

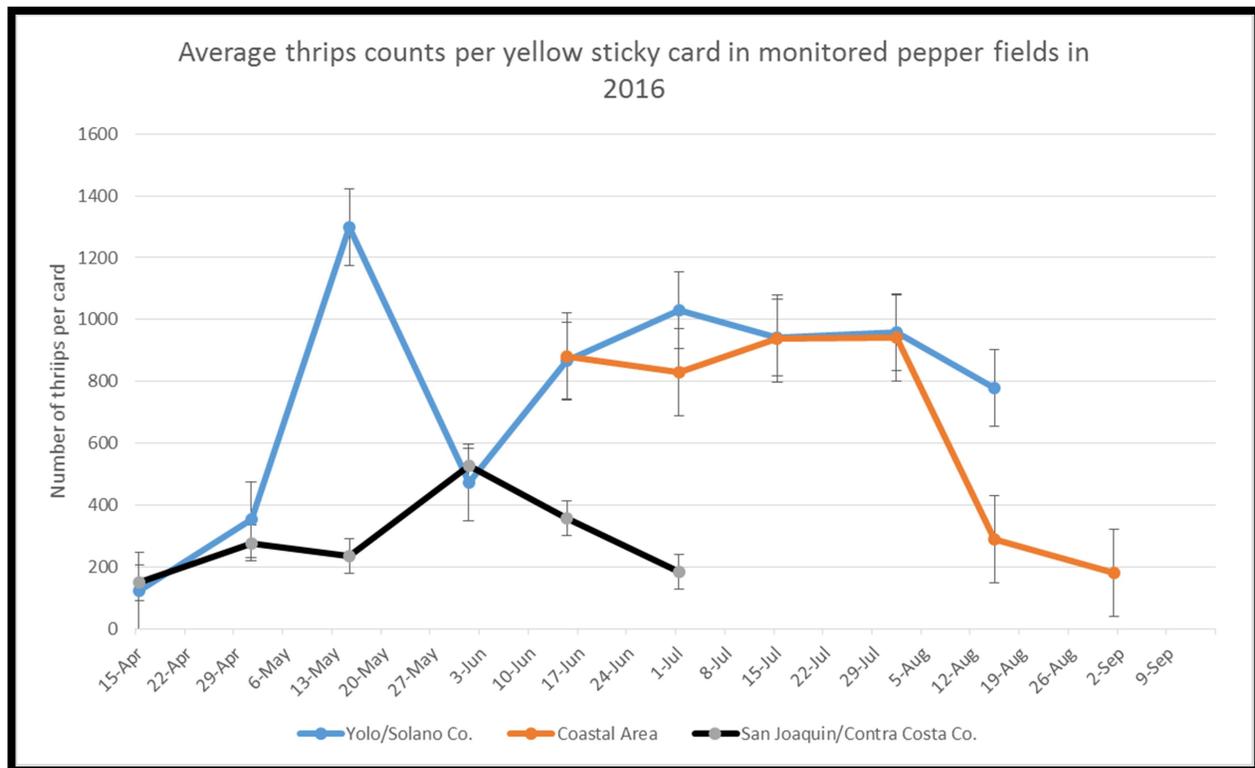
## Monitoring of thrips and *Tomato spotted wilt virus* (TSWV) in California peppers and the development of a regional IPM strategy for reducing the incidence and severity of TSWV.

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Thrips and *Tomato spotted wilt virus* (TSWV) incidence in pepper fields in the Central Valley (Yolo, Solano, San Joaquin and Contra Costa counties) and the coastal area (Santa Clara and San Benito counties) were monitored for the third year in 2016. The overall goal is to better understand the dynamics of thrips and TSWV development and to develop and implement a regional IPM program.

**High thrips populations precede appearance of TSWV and late-planted fields have highest TSWV incidences.** In Yolo/Solano Co., relatively high populations of western flower thrips (*Frankliniella occidentalis*) were detected in pepper fields soon after transplanting (late April, Fig. 1). This was similar to 2013-2015. High thrips populations persisted through harvest in all monitored pepper fields. However, in 2016, thrips populations were substantially less than previous year's populations (e.g., 500-1,500 vs. >1,000-5,000 thrips/card/two weeks). In 2016, TSWV was first detected in transplanted fields in Yolo/Solano Co. a month after planting, i.e., mid- to late May. In contrast, TSWV was not detected in direct-seeded fields until late June to early July, a month after germination. In San Joaquin and the coastal area thrips populations were lower (San Joaquin Co.) or were detected later. TSWV symptoms were not observed until late-July at which time low levels of infection (2-5%) were detected in all of these monitored transplanted pepper fields. TSWV was eventually detected in all 14 monitored fields, including some with TSWV-resistant pepper varieties (with the *Tsw* gene), but at low incidences (Table 1).

**Figure 1.** Average thrips counts per yellow sticky card in monitored pepper fields in 2016.



Overall, TSWV incidences in early-planted monitored fields remained low (2-5%) through harvest, similar to 2013-2015. Incidences were higher (7-9%) in some late-planted fields and/or in parts of monitored fields that were harvested as red fruit in 2016 (Table 1). An exceptionally high incidence of TSWV in 2016 (65%) was observed in a late direct-seeded field in Solano Co. This field was planted adjacent to a processing tomato field that had TSWV symptoms and was in close proximity to weedy almond/walnut orchards (Table 1). Thrips and weed management in this pepper field was implemented rather in the season, after the TSWV outbreak had occurred.

Thus, our results continue to indicate that the virus needs to build-up early in the season (e.g., in early-planted pepper or tomato fields) to generate inoculum responsible higher incidences in for late-planted fields. Thus, early thrips and weed management will delay the appearance of TSWV.

**Table 1.** Pepper fields monitored in 2016: Locations, incidences of TSWV and other viruses, and

Monitored Pepper Fields in 2016						
Fields	Solano County		TSWV %	TRI	Points	Other Virus Incidences
ES	Rd 87, Esparto	Transplanted	4	Moderate (100-150)	115	4% AMV and 4% CMV
KY	Kentucky Ave., Woodland	Transplanted	3	Moderate (100-150)	120	4% AMV and 1% CMV
RU <sup>a</sup>	Runge Rd., Dixon	Direct-seeded	9	High (>150)	165	3% AMV and <1%BCTV
HC <sup>a</sup>	Hackman Rd., Dixon	Direct-seeded	4-(7%) <sup>a</sup>	High (>150)	160	5% AMV and 2% BCTV
RO	Sikes Rd., Dixon	Direct-seeded	2	Moderate (100-150)	135	3% AMV and <1% BCTV
MX	Maxwell Ln, Davis	Direct-seeded	4	Moderate (100-150)	145	25% AMV and 1% BCTV
SI	Tremont Rd., Davis	Direct-seeded	5	High (>150)	155	3% AMV and <1%BCTV
CU <sup>a</sup>	Curry Rd., Dixon	Direct-seeded	65	High (>150)	185	10% AMV and 1% BCTV
<b>San Joaquin County<sup>b</sup></b>						
Per	S Holt Rd., Stockton	Transplanted	<1	Low (<100)	65	NA
Fon	Bronzan Rd., Manteca	Transplanted	<1	Low (<100)	70	NA
Cul	2 Rivers Rd, Manteca	Transplanted	<1	Low (<100)	75	<1% BCTV
<b>Coastal Areas</b>						
H1	Fallon Rd., Hollister	Transplanted	5	Moderate (100-150)	125	NA
H2	Fairview Rd, Hollister	Transplanted	2	Moderate (100-150)	125	NA
R1	Central Ave., Gilroy	Transplanted	<1	Moderate (100-150)	140	NA

<sup>a</sup>Late planted and/or part of this pepper field was kept for red pepper harvest  
<sup>b</sup>Fields were mixed planted with TSWV resistant and susceptible varieties  
NA= Not assessed

TSWV Risk Index (TRI) values.

**Weeds around pepper fields are not heavily infected with TSWV.** Most weeds collected before and during the pepper growing season in 2016 were symptomless and tested negative for TSWV. A small number of weeds, including rough-seeded buttercup, sowthistle and *Malva* spp., were infected with TSWV (Table 2). Thus, as found in previous years, weeds do not seem to be a major source of the virus in Central California. However, it is worth mentioning here that the late-planted monitored pepper field with the highest TSWV incidence in 2016 was in a close proximity (<1 mile) to walnut fields with TSWV-infected buttercups.

**Bridge crops can be sources of TSWV.** In coastal areas, three lettuce fields, and one each celery, artichoke and carrot fields surveyed near monitored pepper fields had no TSWV symptoms. A fava bean cover crop (volunteers) in a young almond orchard in Solano County also had no TSWV infection. Nevertheless, based on our previous survey results bridge crops can be a source of inoculum early in the season and should be avoided or monitored.

***Alfalfa mosaic virus (AMV)* was the most common virus in peppers but did not seem to cause economic damage.** In 2014 to 2016, AMV was more common than TSWV in direct-seeded monitored pepper fields, with incidences as high as 25% early in the season (Table 1). However, later in the season, the shoots that developed from these initially infected plants did not show obvious symptoms and produced normal fruits. Thus, as in previous years, AMV did not seem to pose a major threat to pepper production, presumably due to the phenomenon of recovery, a type of plant defense against virus infection. Additionally, low incidences of other pepper-infecting viruses including *Cucumber mosaic virus (CMV)* and *Beet curly top virus (BCTV)* were detected in some of the monitored pepper fields (Table 1), but these infections did not result in economic losses.

Table 2. Results of survey of weeds in Yolo, Solano, San Joaquin and costal area counties for TSWV infection in 2016.

Weed	Tested/ number(+)	Weed	Tested/ number (+)
Dandelion	1 (0)	Bur Clover	1 (0)
Prickly Lettuce	5 (0)	<b>Sowthistle</b>	10 (1)
Bindweed	12 (0)	Nettle	2 (0)
Fava/Pea	3 (0)	Mustard	3 (0)
Chickweed	4 (0)	Groundsel	2 (0)
Knotweed	1 (0)	Cutleaf Geranium	1 (0)
Swine cress	3 (0)	Miner's Lettuce	5 (0)
London rocket	5 (0)	Henbit	3 (0)
Redmaids	3 (0)	Fiddleneck	4 (0)
Shephard's purse	2 (0)	Poison hemlock	3 (0)
<b>Malva</b>	21 (1)	Pineapple weed	4 (0)
Filaree	9 (0)	Chinese lantern	2 (0)
<b>Rough-seeded Buttercup</b>	14 (4)	Pigweed	2 (0)
Lamb's quarter	2 (0)	Others	13 (0)
			<b>Total: 140 (6)</b>
(+) = number of plants that tested positive for TSWV by immunostrips and/or RT-PCR			

**A degree-day model allows prediction of when to commence spraying for thrips and the risk index allows growers to identify fields at risk for TSWV.** In 2016, our degree-day model predicted generations of adult thrips in peppers with ~80% accuracy. For all years, the appearance of second generation should trigger spraying for early planted pepper, whereas it is the third generation for late-planted fields.

The TSWV risk index (TRI) for peppers assigns fields risk ratings of: high, moderate and low (Table 1). In 2016, when TRI values of these 14 fields were compared with the actual TSWV incidences in these fields, there was a good correlation, i.e., fields with high TRI values had highest incidences of TSWV and fields with lowest TRIs had lowest incidences (Table 1). Thus, we believe that the TRI for pepper fields can accurately predict the extent of TSWV outbreaks in

pepper fields in the Central Valley of California, and help growers know the extent to which they need to manage thrips/TSWV.

The degree-day model was made available for pepper growers in the Central Valley and coastal production areas in 2016 and can be accessed via the webpage below. We will continue to prepare a designated webpage for pepper TRI and will make it available for pepper growers for the 2017 growing season.

[http://ucanr.edu/sites/TSWVfieldriskindex/Thrips\\_Population\\_Projections/](http://ucanr.edu/sites/TSWVfieldriskindex/Thrips_Population_Projections/)

**IPM Strategy for TSWV in peppers.** Using the information generated in this project, we have developed the following **IPM program for TSWV and thrips in peppers in the Central Valley of California**. Implementation of this program (all or in part), especially on a regional level, should reduce TSWV to levels where economic losses are minimized.

### **Before planting**

**i) 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 tomato or susceptible bridge and cover crops and weedy orchards or late planting dates).

**ii) use TSWV- and thrips-free transplants**

**iii) plant TSWV resistant varieties** (possessing the *Tsw* gene)-these are available but may not be necessary if other practices are followed. Resistant cultivars should be used in hot-spot areas or in late-planted and red pepper fields, especially those that will be established near early-planted pepper or tomato fields.

**iv) implement weed management**-maintain weed control in and around pepper 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 peppers.

### **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 (usually 2<sup>nd</sup> and/or 3<sup>rd</sup> thrips generations).

**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 pepper fields.

### **After harvest**

**i) promptly remove and destroy plants after harvest**

**ii) avoid planting bridge crops** and cover crops that are thrips/TSWV reservoirs (e.g., fava bean and radicchio) 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 year's pepper fields.