Transmission of Tomato Spotted Wilt Virus by the Western Flower Thrips to Weeds and Native Plants Found in Southern Ontario

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ABSTRACT

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Weed species and native plants occurring in southern Ontario, grown from seed or collected from the field, were exposed in a growth room to natural transmission of tomato spotted wilt virus (TSWV) by the western flower thrips (WFT), *Frankliniella occidentalis*. These plants were assayed for TSWV by both enzyme-linked immunosorbent assay (ELISA) and bioassay on suitable indicators, and thrips reproduction was examined on plants susceptible to TSWV. Of 302 native plant species tested, 113 species representing 35 families were field susceptible to TSWV, 62 species of which are first reported hosts for this virus. Eighty-six percent of these plants were ovipository hosts for the WFT.

Additional keywords: Thripidae, vector

In Ontario, tomato spotted wilt virus (TSWV) has become increasingly important in many greenhouse ornamental and vegetable crops (12,20,21). The virus is associated principally with one of its vectors, the western flower thrips (WFT), *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae), which has rapidly invaded greenhouses across Canada (12,21,25), and represents the predominant thrips species in Ontario greenhouses (12). With the wide distribution of this species in many greenhouses, it is probable that one or more biotypes will adapt to Ontario field conditions, as has occurred in British Columbia (6,24). Similarly, in the Niagara peninsula, live WFTs have been found on ornamentals bordering greenhouses in midwinter (A. B. Broadbent, *unpublished*). Once an endemic population of the WFT is established outdoors, TSWV will likely be disseminated to native plant species which will subsequently act as reservoirs for the virus and possibly the thrips. A continuance of reports of new natural hosts of this virus may be expected because 35 families of plants already are represented by one or more hosts.

The potential for TSWV transmitted by WFT to cause significant losses in Ontario crops will depend largely on the success with which the thrips becomes established on indigenous plant species and the extent to which those species become reservoirs of the virus (17). This paper describes a survey of both native Ontario weeds and native plants (subsequently referred to as test plants) to determine which species could act as reservoir hosts for TSWV and the WFT, both in the field and in the greenhouse.

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MATERIALS AND METHODS

The book *Ontario Weeds* (1) was used as a compendium of weed species of southern Ontario. Test plants used in this study were obtained by several means. Seed was procured from the following sources: T. Leech, Herbarium, McMaster University, Hamilton, Ontario; C. Crompton, Biosystematics, Agriculture Canada, Central Experimental Farm, Ottawa, Ontario; P. B. Cavers, Department of Plant Sciences, University of Western Ontario, London, Ontario; and G. W. Anderson, Department of Crop Sciences, and J. F. Alex and M. Dykstra, Department of Environmental Biology, University of Guelph, Guelph, Ontario. Seeds were germinated as described by Anderson (5) and grown in a greenhouse (25 C) with supplementary high-pressure sodium vapor light (250 $\mu E \cdot m^{-2} \cdot s^{-1}$, 16-hr photoperiod). Greenhouses used to rear plants were maintained insect-free.

To determine the field susceptibility to TSWV (susceptibility to thrips transmission) of plant species for which seed was unavailable or germination difficult, young plants were collected from field locations across southern Ontario, with emphasis being directed to those areas where crops susceptible to TSWV were found. The collection included species found in and adjacent to greenhouses and weeds associated with both cultivated and fallow land surrounding vegetable production regions in southern Ontario. After identification (7), test plants were transplanted into 13-cm-diameter clay pots and maintained in the greenhouse before testing for field susceptibility to TSWV.

Disease surveys were conducted between June 1988 and October 1989 in greenhouse and field locations where susceptible ornamental or vegetable crops were grown. Most collection sites had a known history of the disease. Collections were made from 18 greenhouses containing ornamental crops and 14 fields with vegetable crops across southern Ontario (Fig. 1). Native plant species were collected randomly from these areas and kept refrigerated until assayed for virus.

Evaluation of field susceptibility to TSWV was conducted in a 6.5 × 2.9 m growth room programmed for 24/18 C (day/night), 70% RH, and illuminated with mixed sodium vapor and metal halide lamps (200 $\mu E \cdot m^{-2} \cdot s^{-1}$, 16-hr photoperiod). Each plant species (six to 20 replicates per species) was randomly arranged in a double row with alternating rows of TSWV-infected florists' chrysanthemum (*Dendranthema grandiflora* Tzvelev 'Polaris' and 'Palisade') and tomato (*Lycopersicon esculentum* Mill. 'Glamour') infested with WFT (*F. occidentalis*). Nymphs from a laboratory culture of the WFT (2) were used to infest the donor plants 21 days before the introduction of the test plant species. An isolate of TSWV from naturally infected chrysanthemums was used in the study (21). Twelve healthy flowering chrysanthemum plants (cv. Pico), which were replaced weekly, were randomly positioned among the donor plants to maintain a supply of pollen for the thrips. At weekly intervals, healthy petunia (*Petunia* × *hybrida* Hort. Vilm.-Andr. 'Calypso') plants were exchanged with petunia plants that had been randomly placed among the test plants to monitor both thrips feeding and virus transmission (4). All plants were regularly watered each morning to minimize moisture stress. As previously reported (27), loss of moisture by weeds made them less suitable as hosts for the WFT, thus affecting feeding intensity and duration.

Test plants were assayed after a 6-wk exposure to the TSWV/WFT complex. Leaves sampled from different parts of each plant were triturated in ELISA extraction buffer (1:19, g/ml, tissue/buffer) (16) using a self-cleaning MEKU roller juice press (Erich Pollahne, Am Weingarten 14, 3015 Wennigsen, Germany). The direct double-antibody sandwich

ELISA was used for virus detection, as described by Clark and Adams (16). A polyclonal serum, prepared against the same TSWV isolate (21), was used in all tests. All assays were done in Immulon 2 flat-bottomed Removawell plates with 200 μl of reagent used for each step.

After washing, tissue triturates were loaded into three replicate wells and incubated for 16–22 hr on a rotary shaker at room temperature. Alkaline phosphatase (Type 7), conjugated to TSWV IgG (1 μg of protein per milliliter) at an enzyme/protein ratio of 2.5:1 (v/v) with 0.06% glutaraldehyde (16), was added for 4 hr at room temperature. Substrate absorbance was measured at 405 nm in a Eurogenetics MPR-44 microplate reader (Eurogenetics Ltd., Tessenderlo, Belgium). Test samples were considered positive if their absorbance values exceeded twice that of healthy *Datura stramonium* L. control samples. Over the 2-yr period, typical healthy control values had a mean absorbance of 0.06 (± 0.008). All samples giving a positive ELISA or borderline ELISA reaction were rubinoculated on Carborundum-dusted leaves of *P. hybrida* and *D. stramonium*. Presence of virus was confirmed by typical necrotic leaf spots 3–5 and 10–14 days, respectively, after inoculation. Symptoms of virus infection were recorded where possible for all test plants susceptible to TSWV. Symptoms often became indiscernible as some species reached maturity.

To establish the validity of ELISA, four healthy plants and four plants infected with TSWV of *D. grandiflora* 'Palisade', *D. stramonium*, *Sinningia speciosa* (Lodd.) Hiern., *L. esculentum*, *Nicotiana glutinosa* L., and *P. hybrida* were assayed by ELISA and the triturate rubinoculated onto petunia. A positive reaction on petunia plants was based on the development of typical necrotic lesions 3–5 days after inoculation.

Test plants demonstrated to be hosts of TSWV were maintained in the greenhouse for thrips reproduction studies. Leaf disks (1–2 cm diameter) of these plants were placed in glass vials (9.5 × 2.3 cm) containing 10 ml of 1% Bacto water agar to maintain moisture. Ten adult WFTs (80% female adults), reared on healthy chrysanthemum, were added to each vial. The vials were capped with 100-μm nylon mesh (Nitex) and the vial perimeter was secured with rubber O-rings. Each test involved a minimum of six vials (replicates) per plant. Palisade was used as a standard host plant.

Vials were maintained in a growth room for 7 days at 27 ± 1 C, 65 ± 5% RH, and 100 $\mu E \cdot m^{-2} \cdot s^{-1}$, 16-hr photoperiod, for oviposition and subsequent egg hatch. On day 7, the number of live first instar nymphs in each vial was assessed. The presence of one or more nymphs for each test plant in all replicates was considered indicative that the plant being tested potentially would support reproduction of WFT.

RESULTS AND DISCUSSION

High populations of adult thrips were maintained in the growth room throughout the duration of the study, with uniform dispersal occurring from donor plants to test plants. A wide range of foliage damage (feeding scars) caused by WFT was observed on many of the test plants within several weeks of exposure to thrips. Previous studies assessing feeding preferences of the WFT in chrysanthemum similarly demonstrated significant levels of thrips feeding during exposure periods of 2–4 wk (13). Throughout the study, petunia indicator plants used to monitor virus transmission demonstrated numerous (10–30) necrotic lesions associated with viruliferous thrips feeding, verifying a high inoculum pressure.

Assay of host indicators demonstrated a 100% correlation between ELISA and rubinoculation bioassays. In the test plant assays, 27 of 113 plants positive in ELISA were negative by bioassay. This may be attributable to the presence of chemical inhibitors in the sap that affect transmission but not ELISA (23). Low concentration of virus, variable distribution of virus within the plant, and lability of the virus during mechanical transmission have all been identified as factors limiting TSWV transmission (3,8,21). Physiological plant age, time since inoculation, and plant anatomy have also been shown to influence reliability of the TSWV bioassay procedure (14).

Between June 1989 and October 1990, 302 native plant species were either grown from seed or collected from field locations across southern Ontario. When exposed to the TSWV/WFT complex, 186 species (common name in parentheses) were field resistant to TSWV as listed (numbers represent number of plants tested): ACERACEAE: *Acer negundo* L. (Manitoba maple) 9. AMARANTHACEAE: *Amaranthus albus* L. (tumble pigweed) 10; *A. blitoides* S. Wats. (prostate pigweed) 10. ANACARDIACEAE: *Rhus radicans* L. (poison-ivy) 6; *R. typhina* L. (staghorn sumac) 5. APIACEAE: *Zizia aurea* (L.) W. Koch (golden alexanders) 7. APOCYNACEAE: *Apocynum androsaemifolium* L. (spreading dogbane) 10. ARACEAE: *Arisaema triphyllum* (L.) Torr. (jack-in-the-pulpit) 5. ASCLEPIADACEAE: *Asclepias incarnata* L. (swamp milkweed) 7; *A. syriaca* L. (common milkweed) 11. BERBERIDACEAE: *Podophyllum peltatum* L. (mayapple) 5. BORAGINACEAE: *Anchusa arvensis* Bieb. (small bugloss) 5; *Cynoglossum virginianum* L. (wild comfrey) 5; *Lappula echinata* Gilib. (stickseed) 5. CARYOPHYLLACEAE: *Dianthus barbatus* L. (sweet-William) 6; *Silene cucubalus* Wibel (bladder campion) 6; *S. noctiflora* L. (night-flowering catchfly) 7; *S. cserei* Baumg. (biennial campion) 6. CHENOPODIACEAE: *Atriplex* spp. (atriplex) 8; *A. hastata* L. (halberdleaf atriplex) 6; *A. hortensis* L. (garden atriplex) 6; *A. patula* L. (spreading atriplex) 5; *Kochia scoparia* (L.) Schrader (summer cypress) 6. COMPOSITAE: *Achillea millefolium* L. (yarrow) 7; *A. ptarmica* L. (sneezeweed) 5; *A. tormentosa* L. (woolly yarrow) 5; *Anaphalis margaritacea* (L.) Benth. & J. D. Hook. (pearly everlasting) 5; *Anthemis cotula* L. (stinking mayweed) 5; *Artemisia biennis* Willd. (biennial wormwood) 14; *A. vulgaris* L.

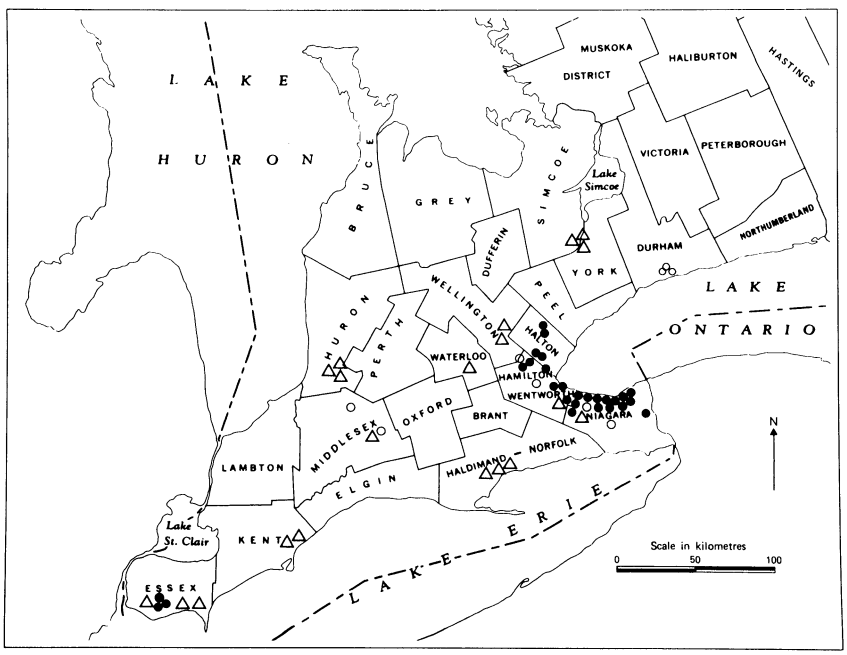

Fig. 1. Sampling locations used in survey for TSWV in (△) field and (○) crops. Solid symbols indicate the presence of virus. Each symbol represents one or more sample sites.

Table 1. Plant species found in southern Ontario determined to be field susceptible to tomato spotted wilt virus (TSWV), as determined by ELISA and bioassay, and species supporting western flower thrips oviposition

Latin name	Common name	No. plants positive for TSWV/total no. of plants[a]	Symptoms[b]	Ovipository host for WFT
AMARANTHACEAE				
Amaranthus caudatus L.	Love-lies-bleeding	5/5 B	nll,m.sm	+
A. powellii S. Wats.	Green pigweed	6/8	nll,m.sm	···
A. retroflexus L.	Redroot pigweed	16/20 B	nll,m.sm	+
A. spinosus L.	Spiny amaranth	6/8 B		···
Gomphrena globosa L.	Globe amaranth	6/8 B	sm,nll,str	···
APOCYNACEAE				
Vinca rosea L.	Periwinkle	3/7	sm	···
ARISTOLOCHIACEAE				
Asarum canadense L.*[c]	Wild ginger	4/6 B	m.sm	+
BALSAMINACEAE				
Impatiens capensis Meerb.*	Jewelweed	3/7	···	···
BORAGINACEAE				
Myosotis sp.	Forget-me-not	4/7	···	···
CAMPANULACEAE				
Campanula americana L.	Tall bellflower	3/7	···	···
C. rapunculoides L.	Creeping bellflower	4/6	nr,lp,st	···
CARYOPHYLLACEAE				
Agrostemma githago L.*	Purple cockle	8/8 B	sm	+
Cerastium vulgatum L.*	Mouse-ear chickweed	10/11 B	m.sm	+
Lychnis alba Mill.*	White cockle	5/7 B	sm	···
Saponaria officinalis L.	Bouncing-bet	4/8	···	···
Spergula arvensis L.*	Corn spurry	4/7 B	m.sm	···
Stellaria media (L.) Cyrill	Common chickweed	12/15 B	m.sm	+
CHENOPODIACEAE				
Chenopodium album L.	Lamb's-quarters	15/17 B	nll	+
C. amaranticolor	Lamb's-quarters	10/13 B	···	+
C. gigantospermum Aellen*	Maple-leaf goosefoot	5/5 B	···	+
C. glaucum L.*	Oak-leaf goosefoot	8/10 B	···	+
C. murale L.	Nettleleaf goosefoot	5/7 B	···	···
Salsola pestifer A. Nels.*	Russian-thistle	4/6	···	···
CONVOLVULACEAE				
Convolvulus arvensis L.	Field bindweed	6/9 B	···	+
C. sepium L.*	Hedge bindweed	5/7 B	···	+
Ipomoea congesta R. Br.	Blue morning-glory	9/9 B	···	−
COMPOSITAE				
Ambrosia artemisiifolia L.*	Common ragweed	13/23 B	···	···
A. trifida L.*	Giant ragweed	5/5 B	···	−
Antennaria neglecta Greene.*	Field pussytoes	4/6 B	···	···
Arctium lappa L.	Great burdock	8/11 B	···	+
A. minus Bernh.*	Common burdock	···	···	+
Aster cordifolius L.*	Bluewood aster	5/6 B	s.sm,st,ld,r	+
A. laterifolus (L.) Britton*	Calico aster	5/9 B	sm,st,ld,r	···
A. novae-angliae L.*	New England aster	9/13 B	m.sm,nr,cl	···
Bidens sp.	Beggarticks	8/13 B	m.sm,nr,cl	···
Bidens vulgata Greene	Tall beggarticks	7/11 B	m.sm,nr,cl,vb	+
Carduus acanthoides L.*	Plumeless thistle	4/5	···	···
Cichorium intybus L.	Chicory	12/16 B	sm	+
Chrysanthemum leucanthemum L.*	Oxeye daisy	5/5 B	f,sm	+
Centaurea cyanus L.	Cornflower	6/9	···	···
Cirsium arvense (L.) Scop.*	Canada thistle	10/13 B	m.sm	−
C. vulgare (Savi) Ten.	Bull thistle	9/13 B	···	+
Coreopsis lanceolata L.	Tickseed	3/6 B	m.sm.,cl.	+
Crepis capillaris (L.) Wallr.	Smooth hawksbeard	4/6 B	···	···
*Erigeron canadensis**	Horseweed	3/10	···	−
E. strigosus Muhl. ex Willd.*	Rough fleabane	6/11 B	nr,cr,sm	···
Eupatorium maculatum L.*	Joe-Pye-weed	5/5 B	sm	+
Galinsoga ciliata (Raf.) Blake	Hairy galinsoga	15/18 B	sm	+
Gnaphalium uliginosum L.*	Low cudweed	5/5	···	···
Lactuca canadensis L.*	Canada lettuce	7/9 B	sm	···
L. serriola L.*	Prickly lettuce	6/10 B	sm	···
Matricaria maritima L. var. *agrestis* (Knaf.) Wilm.*	Scentless chamomile	6/9 B	···	···
M. matricarioides (Less.) C. L. Porter*	Pineapple-weed	3/9 B	sm	+
Senecio jacobaea L.	Tansy ragwort	6/8 B	nr,sm,ld	−

(*continued on next page*)

[a] B indicates positive bioassay.

[b] Symptom abbreviations: cl = chlorosis, cr = chlorotic ring spots, lc = interveinal chlorosis, ld = leaf deformity, lp = line patterning, m = mild, nll = necrotic local lesions, nr = necrotic rings, r = rosetting, sc = systemic chlorosis, sm = systemic mosaic/mottling, st = stunting, str = streaking, tn = tip necrosis, vb = vein-banding, vg = veinal greening. Absence of description indicates no symptoms apparent or latent infection.

[c] * = New host recording. Biennial or perennial host.

Table 1. (*continued from preceding page*)

Latin name	Common name	No. plants positive for TSWV/total no. of plants[a]	Symptoms[b]	Ovipository host for WFT
S. vulgaris L.*	Common groundsel	5/11 B	...	...
Sonchus asper (L.) J. Hill.	Spiny annual sowthistle	14/18 B	...	+
S. oleraceus L.	Annual sowthistle	12/16 B	sm	+
Taraxacum officinale Wigg.	Dandelion	8/12 B	sm	+
Tussilago farara L.*	Coltsfoot	3/8	m.cl	+
Xanthium strumarium L.	Cocklebur	6/9 B	...	+
CRASSULACEAE				
Sedum spp.*	Sedum	5/5 B	sm	+
CRUCIFERAE				
Alliaria officinalis Andrz.*	Garlic mustard	5/9 B	m.sm	+
Barbarea vulgaris R. Br.*	Yellow-rocket	4/14	...	+
Capsella bursa-pastoris (L.) Medik.	Shepherd's-purse	10/13 B	sc	+
Cardamine oligosperma Nutt.*	Cress	7/11 B	...	+
Erysimum cheiranthoides L.*	Wormseed mustard	10/12 B	sm,st	−
Hesperis matronalis L.*	Dame's-rocket	4/11	m.sm	+
CUCURBITACEAE				
Echinocystis lobata (Michx.) Torr. & A. Gray*	Wild cucumber	6/8 B	cll,nll,ld,s,str	...
CYPERACEAE				
Cyperus esculentus L.*	Yellow nut sedge	5/10	...	...
FABACEAE				
Cassia occidentalis L.*	Coffee senna	3/8	nll,st,sm	...
GERANIACEAE				
Geranium robertianum L.	Herb-robert	5/8 B	m.sm	+
LABIATAE				
Lamium amplexicaule L.*	Henbit	3/5 B	...	...
Marrubium vulgare L.	Horehound	3/5	...	...
Mentha arvensis L.*	Field mint	2/5	...	...
LAMIACEAE				
Monarda fistulosa L.*	Wild bergamot	5/9	...	...
LEGUMINOSAE				
Lupinus spp.	Lupine	6/8 B	nr,ld	+
Medicago lupulina L.*	Black medick	8/18 B	...	+
Melilotus officinalis (L.) Lam.	Yellow sweet-clover	6/8 B	sm,nr,cr	...
Trifolium repens L.	White clover	6/8 B	sm,nr,cr	+
LILIACEAE				
Maianthemum canadense Desf.*	Wild-lily-of-the-valley	5/5	m.mosaic	+
MALVACEAE				
Hibiscus trionum L.*	Flower-of-an-hour	5/5 B	...	...
Malva neglecta Wallr.	Common mallow	13/18 B	...	...
M. parviflora L.	Small-flowered mallow	10/12 B	...	...
ONAGRACEAE				
Oenothera biennis L.*	Yellow evening-primrose	10/14 B	m,sm	...
OXALIDACEAE				
Oxalis stricta L.*	European woodsorrel	3/5 B	m.sm	+
PAPAVERACEAE				
Papaver sp.	Poppy	4/7	m.sm,st	...
PLANTAGINACEAE				
Plantago lanceolata L.*	Narrow-leaved plantain	8/12 B	m.sm	+
P. rugelii Decne.	Rugel's plantain	8/11 B	cl,m.sm	...
POLYGONACEAE				
Fagopyrum esculentum Moench*	Buckwheat	8/10 B	m.sm	+
Polygonum spp.	Bindweed	10/15 B	...	...
Polygonum aviculare L.*	Prostrate knotweed	9/14 B	...	...
P. convolvulus L.*	Wild buckwheat	7/11 B	m.sm	+
P. persicaria L.*	Lady's-thumb	14/17 B	cll,m.sm	+
Rumex crispus L.*	Curly dock	10/19 B	...	+
PORTULACACEAE				
Portulaca oleracea L.	Purslane	12/17	tn,ld,sm	+
PRIMULACEAE				
Anagallis arvensis L.*	Scarlet pimpernel	3/5 B	m.sm	...
RANUNCULACEAE				
Aquilegia vulgaris L.	Columbine	3/5	...	+
Ranunculus acris L.*	Tall buttercup	6/8 B	lp,ns,sm	...
R. abortivus L.*	Small-flowered buttercup	4/6	...	...
R. arvensis L.	Corn buttercup	4/5	vg,ic	...
SCROPHULARIACEAE				
Verbascum thapsus L.*	Common mullein	9/13 B	m.sc,m.sm	−
SOLANACEAE				
Datura stramonium L.	Jimsonweed	8/10 B	nl,sm,ld	+
Physalis heterophylla Nees*	Clammy groundcherry	4/6 B	sm,st	...
Solanum americanum Mill.	American nightshade	4/5 B	...	...
Solanum carolinense L.	Horsenettle	6/6 B	...	...

(*continued on next page*)

Table 1. (*continued from preceding page*)

Latin name	Common name	No. plants positive for TSWV/total no. of plants[a]	Symptoms[b]	Ovipository host for WFT
S. dulcamara L.	Climbing nightshade	5/9 B	···	···
S. nigrum L.	Black nightshade	9/10 B	m.sm	
S. ptycanthum Dunal in DC.*	Eastern black nightshade	7/8 B	···	+
UMBELLIFERAE				
Carum carvii L.*	Caraway	5/6	···	−
Conium maculatum L.*	Poison-hemlock	5/6 B	···	···
URTICACEAE				
Pilea pumila (L.) A. Gray.*	Clearweed	5/6 B	···	+
VERBENACEAE				
Verbena spp.	Vervain	3/6 B	sn,m.sm	···
Verbena hastata L.	Blue vervain	3/7 B	···	···

(mugwort) 6; *Centaurea maculosa* Lam. (spotted knapweed) 5; *C. nigra* L. (black knapweed) 10; *Echinops sphaerocephalus* L. (globe thistle) 5; *Erigeron annuus* (L.) Pers. (annual fleabane) 18; *E. philadelphicus* L. (Philadelphia fleabane) 5; *Eupatorium rugosum* Houtt. (white snakeroot) 6; *Helianthus tuberosus* L. (Jerusalem artichoke) 6; *Hieracium aurantiacum* L. (orange hawkweed) 6; *H. pratense* Tausch. (yellow hawkweed) 5; *Inula helenium* L. (elecampane) 5; *Onopordum acanthium* L. (Scotch thistle) 5; *Senecio aureus* L. (golden ragwort) 11; *Silybum marianum* (L.) Gaertn. (milk thistle) 5; *Solidago* spp. (goldenrods) 23; *S. caesia* L. (blue-stem goldenrod) 5; *S. canadensis* L. (Canada goldenrod) 8; *S. flexicaulis* L. (zigzag goldenrod) 9; *S. graminifolia* (L.) Salisb. (lance-leaved goldenrod) 7; *S. nemoralis* Aiton (gray-stem goldenrod) 5; *Tanacetum vulgare* L. (tansy) 5; *Tragopogon dubius* Scop. (goat's beard) 5. CONVOLVULACEAE: *Convolvulus sepium* L. (hedge bindweed) 5. CRUCIFERAE: *Brassica nigra* (L.) W. Koch (black mustard) 7; *Diplotaxis tenuifolia* (L.) DC. (narrowleaf wall rocket) 5; *Erysimum hieraciifolium* L. (tall wormseed mustard) 5; *Lepidium campestre* (L.) R. Br. (field peppergrass) 9; *L. densiflorum* Schrad. (common peppergrass) 5; *L. virginicum* L. (poor man's peppergrass) 5; *Sinapis arvensis* L. (wild mustard) 9; *Sisymbrium altissimum* L. (tumble mustard) 7; *S. loeselii* L. (tall hedge mustard) 5; *Thlaspi arvense* L. (field penny cress) 7. DIPSACEAE: *Dipsacus sylvestris* Huds. (teasel) 7. EQUISETACEAE: *Equisetum arvense* L. (field horsetail) 10. EUPHORBIACEAE: *Acalypha rhomboidea* Raf. (rhombic copperleaf) 6; *Euphorbia cyparissias* L. (cypress spurge) 6. FUMARIACEAE: *Fumaria officinalis* L. (fumitory) 5. GERANIACEAE: *Geranium maculatum* L. (wild geranium) 8. GRAMINEAE: *Agropyron repens* (L.) P. Beauv. (quackgrass) 10; *Avena fatua* L. (wild oats) 20; *Brachiaria* sp. (fringed signalgrass) 8; *Bromus inermis* Leyss. (smooth brome) 6; *B. secalinus* L. (cheatgrass) 10; *Cenchrus longispinus* (Hack.) Fern. (longspine sandbur) 10; *Dactylis glomerata* L. (orchardgrass) 10; *Digitaria* spp. (crabgrass) 7; *D. ischaemum* (Schreb.) Schreb. ex Muhl. (smooth crabgrass) 15; *D. sanguinalis* (L.) Scop. (large crabgrass) 10; *Echinochloa colonum* (L.) Link. (jungle ricegrass) 8; *E. crusgalli* (L.) P. Beauv. (barnyard grass) 18; *Hordeum jubatum* L. (foxtail barley) 6; *H. vulgare* L. (common barley) 17; *Leersia oryzoides* (L.) Sw. (rice cutgrass) 5; *Lolium perenne* L. (perennial ryegrass) 10; *L. persicum* Boiss. & Hohen. ex Boiss. (Persian darnel) 6; *Muhlenbergia frondosa* L. (wirestem muhly) 15; *Panicum capillare* L. (witch grass) 14; *P. dichotomiflorum* Michx. (fall panicum) 8; *P. miliaceum* L. (proso millet) 14; *Phalaris canariensis* L. (canarygrass) 10; *Phleum pratense* L. (timothy) 10; *Poa annua* L. (annual bluegrass) 10; *P. compressa* L. (Canada bluegrass) 10; *Setaria faberi* Herrm. (giant foxtail) 9; *S. geniculata* (Lam.) P. Beauv. (knotroot foxtail) 10; *S. glauca* (L.) P. Beauv. (yellow foxtail) 13; *S. verticillata* (L.) P. Beauv. (bristly foxtail) 6; *S. viridis* (L.) Beauv. (green foxtail) 10; *Sorghum halepense* (L.) Pers. (johnsongrass) 10. HYPERICACEAE: *Hypericum perforatum* L. (St.-John's-wort) 7. LABIATAE: *Galeopsis tetrahit* L. (hemp-nettle) 6; *Glechoma hederacea* L. (groundivy) 5; *Leonurus cardiaca* L. (motherwort) 18; *Lycopus americanus* Muhl. ex Barton (cut-leaved water horehound) 7; *Mentha spicata* L. (spearmint) 5; *Monarda fistulosa* L. (wild bergamot) 8; *Prunella vulgaris* L. (heal-all) 9; *Satureja vulgaris* (L.) Fritsch (wild basil) 5. LEGUMINOSAE: *Coronilla varia* L. (crown vetch) 5; *Desmodium tortuosum* (Sw.) DC. (beggarweed) 5; *Lathyrus latifolius* L. (everlasting pea) 5; *L. tuberosus* L. (tuberous vetchling) 5; *Lotus corniculatus* L. (bird's-foot trefoil) 8; *Medicago sativa* L. (alfalfa) 4; *Melilotus alba* Medik. (white sweet-clover) 12; *Trifolium campestre* Schreb. (large hop clover) 8; *T. pratense* L. (red clover) 21; *Vicia angustifolia* L. (narrowleaf vetch) 5; *V. cracca* L. (tufted vetch) 13. LILIACEAE: *Trillium* spp. (trillium) 7. LYTHRACEAE: *Lythrum salicaria* L. (purple loosestrife) 5. MALVACEAE: *Abutilon theophrastii* Medik. (velvetleaf) 7; *Malva sylvestris* L. (high mallow) 6. OLEACEAE: *Fraxinus* spp. (ash) 8. ONAGRACEAE: *Circaea quadrisulcata* (Maxim.) Franch. & Sav. (enchanter's nightshade) 5; *Epilobium angustifolium* L. (fireweed) 6; *E. glandulosum* Lehm. (northern willow herb) 17; *E. hirsutum* L. (hairy willow herb) 5. PAPAVERACEAE: *Chelidonium majus* L. (greater celandine) 5. PHYTOLACCACEAE: *Phytolacca americana* L. (pokeweed) 7. PLANTAGINACEAE: *Plantago major* L. (broadleaf plantain) 19; *P. media* L. (hoary plantain) 6. POLYGONACEAE: *Polygonum cuspidatum* Siebold & Zucc. (Japanese knotweed) 6; *P. lapathifolium* L. (pale smartweed) 14; *P. pensylvanicum* L. (Pennsylvania smartweed) 5; *P. scabrum* Maench. (green smartweed) 6; *Rumex acetosa* L. (green sorrel) 5; *R. acetosella* L. (sheep sorrel) 5; *R. obtusifolius* L. (broadleaf dock) 15. PRIMULACEAE: *Lysimachia ciliata* L. (fringed loosestrife) 6; *L. nummularia* L. (moneywort) 6. RANUNCULACEAE: *Actaea alba* (L.) Mill. (white baneberry) 5; *Anemone riparia* Fernald (thimbleweed) 5; *Hepatica nobilis* Schreb. (hepatica) 5; *Ranunculus repens* L. (creeping buttercup) 5; *Thalictrum dioicum* L. (early meadowrue) 5. ROSACEAE: *Agrimonia* spp. (agrimony) 6; *Crataegus* spp. (hawthorn) 5; *Geum aleppicum* Jacq. (yellow avens) 6; *G. virginianum* L. (rough avens) 6; *Fragaria virginiana* Duchesne (wild strawberry) 9; *Potentilla anserina* L. (silverweed) 5; *P. argentea* L. (silvery cinquefoil) 6; *P. norvegica* L. (rough cinquefoil) 12; *P. recta* L. (sulphur cinquefoil) 8; *P. simplex* Michx. (common cinquefoil) 5; *Rosa multiflora* Thunb. ex J. A. Murray (wild rose) 7; *Rubus allegheniensis* Porter (common blackberry) 5; *R. hispidus* L. (northern dewberry) 5; *R. idaeus* L. var. *idaeus* L. (red raspberry) 5; *R. occidentalis* L. (black raspberry) 5. RUBIACEAE: *Galium aparine* L. (cleavers) 6; *G. verum* L. (yellow bedstraw) 5. SAXIFRAGACEAE: *Mitella diphylla* L. (mitrewort) 5; *Ribes cynosbati* L. (gooseberry) 5; *Tiarella cordifolia* L. (foamflower) 6. SCROPHULARIACEAE: *Chaenorrhinum minus* (L.) Lange. (dwarf snapdragon) 5; *Digitalis purpurea* L. (foxglove) 5; *Linaria dalmatica* (L.) Miller (Dalmatian

toadflax) 5; *L. vulgaris* Mill. (toadflax) 5; *Verbascum blattaria* L. (moth mullein) 5; *Veronica agrestis* L. (field speedwell) 5; *V. officinalis* L. (common speedwell) 7; *V. peregrina* L. (purslane speedwell) 8; *V. serpyllifolia* L. (thyme-leaved speedwell) 6. UMBELLIFERAE: *Cicuta maculata* L. (spotted water-hemlock) 5; *Cryptotaenia canadensis* (L.) DC. (honewort) 5; *Daucus carota* L. (wild carrot) 21; *Heracleum lanatum* Michx. (cow-parsnip) 6; *Pastinaca sativa* L. (wild parsnip) 5; *Sium sauve* Walter (water-parsnip) 5; *Zizia aurea* (L.) W. Koch. (golden alexanders) 5. URTICACEAE: *Urtica dioica* L. (stinging nettle) 17. VIOLACEAE: *Viola arvensis* J. A. Murray (field violet) 5; *V. eriocarpa* Schwein. (smooth yellow violet) 5; *V. palmata* L. (wood violet) 5; *V. septentrionalis* Greene (northern blue violet) 5. VITACEAE: *Parthenocissus quinquefolia* (L.) Planch. (Virginia creeper) 6; *Vitis* spp. (wild grape) 19.

One hundred and thirteen plant species, representing 35 families, assayed positive for TSWV (Table 1). Most plants susceptible to TSWV were found in the Compositae and Solanaceae families, with fewer species in the Caryophyllaceae, Chenopodiaceae, Leguminosae, and Polygonaceae. Of these, 62 are first reports as hosts for this virus (Table 1). TSWV has the widest host range of any reported plant virus (15,18) and now occurs in about 300 species, including those found susceptible in this study.

Although primary symptoms resulting from thrips feeding were often difficult to discern, visible local symptoms usually consisted of chlorotic or necrotic lesions. Systemic symptoms were generally more severe, including mosaic mottling, chlorotic or necrotic ring spots, leaf deformation, and stunting. These symptoms were similar to those caused by TSWV in other hosts (29). Many infected plants remained symptomless. Symptomless infections by TSWV have been reported in other hosts, and some species often outgrow the initial symptoms (9,21,26).

Symptoms caused by TSWV are often variable, depending on the age of the plant, when it became infected, its nutritional level, and environmental conditions (11,22). Mild systemic mottling, evident in young plants of the *Aster* sp., was not seen as plants reached maturity and set seed. Symptoms apparent in controlled environment conditions may not necessarily be the same as those seen under field conditions. Early season plants, grown under cool conditions, may exhibit different symptoms from plants grown at higher temperatures. Cyclamen plants exhibited necrotic foliar symptoms when grown at 13 C in the greenhouse, but when the temperature was increased to 22 C, they became symptomless (3). Because TSWV may not be widely distributed in the field in Ontario, it was considered inadvisable to compare symptomatology on field vs. growth room-reared plants.

In 1,360 weed samples collected across southern Ontario from 22 greenhouses of ornamental plants (Fig. 1), TSWV was most commonly found in chickory, chickweed, dandelion, lamb's-quarters, mallow, oxalis, plantain, purslane, and shepherd's-purse growing along groundbed borders or around cull piles outside the greenhouses. Weed species varied from one greenhouse to another, depending on weed control practices. In general, high levels of infected weeds in a greenhouse coincided with heavy losses in susceptible ornamental crops, such as alstroemeria (*Alstroemeria*), begonia *Begonia* × *hiemalis* Fotsch.), chrysanthemum, cineraria (*Senecio* × *hybridus* (Willd.) Regel), cyclamen (*Cyclamen persicum* Mill.), gerbera (*Gerbera jamesonii* H. Bolus ex J. D. Hook.), gloxinia (*S. speciosa*), impatiens (*Impatiens wallerana* J. D. Hook.), schefflera (*Schefflera arboricola* Hayata), and stephanotis (*Stephanotis floribunda* Brongn.).

Sampling of weeds and native plant species across southern Ontario (Fig. 1) failed to reveal any evidence of TSWV in field populations. Although the virus has been reported to occur naturally in Ontario (10,25), the absence of an efficient vector in the field has prevented disease losses in field vegetables. However, in 1989, both WFT and TSWV were introduced with tomato and pepper transplant stock from Georgia. The stock was widely planted in southwestern and central Ontario. Sampling of several of these fields in 1990 failed to identify native reservoirs of TSWV or the presence of the WFT. Several factors are likely responsible for this, including a cool, wet spring in 1989 which minimized secondary virus spread from infected fields and the apparent failure of the WFT to overwinter.

Although neither the virus nor vector is currently endemic in field crops in Ontario, the TSWV/WFT complex represents a potential threat to field vegetable production. This concern is justified from three points of view: 1) the potential development of a biotype of WFT that can overwinter in Ontario; 2) the likely infection of field vegetables through the distribution of TSWV-infected/ WFT-infested bedding plants or nursery transplant stock; and 3) the establishment of WFT and TSWV in outdoor cull piles of TSWV-infected plant debris encouraging thrips to move to native plants. Therefore, a significant increase in virus incidence could occur within populations of susceptible annual and perennial plant species. Carryover of virus into subsequent growing seasons would be facilitated largely through biennial and perennial plants (Table 1) that are prevalent throughout southern Ontario.

Most of the plants (86%) evaluated in the laboratory were ovipository hosts for WFT (Table 1). The species that supported the highest numbers of live nymphs were cocklebur, curly dock, eastern black nightshade, bluewood aster, herb robert, jimsonweed, lamb's-quarters, lupine, purslane, and white clover. In the greenhouse or field, however, the preference for weeds by the WFT may be influenced by the presence of mixed populations of other cultivated and native plant species. Further studies are necessary to examine the feeding preferences and suitability of such species as reproductive hosts of the WFT. Elimination of these weeds, which may act as both reservoir hosts for virus and thrips, is an important part of an integrated control strategy for the WFT/ TSWV complex in the field and in greenhouse crops.

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