trujillo, 1986) and in thrips (Cho *et al.*, 1988; Bandla *et al.*, 1994).). When tested in different forms of ELISA, TSWV appears to exhibit great variation with antisera raised to different virus antigens (de Avila *et al.*, 1990; Law & Moyer, 1990; Wang & Gonsalves, 1990). The double antibody sandwich (DAS) direct ELISA using polyclonal antibodies to the whole virion is recommended over the use of antibodies to structural proteins for detecting a diverse selection of isolates of TSWV (Sherwood *et al.*, 1989; Huguenot *et al.*, 1990; Wang & Gonsalves, 1990). Adam *et al.* (1991) have reported the development of TSWV-specific monoclonal antibodies. Adam *et al.* (1995) have described an assay which will detect tospoviruses generally, based on antibodies to the G proteins of the virus. Dot-blot immunoassay has also been used (Hsu & Lawson, 1991).

The use of cDNA probes (Ronco *et al.*, 1989; Rice *et al.*, 1990) and riboprobes (Huguenot *et al.*, 1990) has been proposed but is not yet widely applied in the identification and diagnosis of TSWV. A PCR-based assay has been developed by Mumford *et al.* (1994). A method based on immunocapture and PCR amplification has been proposed by Nolasco *et al.* (1993), and a reverse transcriptase (RT)-PCR test by Weekes *et al.* (1996).

Detection of TSWV particles by electron microscopy can be achieved by examination of leaf dip preparations but it is necessary to prevent distortion of particles by fixation. Although the preparation of thin sections from tissues of infected plants is time-consuming, this method is very reliable for the identification of TSWV because of the relatively uniform particles and presence of typical viroplasms. Louro (1995) has devised a tissue-print immunoassay for TSWV.

MEANS OF MOVEMENT AND DISPERSAL

TSWV is liable to spread naturally with its vectors (EPPO/CABI, 1997c). In international trade, it may be carried by susceptible host plants, whether pot plants or plants for planting, and will be especially liable to spread if these plants also carry vectors. TSWV is not seed-transmitted.

PEST SIGNIFICANCE

Economic impact

TSWV has become an increasingly important factor contributing to economic losses in many food and ornamental crops throughout the world. Destructive outbreaks of TSWV have occurred in France and Spain in protected and field crops of tomatoes, *Capsicum* and *Anemone*, associated with the establishment and rapid spread of the vector *Frankliniella occidentalis* (see Biology) (EPPO/CABI, 1997c). Crop losses may be as high as 100% (Berling *et al.*, 1990; Rodriguez, 1990). In some areas of Argentina, Brazil, Canada, Denmark, Italy, Netherlands, UK and USA, TSWV has become one of the most important diseases. The most seriously affected crops include *Capsicum annuum*, chrysanthemums, *Cyclamen*, *Senecio cruentus*, *Sinningia* spp. and tomatoes.

Control

As there is no direct means of controlling the virus, the method of control must either be aimed at the thrips vectors or involve the application of sanitation measures. Seedling beds should be isolated from decorative flowering plants or susceptible crops and the surrounding areas kept free from weeds. The inside and outside of glasshouses should be kept free from weeds, thus reducing all possible sources of infection and reducing thrips populations. Fine-mesh netting may possibly be useful for excluding thrips (Lacasa *et al.*, 1994). Susceptible decorative plants should preferably not be grown in the vicinity of the glasshouse. The glasshouse should be inspected regularly as often as possible after planting. The presence of thrips in the crops should be monitored using yellow sticky cards. If the disease appears in a crop, infected plants should be rogued and destroyed immediately and the house treated with insecticide against thrips.

Similar precautions should be taken for field crops. Although chemical control is possible (Bournier, 1990), *F. occidentalis* has been found to develop resistant populations if certain insecticides are used repeatedly (EPPO/CABI, 1997c). It is therefore important to rotate insecticides with different active substances. For ornamental hosts (chrysanthemums, pelargoniums) for which virus-free certification schemes are applied, TSWV is now one of the most important viruses to be tested for (OEPP/EPPO, 1992, 1997). Promising results with biological and integrated control measures against thrips in glasshouses have been achieved in several countries (Bennison, 1988; Bonde, 1989; Gillespie, 1989; Ramakers *et al.*, 1989; Trottin-Caudal & Grasselly, 1989). Currently, the main biological agents used are the predatory mite *Neoseiulus cucumeris* and the predatory bug *Orius insidiosus* (Hatala-Zsellér & Kiss, 1999; Maisonneuve, 1999; Navrátilová, 1999). Indigenous *Orius* spp. are now preferred.

Reports about the virus-vector relationship and reduction in TSWV epidemics by chemical treatment are very limited. However, in Brazil, reduction in disease incidence in tomato crops has been reported (Costa *et al.*, 1977). In Louisiana (US), aluminium-surfaced mulch reduced the numbers of trapped thrips by 33-68% and the incidence of TSWV by 60-78% in tomatoes and *Capsicum annuum* (Greenough *et al.*, 1990).

Yudin *et al.* (1990) devised disease-prediction and economic models that enable growers with lettuce fields affected by TSWV to make management decisions early in the planting cycle. Early disease incidence was a better predictor of disease incidence at harvest than thrips abundance. Aramburu *et al*. (1997) and Moriones *et al*. (1998) have studied the epidemiology of TSWV in tomato fields in Spain and are developing strategies for reducing losses by appropriate thrips control.

Sources of resistance to TSWV have been found in *Lycopersicon* spp. Lack of success in introducing this resistance into commercial tomato cultivars appears to result from the virus-strain specificity of the gene controlling resistance. Nevertheless, screening for sources of resistance in tomatoes (Czuber & Miczynski, 1981; Paterson *et al.*, 1989) and other crops continues. In lettuces, two cultivars (Tinto and Ancora) are reported to be resistant to TSWV in Hawaii (US) (O'Malley & Hartmann, 1989). Transgenic plants of *Nicotiana benthamiana* containing the nucleoprotein gene of TSWV were resistant to the virus (Vaira *et al.*, 1995).

Phytosanitary risk

TSWV was added to EPPO A2 list in 1997; it is also a quarantine pest for CPPC. The recent introduction and rapid and extensive spread of the vector *Frankliniella occidentalis* in the EPPO region has provided a means of rapid dissemination of this virus, which was previously rare or absent. Its economic importance has rapidly become apparent wherever it occurs, in the first instance on glasshouse crops of ornamentals and vegetables, but also, as *F. occidentalis* established itself out of doors in southern Europe, on outdoor vegetable crops. It should be noted that both vector and virus are now present in the majority of EPPO countries. Only a rather small group of countries is now free from TSWV. Efforts are being made to keep plants for planting free from TSWV, which may eventually be considered as a regulated non-quarantine pest, rather than as a quarantine pest.

PHYTOSANITARY MEASURES

Measures should be taken to ensure that plants for planting of susceptible vegetable and ornamental hosts are free from TSWV. Nurseries producing such plants should actively control the vectors and should destroy any heavily infected crops. Countries in which TSWV is absent or rare should above all aim to prevent the introduction of *F. occidentalis*, or to control this pest effectively if it is present .

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