

Tomato Spotted Wilt Virus of Agronomic, Vegetable, and Ornamental Crops

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Introduction

In 1919, tomato spotted wilt virus (TSWV) was first described in tomato in Australia. By 1920, TSWV was found in all Australian territories and since that time, TSWV has spread to many areas of the world. By 1926, TSWV was found in Hawaii in pineapple. By 1935, TSWV became epidemic in California. In 1938, TSWV was found in greenhouse-produced tomatoes in Cleveland, Ohio. Since the late 1960's, TSWV has caused significant damage to tomatoes in Hawaii and in the 1980's, TSWV has severely affected lettuce and pepper production there. In 1971, TSWV was found in peanuts in Texas. In 1985 and 1986, some peanut fields in Texas were destroyed by TSWV. However, the incidence of TSWV in Texas-produced peanuts was significantly less from 1987 to 1989. In 1990, the incidence in some peanut fields was over 50%.

In Louisiana, TSWV was first found with certainty in 1972. By 1988, incidences of TSWV in solanaceous crops ranged from 25% to 75% in Louisiana.

In Georgia, TSWV was identified in 1970, once, but it could not be found in a field sur-

vey in 1983. By 1989, however, TSWV became a serious problem in tobacco, peanut, and tomato in south Georgia, where incidences exceeded 50% in some fields. In 1990, some tobacco fields were plowed down because of TSWV.

In Florida, some evidence suggests that TSWV may have occurred in tomato in 1974. TSWV was first identified in tomato and peanut in the panhandle area in May and June 1986, respectively. Since 1986, TSWV has been found also in tobacco, pepper, watermelon, potato, impatiens, gloxinia, and gladiolus (maybe in 1985 also) in Florida. By 1999 incidences of TSWV in a few tobacco fields have increased to greater than 50%. For peanut, the incidence in most fields has been between trace amounts to 7%, but in some peanut plantings, the incidence has been 60-90%. In 1988, TSWV was identified in tomato in Dade County. Meanwhile, higher populations of western flower thrips have been found in central and south Florida. Thus, TSWV and its vectors are considered to be well established throughout the state of Florida. TSWV is a major threat for the production of many crops with incidences in tomato being more than 50% by the fall of 1990 in the south Georgia and north Florida area.

The case histories mentioned above clearly

demonstrate how TSWV can appear in some area and over time, increase to devastating proportions. In contrast, some areas of the United States have had serious problems with TSWV in some production systems but over time TSWV became a minor problem for unknown reasons. Nearly total crop destruction has occurred in South Georgia in tobacco and peanuts in some fields in recent years. Much remains to be learned about this enigmatic virus.

In this publication, tomato spotted wilt virus is used to designate the causal agent for the disease Tomato Spotted Wilt. However, some of the original photographs, particularly on some ornamentals, may have been impatiens necrotic spot, a disease caused by a related, but distinct, virus. Impatiens necrotic spot virus has a considerably narrower host range.

Host range

TSWV infects many plant species. Some of the common crops that are susceptible to TSWV are listed in Table 1. A major source of virus can be weeds, but in practical terms it may not be possible to eradicate the weed sources because they are numerous and, very likely, are not even adjacent to commercial crop fields. Also, at this time we do not know what weeds function as hosts and sources for TSWV in Florida. In other areas of the United States and the world, many weeds have been identified as potential hosts for TSWV. Certainly, weed control in and around production fields and greenhouses is encouraged.

Methods of spread

The primary movement of TSWV from one plant to another is by the feeding of thrips (singular or plural). Thrips are extremely small insects 0.5 to 5 mm (Figure 1) that inhabit flowers, leaves, and the soil. Six species of thrips can transmit TSWV. Western flower thrips, onion thrips, and tobacco thrips are among the

vectors for TSWV that occur in Florida.

Thrips arise from eggs deposited in tender tissues of stems, leaves, or flowers. The immature forms (larvae) begin feeding as soon as they hatch. When larvae (wingless) feed on infected tissue for 15 minutes or more, they may acquire the virus internally. As the feeding period lengthens, the probability for the thrips to acquire the virus is increased. Full grown larvae fall to the soil and become pupae that do not feed on the plant. Later, winged adults emerge from the pupae. Only adults are capable of transmitting the virus to a plant. Adult thrips may carry the virus for its entire life, but the virus is not passed on to the egg stage. The next generation acquires the virus by feeding upon infected plants. The time from the egg to the adult stage varies with many factors but has been measured at 14 days at 85°F for western flower's thrips,

In north Florida, populations of thrips found in flowers have been highest from late April to early June. It is during and shortly after this time that symptoms of TSWV begin to appear in tomato, peanut, pepper, and tobacco in north Florida. During the summer, active populations of thrips in flowers have declined followed by a small increase in populations in the fall. Thrips that inhabit leaves feed actively on peanut, tomato, and other plants during the summer months in north Florida.

Up to the spring of 1990, the occurrence of TSWV in tomato, for example, has been highest in the spring when populations of flower-inhabiting thrips are highest. Fall plantings of tomato, when populations of flower-inhabiting thrips are lower, had lower incidences of TSWV than spring plantings in 1986, 1987, 1988, and 1989. However, in summer plantings of tomato in 1990 in the south Georgia and north Florida area, incidences in some fields exceeded 50%. In Hawaii, populations of thrips tend to be high during most of the year, which may explain partially why TSWV has been so severe there

for many years.

Plant sap from an infected plant can be a source of TSWV. Thus, any kind of mechanical injury to an infected plant that moves infectious sap to another plant can serve as a method of transmission. Mechanical transmission does not appear to be a major method of spread for TSWV in commercial situations when compared to spread by thrips. However, one should avoid contact with infected plants where field operations such as suckering, topping, tying, and transplanting are used. It may be beneficial to have separate individuals rogue infected plants before other field operations that require plant contact are conducted.

Seed transmission of TSWV has not been documented with certainty. Clonally propagated plants from shoots, suckers, bulbs, stems, and tubers are likely to be infected with TSWV if the mother plant is infected because, as with most viral diseases, infections become systemic to some degree. Transplants of infected plants have been a source of TSWV and many other diseases.

Symptoms

Probably no other plant pathogen causes such an array of symptoms as TSWV. Some plants or varieties of crops may be infected without expressing symptoms. Until you become familiar with the common symptoms of TSWV associated with specific crop species, it is recommended that laboratory diagnoses be relied upon.

Symptoms caused by TSWV are variable. Several strains of TSWV have been identified around the world and each strain may cause different symptoms in different crop species and varieties of crop species. Symptoms in certain crops are evident only under certain environmental conditions (e.g., no symptoms occur in *Stephanotis* during hot temperatures). In to-

bacco, fewer lesions and later-development of lesions occurred at 60°F when compared to 68°F. Usually, as plants become older, infection results in progressively reduced symptoms. For example, the degree of stunting in tobacco is less when older plants are infected. Also, tomato fruit may not express severe symptoms when infection occurs after those fruit are set.

Symptoms may develop from 3 to 14 days after inoculation, but in some situations symptoms may not occur for weeks. An array of symptoms are presented in Figures 2-24. Other symptoms can occur and may mimic other diseases. In Figure 2 are pictured small etchings in leaves of peanuts accompanied by leaf curling, which are caused by the feeding of thrips. Damage from feeding of thrips can cause leaf deformations but in peanut such damage is not considered to be of economical importance. The primary damage from thrips to peanut is their transmission of TSWV. However, feeding and egg-laying of thrips in blossoms and on recently formed fruit of tomato can cause fruit abortion and cosmetic fruit scars, respectively.

Control and tactical decision making

In some situations, control of TSWV will not be possible. Control measures for TSWV are not yet available for many situations, particularly in outdoor plantings. The following lists contain information that relate to the control of TSWV.

Field and greenhouse considerations.

- Identify the presence of TSWV as soon as possible. Make a strong effort to familiarize yourself with the many symptoms caused by TSWV in the crops you grow. Control actions that begin early are likely to be most effective.
- Plantings of susceptible crops should be separated from each other as much as possible on a geographical and a time basis.

- Roguing of infected plants is not discouraged, but some studies have shown roguing is not effective in field situations. For greenhouses, roguing has been helpful for control when coupled with other methods.
- Immature fruit that is harvested (e.g., green tomatoes) should be inspected prior to shipment for subtle light-colored ringspots or spots that will not ripen normally. For example, green tomato fruit with such spots will ripen with yellow spots or blotches. To minimize such occurrences, known infected plants can be marked in the field and pickers should be instructed not to harvest from such plants.
- Inspect plantings for thrips by using acceptable sampling methods such as yellow or blue sticky traps. This may be one way of determining how often to spray insecticides. In greenhouses, insecticidal sprays every three or four days may be necessary.
- Minimize field and greenhouse operations such as cultivation during periods when thrips are abundant if possible. Disturbance of plants at these times may further encourage movement of thrips.
- Use resistant varieties if available. Currently, several varieties (Southern Runner, Georgia Green, Virugard) of peanut are resistant to TSWV. With ornamentals, some varieties are notably more susceptible than others. For example, New Guinea impatiens is highly susceptible. Also, chrysanthemum varieties differ in reaction type to TSWV. Certainly if you observe that one variety is more resistant than another, that information should be considered.
- Use of currently available insecticides either as granular soil treatments or foliar sprays has reduced damage from thrips

in peanuts and tomatoes. However, the use of insecticides as foliar sprays has not been successful in reducing TSWV on a consistent basis. In some studies more TSWV occurred where foliar insecticidal sprays were used. Possibly, insecticides stimulate movement of winged forms which results in additional spread of disease. Perhaps, spray intervals would have to be shortened to attain some control of TSWV. If so, production costs would increase and integrated pest management programs would be jeopardized. Another consideration is the lack of control of thrips in adjacent crops. If thrips are controlled in one field with insecticides, thrips from outside the field may infest your sprayed field and the thrips must feed for at least one hour on sprayed plants before they die. Remember, fifteen minutes or more of feeding is required for transmission of TSWV. In furrow treatment with Thimet during planting of peanut has reduced TSWV. Use of Admire insecticide in the transplant water for tobacco has reduced TSWV.

- Pyrethroid insecticides have been noted for flushing out thrips. Thrips tend to dwell in hidden places making it difficult to reach with sprays. Combinations of pyrethroid insecticides with other types of insecticides may provide better control. Resistant strains of thrips to insecticides may occur if the same chemical is used repeatedly. Alternating different chemical types during the crop period can reduce the occurrence of resistant strains and increases the possibility of control of immature stages which are more difficult to kill when compared to adults.
- Sprays of crop oils have not proven successful for control of TSWV.
- Crops that are produced during the periods of time that thrips are active (e.g.,

April, May, and June in North Florida) are more likely to be infected by TSWV.

- Consider less intensive crop production of susceptible crops, particularly on an overlapping basis. This has been beneficial for control of TSWV in greenhouses. Sometimes diseases can become so severe every year that laws have been established that prohibit the planting of that crop for a given period of time (e.g., one-month lettuce-free period). This is an act of desperation but may be necessary. Production of vegetables in Florida has become more intensive over a wider geographical area. Such situations enhance crop pests if there is no down time for the crops.
- Determine what the financial break-even point is for a crop at various times in the season. If the severity of TSWV becomes high early in the season, it may be best, financially, not to continue producing that crop. This is an important decision as much of the cost of production with some crops occurs toward the middle to the end of the season, particularly harvesting and post-harvest costs. This tactic has been used in Hawaii for lettuce production.

Additional considerations for field plantings.

- Use crop rotation with non-susceptible crops (see Table 1) if possible. Also, avoid double cropping with susceptible crops (e.g., tomato followed by pepper). Thrips pupate in the soil.
- Plowing and thorough seedbed preparation should aid in the reduction of population of pupae in the soil. Also, a seedbed that is prepared early reduces seedling blights which inhibit young plant vigor. For peanut, minimum tillage has reduced TSWV compared with conven-

tional plow-plant systems.

- Purchase certified disease-free transplants or grow your own disease-free transplants.

In field situations, every effort should be made to encourage high vigor of seedlings and young plants. TSWV seems to be more common, at least in peanut, where plant stands are thin. Thus, young plant health should be given the highest priority. Seed with a high germination rate and high vigor will aid in attaining rapid growth of young plants. High seeding rates should be used for crops such as peanut. Thick stands aid in the control of TSWV. However, thicker plantings may encourage buildup of foliar diseases such as peanut leaf spot. If you choose to use thick plantings, be prepared to enhance your peanut leaf spot control program with earlier and more frequent fungicide applications.

- For tobacco and tomato, increasing the plant population in the row to compensate for infected plants may offset some yield loss. In Florida, in-row spacing of tobacco should not be less than 16 inches. Quality in down-stalk tobacco leaves is enhanced with increased in-row spacing. For tomato, plant spacing can be reduced in the row to 12 inches to compensate for infected plants. However, more rigorous pruning and spray programs for pests may be necessary because of the thicker leaf canopy.
- Weed control may or may not be important for the control of TSWV in field situations. First, the number of weed species that are susceptible is enormous. Secondly, the pertinent weed species that harbor TSWV in Florida are not known at this time. Because thrips can migrate from beyond the confines of a field, in-

infected weeds or crops away from the production field may be the source of virus. Regardless, a good weed control program in and around the field is recommended.

- Field plantings of susceptible crops (Table 1) should not be next to greenhouse or transplant production sites. It has been observed in some localities in the United States that TSW tends to be more severe in fields that are near ornamental plantings and greenhouse production areas.

Additional considerations for the greenhouse.

- Use certified, disease-free plant material.
- For greenhouse production areas, do not reuse soil from infested plantings unless it has been sterilized. This should reduce pupae of thrips.
- Destruction of weeds and infected crop plants has aided in the control of TSW

in the greenhouse. Sanitation in and around greenhouses is imperative.

- Adjusting greenhouse temperatures may provide delays in expression of symptoms. For example, it has been noted that cooler temperatures delay symptom expression in chrysanthemum. However, because infected, symptomless plants are a source of virus, it might be best to avoid cooler temperature so that infected plants express symptoms sooner which would allow for earlier roguing.
- Small mesh screens (100-400) should be used for greenhouse ports to minimize entrance of thrips. Also, entrance ports should have a separate foyer type entrance to reduce direct movement of thrips from the outside. Fans that exhaust air should also reduce the entrance of thrips into greenhouses.

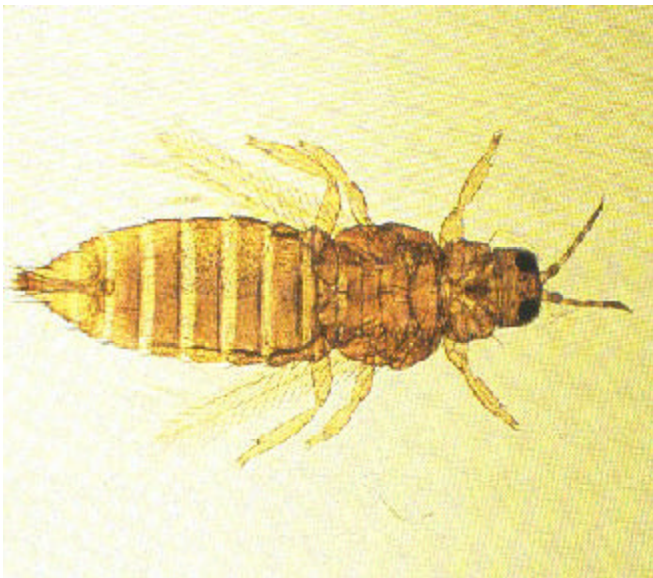


Figure 1. Thrips.



Figure 2. Discoloration from TSWV and deformation from thrips in peanut leaves.

Table 1. Some common plant species (not including weeds) that are infected by TSWV.

Common name	Scientific Name	Common name	Scientific Name
Agronomic and Vegetable Crops		Ornamentals (continued)	
Tobacco	<i>Nicotiana tobacum</i>	Nasturtium	<i>Tropaeloun majus</i> and others
Tomato	<i>Lycopersicon esculentum</i>	Impatiens	<i>Impatiens</i> spp
Pepper	<i>Capsicum annum</i>	Petunia	<i>Petunia</i> spp.
Potato	<i>Solanum tuberosum</i>	Zebra plant	<i>Aphelandra squarrosa</i>
Eggplant	<i>Solanum melongena</i> var <i>esculentum</i>	Gloxinia	<i>Sinningia speciosa</i>
Lettuce	<i>Lactuca sativa</i> (many varieties)	Statice	<i>Limonium latifolium</i>
Endive	<i>Cichorium endivia</i>	Verbena	<i>Verbena litoralis</i>
Celery	<i>Apium graviolens</i>	Strawflower	<i>Gomphrena globosa</i>
Peanut	<i>Arachis hypogaea</i>	African violet	<i>Saintpaulia ionantha</i>
Spinach	<i>Spinacia oleracea</i>	Ageratum	<i>Ageratum</i> spp.
Bean	<i>Phaseolus vulgaris</i>	Amaranthus	<i>Amaranthus</i> spp.
English pea	<i>Pisum sativum</i>	Anemone	<i>Anemone</i> spp.
Southern pea	<i>Vigna sinensis</i>	Begonia	<i>Begonia</i> spp.
Soybean	<i>Glycine max</i>	Calceolaria	<i>Calceolaria</i> spp.
Watermelon	<i>Citrullus vulgaris</i>	Calenclula	<i>Calendula officinalis</i>
Cucumber	<i>Cucumis sativus</i>	Exacum	<i>Exacum</i> spp.
Cauliflower	<i>Brassica oleracea</i> var <i>botrytis</i>	Geranium	<i>Geranium</i> spp.
Broccoli	<i>Brassica oleracea</i> var <i>botrytis</i>	Snapdragon	<i>Antirrhinum</i> spp.
Fruit crops		Dusty miller	<i>Senecio cineraria</i>
Papaya	<i>Carica papaya</i>	Madagascar-jasmine	<i>Stephanotis floribunca</i>
Pineapple	<i>Ananas sativus</i>	Ranunculus	<i>Ranunculus</i> spp.
Ornamentals		Cyclamen	<i>Cyclamen</i> spp.
Amaryllis	<i>Amaryllis</i> spp.	Cineraria Hydrangea	<i>Hydrangea</i> spp.
Gladiolus	<i>Gladiolus</i> spp.	Gypsophila	<i>Gypsophila</i>
Calla lilly	<i>Zantedeschia</i> spp.	Gerbera daisy	<i>Gerbera jamesonii</i>
Lillies (various)		Peony	<i>Peony</i> spp.
Dahlia	<i>Dahlia</i> spp.	Sage	<i>Salvia</i> spp.
Marigold	<i>Tagetes</i> spp.	Forget-me-not	<i>Myosotis scorpiodes</i>
Chrysanthemum	<i>Chrysanthemum</i> spp.	Morning glory	<i>Ipomea</i> spp.
Aster	<i>Aster</i> spp.	Coleus	<i>Coleus</i> spp.
Zinnia	<i>Zinnia</i> spp.	Larkspur	<i>Delphinium</i>
Coreopsis	<i>Coreopsis</i> spp	Lupine	<i>Lupinus</i> spp.
		Evening Primrose	<i>Oenothera</i> spp.



Figure 3. Discoloration of peanut leaves.



Figure 4. Plant stunting and ringspots in leaves of peanut.



Figure 5. Early leaf wilting in tomato.



Figure 6. Severe leaf wilting in tomato.



Figure 7. Petiole (leaf stem) and leaf discoloration in tomato.



Figure 8. Brilliant leaf discoloration in tomato.



Figure 9. Light colored fruit spots in tomato.



Figure 10. Dark colored fruit spots in tomato.



Figure 11. Severe fruit spots in cherry-type tomato.



Figure 12. Severe fruit spotting and deformation in tomato.



Figure 13. Severe wilt in young tobacco plant.



Figure 14. Severe wilt in old tobacco plant.



Figure 15. Discoloration in outer stem tissue of tobacco.



Figure 16. Discoloration in outer and inner stem of tobacco.



Figure 17. Leaf discoloration along leaf veins in tobacco.



Figure 18. Leaf discoloration on one side of tobacco plant.



Figure 19. Leaf symptoms in Gloxinia.



Figure 20. Leaf symptoms in Aphelandra.



Figure 21. Mosaic pattern in leaves of New Guinea Impatiens.



Figure 22. Ringspotting in leaves of Impatiens.



Figure 23. Petiole discoloration in Ciniaria.



Figure 24. Flower mosaic in Gloxinia.