Project title: Western Flower Thrips Abundance and Incidence of Tomato Spotted Wilt in Processing Tomato Fields in the Central Valley of California (2008)

Principal investigator: Robert L. Gilbertson

Department of Plant Pathology, University of California, Davis

Cooperating personnel: Ozgur Batuman, Postdoctoral Researcher, UCD

Michelle LeStrange, Farm Adviser, Kings County

Tom Turini, Farm Adviser, Fresno County

Scott Stoddard, Farm Adviser, Merced County

Diane E. Ullman, Department of Entomology, UCD

Abstract

The goal of this project is improved understanding of thrips population dynamics and *Tomato spotted wilt virus* (TSWV) incidence in Central California, and development an IPM strategy for TSWV. Population densities of western flower thrips (WFT; *Frankliniella occidentalis*) and TSWV incidence were monitored in processing tomato transplant-producing greenhouses and associated fields in the Central Valley of California for a second year in 2008. Thrips were monitored with yellow sticky cards and in tomato flowers, whereas as TSWV incidence was assessed visually or with sensitive indicator plants. Similar to 2007 results, transplants had low thrips populations and no TSWV. Monitoring of representative direct-seeded and transplanted tomato fields (including those established with monitored transplants) in Fresno, Kings and Merced Counties revealed up to four-fold higher thrips populations in 2008 compared with 2007; highest populations were detected from April-August, with a peak in May. TSWV did not appear until late May, but subsequently appeared in most monitored fields, at relatively low incidences (3-19%) up through harvest. TSWV was infrequently detected in thrips by RT-PCR. In Merced, TSWV was detected earlier (mid-April), although thrips populations increased later (May) than in Fresno County. TSWV in monitored tomato fields in Merced was low (3-6%), and TSWV was infrequently detected in thrips. No single significant inoculum source for thrips/TSWV was identified: almond orchards had low thrips populations, and no TSWV and winter and spring weed surveys revealed very low TSWV infection (<0.1%). Lettuce and radicchio fields had moderate (spring) to low (winter) thrips populations and low TSWV infection, with the exception of some fall-planted radicchio fields in Merced. In insecticide trials, a number of materials reduced thrips numbers, but the effect was temporary (~7 days). Thus, our results indicate that low levels of initial TSWV inoculum build-up in early-planted crops, with highest levels in later-planted fields having high thrips populations. Based upon these findings, an integrated pest management strategy for TSWV in Central California is proposed.

Objectives

The objectives of this study were 1) to determine thrips populations and TSWV incidence associated with greenhouse-produced tomato transplants, 2) to determine whether any linkage exists between thrips and TSWV and greenhouse-produced transplants and outbreaks of TSWV in the field, 3) to gain insight into potential sources of TSWV for tomato in the Central Valley, 4) to assess various thrips control methods and 5) to develop an integrated pest management strategy for TSWV in the Central Valley.

Materials and Methods

Thrips monitoring in transplant greenhouses. Three transplant greenhouses (California Transplant in Newman, Mezzei in Fresno and Westside Transplant in Huron) were monitored again for thrips and TSWV incidence in 2008. These greenhouses produce tomato transplants in southern Fresno County. Yellow sticky cards were again used to monitor thrips. At each site six to ten yellow sticky cards were placed with tomatoes in a greenhouse, and four sticky cards were placed outside around the periphery of the property. Cards were changed weekly from March to June at two sites. At California Transplant, continuous monitoring around the periphery has been ongoing since March 2007. Population densities of thrips were estimated by counting thrips on yellow sticky cards in the laboratory with a dissecting microscope at 40x magnification. Thrips were counted and identified to species and gender.

Thrips monitoring in representative fields. Table 1 lists the 31 fields that were monitored in 2008. A yellow sticky card was placed in each of the four corners of a field just above the canopy. Cards were changed weekly or biweekly beginning in February and up to harvest. Thrips were counted as described above. Population densities of thrips were also estimated weekly by randomly collecting flowers, placing these into vials with 70% ethanol and returning vials to the laboratory for counting. Flower samples were collected from the same sites where yellow sticky cards were placed (four sites per field and 10 flowers per site). Total numbers of thrips adults and larvae were counted and identified to species.

Indicator plants. In order to detect TSWV early in the growing season (i.e., before tomatoes start showing obvious symptoms) fava bean plants, a sensitive TSWV indicator, were placed near each yellow sticky card placed in greenhouses and fields. Indicator plants were seeded and grown in an insect-free greenhouse at UC Davis. The potted 10-day-old indicator plants were changed weekly along with the yellow sticky cards.

Indicator plants were brought to the laboratory at UC Davis, kept for 10 days, and then symptom development and thrips populations assessed.

TSWV incidence and detection. Percent TSWV incidence in tomato, lettuce and radicchio fields was determined by visually examining plants at the four locations in each field. At each location, all plants in 10 yards (meters) of each of 5 randomly selected rows (each separated by 5 rows) were examined. An overall incidence of tomato spotted wilt at each site of the field (four per field) was calculated (presented as number of infected plants per 100 row feet and % incidence). Disease incidence was assessed weekly and selected plants tested with ImmunoStrips (AgDia) and RT-PCR by using *N* gene-specific primers.

Isolate collection and genetic diversity of TSWV. Symptomatic plants were also randomly collected from different locations. In order to assess the genetic diversity of TSWV isolates from the Central Valley, the fragment of RNA encoding the *N* gene was amplified by PCR and the sequence of the *N* gene determined and compared among isolates.

Table 1. List of monitored fields and their locations in 2008.

Fresno & Kings Counties	Locations	Merced County	Locations
Harris Almond	Coalinga	LG1 Rad-Winter Rad	Le Grand Ranch
Sano Almond	Firebaugh	LG2 Rad-Winter Rad	Le Grand Ranch
Almond 1,2 and 3	S Huron	CD1 Rad-Winter Rad	Childs Ave
Hammik TP	Firebaugh	CD2 Rad-Winter Rad	Childs Ave
5 Star TP	Five Points	CW1 Rad-Winter Rad	Chowchilla
5 Star DS	Five Points	AT1 Rad-Winter Rad	Athlone / S Mush Rd
Sano TP	Firebaugh	LG3 Rad-Spring Rad	Le Grand Ranch
Harris Ogan. Fresh Market	Coalinga	CD3 TP-Fresh Market	Childs Ave/ Arboleda
Wside TP(30th Ave)	West Side	CD4 TP-L. Fresh Market	Childs Ave
Woolf Las/Trac TP	S Huron	LG4 TP-Processing	Le Grand Rd
Woolf Creek 1 DS	W Huron	LG5 TP-L. Fresh Market	Le Grand Rd
Woolf Creek 2 TP	W Huron	MN1 TP-Processing	Minturn / B. Hollow
Jones DS	NE Kettleman City	MN2 TP-L. Fresh Market	Minturn Rd
Jones TP	NE Kettleman City	GT1 TP-Processing	Gillette / Burchell
Huron Rad	S Huron		

TP, transplanted processing tomato; **DS**, direct seeded processing tomato; **Rad**, radicchio; **L**, late planted;

Comparison of insecticides for control of thrips on tomato. The study was conducted at the University of California West Side Research and Extension Center at Five Points, California. Processing tomato seed (variety 303) were sown and sprinkler irrigated on 9 April. Materials selected (Table 2) were based on promise in other thrips insecticide trials, and communication with Pest Control Advisors and chemical company representatives. The experimental design was a four replication randomized complete block and plot size was on 66 inch bed by 50 ft. Materials were applied in the equivalent of 30 gallons of water per acre with surfactant Induce 0.25% on 21 July. On 25 July, ten 12 inch shoots per plot were collected and shaken onto a white material. Thrips that were moving were counted separately from those that were apparently dead.

Results

Transplant Monitoring

Thrips and TSWV monitoring was initiated in mid-February 2008 in transplant houses. Thrips populations were detected in transplant greenhouses. In general, populations were relatively low (0-200 thrips/card), and highest numbers were identified in May, especially in Mezzei, where ~2,000 thrips/card were detected (Fig. 1). For example, at California (CA) Transplant, the average total thrips count per card was ~10-60, with a peak numbers detected (260 thrips/card) in mid-May. It is important to note here that thrips numbers in the field were also very high in May.

Much higher thrips populations were detected outside of the greenhouses through mid-May (~300-5800 thrips/card), with numbers decreasing by early July (Fig. 1). Average thrips counts per card for outside of Westside Transplant (WSTP) and Mezzei transplants (~35-1970 thrips/card) were higher than CA Transplants (~6-260 thrips/card) (Fig. 1). The overall higher thrips populations at Mezzei and WSTP can be attributed to these greenhouses being closer to agriculture production and not being enclosed, whereas greenhouses of CA Transplant are more isolated and are enclosed. Thrips captured from all these greenhouses were identified as western flower thrips, and the numbers of females were three-fold higher than males.

In general, thrips populations associated with transplants were similar in 2007 and 2008, with the exception of the high populations form Mezzei in 2008. No obvious thrips damage was observed on transplants, nor were symptoms of TSWV observed on transplants. Consistent with this, no TSWV symptoms were observed on the fava bean indicators in greenhouses. Together, these results indicate that transplants are not an important inoculum source for thrips or TSWV in the field.

Field Monitoring

Field monitoring for thrips and TSWV was initiated in transplanted and direct-seeded fields in early March 2008. As in 2007, thrips populations were slightly greater in direct-seeded fields, which is consistent with transplants not being an important source of thrips in the field. In 2008, the overall thrips populations was considerably higher (as much as four-fold) than in 2007, and populations remained high for a longer period of time (through September) (Fig. 2). In Fresno and Kings County locations, thrips populations peaked in mid-May (2,000-5,000/card), and then remained at moderate levels (2,000/card) through August. In Merced, thrips populations increased later (in May), but then remained high through September (Fig. 3). All thrips captured in the field were identified as western flower thrips, and female thrips populations were three-fold higher than male populations.

Flower sampling was initiated when plants started flowering. Average thrips numbers in flowers were four-fold higher in 2008 (0.5-2/flower in 2007 and 2-8/flower in 2008), and populations persisted throughout the growing season (Fig. 4). Thrips larvae were commonly found in flowers, which could favor secondary virus spread and evidence of this came from finding late season TSWV infections where only one shoot on a plant developed TSW-like symptoms.

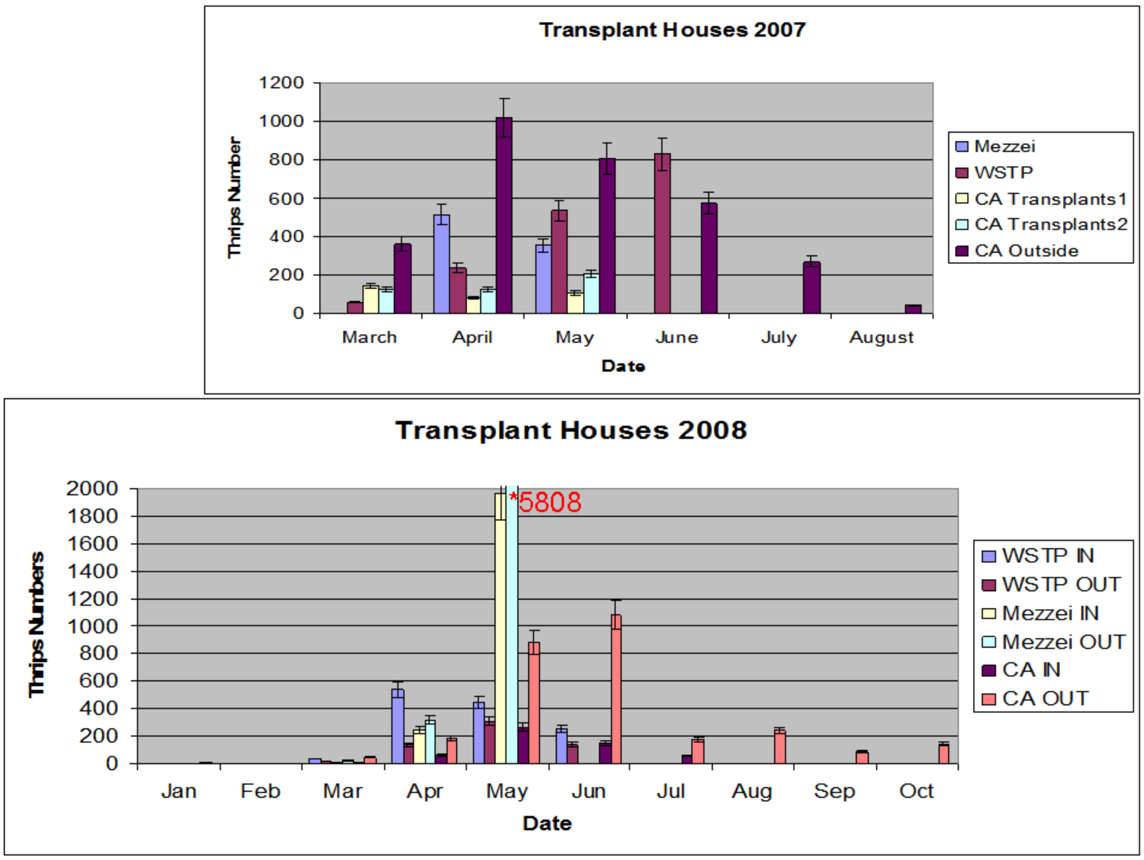


Figure 1. Average thrips counts on yellow sticky cards in tomato transplant greenhouses. *5808 indicates average thrips count/card at out side of Mezzei transplant greenhouses.

The first detection of TSWV in tomato plants was in Merced on 18 April in a transplanted fresh market field on Childs Road. However, TSWV incidence remained low (3-6%) throughout the season in monitored fields in Merced. In contrast, TSWV was not observed in Fresno/Kings Counties until late May, which was a month later than in 2007. TSWV incidence in Fresno/King Counties started increasing in June and, by July-August, the disease was found in most fields and incidences ranged from 5-19% (Fig. 5).

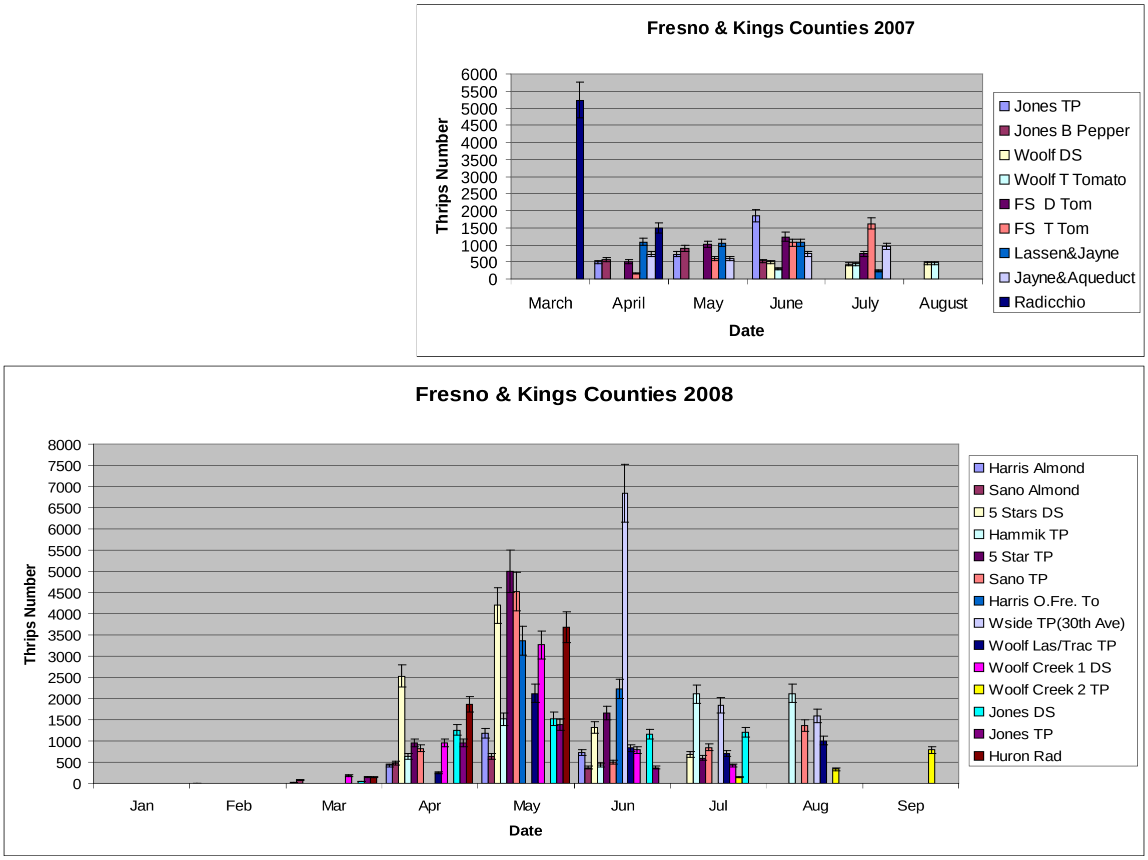


Figure 2. Average thrips counts per yellow sticky card in monitored fields in Fresno and Kings Counties. T and TP, transplant; D and DS, direct seeded; Rad, radicchio; and O.Fre.To, organic fresh market tomato

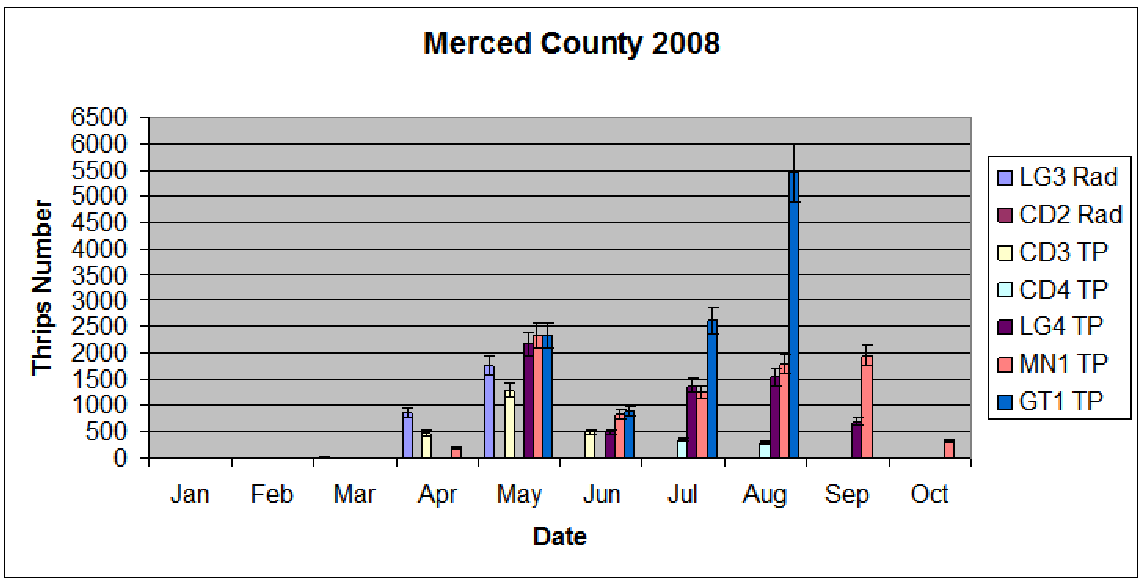
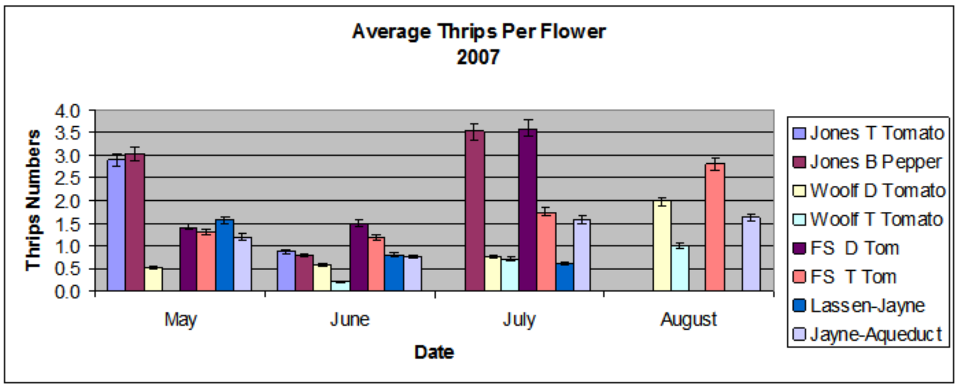


Figure 3. Average thrips counts per yellow sticky card in monitored fields in Merced County. TP, transplant; DS, direct seeded; and Rad, radicchio

The highest incidence was in later-planted fields with high thrips populations. TSWV infections levels did not increase in September or October. Thus, the overall incidence of TSWV in 2008 was slightly higher than in 2007, but the over all pattern of disease development was similar in both years. Furthermore, significant economic losses due thrips/TSWV were not reported for the monitored fields in 2007 or 2008.

In 2008, the incidence of curly top disease was greater than in 2008, and this complicated disease diagnosis as early symptoms of both diseases are similar. Interestingly, during the course of testing many symptomatic plants, we found infection by either TSWV or curly top virus, but never a mixed infection of both.



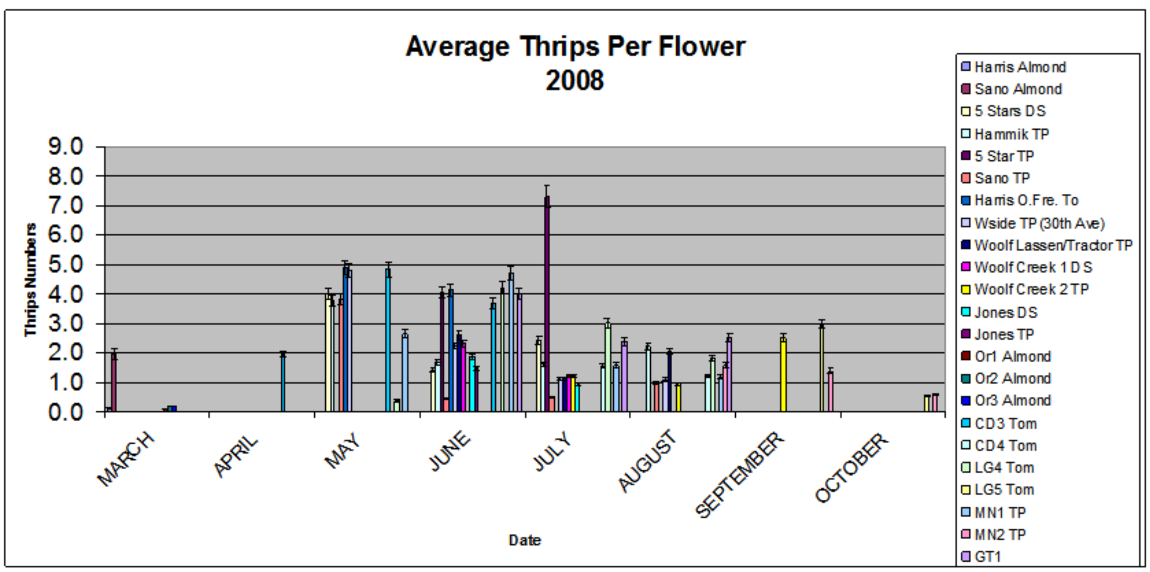


Figure 4. Average thrips counts per flower in monitored fields in Merced, Fresno and Kings Counties. T and TP, transplant; D and DS, direct seeded; Rad, radicchio; and O.Fre.To, organic fresh market tomato

Survey of potential hosts for TSWV and thrips

To search for potential hosts for TSWV and thrips before, during and after the season, we monitored representative almond orchards; spring-planted lettuce in Fresno and spring-and fall-planted radicchio in Merced; and numerous weeds collected in the winter and spring. The radicchio planted in fall of 2007, especially direct seeded fields in Merced, had highest thrips populations and TSWV incidences (up to 95% infection), but thrips populations declined considerably into the winter. In spring-planted lettuce and radicchio very low incidences of TSWV were observed, although thrips populations were increasing in these fields. Collected thrips samples were also identified as western flower thrips.

Interestingly, an early planted pepper field in Merced, which was in close proximity to the heavily infected fall-planted radicchio field (already harvested) had extremely high thrips populations, especially in early April (30-70 thrips/flower) and an unusually high incidence of TSWV (>70%, and data not shown). However, as the spring-planted radicchio field (LG3; that was monitored) in this same location had very low level of TSWV (<0.1%), it is not clear where the major source of TSWV inoculum for this field came from.

Almond flowers were collected and thrips from these flowers were counted and tested for TSWV with RT-PCR. Thrips population densities were low both on yellow sticky cards and in flowers, and indicator plants placed in these orchards remained free of TSW-symptoms. To date, no TSWV has been detected in thrips from almond orchards or in almond trees. Thus, almonds do not seem to play a major role in TSWV in tomato.

In areas with recent outbreaks of TSWV, plants other than tomato were collected and tested for the virus. Plants tested include lettuce, spinach, London rocket, barnyardgrass, bindweed, bur clover, nettle, black nightshade, common sunflower, dodder, fiddleneck, lambsquarters, malva, pepper, pigweed, prickly lettuce, purslane, groundsel, mustard, almond, fig, Russian thistle, sowthistle, jimsonweed, cardone and tree tobacco. Most samples tested were negative for TSWV, only lettuce, pepper, spinach, London rocket, cardone, malva, prickly lettuce, groundsel and sowthistle tested positive for the virus, but incidence was very low (<0.1%).

Genetic diversity of TSWV Isolates from the Central Valley

Selected tomato, pepper, radicchio, lettuce, and weeds showing virus-like symptoms were collected and tested for TSWV in 2008 by RT-PCR. The amplified *N* gene DNA fragment from selected TSWV isolates was cloned and sequenced to determine the genetic diversity of the TSWV in the Central Valley of California. Sequence analysis of TSWV *N* genes revealed a very closely related group of isolates, as no major differences were found, irrespective of the host and location the isolate came from. Similar results were obtained with TSWV sequences amplified from thrips. These results indicate that in

Central California, the TSWV population is fairly homogeneous, and likely represents a geographically isolated population.

In RT-PCR tests performed with randomly collected thrips, most of the insects were negative, indicating that most of the thrips were not carrying the virus. This is also consistent with the relatively low levels of TSWV in tomato in 2008 despite the high thrips populations in the fields; if more of these thrips were carrying the virus then the TSWV incidence would likely have been much higher. Thus, there was no correlation between thrips populations and TSW disease incidence.

Insecticide Trial

One approach to management of TSWV is chemical control of the thrips vector. Live thrips count means differed significantly among treatments, whereas there were no significant differences in dead thrips counts among treatments (P=0.05). Based on live thrips counts the materials that were significantly better than the untreated control included Dimethoate, Mustang with Beleaf, Radiant, Lannate and Surround. Dimethoate, Mustang with Beleaf, Radiant and Lannate were among the best performing materials last year also. Surround, which is a treated kaolin clay, also showed promise in the 2008, but was not included in the 2007 trial.

Table 2. Comparison of insecticides for control of thrips on tomato.

	Four days after treatment		
	Alive		Dead
Dimethoate 4EL 1 pt/a	0.00	c	11.25
Mustang 4.3 fl oz + Beleaf 50SG 2.8 oz/a	0.25	bc	10.00
Radiant 6.0 fl oz/a	0.25	bc	15.50
Lannate SP 1 lb	0.50	bc	14.50
Surround 25 lbs/a	0.50	bc	9.00
Mustang 4.3 fl oz/a	1.25	abc	18.00
Leverage 5.1 fl oz/a	1.25	abc	14.00
Baythroid XL 2.8 fl oz + Diazinon AG500 4qts	1.75	abc	12.75
Movento 5.0 fl oz/a	2.75	ab	15.25
Venom 70DG 4 oz/a	3.25	ab	19.50
Untreated control	4.25	a	21.75

[w] Means followed by the same letter do not differ significantly as determined by Least Significant Difference on log transformed data (P• 0.05).

Integrated pest management for TSWV in Central California

Based upon our findings the following IPM approach for managing TSWV is proposed:

A) Preplant

- **i) planting location/time of planting-**avoid hot spots known to have had high TSWV the previous year and avoid planting near and winter fields of potential bridge crops (e.g., radicchio).
- **ii) resistant cultivars-**these are available, but may not be necessary if other practices are followed.
- **iii) weed management-**maintain weed control in and around tomato fields as weeds are potential TSWV hosts.

B) Production

- **i) thrips/sentinel plant monitoring-**monitoring thrips populations and TSWV incidence can indicate when to apply insecticides for thrips control, thereby reducing TSWV spread.
- **ii) weed management** -maintain effective weed control in and around tomato fields.

C) After harvest

- **i) sanitation** -immediately plow under crop residue following harvest.
- ii) **bridge crops-**minimize the planting of bridge crops that will maintain thrips/TSWV in the absence of tomato and or provide inoculum for spring-planted tomatoes

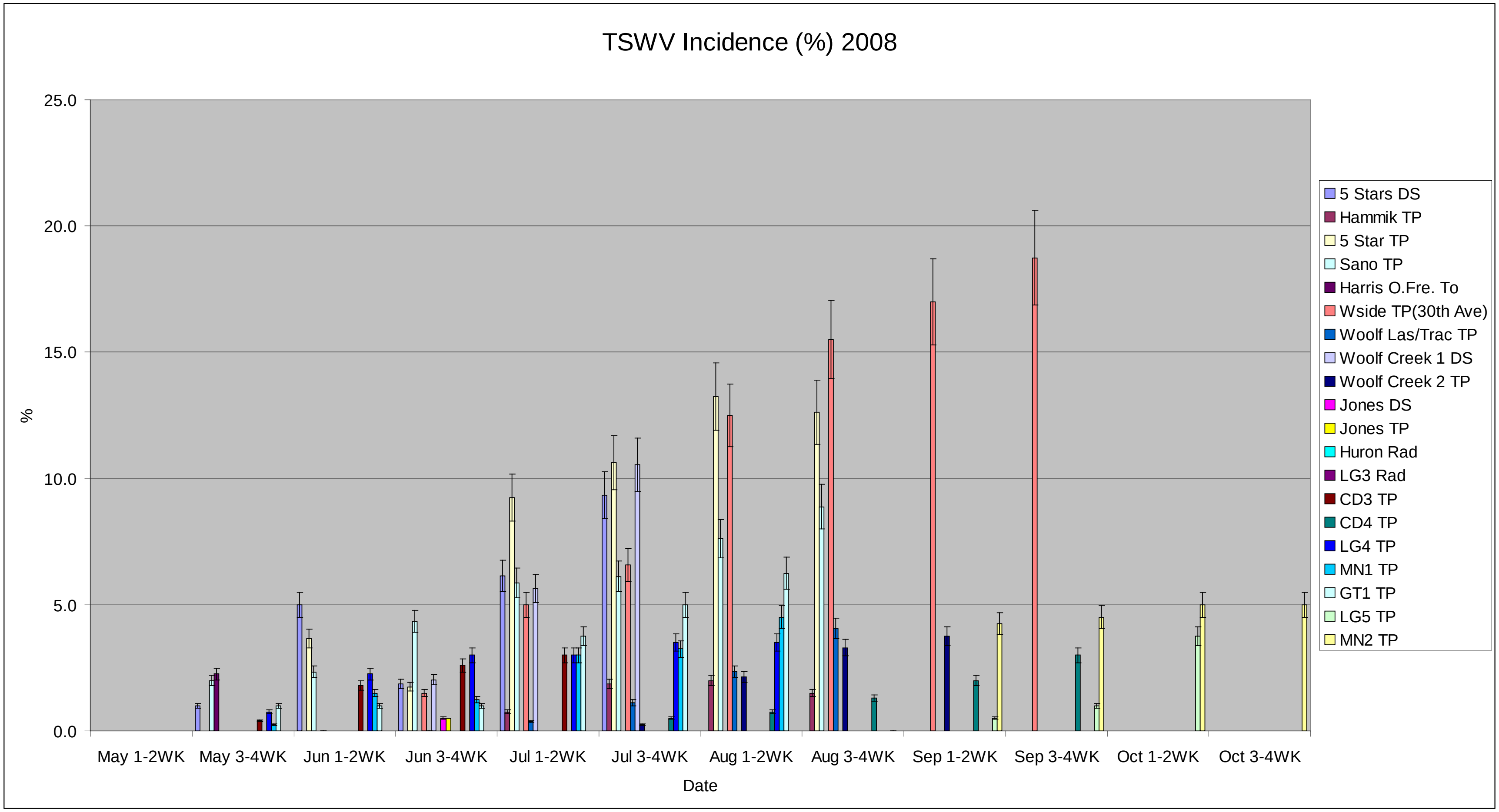


Figure 5. Percent of TSWV incidence in monitored fields in 2008.