

**Project Title:**

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

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**Abstract:**

The goal of this project is improved understanding of thrips population dynamics and *Tomato spotted wilt virus* (TSWV) incidence in processing tomatoes 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 fourth year in 2010. Thrips were monitored with yellow sticky cards and in tomato flowers, whereas TSWV incidence was assessed visually or with sensitive indicator plants. Similar to previous year's survey results, tomato transplants had low thrips populations and no detectable TSWV infection. Monitoring of representative direct-seeded and transplanted tomato fields (including those established with monitored transplants) in Fresno, Kings, Merced, Yolo and Colusa Counties in 2010 revealed lower thrips populations in May-August compared with previous years; however, populations in 2010 were much higher in September-October compared to those detected in previous years. In 2007-2009, thrips populations began to increase in April, peaked in May and gradually declined, with low populations detected in September. However, due to cool weather conditions early in the growing season, this trend was different in 2010. Thrips population, especially in early-planted fields, started to increase during March, peaked in May-June, and stayed high until August.

In late-planted fields, thrips populations continued to increase through September and then slowly decreased through November. TSWV was first detected in mid-March in Yolo and Colusa and early April in Merced; however, in Fresno and Kings Counties, it did not appear until 19 April and 27 May, respectively. Thus, in 2010, detection of TSWV in Fresno and Kings Counties was a month and two months later than Yolo County, respectively. Eventually, TSWV was detected in most monitored fields. Overall incidence of TSWV in processing tomato fields was low early in the 2010 growing season, i.e., 0-4%, 0-5% and 0-7% in monitored fields in Merced, Yolo/Colusa and Fresno/Kings Counties, respectively. However, in some later-planted fields, incidence reductions were not statistically significant. Thus, our results in 2010 were consistent reached up to 11-21% in Yolo, Colusa, Fresno and Kings Counties. Based on discussions with our farm advisor cooperators and growers, TSWV did not cause economic losses in any of the monitored fields. Inoculum sources for thrips/TSWV vary depending on the county and agricultural production area. Thus, there is no single main source of the virus throughout the state. Almond orchards had low thrips populations, and winter and spring weed surveys revealed very low TSWV infection (<0.1%). However, weeds can be significant inoculum sources if allowed to multiply in fallow fields.

In Fresno, spring lettuce fields had low thrips populations and low levels of TSWV infection. However, due to substantial overlap of tomato with fall lettuce, high incidences of TSWV (15-100%) developed in some lettuce fields. In Merced, the implementation of effective thrips and TSWV management practices in radicchio has helped to reduce the importance of this thrips and TSWV inoculum source, resulting in low TSWV incidences in monitored processing tomato fields through out the season. In Yolo County, thrips and TSWV were not detected in winter-planted fava beans or in most of the weeds sampled; thus, it was not clear what the major source of TSWV was in 2010. RT-PCR testing of collected thrips revealed that most thrips were not carrying the virus, even in late in the season, and this supports the importance of maintaining good thrips control early in the season (to keep population of virus-carrying thrips low). In insecticide trials in 2010, materials that reduced thrips numbers included Radiant (spinosad), dimethoate, Beleaf, Hero and HGW86+ Brigade. However, in 2010, these with our proposed model of TSWV infection of processing tomatoes in California: low levels of initial TSWV inoculum are increased in early-planted crops, with highest levels of infection in later-planted fields, especially those with high thrips populations. Based upon these findings, we continue to validate and improve the integrated pest management (IPM) strategy for TSWV in processing tomatoes in California.

#### **Objectives:**

The objectives of this project were 1) to determine thrips populations and TSWV incidence associated with greenhouse-produced tomato transplants in 2010, 2) to determine whether any linkage exists between greenhouse-produced transplants and outbreaks of thrips or TSWV in the field, 3) to gain insight into potential sources of thrips and TSWV for tomatoes in the Central Valley, 4) to assess various thrips control methods and 5) to develop and validate 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, Westside Transplant in Huron and Speedling in Watsonville) were monitored for thrips and TSWV in 2010. These greenhouses produce tomato transplants for planting in southern Fresno, Kings, Merced, Yolo and Colusa Counties. Yellow sticky cards were again used to monitor thrips. At each site, six to ten yellow sticky cards were placed among tomato transplants in a greenhouse, and four sticky cards were placed around the periphery of the property. Cards were changed weekly or biweekly from March to June at all sites. At California Transplant, continuous monitoring around the periphery has been ongoing since March 2007. Population densities 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.

**Indicator plants.** In order to detect TSWV early in the growing season (i.e., before tomatoes start showing obvious symptoms) fava beans, a sensitive TSWV indicator, were placed near some of the yellow sticky cards in greenhouses (5-7 fava bean pots per greenhouse). 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.

**Thrips monitoring in representative fields.** Table 1 lists the 45 fields and their locations that were monitored in 2010. A total 25 tomato fields, and 20 fields planted

with other crops in these processing tomato production regions were monitored for thrips and/or TSWV. Yellow sticky cards were placed in each of the four corners of each field, just above the canopy.

For the tomato fields, cards were changed weekly or biweekly beginning in March and up to harvest (August-November). Thrips were counted as described above. Population densities of thrips were also estimated weekly or biweekly 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.

**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 to confirm TSWV infection.

**Isolate collection and genetic diversity of TSWV.** In 2010, selected crop and weed plants with TSWV symptoms, or in a few cases without obvious symptoms, were confirmed to be infected with TSWV by immunostrips or RT-PCR and then used to further investigate the nature of the TSWV isolate. To assess the genetic diversity of these TSWV isolates from the Central Valley, the fragment of RNA encoding the *N* gene was amplified by RT-PCR and the sequence of the *N* gene determined and compared with sequences of isolates previously collected from tomato and other crops.

**Comparison of insecticides for control of thrips on tomato.** A trial was conducted at UC West Side Research and Extension Center to assess the performance of insecticide treatments against Western flower thrips. The processing tomato variety H8004 was transplanted on 30 April and irrigated with buried drip (depth of 10 in.). The selection of materials tested was based on results of in previous thrips insecticide trials, and communication with Pest Control Advisors and chemical company representatives. The experimental design was a four replication randomized complete block. Materials were applied with a CO<sub>2</sub>-pressurized backpack sprayer at 30 psi with equivalent of 25 gallons of water per acre with surfactant Induce 0.25% on 15 July. On 19, 22 and 29 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. In addition, on 21 July, ten 12 inch long shoots in each plot were cut, put in a 1 gallon plastic bag. Two liters of water with 0.5 ml Tween 20 was added to each bag. The shoots were removed and the water was poured into a 100 mesh sieve. The water was added and the thrips were poured out the top of the sieve into a 20 ml tube. The thrips were counted within the following 5 days with a dissecting scope.

**Table 1. List of monitored fields and their locations in 2010.**

| Fresno & Kings Counties  |                     | Fresno & Kings Counties |                   | Yolo/Colusa Counties  |                       | Locations |  |
|--------------------------|---------------------|-------------------------|-------------------|-----------------------|-----------------------|-----------|--|
| 5 Star DS Proc To        | Five Points         | Almond Harrits          | Coaltinga         | Rominger Org. TP Proc | Winters               |           |  |
| 5 Star TP Proc To        | Five Points         | Garcia&Church Lettuce   | Five Points       | Bradford DS Proc To   | Yolo County Ln        |           |  |
| Butte&Oakland DS Proc To | Five Points         | Farming D Lettuce       | Five Points       | T&P 1 TP Proc To      | Williams              |           |  |
| Tanquility DS Proc To    | Tanquility          | Huron FL Lettuce        | Five Points       | T&P 2 TP Proc To      | S. Wilson Bend Rd     |           |  |
| North DS Proc To         | Firebaugh           | Five Points FL Lettuce  | Five Points       | Detling TP Proc To    | Yolo County Ln        |           |  |
| North TP Proc To         | Firebaugh           | Wheat 1                 | Gale & Lassen Ave | Aoki TP Proc To       | Yolo County Ln        |           |  |
| Russel                   | Firebaugh           | Wheat 2                 | Lassen Ave        | Fava Bean             | Winters               |           |  |
| Shields                  | Firebaugh           | Wheat 3                 | Plymouth Ave      | Yolo FL Radicchio     | Knights Landing       |           |  |
| Woolf Creek DS Proc To   | Gale Ave            | Almond Orchards 1       | El Dorado Ave     | <b>Merced County</b>  | <b>Locations</b>      |           |  |
| Woolf Rose TP Proc To    | Gale Ave            | Almond Orchards 2       | Lassen Ave        | BUJ Pepper/Tomato     | Burchell Rd           |           |  |
| Tom1 TP Proc To          | Gale & Siskiyou Ave | Almond Orchards 3       | Plymouth Ave      | GC TP Proc To         | Gunn Club Rd, Gustine |           |  |
| Tom2 TP Proc To          | Jayne & Lassen Ave  | Radicchio SP            | Huron             | BC TP Proc To         | Bert Crane Rd         |           |  |
| Tom3 TP Fresh Market To  | Plymouth Ave        |                         |                   | FR TP Proc To         | Franklin Rd           |           |  |
|                          |                     |                         |                   | TH TP Proc To         | Thornon Rd            |           |  |
|                          |                     |                         |                   | LG TP Proc To         | Le Grand Rd           |           |  |
|                          |                     |                         |                   | AT SP Radicchio       | Athlone Rd            |           |  |
|                          |                     |                         |                   | LG SP Radicchio       | Le Grand Rd           |           |  |
|                          |                     |                         |                   | CW SP Radicchio       | Chowchilla            |           |  |
|                          |                     |                         |                   | LG FL Radicchio       | Le Grand Rd           |           |  |
|                          |                     |                         |                   | AT FL Radicchio       | Sandy Mush Rd         |           |  |
|                          |                     |                         |                   | CD FL Radicchio       | Childs Ave            |           |  |

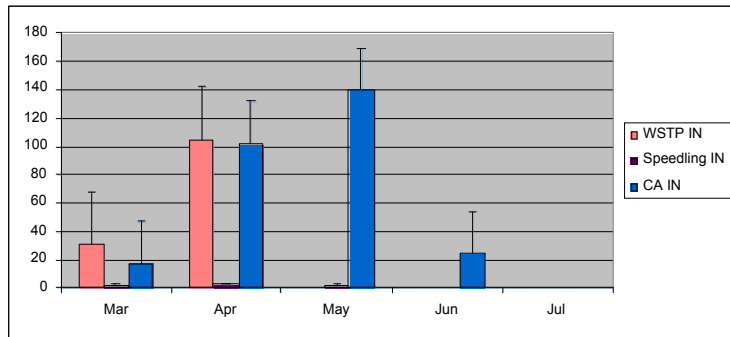
TP, transplanted; DS, direct seeded; Proc, processing; To, tomato; FL, fall planted; SP, spring planted; Org, organic

**Results:****Transplant Monitoring**

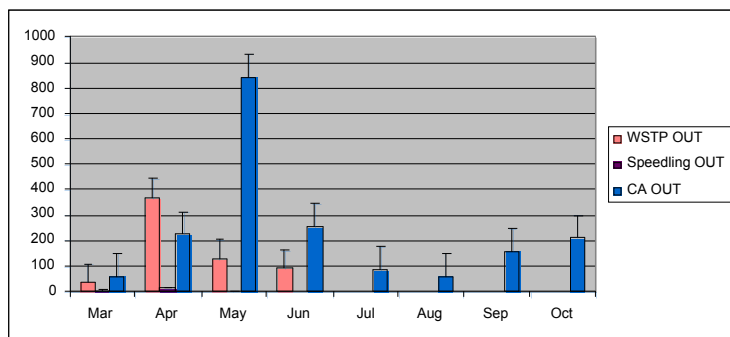
Thrips and TSWV monitoring was initiated in mid-February 2010 in transplant houses. Thrips populations were detected in transplant greenhouses; however, in general, populations were relatively low (2-140 thrips/card and Fig. 1). Highest thrips populations on transplants were identified in last week of April. Population dynamics and thrips levels were similar or slightly lower than in 2007 and 2009, and significantly lower than in 2008 populations. The peak thrips populations in transplant houses, similar to in 2007-2009, corresponded to the time when thrips populations were peaking in the field (May-June). Consistent with this finding, cards outside greenhouses had up to 300-850 thrips/card at the end of May (Figs. 1 and Appendix A2). Population densities also varied among greenhouses. For example, at California (CA) Transplant, the average total thrips count per card was ~10-50, with a peak population (200 thrips/card) detected in late May. At Westside transplants, the average total thrips count per card was ~10-30, with a peak populations (150 thrips/card) detected in mid April. Interestingly, in costal greenhouses at Speedling at Watsonville, thrips populations inside and outside were very low (1-10 thrips/card) from March-May (Fig. 1).

Thrips populations detected outside of the greenhouses peaked from late April (~30-500 thrips/card) through May (up to ~1200 thrips per some cards, and data not shown) with numbers decreasing by early June (Figs. 1 and A2). Average thrips counts per card for outside of Westside Transplant (WSTP) were lower than those outside of CA Transplants in 2010. However, populations outside of Speedling greenhouses (Watsonville) were much lower compared with CA Transplant and WSTP (1-12 thrips/card) (Fig. 1). Thrips captured from all these greenhouses were identified as western flower thrips.

In general, thrips populations associated with transplants were relatively low in 2007-2010 (Figs. 1 and A2). No obvious thrips damage was observed on transplants, nor were symptoms of TSWV observed on transplants that were grown in any of the monitored greenhouses. Consistent with this, no TSWV symptoms were observed on the fava bean indicators in these greenhouses. Together, these results indicate that transplants are not an important inoculum source for thrips or TSWV in processing tomatoes in Central California.



Average thrips populations **inside** Transplant Houses 2010



Average thrips populations **outside** Transplant Houses 2010

**Fig. 1. Average thrips counts on yellow sticky cards in and out side of monitored tomato transplant houses in 2010. WSTP, Westside Transplants-Huron; Speedling, Watsonville; CA, California Transplants- Newman.**

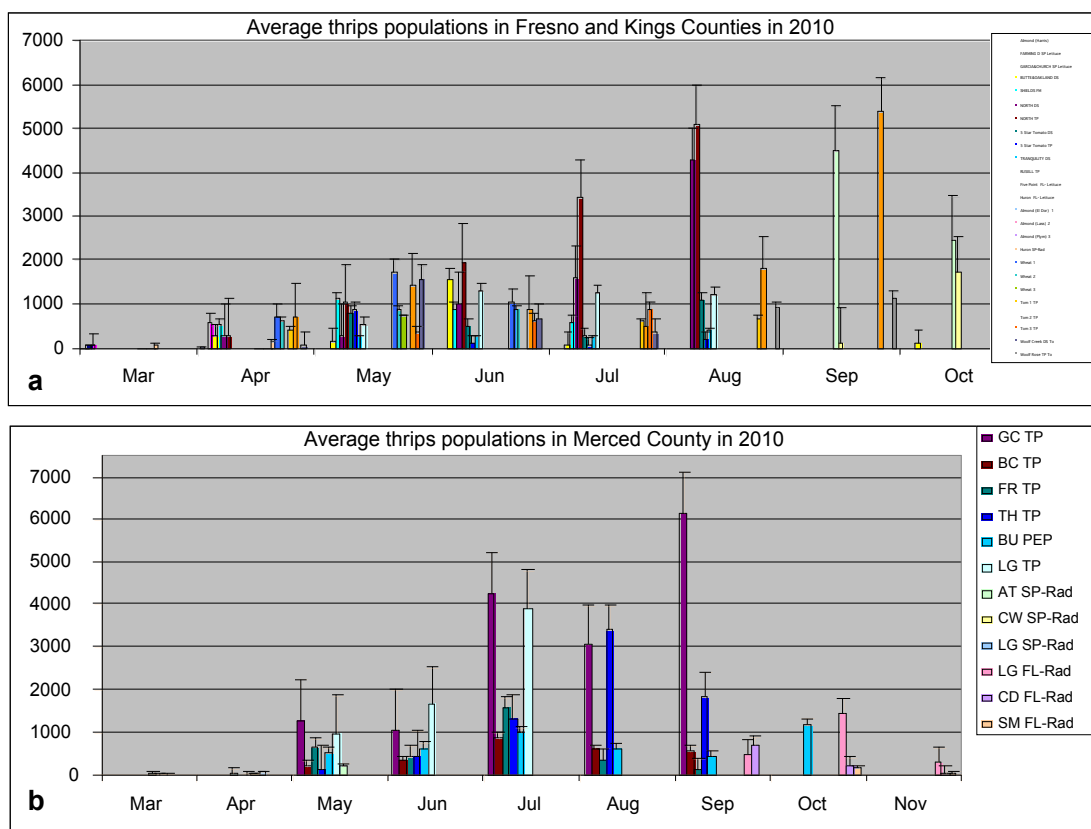
### Field Monitoring

Because of delays in tomato planting due to cool weather conditions, field monitoring for thrips and TSWV was initiated in transplanted and direct-seeded fields in mid March 2010. In 2010, most of the fields that were monitored were transplanted as there were relatively few direct-seeded fields, especially in Merced, Yolo and Colusa Counties. In 2010, thrips populations were higher in transplanted fields versus direct-seeded fields in one location (Woolf fields), but not in another location (Five Star fields) in Fresno and Kings Counties (Figs. 2a and A1). Overall thrips populations in 2010 were lower during May-August compared with previous years (2008 and 2009). However, thrips populations were much higher in 2010 in September-October compared to those in 2007-2009 (Figs. 2ab, 3a, A1, A3 and A4).

In 2009, the average thrips populations in Fresno and Kings Counties were slightly higher than those detected in 2007, but still considerably lower those detected in 2008 (e.g., maximum populations were 2000 and 3500 in 2007 and 2009, respectively, compared with 7000 in 2008). In 2010, populations in early-planted fields started to increase in late April and peaked in May-June, similar to those in 2007 and 2008. However, in later-planted fields, populations increased in August-September and remained high for a longer period of time (through November) than previous years, which was probably due to delay of growing season in 2010 (Figs. 2a, A1, A3 and data not shown).

In Fresno and Kings County locations, thrips populations in most fields remained at moderate-high levels (1,500/card) through August, but then substantially increased in

September (4,000-5,500/card), especially in late-planted fields (when thrips were migrated from early-planted tomato fields). Populations dropped in October, but were still relatively high levels (2,000-3,000/card) in fall-planted lettuce in these locations (Fig 2a and A1).



**Fig. 2. Average thrips counts per yellow sticky card in monitored fields in Fresno and Kings (a) and Merced (b) Counties in 2010.**

In Merced, thrips populations started to increase in May, peaked in July-August then gradually decreased through November (Figs. 2b, A1 and A3). Population densities detected in 2010 were lower than those detected in 2008 and 2009 during April-August (e.g., average high populations of 2300, 1300 and 1000 thrips per card in 2008, 2009 and 2010 in August, respectively and Fig. A3). However, the trend of thrips build-up in Merced was slightly different in 2010 compared with 2008 and 2009. In 2008-2009, thrips populations started increasing in April, peaked in May and slowly decreased through September (Fig. A3). In 2010, thrips populations started increasing in May, stayed high in June-October, and decreased in November (Fig. 2b).

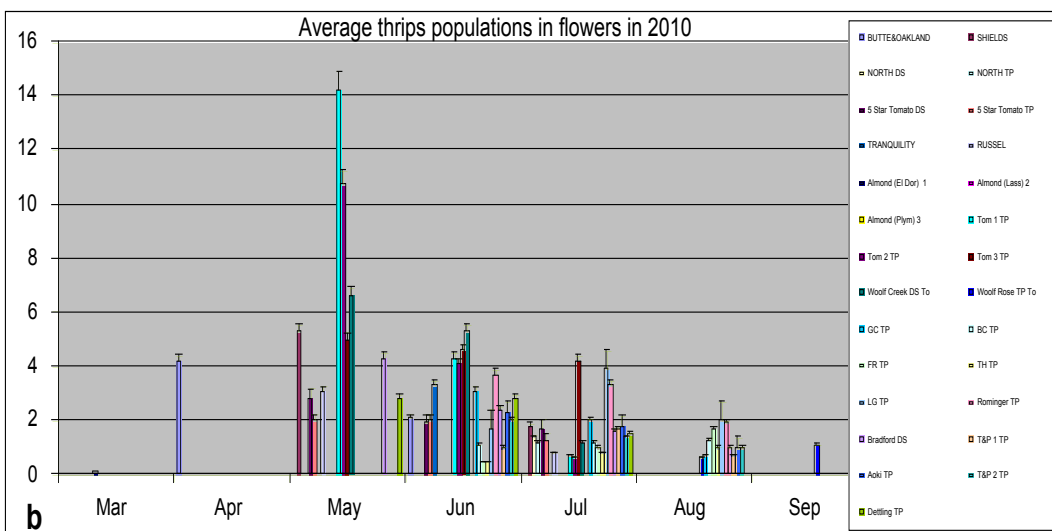
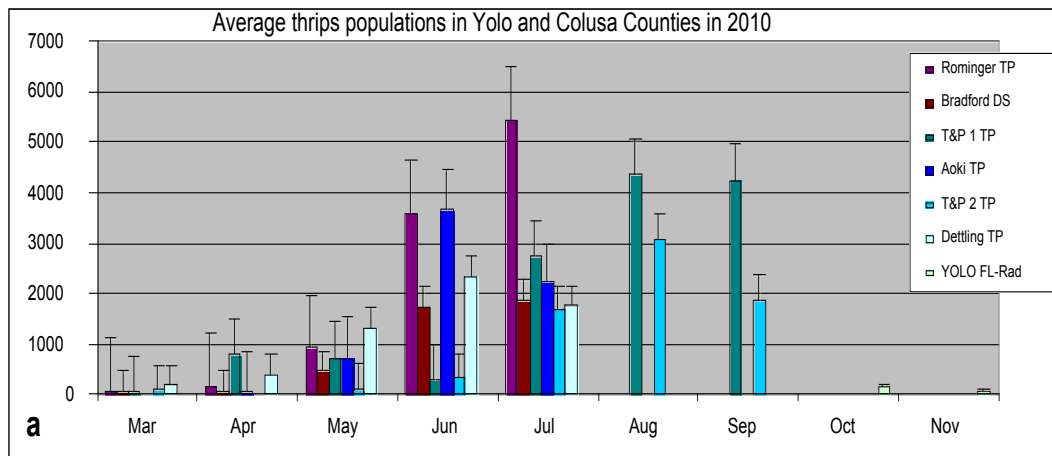
Yolo and Colusa Counties processing tomatoes were monitored for thrips populations and TSWV incidence for a second year in 2010. Overall thrips populations were substantially lower than in 2009 throughout the growing season, but similar to other counties, thrips populations were significantly higher in September (Figs. 3a, A1 and A4). Thrips populations started to build-up in late May, and increased in June-July when

populations peaked. Populations remained high through September (Figs. 3a and A1). In Yolo and Colusa, thrips populations were relatively high in late July (1,700-3,000 thrips per card); however, in an organic processing tomato field, populations were up to three-fold higher (up to 6,500 thrips per card). Also, in relatively later-planted fields (TP1 and TP2), thrips populations peaked in late August-September instead of June-July (Figs. 3a and A1).

In 2010, the overall trends of thrips population build-up and densities in Yolo and Colusa Counties was similar to those in other counties in 2010 (Figs. 3a, A1 and A4). The thrips populations in monitored fields remained high (1,500-4,500 thrips per card) through September until their harvest. All of the monitored fields in Yolo and Colusa counties were harvested by the end of September. In mid October, we started to monitor a radicchio field in an organic farm in Yolo County. In this field, thrips populations were significantly lower than thrips populations detected in tomato fields in September (average 150 and 48 thrips per card in late October and early November, respectively, and Fig 3a).

Flower sampling was initiated at bloom stage of development. Average thrips numbers in flowers in 2010 were higher than in 2007, similar to numbers detected in 2008, but slightly lower than numbers in 2009 (1-3, 2-5, 2-9 and 2-6 thrips per flower in 2007, 2008, 2009 and 2010, respectively).

In some fields in 2010, the highest thrips populations detected in flowers were in May, similar to in 2007-2009 (3-15 thrips per flower), but in most of the monitored fields populations remained in range of 2-6 thrips per flower through out the blooming stage. Thrips populations persisted in flowers throughout the growing season (Fig. 3b and data not shown). In 2010, thrips larvae were commonly found in flowers, similar to 2007-09. This indicates that thrips are reproducing on tomatoes, and may indicate the potential for secondary spread of TSWV. Evidence for this came from the observation of a significant increase of late season TSWV infections in which only one shoot on a plant developed spotted wilt symptoms in 2010. This was also observed in 2008 and 2009 but to a lesser extent.



**Fig. 3. Average thrips counts per yellow sticky card in monitored fields in Yolo and Colusa Counties in 2010 (a). (b) Average thrips counts per flower in monitored fields in all counties in 2010.**

All thrips captured in the monitored fields in 2010 were identified as western flower thrips and, consistent with previous results, female thrips populations were about three-fold higher than male populations.

The first detection of TSWV in tomato plants was in Yolo County in late March in a relatively early transplanted processing tomato field in Dunnigan (Dettling). TSWV was first detected in a pepper and a fresh market tomato field in Merced about a week later (early April). In Fresno and Kings Counties, TSWV was not detected until 19 April and 27 May in 2010, respectively. This was much later than in previous years. For example, TSWV was first detected on 24 April in 2007, and in the first week of May in 2008-2009. Thus, in 2010, detection of TSWV in Fresno and Kings Counties was one or two months later, respectively, than in Yolo County.

Overall incidence of TSWV in processing tomato fields remained low early in the growing season in 2010, i.e., 0-4%, 0-5% and 0-7% in monitored fields in Merced, Yolo & Colusa and Fresno & Kings Counties, respectively (Fig. 4). In Merced, TSWV

incidence, except in the monitored BU pepper/fresh market tomato field (16%), was relatively low (0-4%) in monitored fields throughout the season (Fig. 4). However, in some late-planted monitored fields in Yolo & Colusa and Fresno & Kings Counties, TSWV incidence reached up to 11-21% by the end of the season (Fig. 4). Even higher rates of TSWV infection were reported or observed in late-planted fields that were not monitored. For example, an unmonitored late-planted processing tomato field in Yolo and Colusa that was established next to a monitored field with confirmed TSWV infection (Bradford DS and Aoki TP), had high thrips populations and TSWV incidences, especially in some of the varieties in this field (incidences ranged from 15-100%). The highest incidence of TSWV was in fields that had high thrips populations through out the season (i.e., Dettling, Bradford and Aoki in Yolo and Colusa Co., North DS and TP fields, Russell TP and Tom1 TP fields in Fresno and Kings Co.; and Fig. 4). However, this was not always the case, and this raised questions about the relative efficiency with which thrips populations in different area transmit TSWV. Thus, the highest detected thrips populations were in Rominger (transplanted organic processing tomato) and in GC (transplanted processing tomato) fields in Yolo and Merced Counties, respectively, but TSWV incidence in these fields was lower than most of the monitored fields (<1-4% and Figs. 2b, 3a, 4 and A1).

Although TSWV eventually appeared in all monitored fields in 2010, the incidence remained less than 5% in most fields, similar to 2008 and 2009, but with higher levels of infection later in the season in 2010. Thus, the overall incidence of TSWV in monitored fields in 2010 (0-21%) was slightly higher than in 2007-2009. However, the overall pattern of disease development was similar in all these years (low TSWV incidence in early-planted fields and higher incidence in late-planted fields). Furthermore, significant economic losses due thrips/TSWV were not reported for the monitored fields in 2007-2010.

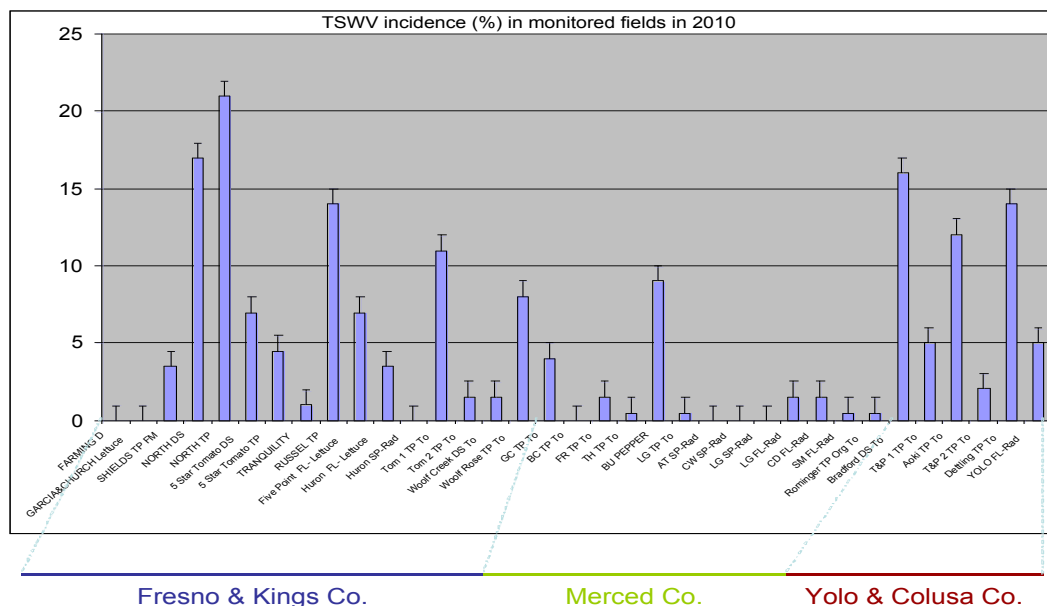


fig. 4. Final percent of TSWV incidences in monitored fields in 2010.

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### **Detection of other tomato-infecting viruses**

In 2010, the incidence of the new tomato-infecting ilarvirus, *Tomato necrotic spot virus* (ToNSV), curly top disease and *Alfalfa mosaic virus* (AMV) was also monitored. This was important in order to avoid misdiagnosis of TSWV and to get an understanding of the overall importance of viruses infecting processing tomatoes in California. In 2010, we detected a new tomato-infecting virus in Yolo and Colusa tomato fields: *Pelargonium zonate spot virus* (PZSV). This is a pollen and seed borne virus known to occur in Europe, and it was likely introduced in association with seed. However, these are reports that it might also be thrips transmitted via infected pollen. The overall incidence of PZSV was <1% and it did not appear to spread within the field.

The presence of these viruses complicates disease diagnosis, especially early in the season when symptoms induced by TSWV and some of these other viruses can be very similar.

We have now developed specific primers for all of these tomato-infecting viruses and can readily differentiate plants infected with the different viruses with PCR (curly top viruses) or RT-PCR (AMV, PZSV and ToNSV) assays. This is important because some of these other viruses can be more prevalent than TSWV. For example, in the GC field in Gustine, a transplanted processing tomato field in Merced County, the incidence of AMV was 8%, curly top 10%, TSWV 4%, and ToNSV <1%. The GC field was planted next to an old alfalfa field and was relatively close to foothills. Whenever this alfalfa field was cut, high populations of thrips (as were seen on cards and feeding damage on plants) and aphids (presumably carrying AMV) moved into the field. This also indicated that the high populations of thrips migrating from the alfalfa field did not carry TSWV. In some processing tomato fields in Fresno County, a high incidence of ToNSV (up to 20%) was reported in 2010.

Finally, mixed infections of more than one virus can also occur in the field. In 2007 and 2008, during the course of testing many symptomatic plants, we found infection by either TSWV, curly top virus or AMV, but never a mixed infection of any of those. However, in 2009 and 2010, we found a few mixed infections of TSWV and curly top virus, TSWV and AMV, curly top and AMV, or TSWV and ToNSV. Together, these results indicate the need for testing for multiple viruses to confirm the identity of the virus(es) in a particular field and to allow for the selection of appropriate management strategies.

### **Survey of potential hosts for TSWV and thrips**

To search for potential hosts of TSWV and thrips before, during and after the processing tomato season, we again monitored representative almond orchards, spring- and fall-planted lettuce in Fresno, spring- and fall-planted radicchio in Merced, and numerous weeds collected in the winter and spring.

Almond flowers were collected and thrips from these flowers were counted and tested for TSWV with the RT-PCR assay. Thrips population densities were low on yellow sticky cards placed in the almond orchards and in flowers (see Figs. 2a, 3b and A1 for March 2010). To date, TSWV has not been detected in thrips from almond orchards or in almond trees. These results are consistent with almonds not playing a major role in TSWV epidemiology.

Thrips populations in monitored spring-planted lettuce fields in Fresno County were low and TSWV was detected sporadically in these fields in 2010. Overall, spring lettuce fields in Fresno had very low incidences of TSWV (0-1%) and do not appear to be inoculum sources for early season tomato fields (Figs. 2a, 4 and A1). However, because of the cool weather conditions early in the growing season in 2010, the tomato growing season significantly overlapped with fall lettuce production in Fresno area in 2010.

Furthermore, this overlap occurred in September when thrips populations in tomatoes were still at very high levels (>5,000 thrips per card in some fields and Figs. 2a and A1). During the harvest of late-planted processing tomatoes, high populations of viruliferous thrips probably moved into fall-planted lettuce fields, especially those in close proximity to tomato fields. Consequently, high TSWV incidence (15-100%) developed in some of these lettuce fields. We are continuing on our surveys in two fall-planted lettuce fields in Five Points and Huron locations. In these fields, thrips populations were still in high levels in October (1,700-2,400 thrips per card) and TSWV incidence were 3.5 and 7% in the Huron and Five Points fields, respectively. It will be very important to monitor, especially later in winter, spring-planted lettuce to see if TSWV develops and if these fields can serve a source of virus for tomatoes in 2011.

Radicchio fields in Fresno and Merced, which were initially under plastic, did not have plants infected with TSWV, and thrips populations were low during the winter of 2010 (Figs. 2ab, 4 and A1). In spring 2010, TSWV appeared in all monitored radicchio fields, but incidence was sporadic and did not reach to the levels to cause economic losses in this crop or to be an inoculum source for tomatoes in Merced and Fresno Counties. Furthermore, effective sanitation of harvested crops has reduced the role of radicchio as a TSWV bridge crop in Merced County and this was reflected by the low incidence of TSWV in tomato in 2008-2010 (Fig. 4 and data not shown). Thus, we believe the importance of radicchio as a TSWV inoculum source for tomato has been substantially reduced.

However, similar to lettuce situation in Fresno, the tomato growing season also overlapped with radicchio plantation in Merced in fall 2010. Consequently, low TSWV incidence (0-5%) in some parts of some fall-radicchio fields was recorded. Thus, we are continuing to monitor these fields, and it will be very important to document whether fall-planted (winter) radicchio will overlap with spring-planted radicchio or tomatoes in 2011. Thus, we are continuing our surveys in five fall-planted radicchio fields in Merced and Yolo Counties.

In these fields, thrips populations have declined considerably to low levels (30-300 thrips per card) in October, and TSWV incidences are about 1 and 5% in Merced and Yolo fields, respectively (Figs. 2b, 3a, 4 and A1).

In areas with recent outbreaks of TSWV, weeds and plants other than tomato were collected and tested for the virus (Table 2). Most samples tested were negative for TSWV, although radicchio, lettuce, pepper, London rocket, cardone, nasturtium (an ornamental), groundsel (pineapple weed) and black nightshade tested positive for the virus. However, the overall incidence of TSWV infection in these weeds was very low (<0.1%). To date, we have not found evidence of any weed that is extensively infected by TSWV. Interestingly, in 2009, some bindweed samples, a perennial weed known as TSWV/thrips host, were infected with TSWV and showed symptoms of virus infection. Thus, this year we extensively surveyed bindweed for TSWV infection. However, we did not find TSWV infection of bindweed in 2010 (Table 2). Nevertheless, we will again be surveying bindweed in areas having TSWV outbreaks in 2011 to determine whether this common perennial weed is a potential inoculum source.

In 2010, surveys were conducted in Yolo and Colusa counties (January-March) in order to try to identify inoculum sources of thrips and TSWV for processing tomato fields. We found a fava bean field in one location. Our initial surveys of these fava beans revealed

very low thrips populations and no TSWV infections. Again, because fava beans are very good host for both thrips and TSWV (note that we use fava beans as indicator plants in our TSWV monitoring) fava bean can represent a possible bridge crop and/or reservoir for TSWV and thrips for processing tomato fields and we will be looking for such fields in Yolo and Colusa counties in 2011.

**Table 2. Weed survey results for TSWV incidence during 2010.**

| Weed <sup>a</sup> | Tested (+) | Weed <sup>a</sup> | Tested (+) |
|-------------------|------------|-------------------|------------|
| Black nightshade  | 10 (1)     | Lambs quarters    | 17 (0)     |
| Bindweed          | 160 (0)    | Malva             | 57 (0)     |
| Bur clover        | 18 (0)     | Mustard           | 14 (0)     |
| Groundsel         | 46 (1)     | Prickly lettuce   | 85 (0)     |
| Wild radish       | 20 (0)     | Sowthistle        | 65 (0)     |

**(+) number of plants tested positive for TSWV by Immunostrips and RT-PCR. <sup>a</sup>, Total weed samples from all Counties**

Furthermore, because various seed production fields are established around our monitored tomato fields in Yolo and Colusa counties, we regularly visited such plots to look for tospovirus-like symptoms in various crops. A report from Georgia indicated that Vidalia onions were found to have a mixed infected of TSWV and *Iris yellow spot virus* (IYSV), another tospovirus.

This report alerted us to look for possible tospovirus infections in onions. However, in our surveys we did not find any evidence of TSWV/IYSV infections in onion fields during 2008 and 2009. However, in 2010, we confirmed an IYSV infection in an onion in Colusa County. However, IYSV incidence was very low in these onion plots.

We also conducted TSWV inoculation experiments with onion and alfalfa plants to gain insight into whether these crops can be infected with the virus. Two approaches were used for inoculation with TSWV: sap-inoculation and thrips transmission assays, both under laboratory/greenhouse conditions. Despite our numerous attempts with both assays, we were not able to infect onions and alfalfa with TSWV, whereas positive control *Datura* plants were infected with both methods (indicating that these methods were successful in delivering the virus to the inoculated plants). Together, these results suggest that onion and alfalfa are not TSWV-inoculum sources for processing tomatoes, however, they are very good sources for thrips, as they harbored very high populations of thrips before, during and after tomato growing season.

#### **Genetic diversity of TSWV Isolates from the Central Valley**

Selected tomatoes as well as other crops such as pepper, radicchio and lettuce, and weeds with or without obvious virus-like symptoms were collected and tested for TSWV in 2010 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, and no major differences were found, irrespective of the host, location and year of isolation. Similar results were obtained with TSWV sequences amplified from thrips. These results indicate that in Central California, the TSWV population is still fairly homogeneous, and likely represents a geographically isolated population.

### **Detection of TSWV in thrips and studies of thrips biology**

Thrips from flower samples that were collected from each monitored field were pooled in a way to represent the biweekly population from each field, and tested by RT-PCR throughout the season. In RT-PCR tests performed with randomly collected thrips, most of the insects were negative, whereas lab-reared viruliferous thrips controls and some of the thrips samples that were collected from infected tomatoes were positive. These results indicate that most of the thrips in the processing tomato fields were not carrying the virus. This is also consistent with the relatively low levels of TSWV in tomato in 2010, despite of the very high thrips populations in many of these fields (i.e., Rominger and GC fields in Yolo and Merced Counties, respectively). If more of these thrips were carrying the virus, it is likely that the incidence of TSWV would have been much higher. Thus, there was no correlation between thrips populations and TSW disease incidence.

In 2009, we found that thrips populations were relatively high in Yolo County processing tomato fields, but TSWV incidence was not any higher than that in other monitored counties. These results suggested that thrips populations in different areas may have different virus transmission efficiency, as was previously reported in other parts of the world. To test this idea and to study thrips biology more thoroughly, we successfully established a thrips rearing system in our laboratory and established colonies from Fresno and Yolo Counties. We are currently testing their TSWV transmission efficiency. In our initial TSWV-transmission experiments with thrips reared from Fresno, we successfully inoculated *Datura* plants with TSWV. Similar experiments in our laboratory are currently ongoing with thrips reared from Yolo County. In these experiments both male and female thrips populations were used to conduct these assays.

The next step is to assess transmission efficiency of male and female thrips separately, and to compare their transmission efficiency with each other (i.e., gender and geographic origin). Note that, we are currently conducting these experiments with the laboratory host plant *Datura*, a known system that has been previously established and successfully used by many laboratories in these types of tests. In the future, we may try to develop similar system to conduct these experiments on processing tomatoes.

### **Insecticide Trial**

In 2010, a trial was conducted at UC West Side Research and Extension Center to assess the performance of insecticide treatments against Western flower thrips. The processing tomato variety H8004 was transplanted on 30 April and irrigated with buried drip (depth of 10 in.). All materials were applied on 15 July. Flower samples were collected on 19, 22 and 29 July. Thrips counts only from 21 and 22 July are presented here (Table 3) and the other samples are currently being processed. The thrips were counted within the following 5 days with a dissecting scope. Because the nymphs are less likely to migrate from external sources, we would suspect that the nymph counts are a more reliable indicator of efficacy than the adult counts. The treatments with the numerically lowest thrips counts included in Table 3. However, these treatments were not statistically different from the untreated control in 2010. In 2007-2009 trials, thrips levels in Radiant, Beleaf and HGW86 treatments had significantly lower thrips population densities than the untreated controls. In addition, dimethoate and Lannate consistently demonstrated efficacy in the 2007-2009 trials.

At UC West Side Research and Extension Center in 2010, TSWV incidence was very high and there were no differences among treatments. While this is consistent with findings in which there was no observed affect where Platinum/Venom was injected, it is the first season of four in which there was no reduction in TSWV symptoms where foliar applications were made. It is possible that this is due to the relatively small trial area and

the overall higher TSWV pressure in the area in 2010 as compared to the previous two years.

Thus, the trial was likely inundated with virus-carrying thrips coming in from outside of the field. Therefore, any spread that occurred, or did not occur, within the 28 bed by 300 ft trial may have masked by the large amount of inoculum from an external source.

**Table 3. Comparison of insecticides for control of thrips on tomato in 2010 (Prelim. data)**

| Treatment                 | 21 July, 2010 (leaf wash, 10 shoots) |        | 22 July, 2010 (flower counts, 25 flowers) |        |
|---------------------------|--------------------------------------|--------|---|--------|
|                           | Nymphs                               | Adults | Nymphs                                    | Adults |
| Radiant 6.0 fl oz/a       | 23.25                                | 72.5   | 0.75                                      | 25.25  |
| Beleaf 50SG 2.8 oz/a      | 25.5                                 | 62.25  | 1.5                                       | 24     |
| HGW86 10 SE 13.5 fl oz    | 26.25                                | 54.5   | 1.25                                      | 39     |
| Venom                     | 37.75                                | 63.5   | 6.5                                       | 27.75  |
| Leverage 5.1 fl oz/a      | 38                                   | 55.75  | 4.75                                      | 45.5   |
| Provado                   | 39                                   | 66     | 1.25                                      | 40.75  |
| Dimethoate 4EL 1.0 pt/a   | 40.25                                | 34.25  | 2   | 29.25  |
| Actara                    | 41.5                                 | 57.25  | 3.5                                       | 30     |
| Assail                    | 46                                   | 68     | 4.25                                      | 38     |
| Surround 25 lbs/a         | 46.75                                | 56     | 2.75                                      | 29     |
| Untreated control         | 54                                   | 45.75  | 2.5                                       | 33.75  |
| Requiem (QRD 452) 3.0 qts | 84                                   | 67.75  | 4.25                                      | 32.75  |
| LSD                       | 39.027                               | 25.133 | 2.263                                     | 10.857 |
| CV (%)                    | 64.8                                 | 29.80  | 53.56                                     | 22.93  |

**Note: Update and more detailed information on: i) insecticide trial, ii) influence of thrips control programs on TSWV incidence and yield on processing tomato and iii) TSWV incidence among processing tomato varieties in 2010, will be provided in Fresno County Vegetable Crops web site ([http://cefresno.ucdavis.edu/Vegetable\\_Crops/](http://cefresno.ucdavis.edu/Vegetable_Crops/)).**

### **Integrated pest management for TSWV in Central California**

Based upon our accumulated research findings on thrips population densities and TSWV development on processing tomatoes in Central Valley of California, the IPM approach for managing TSWV in processing tomatoes has been recently outlined in a flyer and distributed. The flyer is available for interested parties upon request. The IPM program is outlined below and continues to be modified and validate.

#### **A) Preplant**

**i) planting location/time of planting**-avoid hot spots known to have had high TSWV the previous year and avoid planting near winter fields of potential bridge crops (e.g., radicchio and lettuce).

**ii) resistant cultivars**-these are available, but may not be necessary if other practices are followed. Resistant cultivars can be used in hot-spot areas or in late planted fields, especially in near those fields in which TSWV infections have already been identified.

**iii) weed management**-maintain weed control in and around tomato fields and in especially nearby fallow fields as weeds are potential TSWV hosts. Our results in 2009 indicate that if weeds are allowed to grow in fallow fields that they can amplify thrips and TSWV and serve as inoculum sources for processing tomatoes.

## **B) Production**

**i) monitoring for thrips/TSWV**-monitoring thrips populations and TSWV incidence can indicate when to apply insecticides for thrips control, thereby reducing TSWV spread. All evidence indicates that thrips management should be initiated early (e.g., April/May) to reduce the development of virus-carrying adult thrips that can spread the virus within and between fields. This may even need to be done before disease symptoms are observed.

**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. If this is not possible (e.g., lettuce in Fresno and radicchio in Merced), thrips management should be practiced if necessary (note that our results indicate that thrips populations are low in the winter) and prompt sanitation (plowing under old crops and residues) should be practiced.

## **Current situation of thrips and TSWV in California**

Western flower thrips and tospoviruses have emerged as major pests in California crops and are likely to continue to be a problem.

Difficult to predict when and where TSWV outbreaks will occur.

Not all aspects of thrips and TSWV biology fully understood.

No single approach is adequate for management of thrips or TSWV.

Evidence that the IPM approach is effective:

Losses due to TSWV in monitored fields have been minimal

Growers using some or all of the IPM practices have not experienced significant losses due to TSWV

Progress in managing thrips and TSWV in radicchio in Merced has been associated with substantial reductions in TSWV

However, some late-planted fields, particularly in Fresno, did have high TSWV incidences in 2010

In 2010, no economic losses due to TSWV was reported



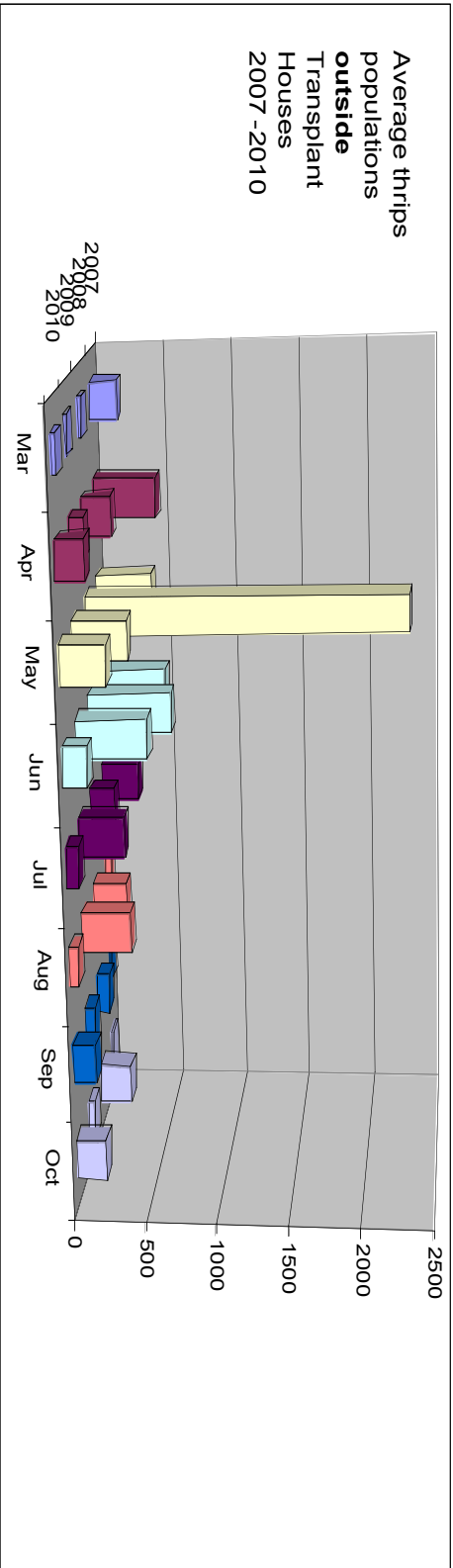
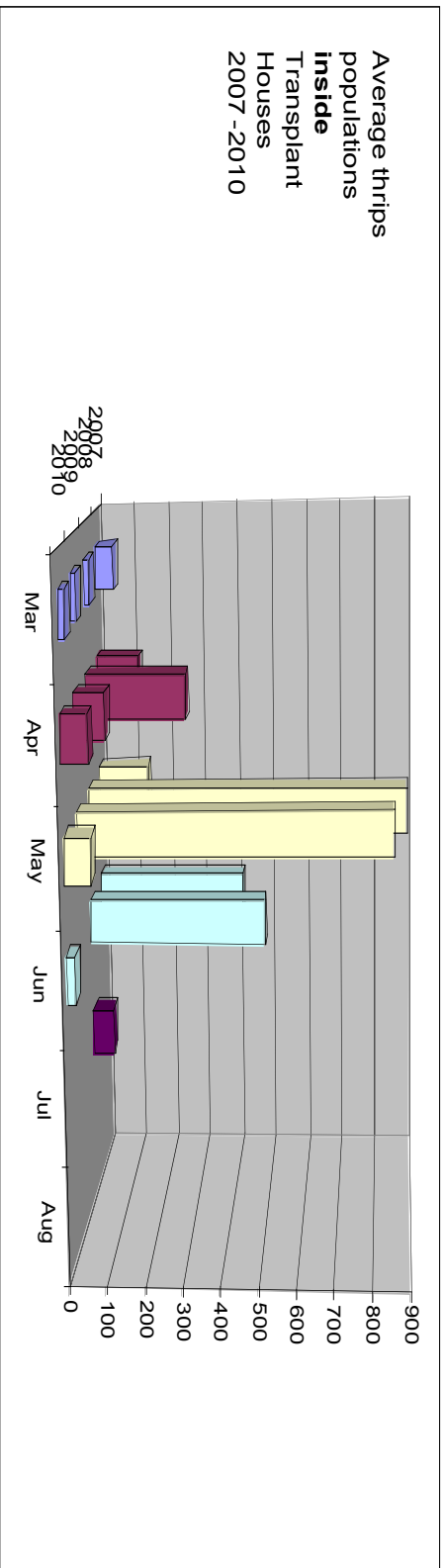
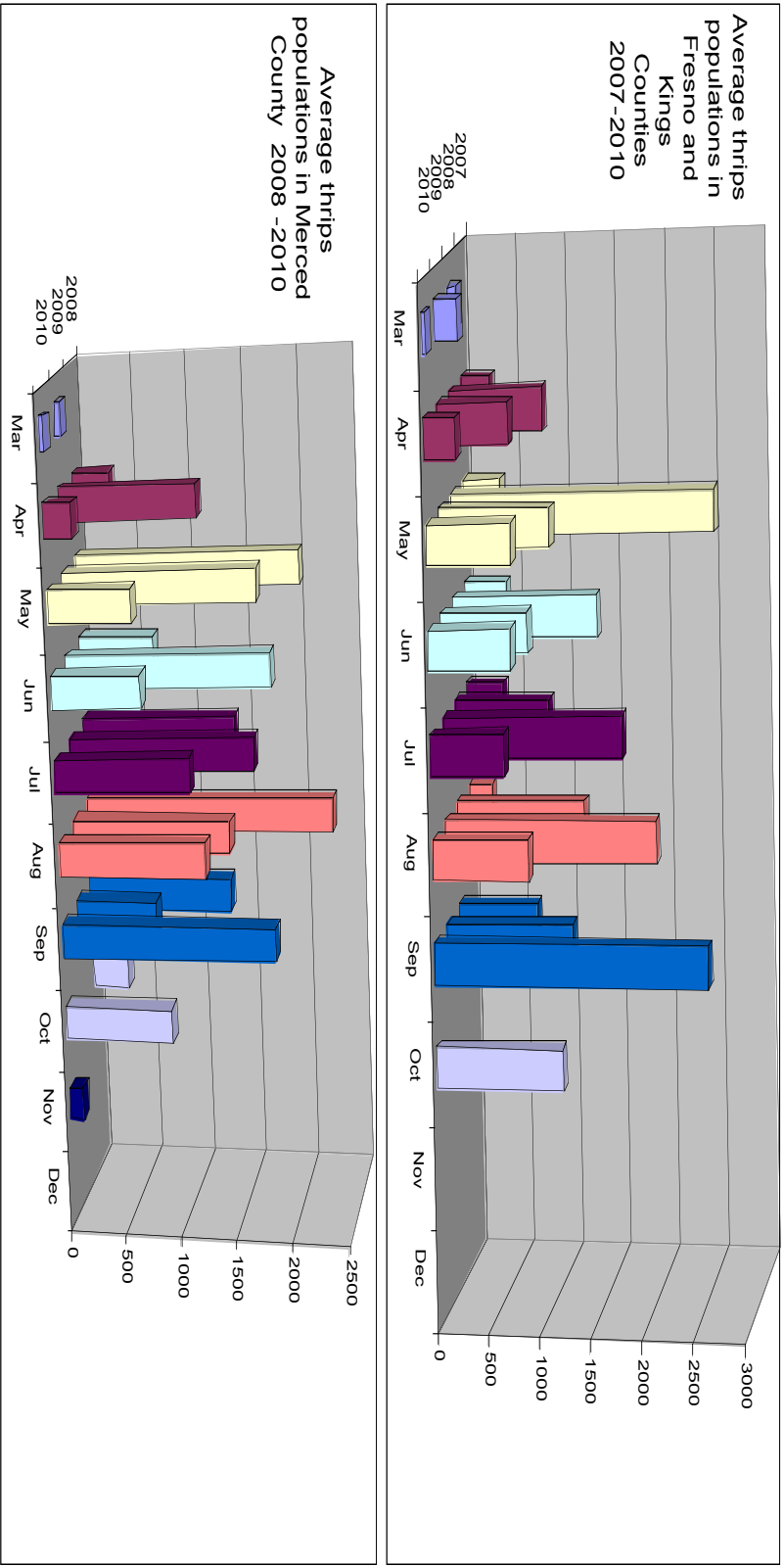


Figure A2. Almanac of the average thrips counts on yellow sticky cards in and out side of tomato transplant houses in 2007- 2010.



**Figure A3. Almanac of the average thrips counts on yellow sticky cards in Fresno and Kings (upper), and Merced Counties (lower) in 2007-2010 and 2008-2010, respectively.**

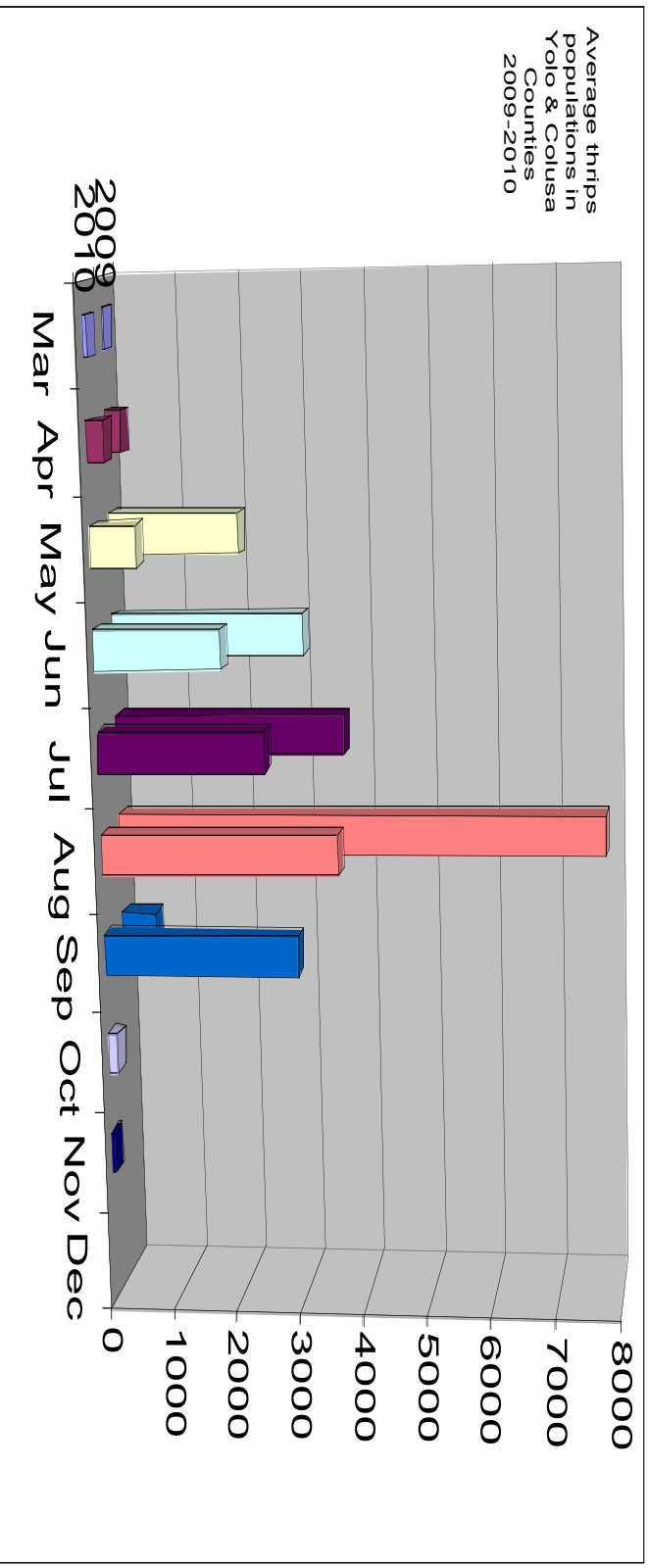


Figure A4. Almanac of the average thrips counts on yellow sticky cards in Yolo and Colusa Counties in 2009 and 2010.