Project title: Development and application of a degree-day model and risk index to predict development of thrips and *Tomato spotted wilt virus* (TSWV) and implement an IPM strategy in California processing tomato fields

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Summary

The goal of this project is the development and implementation of a predictive thrips phenology (degree-day) model and *Tomato spotted wilt virus* (TSWV) risk index (TRI) and to focus our ongoing monitoring efforts in northern counties (Solano, Yolo, Colusa, Sacramento and Sutter) and San Joaquin County (SJC). The long-term goal is to provide accurate and real-time information to growers about the population dynamics of thrips and development of TSWV infection to facilitate effective disease management with the integrated pest management (IPM) strategy that has been developed as part of this project. In 2013, monitoring of tomato fields in northern counties (fifth year), and in San Joaquin County (first year) revealed similar thrips population dynamics, with a build-up of thrips populations beginning in early-April, a rapid population increase in early-May and moderately high populations through the summer. TSWV was first detected in a monitored tomato field on 11 April in the Brentwood area in SJC and not until 1 May in a field on the Yolo/Colusa county line area. TSWV was eventually detected in all monitored fields, but overall incidences were low (<1-20%). However, high incidences (up to 80%) were found in parts of two fields (one in Colusa and another in Sacramento/SJC) by early June. Winter and spring weed surveys revealed very low levels of TSWV infection (~2% of all weeds tested). A notable exception was rough-seeded buttercup (*Ranunculus muricatus*) in SJC and northern counties where this weed was identified as a potentially important reservoir of TSWV. Large numbers of buttercup weeds showed virus disease symptoms and high rates (85%) of TSWV infection were detected. TSWV-infected buttercups were detected in 9/17 walnut orchards surveyed, and this may explain grower observations of high TSWV incidences in tomato fields near walnuts. Results of our laboratory experiments on the role of the soil-emerging adult thrips as an inoculum source for early season tomatoes revealed that thrips can stay dormant in soil for at least 7 weeks and that some emerging adults retained the virus and were able to infect plants. These results strongly suggest that adult thrips emerging from soil can be an inoculum source of TSWV. During the 2013 growing season, the web site for the thrips phenology (degree-day) model was made available for growers, and was regularly updated to provide thrips population projections for each area. This model accurately predicted the timing of adult thrips generations (>80% accuracy) in monitored areas. Thus, we believe that this model can be used as a reliable predictor of when thrips

populations begin to increase in the spring and when it is best to apply thrips management strategies (e.g., early-mid-April in the northern counties and SJC in 2013). The prototype TSWV risk index (TRI) calculator was also made available on the web as well as on Smartphone, tablet and computer friendly interfaces. Growers submitted required field information interactively to the TRI calculator and received a prompt response from us with the TRI value for their field (low, moderate and high risk) and brief recommendations on how to prevent TSWV outbreaks. The TRI was moderate for most monitored fields in 2013. However, a number of low and high risk fields were identified, and the TSWV incidences in these fields were accurately predicted by the TRI. Thus, we believe that the IPM strategy for thrips and TSWV can be highly effective at reducing disease incidence, particularly if followed regionally. Key aspects include proper timing of thrips management strategies and identifying high risk fields where intensive IPM practices should be implemented. We now hope to put more efforts into encouraging the use and uptake of the grower-friendly thrips degree-day model and risk index, and to further publicize the IPM strategy for regional thrips and TSWV management.

Objectives

The objectives of this project in 2013 were to 1) conduct surveys of selected processing tomato fields to gain insight into when and from where thrips and TSWV enter into commercial processing tomato fields and to use this data to assess the reliability of our degree-day model to predict the appearance of thrips populations in 2013, 2) gain insight into potential sources of thrips and TSWV for tomatoes in the Central Valley, 3) assess the capacity of mixed infections of TSWV and *Tomato mosaic virus* (ToMV) to overcome the Sw-5 resistance gene in tomato, 4) assess the role of soil-emerging thrips in TSWV epidemiology, 5) continue to refine and validate a thrips phenology model and a TSWV risk assessment system, and 6) continue to develop and assess an IPM strategy for TSWV in the Central Valley.

Information on Materials and Methods can be found in our CTRI proposal for 2013 and are available upon request.

RESULTS

Field Monitoring: Our monitoring efforts for thrips and TSWV were initiated in selected fields beginning 1 March in the northern production area (Solano, Yolo, Colusa, Sacramento and Sutter Counties) and processing tomato production areas of San Joaquin County (SJC). In 2013, we monitored six processing tomato fields in northern counties and five in SJC. All were established with transplants except one that was direct-seeded in the Brentwood area of SJC. Table 1 lists the 11 monitored fields and indicates the final TSWV incidence and TSWV Risk Index (TRI) calculated for each field. Additionally, we also monitored a transplant house for thrips and TSWV in SJC.

Thrips populations on yellow sticky cards: In 2013, the build-up of thrips populations started in early-April in SJC and northern counties (150-250 thrips/card/two weeks), and populations rapidly increased in most monitored fields in early-May (>1000 thrips/card/ two weeks). Interestingly, this increase in early-May in northern counties had been observed the last 4 years. A similar pattern for thrips population dynamics with a build-up of thrips populations in early-April followed by rapid population increase in early-May was observed in SJC (Fig. 1). Thus, thrips population dynamics in SJC may be similar to those in northern counties. However, as the season progressed the thrips populations in the northern counties were much higher than in SJC (Fig. 1). Higher thrips populations in northern counties later in the growing season have also been observed in previous years. After populations reached high levels by early-May (>1000 thrips/card), populations fluctuated at relatively high levels (800-2000 thrips/card/two week) until the end of September (Fig. 1).

In 2012, a drop in thrips populations occurred during June-July in all monitored fields in the Central Valley. In 2013, a similar population drop occurred in June-July in all monitored fields. This was not predicted based on our degree-day model; i.e., there was no evidence of a noticeable delay in thrips generations. Thus, it is possible that these decreases in thrips population during June-July reflected the widespread implementation of thrips management (spraying) in monitored fields in early-June.

In 2013, we also monitored a transplant house (an open-type greenhouse) with yellow sticky cards in SJC. The build-up of thrips populations also started in early-April (100-150 thrips/card/two weeks), followed by a rapid population increase in early-May (>2000 thrips/card/ two weeks). This was similar to population dynamics observed in fields in SJC (Fig. 2), with populations in the transplant house sometimes exceeding those in the field. Overall, when compared with our previous surveys conducted in different transplant houses in the Central Valley, especially with those that were open-type houses, this transplant house had relatively high level (~500 thrips/card/ two weeks) thrips populations.

Key finding: Thrips population dynamics were similar in northern and SJC and timing of initial thrips sprays was predicted for early-mid-April.

TSWV incidence: In 2013, the first detection of TSWV in a processing tomato field was on 21 March in a non-monitored field at I-5 and Lassen Ave. in Kings County. TSWV was first detected in our monitored direct-seeded field in SJC on 11 April, and was not detected until 1 May in monitored fields in northern counties. As in previous years, TSWV was eventually detected in all monitored fields. The overall incidence of TSWV in processing tomato fields in SJC and northern counties was very low (<1-20%, Table 1). In two fields, one in Sacramento/SJ county line and another in Yolo/Colusa county line, TSWV was present at higher incidences (20%), with up to 80% incidences in a single corner of each field (<2 acres). As in previous years, the incidence of TSWV was lower in early-planted compared with late-planted fields. Overall, we do not believe that TSWV caused economic losses in any of the monitored fields in 2013. However, a high incidence of TSWV in parts of some fields shows the potential for damage still exists.

We also detected TSWV infection in a small number of tomato transplants (10-15 plants) in our surveyed transplant house in SJC. However, TSWV infected transplants were detected only at the end of the season (July) and in the last shipment of transplants. Thus, we do not think that the infected transplants from this transplant house were significant sources of TSWV inoculum.

In 2013, curly top virus (CTV, 8%) and *Alfalfa mosaic virus* (AMV, 5%) were detected at higher incidences than TSWV in some fields, especially in SJC. AMV was detected in some weed samples collected in and around monitored fields before tomatoes were established. Together with high populations of aphids observed in tomatoes early in the season, it is likely that AMV was moved into tomato fields from surrounding alfalfa and AMV-infected weeds. Additionally, very low (sporadic and <1%) levels of other tomato-infecting viruses including *Tomato necrotic spot virus* (ToNSV) and *Pelargonium zonate spot virus* (PZSV) were detected in monitored fields.

Key finding: TSWV caused little or no economic damage in monitored processing tomato fields in 2013.

Curly top virus outbreak of 2013: Of course, in 2013, the predominant disease problem in tomatoes in the Central Valley was CTV. In late-March, we received leafhopper samples from CDFA and 12 of 14 had very high levels of CTV. We warned CDFA that the combination of high leafhopper populations that they detected with sweep net surveys and the high amounts of CTV in the leafhoppers could lead to curly top outbreaks in processing tomato based upon our previous research. Indeed, within two weeks after testing of the leafhoppers, we began to receive samples for curly top testing from various fields in the Central Valley. Samples continued to be received throughout the growing season, mainly from the southern Central Valley and SJC. To date, we have tested 465 crop, leafhopper and weed samples for curly top and >92% of these were positive.

Since late-April in 2013, a total of 192 tomato samples were received with typical curly top-like symptoms, including stunting and upward leaf curling distortion and vein purpling. These were tested for the presence of *Beet mild curly top virus* (BMCTV) and *Beet severe curly top virus* (BSCTV) by PCR with species-specific primer pairs. A total of 96% of these samples were confirmed to be positive for curly top virus, and 65% and 48% of samples were infected with BMCTV and BSCTV, respectively. Interestingly, the incidence of mixed infection of these viruses was 17%, which is unusually high. BMCTV was more prevalent in Merced and San Joaquin Counties, whereas, both BMCTV and BSCTV were detected in Fresno, Kern and Monterey Counties (Table 2).

We also tested other plant samples with curly top-like symptoms for CTV infection including beet, cucurbit, eggplant, melon, watermelon and pepper (Table 3). Most samples were collected from Fresno County, but beet, cucurbit and pepper samples were also collected from Kern, San Benito, San Joaquin and Ventura Counties. Based on our PCR test results, 90 % of these samples were positive for curly top virus, and 79% and 16% of samples were infected with BMCTV and BSCTV, respectively (Table 3).

Interestingly, the BMCTV involved in 2013 outbreak was determined to be a different strain compared to previously described BMCTV strains. Similarly, most of the BSCTV associated with the 2013 outbreak was a new strain (LH71) composed of parts of BMCTV and BSCTV. It is not clear the role these new curly top virus strains played in the 2013 outbreak.

Survey of potential hosts for TSWV: We continued our efforts to identify reservoir hosts of TSWV before, during and after the processing tomato season in 2013. We focused our efforts around processing tomato fields that were monitored in SJC and northern counties, and we collected numerous weeds from these areas in the winter and spring before tomatoes were established.

Bridge crops: Fall crops (i.e., lettuce and radicchio) were not grown in our surveyed areas during fall/winter seasons in 2013. However, in 2013, spring-planted lettuce and radicchio, potential TSWV bridge crops, were grown in non-surveyed areas (i.e., Fresno and Kings Counties). Surveys of these crops revealed low TSWV incidences.

Fava bean: Early in 2013, we monitored two fava bean fields in Yolo County. Low thrips populations and no TSWV infections were detected in these fields.

Weeds: In 2013, weeds were collected from surveyed areas and tested for TSWV (Table 4). Both in SJC and northern counties, weeds were abundant on roadsides, levees, fallow fields and some orchards. With the exception of buttercups (a new TSWV weed host, see below), most weeds collected before and during 2013 tomato growing season were symptomless and tested negative for TSWV (with immunostrips or PCR). A small number of weeds with symptoms (necrosis and thrips-feeding damage) were infected with TSWV. However, the overall incidence of TSWV infection in weeds was very low (a total of 12 TSWV-infected weeds detected/435 tested; overall incidence 2%). This was similar to results from previous years.

A new potentially important TSWV weed host identified in San Joaquin and northern counties: In our 2013 weed surveys, we identified a new weed host of TSWV: rough-seeded buttercup (*Ranunculus muricatus*). Buttercup is a low-growing biennial plant that produces round leaves and yellow flowers. When infected with TSWV, the leaves develop mosaic and mottling symptoms. TSWV-infected buttercup plants were found in large numbers in and around walnut orchards in SJC (3 of 8 orchards) and northern counties (6 of 9 orchards). TSWV infection rates in patches of buttercups in these orchards ranged from 10-100% (a total of 128 TSWV-infected buttercups detected/149 samples tested, overall incidence 85%; Table 4). Since the beginning of our ongoing project in 2007, buttercup is the only weed species with such a high rate of TSWV infection.

Interestingly, buttercup has become more common in California recent years, although it is not yet a widespread problem. It grows well in wet soils, such as low spots in orchards or at the end of rows where water might accumulate. It does not appear to become established in tomato fields. However, it has also been found in wheat fields and in other orchards (e.g., cherry and almond). Buttercup is a biennial weed, so it would germinate with fall/winter rains and survive through the summer and into the following spring when it would flower and set seed. Because it is biennial, infected plants can carry the virus over multiple years and serve as an inoculum source for processing tomatoes. Thus, in 2014, we hope to continue to survey for the presences of TSWV-infected buttercups to further determine the importance of this TSWV inoculum source.

Key finding: Rough-seeded buttercup may be an important TSWV weed host in California.

Assessment of the potential role of the soil-emerging adult thrips as inoculum sources of TSWV for early planted tomatoes: In 2013, we directed some of our efforts into curly top detection and characterization. This resulted in reduced efforts on the laboratory experiments on the potential for adult thrips emerging from soil to serve as sources of inoculum for early season TSWV infection. Our previous laboratory experiments confirmed that thrips can overwinter in soil as pupae for as long as 7 weeks at 4ºC. Thus, soils can be a potential reservoir for thrips, but TSWV was not detected in these soil-emerging thrips. In 2012 and 2013, we assessed the capacity of adult thrips emerging from soil to be able to transmit TSWV under controlled conditions. In 2013, we established that emerging adult thrips, after a dormant period up to 4 weeks at 4ºC, could still transmit TSWV. The number of emerging adult thrips that transmitted the virus depended on the period of time thrips were in soil as well as the temperature. This strongly suggests that adult thrips emerging from soil can be an inoculum source, and is a possible explanation for how single TSWV-infected plants may be observed within fields early in the season. We hope to complete these experiments in 2014.

Key finding: Adult thrips emerging from soil can be sources of TSWV inoculum.

Assessment the role of TSWV resistant (Sw-5) tomato varieties for selection of 'resistance breaking' TSWV-isolates in California

In the Central Valley, more fields are being planted with tomato varieties carrying the TSWV resistance gene (Sw-5), especially in fields with a history of TSWV or late-planted fields. In 2013, our survey results continued to indicate that Sw-5 plants in the Central Valley did not show typical symptoms of TSWV infection. However, in a couple of processing tomato fields, symptoms were observed in fruits of some Sw-5 plants and these plants were found to have mixed infections with TSWV and *Tomato mosaic virus* (ToMV). A molecular analysis of the N gene of the TSWV isolates from these infected Sw-5 plants failed to show evidence that these were resistance-breaking strains.

In 2013, we conducted laboratory experiments to assess whether mixed infections (TSWV with ToMV) would allow TSWV to infect Sw-5 varieties. In repeated experiments, we were not able to infect Sw-5 tomato varieties (two commercial varieties) with TSWV followed inoculation with TSWV alone or with TSWV + ToMV (via sap inoculation). In these experiments, no TSWV symptoms were observed in Sw-5 varieties, although very severe ToMV symptoms developed within 10-14 days after inoculation (the Sw-5 varieties used are not resistant to ToMV). In parallel experiments performed with susceptible control tomato plants (Early Pak 7; a non Sw-5 variety), typical symptoms developed in plants inoculated with TSWV (bronzing and necrosis) and ToMV (stunting and leaf mottling, mosaic and shoestring) by 10-14 days post-inoculation. In Early Pak 7 plants co-inoculated with TSWV + ToMV, the predominant symptoms were similar to those caused by ToMV, although both viruses were detected in these plants.

In mixed infection experiments (ToMV + TSWV, ToMV then TSWV a week later or TSWV and then ToMV a week later), the most severe symptoms in Early Pak 7 plants (the non Sw-5 variety) were in plants inoculated with ToMV followed by TSWV. However, this was not the case in Sw-5 varieties where all plants developed similar ToMV symptoms. In no cases did TSWV symptoms develop in Sw-5 plants with any of the TSWV/ToMV combinations tested.

A month after inoculations, the presence of the viruses in all inoculated plants (symptomatic and asymptomatic) was determined by ELISA. The ELISA test results with TSWV specific antibody were consistent with the symptoms observed. TSWV was detected only in those plants with typical TSWV symptoms, i.e., Early Pak 7 plants inoculated with TSWV or TSWV + ToMV. Also, consistent with symptom observations, ToMV was detected in all plants inoculated with ToMV, and not in plants inoculated with only TSWV (Sw-5 and non-Sw-5). Thus, these results suggested that mixed infection of ToMV and TSWV is not breaking down Sw-5 resistance. Previously published reports indicated that the Sw-5 gene is not expressed in fruits; thus, the symptoms observed only in fruits were probably due to direct feeding of viruliferous (virus-carrying) thrips on these fruits.

Key finding: Mixed infection of ToMV and TSWV does not break Sw-5 resistance.

Refinement and validation of the degree-day model and the risk index for thrips and tomato spotted wilt disease

In 2013, we started running thrips population projections for 6 locations instead of 4; the additional locations were the Delta-Tracy (Western SJC) and Linden (Eastern SJC). The web site for the phenology (degree-day) model was up and running through September in 2013 for Fresno, Kings, Merced, Western and Eastern San Joaquin and northern counties. We also regularly updated the web page to provide thrips population projections for each area. In 2013, real-time thrips population dynamics (from yellow sticky card counts) and phenology model projections were compared side by side for SJC and northern counties. In general, the phenology model was accurate (over 80%) and reliable. In 2013, the model predicted 7 adult thrips generations for monitored counties and 8 generations for southern counties. For example, in the northern and Western SJC counties, the generations were predicted for April 5, May 6, June 5, June 30, July 23, August 17 and September 9. Furthermore, the projected adult thrips generation times for northern counties and Western San Joaquin were on the same dates (1-2 day earlier or later), but corresponding projections were at least week later for Eastern San Joaquin County. These results indicated the importance of selecting much closer weather stations to production areas for more accurate phenology model predictions (i.e., choosing two or more weather stations per county instead of choosing a single station representing an entire county).

In 2013, a prototype TSWV risk index (TRI) calculator was made available on the web for growers. It was also made available on Smartphone, tablet and computer friendly interfaces. Thus, growers submitted required field information interactively to the TRI calculator and received a prompt response from us with a TRI value for their field (low, moderate and high risk) and brief recommendations for TSWV management. After harvest of our monitored fields, we obtained all data needed to calculate the TRI for each field, and correlated this with actual TSWV incidences in these fields. Most of the fields were placed in the moderate TRI category (Table 1); however, two of the fields that were placed in the high risk category had the highest TSWV incidences (20%). In contrast, fields with low or moderate TRIs had much lower TSWV incidences (Table 1). We are now confident that the TRI is reliable and can be used to accurately predict the potential for TSWV in grower fields. We will continue to fine-tune the current TRI and make it available for growers to use in the 2014 growing season.

Key finding: The thrips phenology (degree-day) model and TSWV TRI are useful tools that growers can use to help implement the IPM strategy for thrips and TSWV management in the Central Valley of California.

Refinement of the IPM strategy for thrips and TSWV in processing tomatoes

By using the information generated in this project, we have developed the following comprehensive IPM program for TSWV and thrips in processing tomatoes in the Central Valley of California. We believe that implementation of this package (all or in part) has helped reduced TSWV to levels where economic losses have been substantially reduced.

Before planting

i) determine the risk index for the field and plan your needs for TSWV management accordingly

ii) evaluate planting location/time of planting-this will involve determining proximity to potential inoculum sources during the time of planting (if possible avoid hot spots, planting near fields with bridge crops or late planting dates).

iii) use TSWV- and thrips-free transplants

iv) plant TSWV resistant varieties (possessing the Sw-5 gene)-these are available, but may not be necessary if other practices are followed. Varieties without the Sw-5 gene can also vary in susceptibility. At least, resistant cultivars should be used in hot-spot areas or in late-planted fields that will be established near early-planted fields in which TSWV infections have already been identified.

v) implement weed management-maintain weed control in and around tomato fields and especially in fallow fields and orchards, as some weeds are TSWV hosts, such as rough-seeded buttercup. If weeds are allowed to grow in fallow fields, they can amplify thrips and TSWV and serve as inoculum sources for processing tomatoes.

During the season

i) monitor fields for thrips with yellow sticky cards or use the predictive phenology (degree-day) model to estimate when thrips populations begin to increase.

ii) manage thrips with insecticides at early stages of crop development and when thrips populations begin to increase (typically late March-early-mid-April).

iii) rotate insecticides to minimize development of insecticide resistance in thrips.

iv) monitor fields for TSWV and remove infected plants early in development (<30 days old) and when percent infection is low (<5%)

v) implement weed management-maintain effective weed control in and around tomato fields.

After harvest

i) promptly remove and destroy plants after harvest (typically done during harvest)

ii) avoid planting bridge crops that are thrips/TSWV reservoirs or monitor for and control thrips and TSWV in these crops

iii) control weeds/volunteers in fallow fields, non-cropped or idle land near next years tomato fields

Table 1. List of monitored processing tomato fields in 2013: their locations, TSWV incidence and TSWV Risk Index (TRI) values.

Monitored Fields in 2013				
	Northern Counties		**TSWV %**	**TRI**
RO	Winters, Yolo		<1	low
BF	County Line, Colusa		20	high
AO	County Line, Colusa	*SW-5 variety*	<1	low
PR	Dixon, Solano		2	moderate
EG	Robin, Sutter		4	moderate
YL	Yolo Town, Yolo		3	moderate
	San Joaquin County			
BR	Bean Ranch, Thornton		20	high
BW	HWY 4, Byron/Brentwood		4	moderate
DL	Delta Rd, Tracy		1	moderate
CP	Copperopolis Rd, Linden		3	high
AL	Alpine Rd, Linden		2	moderate

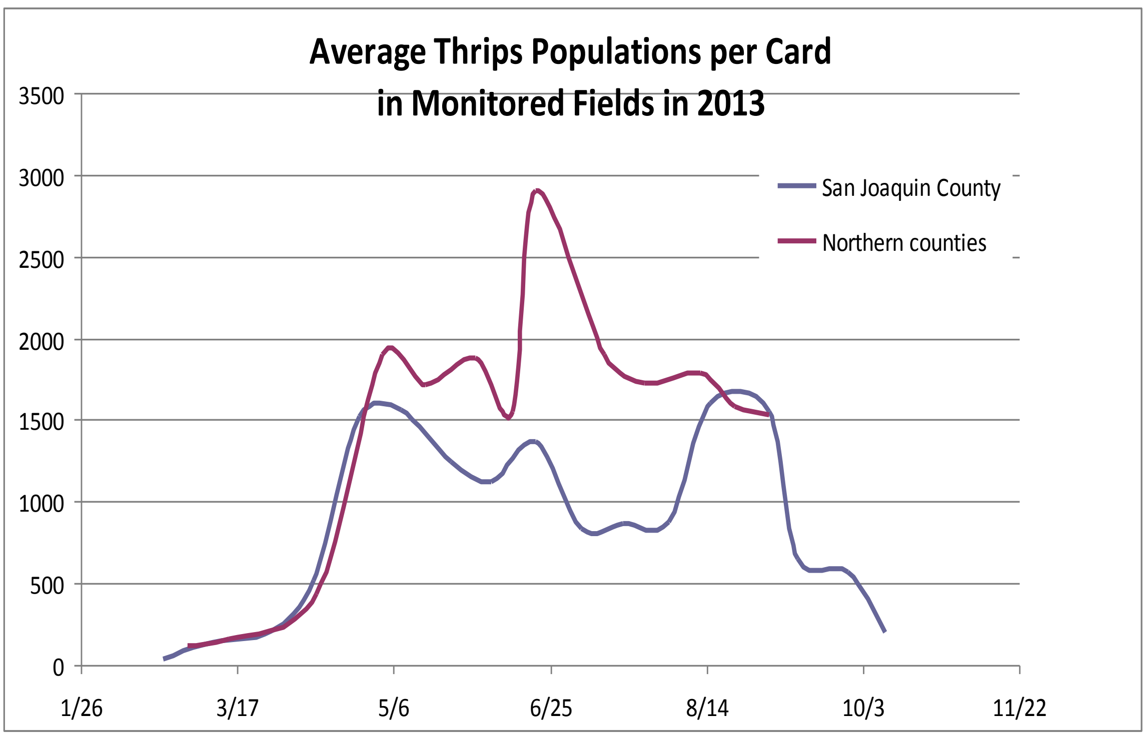

Fig. 1. Average thrips counts per yellow sticky card in monitored fields in northern and San Joaquin Counties in 2013.

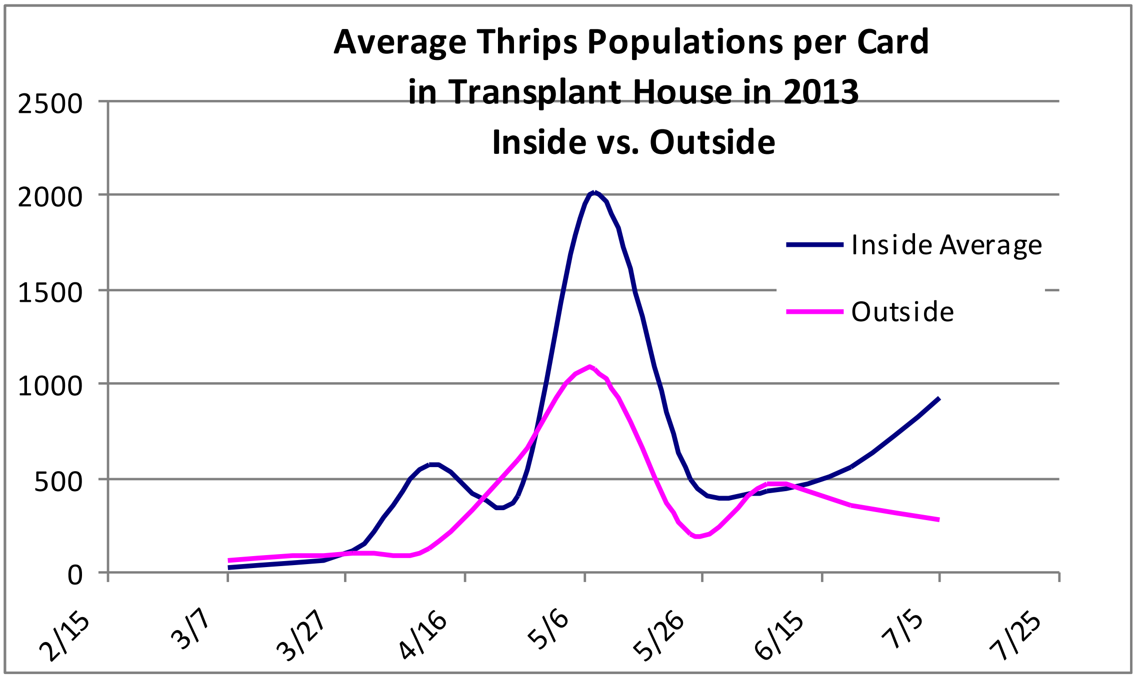

Fig. 2. Average thrips counts per yellow sticky card in monitored transplant house in San Joaquin County in 2013.

Table 2. Summary of curly top virus detection in tomato samples collected from different counties in California from April to August in 2013. All samples were tested for *Beet mild curly top virus* (BMCTV) and *Beet severe curly top virus* (BSCTV) via PCR detection with species-specific primer pairs.

County	Total	BMCTV [a]	BSCTV [b]	Mixed [c]
Fresno	101/102 (99%)	67/102 (66%)	54/102 (53%)	20/102 (20%)
Kern	14/15 (93%)	8/15 (53%)	10/15 (67%)	4/15 (27%)
Merced	13/13 (100%)	11/13 (85%)	4/13 (31%)	2/13 (15%)
Monterey	10/12 (83%)	5/12 (42%)	5/12 (42%)	0/12 (0%)
San Joaquin	43/43 (100%)	34/43 (79%)	16/43 (37%)	7/43 (16%)
San Benito	1/1 (100%)	0/1 (0%)	1/1 (100%)	0/1 (0%)
Yolo	3/6 (50%)	0/6 (0%)	3/6 (50%)	0/6 (0%)
Subtotal	**185/192 (96%)**	**125/192 (65%)**	**93/192 (48%)**	**33/192 (17%)**

[a] BMCTV was found more prevalent in Merced and San Joaquin counties than Fresno and Kern counties [b] Most of BSCTV was identified to be the recombinant virus (LH71) [c] The percentage of mixed-infections of both BMCTV and BSCTV were increased

Table 3. Summary of curly top virus detection in other plant samples collected from different counties in California from June to August in 2013. All samples were tested for *Beet mild curly top virus* (BMCTV) and *Beet severe curly top virus* (BSCTV) via PCR detection with species-specific primer pairs.

County	Plant	Total	BMCTV	BSCTV	Mixed
Fresno	Beet*	2/2	2/2	0/2	0/2
	Cucurbits***	12/12	10/12	5/12	3/12
	Eggplant*	3/6	3/6	0/6	0/6
	Melon**	19/20	17/20	4/20	2/20
	Watermelon**	10/13	10/13	0/13	0/13
	Pepper***	4/4	3/4	1/4	0/4
Kern	Beet*	4/4	4/4	1/4	1/4
San Benito	Pepper***	1/2	0/2	1/2	0/2
San Joaquin	Cucurbits**	9/9	9/9	0/9	0/9
	Pepper***	1/1	0/1	1/1	0/1
Ventura	Cucurbits**	8/8	8/8	0/8	0/8
Subtotal	**All**	**73/81 (90%)**	**64/81 (79%)**	**13/81 (16%)**	**6/81 (7%)**

Asterisks represent the severity of symptoms in each host: * represents no obvious to mild symptom severity; ** represents mild to intermediate symptom severity; *** represents obvious to severe symptom severity

Table 4. Weed survey results for TSWV incidence during 2013.

Weed [a]	Tested (+)	Weed [a]	Tested (+)
Chinese lantern	10 **(1)**	Curly dock	3 (0)
Bindweed	22 (0)	**Malva**	135 **(5)**
Filaree	42 (0)	**Datura**	1 **(1)**
Pineapple weed	4 **(1)**	Monocots	9 (0)
Sowthistle	34 **(4)**	Shepherd's purse	15 (0)
Prickly lettuce	22 (0)	Fiddler neck	3 (0)
London rocket	15 (0)	Pigweed	4 (0)
Buckhorn Plantain	8 (0)	Turkey mullein	5 (0)
Lamb quarters	17 (0)	Groundsel	3(0)
Poison hemlock	26 (0)	Tree tobacco	12 (0)
Pennywort	5 (0)	Nettle	4 (0)
Rough-seeded Buttercup	**149 (128)**	Bermuda buttercup	18 (0)
Wild radish and Mustard	34 (0)	Other common weeds	28 (0)

(+), number of plants tested positive for TSWV by immunostrips and RT-PCR.
a, Total weed samples from all counties surveyed in 2013