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

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Abstract
Western flower thrips (WFT; *Frankliniella occidentalis*) population densities and tomato spotted wilt (TSW) incidence in processing tomato transplant producing greenhouses and associated fields in the Central Valley of California were monitored with aid of yellow sticky cards and indicator plants to improve understanding of disease development to create an effective strategy for disease management. Our results indicated very low populations of thrips on transplants and no evidence of TSW infection. Field monitoring for thrips and TSWV was conducted in representative direct-seeded and transplanted fields in southern Fresno County and Kings County. For field monitoring, transplants from monitored greenhouses were followed, and representative direct-seeded fields also were selected. TSWV was first detected in tomato fields on 20 April and, subsequently, appeared in all monitored fields. The overall incidence was remained low (<3%), through harvest. The overall incidence of TSW was slightly higher in direct-seeded versus transplanted processing tomato fields. In addition, lettuce and radicchio fields were surveyed as possible sources of TSWV for tomato fields. Whereas the spring lettuce had little or no TSWV, high populations of thrips and high levels TSWV infection were found in a radicchio field indicating that it could be a source of inoculum. Furthermore, a variety of thrips management approaches (insecticides and plant activators) were evaluated, and a number of these reduced thrips numbers, although only for ~7 days. An integrated pest management (IPM) strategy for TSWV is proposed.

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

Materials and Methods
Thrips monitoring in transplants greenhouses. Three transplant greenhouses (California Transplant in Newman, Mezzei in Fresno and West Side Transplant in Huron) were monitored for thrips and TSWV incidence. These greenhouses produce tomato transplants for tomato production in southern Fresno County. Yellow sticky cards were

used to monitor thrips. At least six to ten yellow sticky cards were placed in each greenhouse, and four sticky cards were placed outside around periphery of California Transplant. Cards were changed weekly from March to June. However, monitoring was continued around the periphery of California Transplant. Population densities of thrips were estimated by counting thrips on yellow sticky cards in the laboratory with dissecting microscope at 40 x magnification. Thrips were identified to species and numbers of male and female thrips were identified.

Thrips monitoring in representative fields. Thrips monitoring was carried out in eight representative fields and they are listed in Table 1. Five yellow sticky cards were placed at the corners and center of each field just above the canopy. Cards were changed weekly beginning in April up to harvest. Thrips were counted as described above. Population densities of thrips were also estimated weekly by randomly collecting samples of 10 flowers per site in these same monitored fields from May until to harvest. Flower samples were collected from same sites where yellow sticky cards were placed (five sites per field). Flowers were placed in vials containing 70% ethanol and returned to the laboratory for processing. 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) two types of TSWV-sensitive indicator plants (fava beans and petunia plants) 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 laboratory at UC Davis, kept for 10 days, and then symptom development and thrips populations on indicator plants were followed.

TSWV incidence and detection. Percent TSWV incidence in tomato fields was determined by visually examining plants at the five locations in each field. At each location, all plants in 10 yard (meter) a randomly selected section of 5 rows (each separated by 5 rows) were examined. An overall incidence of tomato spotted wilt at each site of the field (five per field) was calculated (presented as number of infected plants per 100 row feet and % incidence). Disease incidence was assessed weekly and was tested for using ImmunoStrip (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 processing tomato fields in which thrips and TSWV were monitored.

Direct-seeded Fields	**Transplanted Fields**
Woolf D. Tomato	Woolf T. Tomato
Lassen & Jayne Tomato	Jayne & Aqueduct Tomato
Five Star D. Tomato	Five Star T. Tomato
Jones T. Tomato	Jones B. Pepper

Radicchio at Lassen

Table 2. List of insecticides tested for control of thrips on tomato.

Trade name (rate of formulated product/acre)
Assail 30SG 4.0 oz
Dimethoate 4EL 1pt
Lannate SP 1 lb
Microthiol 6.0 lbs
Movento 5.0 oz
Radiant 6.0 fl oz
Mustang 4.3 fl oz + Beleaf 50SG 2.8 oz
Mustang 4.3 fl oz
Success 6.0 fl oz
Success 6.0 fl oz + Ecozin Plus 8.0 oz
Venom 70DG 4 oz

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. Treatments are listed in Table 2. Four, 7 and 11 days after treatment, 10 randomly selected flowers from the center bed of each plot were collected and placed in vials containing 70% ethanol. The number of thrips per vial was recorded as previously described. Log transformed data was subjected to analysis of variance. Least significant difference on transformed data ($P \leq 0.05$) was used for mean separation. Non-transformed means are presented as number of thrips per 10 flowers.

Influence of thrips control programs and plant activators/foliar nutrients on TSWV incidence and yield on tomato.

The study was conducted at the University of California West Side Research and Extension Center at Five Points. The experimental design was a split block with 3 replications. Main plot treatments were Platinum 8 fl oz, Platinum 11 fl oz, Admire Pro 10.5 fl oz, or Untreated. Sub-plot treatments were applied to foliage. The insecticides, rates and application dates were as follows: Success 6.0 fl oz on 15 Jun, Dimethoate 4EL 1 pt on 15 Jun, Dimethoate 4EL 1 pt on 15 Jun, Mustang on 17 July, Mustang 4.3 fl oz on 17 Jul and No foliar treatment. In the second study, the materials tested included Actigard 0.3 oz/a (acibenzolar-S-methyl: Syngenta Crop. Protection), Messenger 4.0 oz/a (harpin protein) and Nutri-Phyte 1.5 qts/acre (phosphite, Biagro Western). Each material was applied on three different schedules: a) an early application made prior to transplanting on 21 May (Messenger, Nutri-Phyte) or to plants on 25 May (Actigard), b) four applications c) seven applications. Other treatments were Success alone or the untreated control. Flower samples were collected and thrips numbers were recorded, the number of plants exhibiting TSW-symptoms was recorded and yield was determined as described above. Factorial Analysis of Variance was performed and Least significant difference ($P \leq 0.05$) is presented.

Results

Transplant Monitoring

Thrips and TSWV monitoring was initiated in mid-March 2007 in transplant houses. Thrips populations were detected in these houses, but levels were relatively low (~60-360 thrips/card). For example, at California Transplant, the average total thrips count per card was ~45-150, and this number did not change throughout the season. However, cards outside of the greenhouses had much higher counts through mid-April (~300-2500 thrips/card), but numbers decreased by early July (Fig. 1). Average thrips counts per card for West Side Transplant (WSTP) and Mezzei transplants was higher than CA Transplants (~60-800 thrips/card), and the number of thrips increased throughout the season (Fig. 1). The higher populations of thrips on transplants at Mezzei and WSTP can be attributed to these greenhouses not being enclosed, whereas greenhouses of CA Transplants were. Thrips recorded from all these greenhouses were identified as western flower thrips, and the numbers of female thrips were at three fold higher than male thrips. No obvious thrips damage was observed on transplants, nor was obvious symptoms of TSWV infection were detected on transplants from any of the transplant greenhouses. Consistent with this observation, no symptoms were observed on indicator plants. These results indicated very low populations of thrips on transplants and no evidence of TSWV infection in surveyed greenhouses.

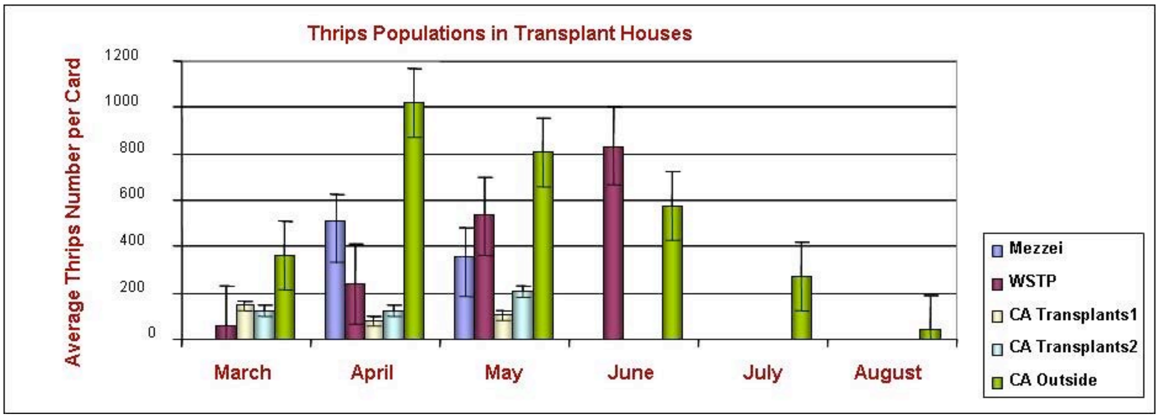

Figure 1. Average thrips counts on yellow sticky cards in tomato transplant greenhouses.

Field Monitoring

Field monitoring for thrips and TSWV was initiated in transplanted and direct-seeded fields late March 2007. Overall, average thrips counts per card for direct-seeded tomato fields were slightly higher than for transplanted tomato fields. Overall thrips population was low, and in some fields no significant increase in thrips populations was observed throughout the season (Fig. 2). Similar to the situation in the transplant greenhouses, thrips captured in the field were also identified as western flower thrips, and female thrips populations were three fold higher than male thrips populations. Flower sampling was started when plants were started to produce flowers. Average thrips numbers in flowers were 5-20 per 10 flowers (0.5-2/flower) and populations persisted throughout the growing season. The presence of thrips larvae in flower samples indicated possible reproduction of thrips in tomato flowers which in turn, indicated the possibility of secondary virus spread within the field.

Thrips populations and TSWV incidence was also monitored in a few lettuce fields (visually) and a radicchio field (with yellow sticky cards) in Huron. Whereas the spring-planted lettuce had little or no TSWV, high populations of thrips and TSWV infection were found in the radicchio field. This field was planted in late November and, when first surveyed, visual inspection revealed high populations of thrips and numerous plants showing spotted wilt-like symptoms. Testing with ImmunoStrips confirmed that these symptomatic plants were infected with TSWV. Thrips monitoring with yellow sticky cards confirmed high thrips populations in this radicchio field up to harvest (>5000/card in March and >1000/card in April). Collected thrips samples were also identified as western flower thrips. Interestingly, the direct-seeded Lassen&Jayne field, which was closest tomato field to the radicchio field, had the highest thrips counts especially in early April (Figs. 2). These results may indicate that Lassen&Jayne tomato field was under continuous exposure to thrips coming from the radicchio field.

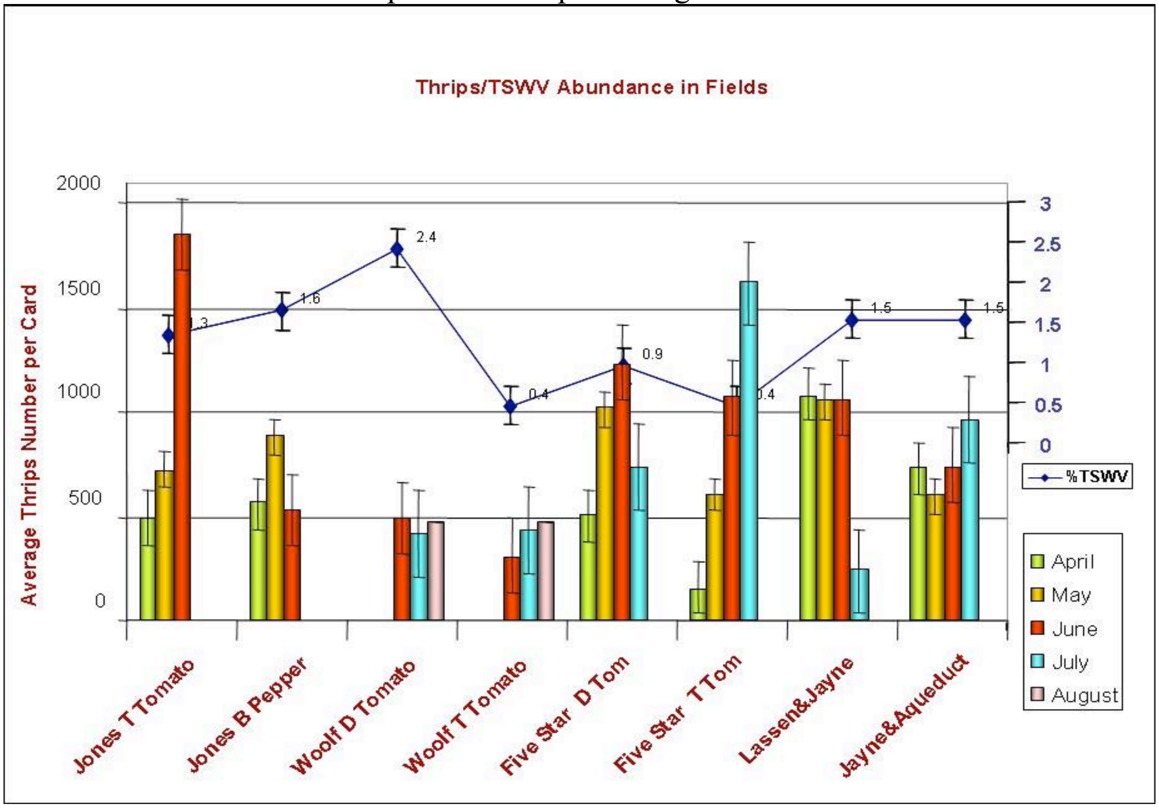

Figure 2. Average thrips counts per yellow sticky card and percent TSWV incidence in monitored fields. T, transplant; D, direct seeded; B, bell; and Tom, tomato

The first detection of TSWV in tomato plants also was observed on 20 April in the Lassen&Jayne direct-seeded tomato field in Huron. TSWV infection was confirmed by testing with ImmunoStrips and by RT-PCR. The number of symptomatic tomato plants in the field was low and no TSW was observed in the other monitored tomato fields in late April. The initial detection of TSWV in the next field, Five Star direct-seeded tomato, was based on the fava bean indicator plants from this field. The following week, tomato plants with TSWV symptoms were detected in this field. While TSWV eventually appeared in all monitored fields by May, the overall incidence was low (<3%) (Fig. 2). Overall incidence was slightly higher in direct-seeded versus transplanted tomato fields, which was consistent with the concept that transplants did not bring the virus into the fields.

Genetic diversity of TSWV Isolates from the Central Valley

Tomato, pepper, radicchio, lettuce and various weeds showing virus-like symptoms were collected and tested for TSWV. The amplified *N* gene DNA fragment from different

TSWV isolates was cloned and sequenced to determine genetic diversity of the TSWV in Central Valley of California. Sequence analysis of TSWV *N* genes did not reveal any major differences among the strains irrespective of the host and location. Thus these strains represented a fairly homogenous group (TSWV-Fresno) with only a few nucleotide changes (data not shown). We were also able to successfully detect TSWV in thrips. Moreover, sequence analysis of these strains revealed that they were similar to strains detected in plants.

Insecticide Trial

One approach to management of TSWV is chemical control of the thrips vector. Four days after treatment, thrips counts were lower than the untreated control in plots treated with Lannate SP, Radiant, and Mustang with Beleaf ($P \leq 0.05$) (Table 3). Counts from plots treated with Assail 30SG, Dimethoate 4EL Mustang, Success and Success with Ecozin Plus were not different than the best performing materials. While there were differences observed among treatments 7 days after applications (daa) were made, none of the treated plots had significantly lower counts than the untreated control. No differences among treatments were observed at 11 daa (Table 3). Thus, it appears that a number of these chemicals can reduce numbers of thrips in tomato, but that the effect is not long lasting.

Influence of Thrips Control Programs and Applications of Plant Activators/Foliar Nutrients on TSWV incidence and Yield of Tomato.

Thrips populations were moderate to high and TSW-symptom incidence was moderate. There were no significant differences in yield or thrips counts P=0.05. The TSW-symptoms were lowest for soil-applied Platinum 11.0 oz/a and a foliar application of Success 6.0 fl oz on 15 Jun P=0.05. However, this treatment was not significantly lower than 10 other treatments P=0.05. In terms of the plant activators, treatments with lower disease incidence than the untreated control included 4 applications of Actigard with Success, 4 applications of Messenger and 4 applications of Nutri-Phyte, with or without Success (P=0.05). On 15 August, treatments with lower disease incidence than the untreated control included 7 applications of Actigard with Success, 4 applications of Actigard with Success, 4 and 7 applications of Messenger, and 1 and 7 applications of Nutri-Phyte (P=0.05). There were no differences among treatments in fruit ratings and there were no differences in yield between any of the treatments and the untreated control.

Table 3. Comparison of insecticides for control of thrips on tomato.

Trade name (rate of formulated product/acre)	**Thrips counts/10 flowers[z]**				
	4 DAT[y]		**7 DAT**		**11 DAT[X]**
Assail 30SG 4.0 oz……………	9.5	abc[w]	10.25(	cd	15.25(
Dimethoate 4EL 1pt……………..	9.0	bc	15.75(	ab	13.00(
Lannate SP 1 lb……….....	9.2	c	17.25(	ab	13.75(
Microthiol 6.0 lbs………………..	16.50	a	19.75(	a	20.75(
Movento 5.0 oz…………………………	16.25	a	13.75(	abc	19.50(

Radiant 6.0 fl oz………………	8.7	c	11.00(	cd	14.50(
Mustang 4.3 fl oz + Beleaf 50SG 2.8 oz	9.2	c	12.00(	bcd	13.25(
Mustang 4.3 fl oz…………..	15.20	abc	13.25(	bcd	15.50(
Success 6.0 fl oz…………	13.25	abc	19.55⁽	a	13.25(
Success 6.0 fl oz + Ecozin Plus 8.0 oz….	11.50	abc	9.0(	d	12.75(
Venom 70DG 4 oz……	14.50	ab	17.00(	ab	12.00(
Untreated Control…..	14.87	ab	12.58⁽	bcd	13.25(

[w] Means followed by the same letter do not differ significantly as determined by Least Significant Difference on log transformed data ($P \leq 0.05$). Non-transformed means are presented.

Integrated pest management of TSWV in California

Based upon our findings and the experience of others, the following IPM approach for managing TSWV can be suggested.

A) Preplant

i) planting location/time of planting-avoid hot spots and winter-planted 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 incidence of TSWV can provide an indication of 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.