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# Arthropod Pest Management in the Lower San Joaquin Valley

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## Summary

During 2019 and 2020 we evaluated tools that are available for integrated pest management of navel orangeworm and spider mites. Mating disruption trials for navel orangeworm confirmed that commercial dispensers releasing pheromone from aerosol or meso-based dispensers are effective at causing pheromone trap shutdown and reduce damage by approximately 50%. Evaluations of sprayable pheromone showed reduced captures of moths in pheromone traps, but not trap shutdown, resulting in numerical but not statistically significant reductions in damage at harvest.

Research on sixspotted thrips confirmed the presence of two periods of thrips activity: one in April and May followed by a second in response to increases in mite density after hull split. We developed threshold models showing that growers need to apply miticides when there are 1.4 mites per leaf, which is approximately 38% of leaves infested, which is consistent with previous work done in the 1980s. Correlations showed that mite density remains unchanged over 7 days if there are 0.42 thrips per yellow sticky trap per week for every 1.0 mite per leaf. During April and May these predictions suggest that no miticide applications are needed if thrips are present in the orchard. After hull split, an alternative threshold model was proposed whereby capture rates of 3 thrips per trap per week suggest that miticides treatments can be avoided because mite densities will not reach treatable levels during harvest.

## Objectives

The focus of our research was to generate and disseminate information on pest management programs that adhere to principles of IPM and help fulfill the almond industry's goals toward increased sustainability. For navel orangeworm our focus was to generate efficacy data on mating disruption that helps improve adoptability. For spider mites our focus was to improve reliance on biological control through the development of monitoring tools and treatment thresholds for spider mites and their natural enemies, particularly sixspotted thrips. We also evaluated the efficacy of miticides and maintained a research orchard.

Mating disruption evaluations consisted of large field trials annually during the first two years of this three-year project (2019 and 2020). They made comparisons of aerosol-based dispensers, MESO dispensers, two to four applications of microencapsulated (sprayable)

pheromone products, and a foam-like product applied aerially by drone. Trials were evaluated using pheromone traps, eggs traps, pheromone traps including a phenyl propionate (PPO) lure, and damage assessments at harvest.

Research on spider mites focused on an improved understanding of the biology of sixspotted thrips, documentation of the relationship between thrips and mite density (predator-prey ratios), and on the impact of miticides in control programs. Biology information was generated through season-long trapping programs that, when combined with data from previous years, could show when thrips are present, and the consistence in their presence across years. Data from the current project were also combined with data from previous projects to strengthen predictive models regarding treatment thresholds that were proposed during previous years of work. Miticide trials were also completed during the 2019 and 2020 seasons. Miticide trials, as well as other research not described in this report, were completed within the experimental almond orchard in Shafter, CA, that is maintained in part through funding from the Almond Board.

## **Annual Results and Discussion**

### Navel orangeworm mating disruption

During 2019 and 2020 we completed field trials on the impacts of seven different mating disruption programs representing four different types of mating disruption products. Over the two years these trials included over 10,000 trap evaluations and more than 500 harvest evaluations containing more than 150,000 nuts. For the sake of brevity in this interim report, these results have been summarized into four charts shown in Figure 1. Charts include a) average pheromone trap captures during the critical period from the initiation of hull split until the end of harvest, b) average adult captures in pheromone traps containing PPO lures during the critical period, c) average egg captures during the critical period, and d) average levels of kernel infestation across all varieties. Data are shown for three of the mating disruption types: aerosols, mesos, and sprayable products. Data for the fourth type of system where pheromone was applied in a foam-like matrix from a drone is discussed separately.

During both years, aerosol-based emitters reduced pheromone trap captures by >96%, pheromone + PPO captures by >69%, and egg captures by >71% during the critical period from the initiation of hull split until the end of pollinizer harvest (Fig. 1a-c). At harvest, average damage levels across all varieties were reduced by 42% and 73% for the two years, respectively (Fig. 1d). Reductions in trap captures and damage at harvest were statistically significant compared to the check for all parameters.

Mating disruption systems using meso emitters resulted in reductions in trap captures and damage that were statistically equivalent to aerosol-based emitters for all evaluated parameters (Fig. 1a-d). Meso-based systems reduced pheromone, pheromone + PPO, and egg trap captures by an average of 94%, 66% and 58% across the two years, respectively (Fig. 1a-c). At harvest, average levels of damage across varieties were reduced by 36% (2019) and 62% (2020) compared to the check that had an averaged 2.1% damage each year across varieties.

Sprayable mating disruption systems reduced the number moths captured in pheromone traps by 55% in 2019 and 39% in 2020, but did not cause trap shutdown (Fig. 1a). This was true for mating disruption programs using 2, 3 or 4 monthly applications of the pheromone (data not shown for each individual program). The application of sprayable pheromone reduced pheromone + PPO captures by 60% in 2019 and by 30% (not significant (NS)) in 2020. Captures of eggs were 17% (NS) and 35% (NS) lower in 2019 and 2020, respectively, when sprayable pheromone was used. At harvest, Nonpareil damage over the two years where pheromone was used was 6% (NS) and 24% (NS) lower than in the untreated check (1.1-1.6% infested), and Monterey damage over the two years was 12% (NS) and 31% (NS) lower than in the untreated check (3.2-3.3% infested). Analysis of data comparing 2, 3, and 4 applications of pheromone at monthly intervals did not reveal any patterns to suggest that programs with more applications were more effective than programs using less (data not shown).

During 2019 we evaluated a fourth type of pheromone delivery system using drones. Pheromone was impregnated into a foamlike-matrix that was dispensed from the drones from automated caulking guns. This application method was only tested for one year in 2019 with very similar results to those previously described for sprayable pheromone products. After one year of field testing, the manufacturers decided to withdraw from the 2020 trial to do further work regarding product development before re-initiating field-level evaluations on large scale.

#### Sixspotted thrips monitoring, biology, and treatment thresholds

Trials on adhesive thickness for traps used for monitoring sixspotted thrips determined that the levels of adhesive are already optimized in cards currently recommended to industry (Trece Pherocon Predator Traps). Reducing the level of adhesive made traps easier to use, but less effective, while increasing the level of adhesive made traps harder to use and did not result in a more effective trap.

During 2019, sixspotted thrips biology was very similar to previous seasons. This included a spring period of activity from mid-April until mid to late May, followed by a period of inactivity when no food (spider mites) were present in June, followed by increased thrips activity through the month of July that peaked in August and September in response to increases in mite prevalence (Fig. 2). We are in the process of incorporating these data into graphics including similar data from previous years as part of a multi-year journal article on sixspotted thrips biology in the Journal of Economic entomology.

Efforts to summarize data on treatment thresholds for Pacific spider mite that incorporate trap captures for sixspotted thrips are ongoing. At this point all data have been collected and summarized, and we are in the final stages of preparing the multi-year results in the Journal of Economic Entomology. Models showed that decisions to treat Pacific spider mite should be made on the first monitoring date with 1.4 mites per leaf (38.1 of leaves infested) to ensure that miticides applications are made prior to reaching the treatment threshold of 5.4 per leaf an average of 4.7 days later (Fig. 3).

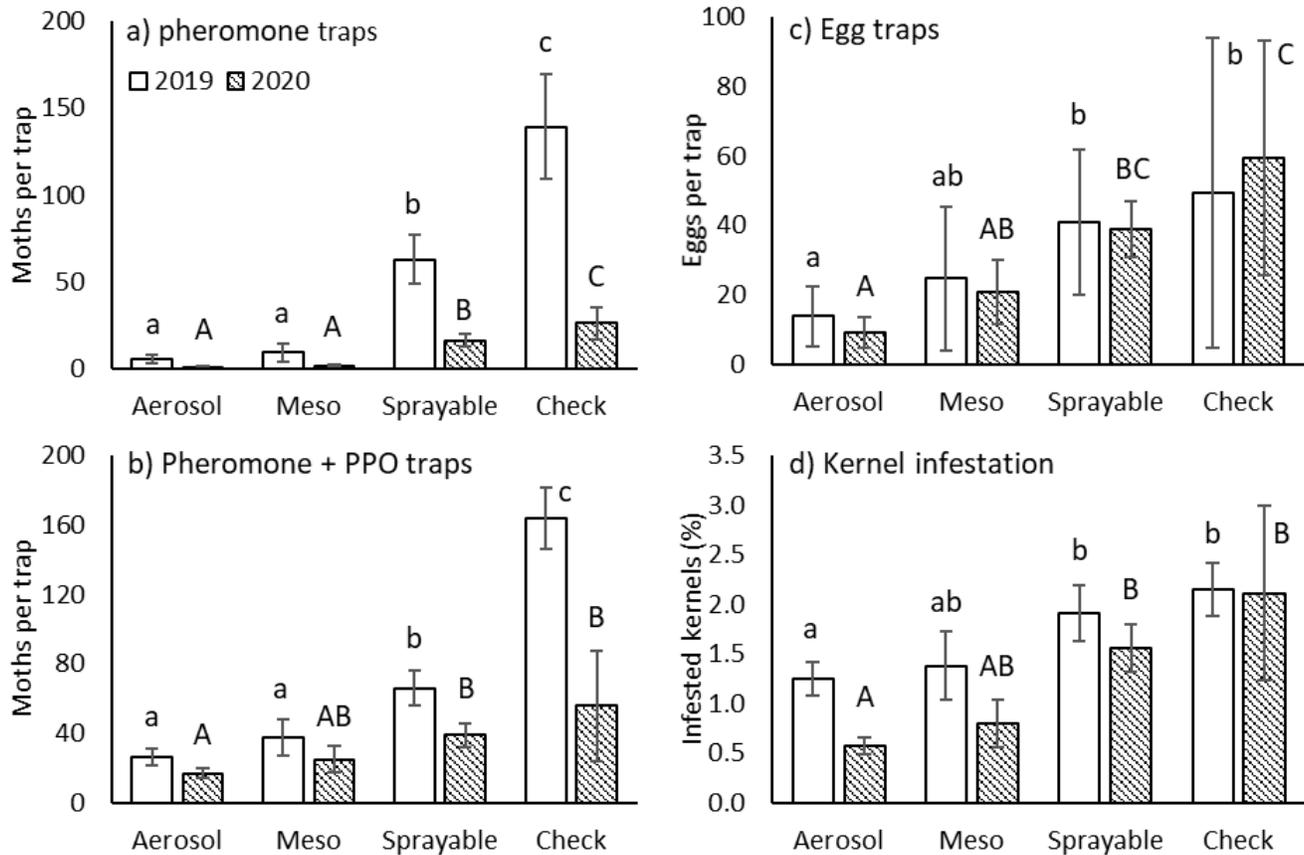


Fig. 1. The effects three types of navel orangeworm mating disruption products during 2019 and 2020 field trials on the number of moths and eggs captured per a) pheromone trap, b) pheromone trap including a phenyl propionate lure, and c) egg trap during the period of peak nut susceptibility from July through September. Also included is the d) average percentage of infested kernels at harvest across nonpareil and pollinator varieties.

Incorporation of thrips data into the model determined that mite density remained unchanged when there were 0.42 sixspotted thrips per trap per week for every one Pacific spider mite per leaf (derived from Fig. 4). For growers considering prophylactic treatments at Pacific spider mite densities below the action threshold of 1.4 per leaf, this confirms that no miticides are needed if sixspotted thrips on cards are present. For orchards where mite density has exceeded treatment thresholds we developed a less accurate, but more practical, model that does not require counting mites on leaves. On average, mite density remained unchanged for seven and 14 days if there were an average of 5 and 3 thrips per trap per week. At thrips densities of 3 per week there were 69.8 and 77.4% probabilities that mite density would decrease within 7 and 14 days, respectively. When spider mite food was present, sixspotted thrips doubled their population every 4.0 days and responded to increases in spider mite density with a lag time of approximately 2-3 weeks (Fig. 5).

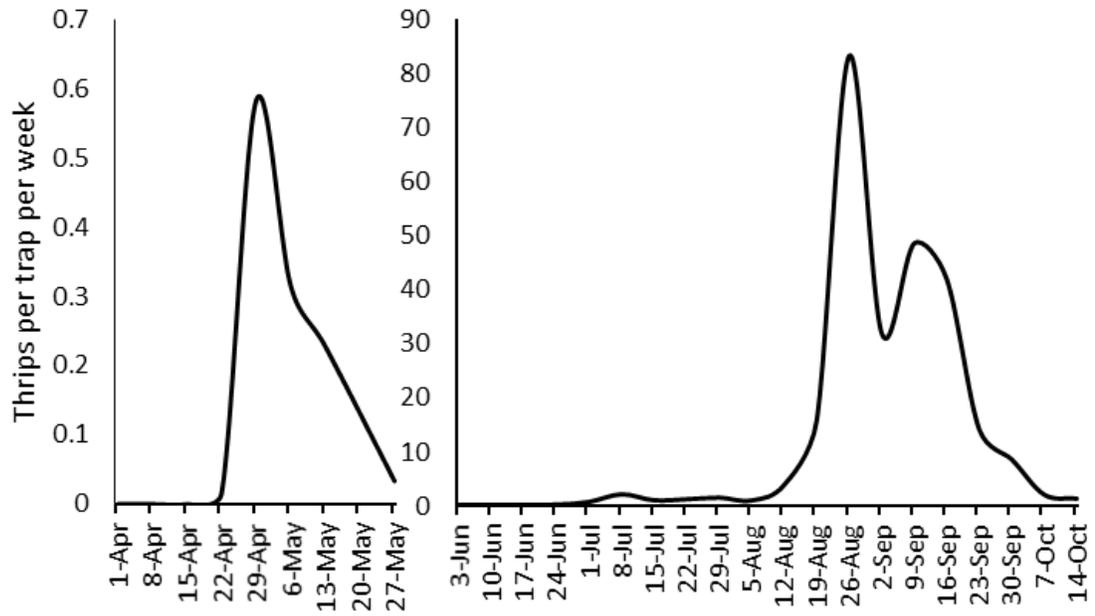


Fig. 2. Average sixspotted thrips capture rates from four commercial almond orchards in Kern County, 2019.

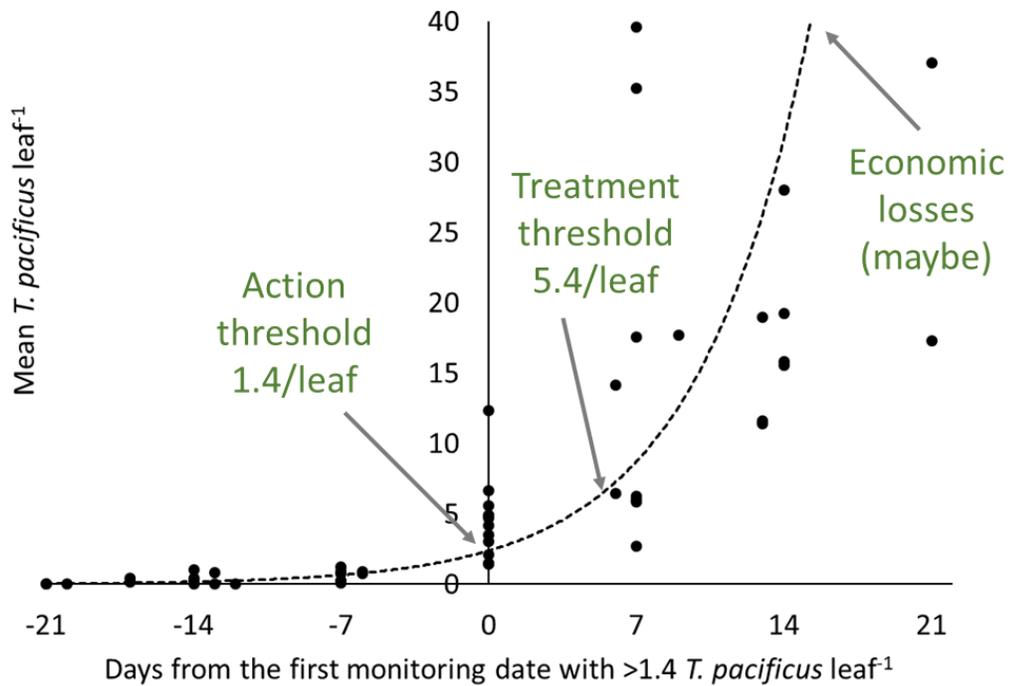


Fig. 3. Action and treatment thresholds for Pacific spider mite based on the average number of mites per leaf.

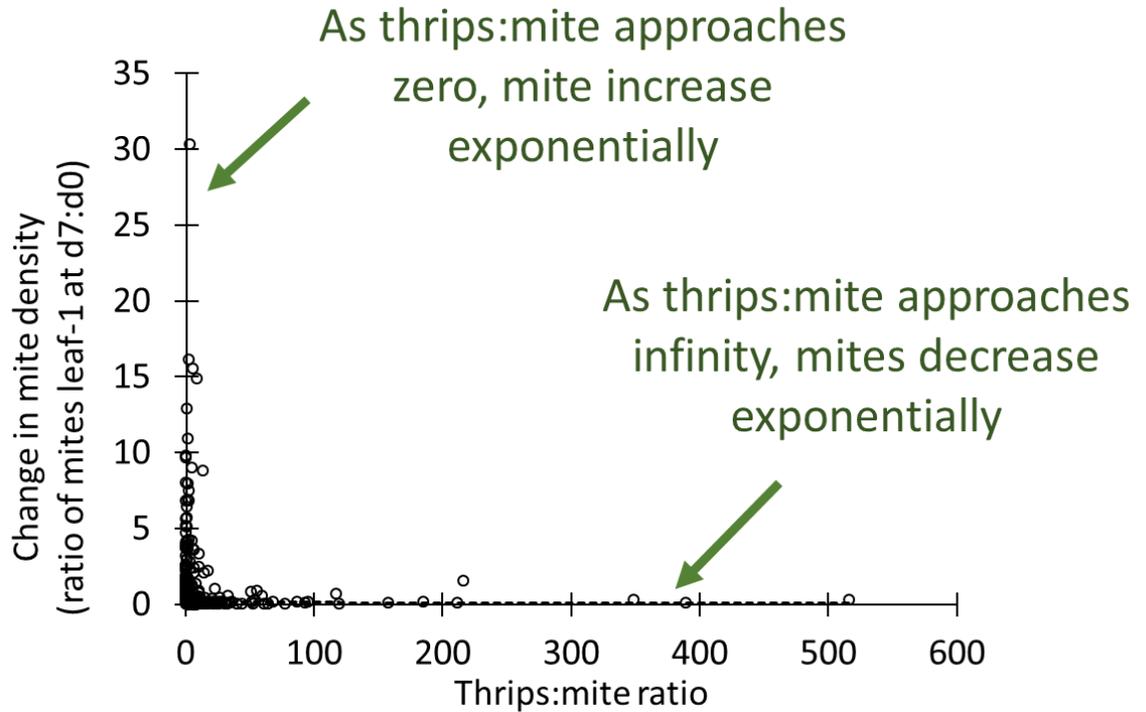


Fig. 4. Relationship between the ratio of thrips per card per week to the number of mites per leaf and the impact it has on the change in Pacific spider mite density over a period of one week.

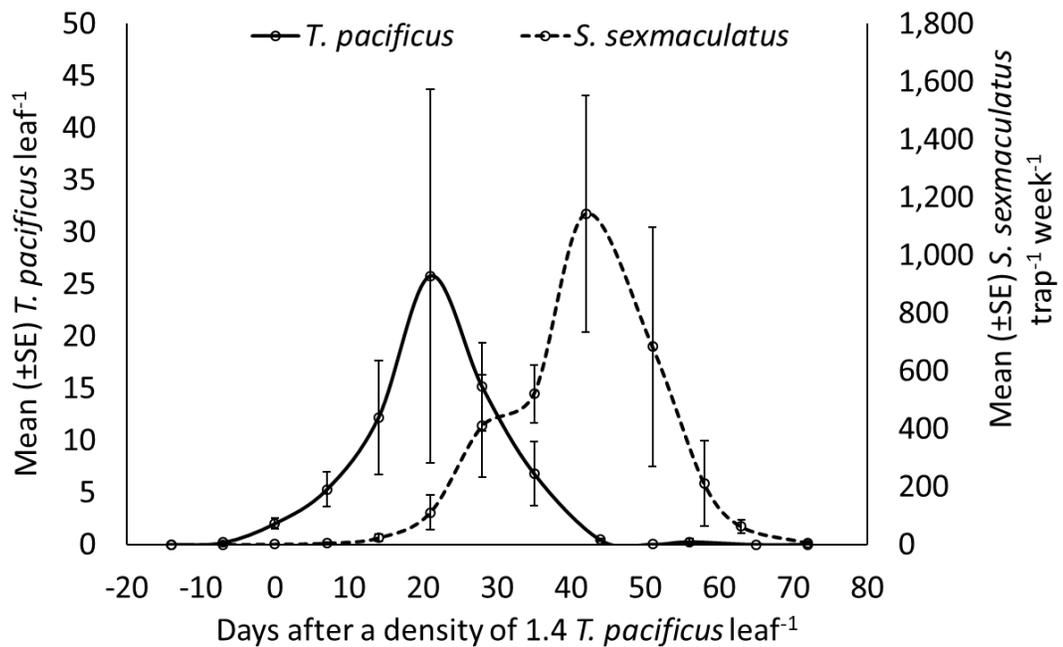


Fig. 5. Relationships and lag times associated with increases and decreases in Pacific spider mite and sixspotted thrips densities.

Miticide trial

Prior to treatment, Pacific spider mite density averaged 3.6 mites per leaf, which is more than twice the almond treatment threshold. Unfortunately, immigration of sixspotted thrips into the research trial caused natural mortality of mites such that mite density never exceeded 3.0 mites per leaf on any evaluation date through 21 DAT (Table 1). There were no significant differences among treatments during evaluations 3, 7, 14 or 21 DAT. The lowest number of cumulative mite-days was observed in plots treated with Nealta (33 mite-days), followed by 415 oil (42 mite-days), followed by all other treatments and the untreated check (52 to 65 mite-days). However, those differences were not significantly different. Similar trends in a lack of significant differences were seen in data on the number of eggs per leaf (data not shown). Lack of significant differences is common in trials overrun by sixspotted thrips because natural enemies disproportionately feed on mites in plots where control with miticides was not attained.

Table 1. The effects of miticide treatments on the density of Pacific spider mites on almond leaves, Shafter, 2020.

| Treatment          | Rate per acre   | Mean spider mites per leaf |        |        |        |        |        | Cumulative mite-days |
|--------------------|-----------------|----------------------------|--------|--------|--------|--------|--------|----------------------|
|                    |                 | Pre-counts                 | 3 DAT  | 7 DAT  | 10 DAT | 14 DAT | 21 DAT |                      |
| Venerate + 415 Oil | 2 qt + 1%       | 3.36                       | 1.14   | 2.60   | 2.10   | 3.98   | 1.25   | 52.9                 |
| Grandevo + 415 Oil | 2 lb + 1%       | 4.64                       | 3.58   | 3.48   | 3.74   | 2.44   | 0.74   | 61.7                 |
| Exp. 1 + 415 Oil   | 5 fl oz + 1%    | 2.13                       | 1.78   | 1.79   | 4.13   | 3.86   | 0.51   | 54.4                 |
| Exp. 2 + 415 Oil   | 2 lb + 1%       | 2.46                       | 2.38   | 2.88   | 4.30   | 4.34   | 0.70   | 65.7                 |
| Exp. 3 + 415 Oil   | 3 qt + 1%       | 4.73                       | 2.23   | 1.71   | 2.63   | 2.68   | 2.00   | 55.1                 |
| Nevalta + 415 Oil  | 13.7 fl oz + 1% | 5.90                       | 1.73   | 1.78   | 1.63   | 1.86   | 0.40   | 33.7                 |
| 415 Oil            | 1%              | 3.06                       | 3.11   | 1.03   | 2.88   | 2.03   | 0.31   | 42.5                 |
| Check              | -               | 2.91                       | 2.91   | 2.55   | 3.03   | 2.59   | 2.09   | 63.0                 |
|                    | <i>F</i>        | 0.24                       | 0.62   | 0.57   | 0.74   | 0.86   | 1.59   | 0.60                 |
|                    | <i>P</i>        | 0.9702                     | 0.7300 | 0.7719 | 0.6393 | 0.5527 | 0.1929 | 0.7490               |

There are no significant differences among means ( $P > 0.05$ , Fisher's Protected LSD) after square root ( $x + 0.5$ ) transformation of the data. Untransformed means are shown.

Almond orchard maintenance

During 2019 and 2020 we continued the maintenance of a 7-acre almond research orchard in Shafter, CA, through partial funding from the Almond Board of California. During 2019 and 2020 this orchard was used for 9 different field experients related to pest management and almond production. Over it's eleven-year lifespan, this orchard, and a parallel orchard funded

by the Almond Board of California at the Westside Research and Extension center through 2013, have now supported 78 unique research trials.

## **Outreach Activities**

### Presentations

11/3/19, Reno, Statewide CAPCA Conference, Mating disruption for NOW, 425  
11/7/19, Tulare, Tulare Chapter CAPCA Mtg., Alternatives to chlorpyrifos, 106  
11/7/19, Visalia, UC Almond Shortcourse, Management of NOW, 160  
11/8/19, Parlier, UC Almond Shortcourse Field Tour, Insect monitoring, 55  
11/12/19, Modesto, Tree and Vine Expo, Mating disruption for NOW, 268  
11/19/19, St. Louis, ESA National Meeting, Mating disruption for NOW, 41  
12/11/19, Sacramento, Mating Disruption Seminar, Mating disruption for NOW, 10  
1/18/20, Monterey, Bayer Grower Education Seminar, Nut crop pests, 43  
1/23/20, Visalia, Statewide Pistachio Day, Mating disruption for NOW, 400  
1/23/20, Madera, Semios Grower Ed. Seminar, Mating disruption for NOW, 25  
1/24/20, Bakersfield, Semios Grower Ed. Seminar, Mating disruption for NOW, 27  
2/26/20, Tulare, LMR Continuing Ed. Seminar, Life after chlorpyrifos, 96  
2/28/20, Avila Beach, Valent PCA Ed. Seminar, Spider mite management, 24  
12/10/20, Virtual, Almond Industry Conference, Insect management, 334

## **Materials and Methods**

### Navel orangeworm mating disruption

Mating disruption trials for navel orangeworm were completed during 2019 and 2020 in commercial almond orchards in Kern County. During each year, four large orchard regions were each divided into fourteen to sixteen 40-acre plots. During each year, seven treatments and a no-mating disruption check were assigned to one plot in each orchard with the remaining plots serving as no-mating disruption buffers between plots. Within each orchard the treatments were assigned to plots randomly with the assigned to an upwind plot to prevent drift from treatments.

During each year, navel orangeworm populations were monitored weekly using two pheromone (wing traps), two pheromone + PPO lure traps (wing traps), and two egg traps within each plot for an approximate 30-week period from March through October. At harvest we collected approximately 300 random nuts off of the ground after commercial shaking at four locations within each plot for NonPareil and Monterey varieties. Nuts were stored at ambient temperatures within a warehouse for approximately two weeks and cracked open manually to inspect for damaged kernels.

In order to maintain brevity in this report and focus on comparisons between application types (aerosol, meso, and sprayable) instead of comparisons within application types (i.e., aerosols or sprayables from different companies), trapping data were summarized by flight, and trapping and harvest data were grouped by application type prior to analysis. Data were analyzed by ANOVA with means separation using Fisher's Protected LSD (0.05).

Table 1. Treatments and application rates for mating disruption products evaluated for navel orangeworm, 2019-2020.

| Treatment                | Manufacturer       | Rate per acre     | Application details                                    |
|--------------------------|--------------------|-------------------|--|
| <b>2019</b>              |                    |                   |  |
| Isomate NOW Mist         | Pacific Biocontrol | 1                 | Installed 26-27 Mar                                    |
| Isomate NOW Mist Pro     | Pacific Biocontrol | 1                 | Installed 1 May  |
| Cidetrak NOW Meso        | Trécé              | 20                | Installed 10-12 Apr                                    |
| Cidetrak NOW MEC         | Trécé              | 4X @ 70 ml/app.   | 22-25 Apr, 25-31 May, 18 Jun to 9 Jul, 26 Jul to 4 Aug |
| Cidetrak NOW MEC         | Trécé              | 2X @ 70 ml/app.   | 7-18 Jul, 26 Jul to 4 Aug                              |
| Checkmate NOW-F          | Suterra            | 2X @ 3 fl oz/app. | 7-18 Jul, 26 Jul to 4 Aug                              |
| SPLAT NOW                | ISCA               | 2X @ proprietary  | Appx. 1 Jul, 1 Aug                                     |
| <b>2020</b>              |                    |                   |  |
| Checkmate Puffer NOW Ace | Suterra            | 1                 | Installed 31 Mar to 1 Apr                              |
| Isomate Mist NOW         | Pacific Biocontrol | 1                 | Installed 31 Mar to 1 Apr                              |
| Cidetrak NOW Meso        | Trécé              | 20                | Installed 15-16 Apr                                    |
| Cidetrak NOW MEC         | Trécé              | 4X @ 70 ml/app.   | 4-14 Apr, 4-30 May, 29 Jun, 28 Jul to 7 Aug            |
| Cidetrak NOW MEC         | Trécé              | 2X @ 70 ml/app.   | 29 Jun, 28 Jul to 15 Aug                               |
| Checkmate NOW-F          | Suterra            | 2X @ 3 fl oz/app. | 29 Jun, 28 Jul to 15 Aug                               |
| Checkmate NOW-F          | Suterra            | 3X @ 2 fl oz/app. | 29 Jun, 13-20 Jul, 7-15 Aug                            |

### Sixspotted thrips monitoring, biology and treatment thresholds

During 2019 and 2020 we wrapped up long-term studies on sixspotted thrips trapping, biology, and on the establishment of treatment thresholds for spider mites that include information on natural enemy density. First, a study was conducted to evaluate seven adhesive variants of the yellow sticky card that proved most efficacious for trapping natural enemies in previous studies. Four traps of each type were placed at random into each of three different almond orchards and recovered after a week. Data were used to determine adhesive tradeoffs regarding thickness.

During 2019 we completed a season-long monitoring program for sixspotted to assist in our understanding of thrips biology throughout the year. One pherocon predator trap was placed at the location of each navel orangeworm trap pheromone trap location from our large scale mating disruption trials. This resulted a grid of 16 predator traps across approximately 600 acres in four separate orchards in Kern County. Traps evaluated weekly from late March through mid-October for the number of sixspotted thrips. Capture data were analyzed graphically and combined with similar data from previous years to determine year-to-year consistency in patterns of sixspotted thrips activity.

During 2019 we also collected data on spider mite density (mites per leaf) and sixspotted thrips density (thrips per trap per week) to include with data from previous years toward our effort to develop treatment threshold models. From mid-August until mid-September, eight trapping locations were established in each of three commercial almond orchards at a time when mites and thrips were both present. Data on mites per leaf and sixspotted thrips per trap per week, coupled with the number of mites per leaf the following week, were converted into datapoints for use in our predictive model alongside similar datapoints collected over the past three years. A combination of linear, exponential, and log-log regressions were used to develop models to validate treatment thresholds for spider mites based on leaf sampling, and provide guidelines regarding sixspotted thrips densities to further refine these thresholds.

#### Miticide trial

During 2019 we conducted a trial in Shafter, CA to evaluate the effects of seven miticides on density of Pacific spider mites in almond. We have done these types of trials for many years, and this year we focused our efforts on new and experimental microbial products. The trial was organized as a randomized complete block design using four blocks of three-tree plots. Treatments were applied to individual trees on 4 Aug with a hand gun at 150 PSI with a water volume of 200 gpa. Mite densities were evaluated 3, 7, 14 and 21 days after treatment (DAT) by counting the total number of motile spider mites and spider mite eggs on 20 random leaves per plot. Data on the average mites per leaf, average eggs per leaf and cumulative mite-days (an additive measure of mite density each day), were analyzed by ANOVA using transformed data (square root ( $x + 0.05$ )) with means separated by Fisher's Protected LSD ( $P=0.05$ ).

### **Publications that emerged from this work**

#### Peer-reviewed

Haviland, D. R., J. P. Rijal, S. M. Rill, B. S. Higbee, C. S. Burks, and C. A. Gordon.

Management of navel orangeworm (Lepidoptera: Pyralidae) using four commercial mating disruption systems in California almonds. *Journal of Economic Entomology*. Accepted

Haviland, D. R., S. M. Rill, and C. A. Gordon. 2020. Evaluation of sticky traps for monitoring *Scolothrips sexmaculatus* (Thysanoptera: Thripidae) and *Stethorus punctum* (Coleoptera: Coccinellidae) as Predators of Spider Mites in California Almonds. *Journal of Economic Entomology*. Accepted

Haviland, D. R., S. M. Rill, and C. A. Gordon. Field biology of *Scolothrips sexmaculatus* (Thysanoptera: Thripidae) as a predator of *Tetranychus pacificus* (Acari: Tetranychidae) in California almonds. *Journal of Economic Entomology*. Submitted

#### Popular press

Haviland, D. R. and J. Rijal. 2019. Mating disruption for navel orangeworm available for organic nut crops. *Organic Farmer*, Oct 2019

#### Posters

Haviland, D. R. 2020. Arthropod Pest Management in the Lower San Joaquin Valley. Almond Industry Conference. Dec 10-12, 2010, Sacramento, CA.

Haviland, D, S. Rill, and C. Gordon. 2020. Treatment thresholds for Pacific spider mite based on the prevalence of its primary predator, sixspotted thrips. Entomological Society of America Annual Meeting, Nov. 15-18, 2020, Orlando, FL.

Haviland D. R., S. Rill, and C. Gordon. Predator-prey relationships between a specialized predator, sixspotted thrips, and its Pacific spider mite prey in California almonds. Entomological Society of America Annual Meeting, Nov. 15-18, 2020, Orlando, FL.