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Final Report: Submitted 27 November 2012; at the request of the CAC, a revised and expanded report (this) is submitted 3 June 2013

Project contract number: CAC 65108

Total funds approved: $331,000 (2007-08: $54,000; both 2008-09 and 2009-10: $66,000; both 2010-11 and 2011-12: $72,500)

Project title: Management and resistance monitoring of avocado thrips and persea mite

Project start date: November 1, 2007

Project end date: October 31, 2012

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EXECUTIVE SUMMARY:

- Avocado thrips was first discovered in California in June of 1996 and by 1998, it was found on 80% of California avocado acreage (Hoddle et al. 2002); this reached 95% by 2002. 1998 crop damage was estimated to be $8.65 million (Hoddle et al. 2003a). At the time it was discovered on avocados in California, avocado thrips had not been reported in any scientific literature we know of and it was a species new to science (it had not been given a scientific name; this was done by Steve Nakahara late in 1997). Thus, we basically started at ground zero in 1997 (a Morse research proposal to the CAC 8-96 was denied; research was first funded by the Hansen Trust 7-97 and then by the CAC starting 11-1-97).

- Abamectin (Agri-Mek = Epi-Mek and many generics) was found to be an extremely effective material when applied against avocado thrips, even when using helicopter application; initial research focused on gathering data to support an annual Section 18 request which was granted for 6 years 1999-2004 until abamectin was finally registered for the 2005 field season.

- Once abamectin was registered, it started also being used for persea mite control in the summer/fall; as of 2005, we shifted much of our research towards finding other chemicals which could be used for either avocado thrips or persea mite control; we became quite concerned about the potential for both of these pests developing resistance to abamectin.

- The current CAC project over the 5-year period 2007-2012 focused on continuing to monitor for avocado thrips and persea mite resistance to abamectin and on developing pesticides in other classes of chemistry that could be used in rotation with abamectin; efficacy data were generated to support registration and working with pest control advisors (PCAs), we began to evaluate the strengths and weaknesses of each of these new products.

- Based largely on research from this project and the efforts of CAC employees Steve Peirce and Guy Witney, who assisted with IR-4 efforts and pushing chemical companies to register pesticides on what they still consider a "minor" crop, the following products were registered for use on California avocados:
  - Delegate (registered in 2007),
  - Danitol (2010),
  - Envidor (2010),
  - Movento (2011),
  - Zeal (2012), and
  - FujiMite (expected mid 2013).

  - Note that all materials are in different classes of chemistry from one another and from abamectin except Movento and Envidor are both in IRAC class 23 (IRAC = Insecticide Resistance Action Committee) – this was not by chance but instead, by design.

- Over the period 2007-2012, we have responded to industry and pest control advisor requests for information and targeted research. We believe it is partially due to our research on chemical control of avocado thrips and persea mite that the industry has been able to deal with these two pests effectively and without excessive damage most (but not all) years over the recent past.

- We are extremely concerned about abamectin resistance developing in populations of one or both of avocado thrips and persea mite. We have "gotten the word" out regarding the danger of resistance and it will remain to be seen whether or not sufficient numbers of growers and PCAs will be willing to use the more expensive alternatives to abamectin so that they do not ruin this product. If abamectin resistance developed, the concern is that the next most popular one or two materials would then be overused, also leading to the eventual loss of those products to resistance.

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INTRODUCTION AND BACKGROUND (adapted from Morse and Hoddle 2012)

Avocado thrips (*Scirtothrips perseae* Nakahara [Thysanoptera: Thripidae]) was first discovered in California in June of 1996 when fruit scarring and the presence of a thrips that appeared similar to citrus thrips (*Scirtothrips citri* Moulton) were noticed on avocados. Pest control advisor (PCA) Charlie Gribble (Biospectrum Inc., Ventura, CA) took samples from an avocado grove near Port Hueneme (Saticoy, Ventura County) to Phil Phillips (Area IPM Advisor, UC Cooperative Extension, Ventura Co.) at about the same time that PCA Joe Barcinas (Entomological Services Inc., Corona, CA) took samples from a grove at the Irvine Ranch (Irvine, Orange County) to Joseph Morse at UC Riverside. Citrus thrips (*Scirtothrips citri* [Moulton]), which is very similar in appearance to the thrips attacking avocados, has rarely been observed on avocados. Thus, the presence of this thrips on avocados causing both leaf and fruit scarring was surprising. Phillips sent thrips samples to the California Department of Food and Agriculture (CDFA) Plant Pest Diagnostics Center (Sacramento, CA) and they were determined to be an unknown species of thrips similar to but different from citrus thrips. In 1997, Steve Nakahara (USDA Systematic Entomology Laboratory, Beltsville, MD) gave this insect a name, calling it avocado thrips, *Scirtothrips perseae* (Nakahara 1997).

It is interesting that prior to avocado thrips showing up in California in 1996, we don't believe there is any published report of its presence or the damage it causes elsewhere in the world. This lack of information is surprising, as avocado thrips feeding damage is readily observable on young fruit at certain times of the year in areas where this pest is native. This feeding damage by avocado thrips may have been confused with something else, perhaps wind scarring, bacterial/fungal diseases affecting the skin of these fruit, or even feeding damage from other species of thrips known to be present in avocado orchards (e.g., *Frankliniella* spp.). Interestingly, after *S. perseae* was described, reports from Mexico were published that this thrips was present and causing damage to Hass fruit (González Hernández et al. 2000). This entrance into the literature is curious given Mexico is the world's largest producer and exporter of Hass avocados and this pest was apparently unknown until after its discovery in California. Consequently, we think it is very likely there are additional pest species attacking avocados in Mexico that await discovery, but whose identity and presence in Mexico are poorly documented, if at all, which could be unintentionally moved into new areas.

By July of 1997, avocado thrips had spread north to San Luis Obispo County and south to San Diego County (Hoddle et al. 2002b). Heavily infested groves in Ventura County showed 50-80% crop damage in 1997 (Hoddle & Morse 1997, 1998). By May 1998, avocado thrips infested 80% of California avocado acreage (Hoddle et al. 1999) and this reached 95% by 2002 (Hoddle et al. 2002b). An economic analysis by Hoddle et al. (2003a) estimated that thrips feeding in untreated infested avocado groves reduced industry revenues by 12% in 1998 and that short run (i.e., over the time period that the industry adapted to managing this new pest) costs were an estimated $8.65 million per year.

Given the speed with which avocado thrips spread (in part likely due to movement of contaminated picking bins containing leaves) and the type of scarring it caused on fruit, the UC Hansen Trust (July, 1997) and the California Avocado Commission (CAC) (Nov., 1997) funded a team of researchers (Hoddle, Morse, Phillips, and Faber) to study various aspects of avocado thrips biology, where the insect originated, whether biological control could be implemented, what pesticides were effective in chemical control, how to best monitor thrips levels, and how treatment decisions should be made. In addition, PCAs were critical to learning how to deal with this new pest, as were many growers who allowed research trials to be conducted in their avocado groves. Steve Peirce (CAC Field Coordinator) was instrumental to the avocado thrips project in coordinating research done at UC Riverside by Hoddle and Morse with that done by UC Cooperative Extension in Ventura County by Phillips, Faber, John Rogers, and SRAs Lynn Wunderlich, Wee Yee, and Eve Oevering, who were hired (sequentially) to work on the project; in helping to arrange field study sites; and in disseminating information about avocado thrips research to growers and PCAs. A second pivotal decision the CAC made was to invite Laurence Mound, a world-renowned authority on thrips identification, biology, and ecology to visit southern California in June 1997, tour field sites infested with avocado thrips, and give us his views on the situation. We clearly remember sitting down with Mound on June 23, his looking at slide mounted thrips specimens Hoddle had prepared, and telling us only five minutes later that this thrips likely originated from Mexico and/or Central America based on specimens he had viewed in past years. This helped set the stage for foreign exploration to determine the likely area of origin of avocado thrips and the potential for classical biological control (i.e., returning to the area of origin to search for natural enemies that co-evolved over millennia with the introduced pest species). Mound was especially critical of tree management in California, and made it clear in meetings where he was presenting his assessment of the avocado thrips situation, that the vast majority of avocado trees in commercial orchards were simply too tall. He viewed this size problem as greatly hampering pest monitoring, pesticide applications, and fruit harvesting, especially on steep hillsides in San Diego County.

Area of Origin and Prospects for Classical Biological Control

As noted above, when initially discovered in California, *S. perseae* was an undescribed species that was new to science, and its country of origin was unknown. The California avocado industry has a long history of relying on biological control as a cornerstone for pest management (Fleschner 1954, Fleschner et al. 1955, McMurtry 1992, Hoddle et al. 2003b) before the arrival of avocado thrips. Consequently, concern over crop damage caused by *S. perseae* prompted funding of a "classical" biological control program by the California Avocado Commission. Because *S. perseae* was an unknown entity when discovered in California, the first step in this biological control initiative was to locate and delineate the home range of *S. perseae* and to simultaneously prospect for natural enemies associated with this pest. Knowing where *S. perseae* originated was also critical for determining potential invasion pathways into California.

Five main reasons justified initial exploration for *S. perseae* in Mexico and Central America: 1) *Scirtothrips perseae* is morphologically more similar to other thrips in this genus from Mexico and Central America than North America and other areas of the world (Nakahara 1997); 2) In 1971, two undescribed specimens of *Scirtothrips* were found on leaves of avocado plants intercepted from Oaxaca, Mexico by APHIS-PPQ at the Port of San Diego, California. One damaged specimen examined was thought to vary slightly from *S. perseae*, but subsequent re-examination by S. Nakahara indicated that it was within the acceptable range of morphological variation for this species. Later, a second thrips specimen from the same interception was located, and both specimens are now considered to be the first known record of *S. perseae*; 3) Host plant surveys in California avocado orchards have found immature stages of *S. perseae* feeding only on avocados and this was the only *Scirtothrips* species causing economic damage to avocados; 4) In California, *S. perseae* outbreaks occur during cool spring weather when avocados are developing young leaves and fruit. Immature leaves and fruit are used for feeding and oviposition by *S. perseae* and population outbreaks are closely synchronized with plant phenology induced by cool weather (Hoddle 2002a). Furthermore, laboratory generated demographic growth statistics are highest for *S. perseae* reared on avocado leaves at low temperatures (≤ 20°C), suggesting that this pest likely evolved closely with avocado to exploit nutritive and oviposition resources induced by low temperatures (Hoddle 2002b); 5) Three geographic races of avocados are recognized; *Persea americana* var. *drymifolia* (Mexican race), *P. americana* var. *guatemalensis* (Guatemalan race), and *P. americana* var. *americana* (West Indian race). The Mexican and Guatemalan races evolved in high altitude regions of central Mexico and Guatemala, respectively. West Indian varieties are thought to have developed in humid lowland Pacific Ocean areas from Guatemala through Costa Rica. Humans transported avocados from these areas of origin, probably as seeds, into other areas of the Americas, and elsewhere.

Laboratory and field studies in California indicated that *S. perseae* appears closely adapted to avocado phenology. Host plant surveys showed a highly restricted host range (i.e., as far as we know, avocado thrips can complete their entire life cycle only on avocado) suggesting this pest may have evolved with *P. americana* somewhere in the natural range of this plant.

Foreign exploration for *S. perseae* and other species of thrips was conducted in Mexico by Hoddle et al. (various regions sampled over 1997 – 2000), Guatemala (1998), Costa Rica (1999), the Dominican Republic (2000), Trinidad (2000), and Brazil (2000). A total of 2,136 phytophagous (plant-feeding) thrips specimens were collected and identified, representing over 47 identified species from at least 19 genera. Foreign exploration efforts indicated that *S. perseae* occurred on avocados grown at high altitudes (>1500 m) from Uruapan in Mexico south to areas around Guatemala City in Guatemala. In Costa Rica, *S. perseae* is replaced by *S. astrictus* as the dominant plant feeding thrips on avocados grown at high altitudes (>1300 m). No species of *Scirtothrips* were found on avocados in the Dominican Republic, Trinidad, or Brazil. Of collected material, ~4% were potential thrips biological control agents. Natural enemies were dominated by six genera of predatory thrips (*Aeolothrips*, *Aleurodothrips*, *Franklinothrips*, *Leptothrips*, *Scolothrips*, and *Karnyothrips*). One genus each of a parasitoid (*Ceranisus*) and predatory mite (*Balaustium*) were found. All of these natural enemies, including the parasitoid, are generalists. Consequently, prospects for the importation of thrips natural enemies for use in a "classical" biological control program in California against *S. perseae* were not pursued as it seemed unlikely that successful suppression of *S. perseae* could be achieved with any of these generalist species. Furthermore, several species were already present in California and known to attack *S. perseae* (e.g., *Franklinothrips*) (Hoddle et al 2002a).

In addition to delineating the geographic distribution of *S. perseae* and collecting natural enemies, foreign exploration allowed the compilation of a list of other phytophagous thrips species associated with avocados that are unknown in California and which could be serious avocado pests should they become established. One species, *Neohydatothrips burungae*, was as common as *S. perseae* on avocados in Mexico and was not known to be present in California when these surveys were originally done. Given the common occurrence of *S. perseae* on avocados in Mexico and its pestiferous nature in California, *N. burungae* was considered an invasive threat to California grown avocados (Hoddle et al. 2002b). Interestingly, this prediction was realized in 2004, when sampling efforts in San Diego County for another invasive avocado pest, the avocado lace bug (*Pseudacysta perseae* [Hemiptera: Tingidae]), resulted in the first collection of *N. burungae* in California (Hoddle 2004). Fortunately, this pest has not become problematic on avocados in California and in fact, appears to be present only on backyard trees near the coast in San Diego Co.

Two other pest thrips species were found during foreign exploration efforts for *S. perseae* that are considered highly dangerous to California's avocados; these are *Pseudophilothrips perseae* (formerly known as *Liothrips perseae*) in Guatemala and *P. avocadis* (formerly *L. avocadis*) in Costa Rica. These phlaeothripids are particularly damaging when they form breeding aggregations (dense adult populations) on small to medium sized Hass fruit. The large red larvae and black adults feed on the fruit surface and cause significant pit-like scarring. Beige-colored eggs are deposited in depressions on the fruit surface, and all life stages (even eggs) are easily visible with the naked eye or a low powered hand lens. The naturally rough surface of Hass fruit is probably highly desirable for these thrips as the "nooks and crannies" provide excellent feeding and hiding places for adults and larvae, as well as protection for eggs (in comparison, avocado thrips uses its ovipositor to insert eggs into plant tissue so they are not exposed). Another sobering thought is the large number of thrips that were collected and identified to species, for which we have absolutely no biological or ecological information (especially *Frankliniella* species). It is possible that some of these species may be serious pests in their home countries, but because they have not been studied, we are ignorant of their invasion potential and the threat they may or may not pose to California avocado growers.

Because foreign exploration efforts identified the home range of *S. perseae* as being central Mexico through to central Guatemala, other questions demanded answers: (1) where in this vast area did California's invading population originate, and (2) how did this founding population come to California? To answer these questions, molecular studies were undertaken. The goal was to use "genetic fingerprinting" to compare the genetic constitution of the California population to collections of *S. perseae* made from various areas in Mexico and Guatemala with the aim of identifying a region that may have been the probable area from which California's population originated (Rugman-Jones et al. 2007).

The DNA analyses revealed that *S. perseae* in California was most closely related to populations in central Mexico, and Coatepec-Harinas, Mexico, was the most likely source of the California population (Rugman-Jones et al 2007). This finding was significant because Coatepec-Harinas is a major avocado breeding center in Mexico and given its significant distance from California (it is ~150 miles southwest of Mexico City and ~1,800 miles from Riverside), it is not a popular destination for the casual U.S. tourist. One possibility is that an avocado enthusiast who visited the breeding station in Coatepec-Harinas was impressed with some new avocado cultivar and illegally moved plant material from this region to California that was infested with *S. perseae* (Hoddle 2004). Additionally, the genetic studies revealed another interesting piece of information; the invading population went through a severe breeding bottleneck indicating that the number of thrips on host plant material entering California was small (Rugman-Jones et al. 2007).

Understanding Avocado Thrips Basic Biology and its Application to Field Situations

Avocado thrips has a life cycle typical of all thrips in the Suborder Terebrantia; females use their ovipositor to lay eggs individually inside suitable plant material, and for avocado thrips, young leaves and small fruit are highly preferred oviposition substrates. Following egg hatch, there are two larval instars, the first and second, that are mobile and whose feeding activities cause economic damage to fruit (such feeding can also result in significant scarring to the undersides of leaves). Following the larval stage, there are two non-feeding and non-motile stages, the propupa and pupa. It is during these two "pupal" stages that larvae undergo metamorphosis into the winged adult form. When ready to pupate, second instar larvae enter a walking phase and they will often look for pupation sites in cracks and crevices in twigs or bark, and sometimes pupation may occur inside the webbed nests of persea mite, another invasive avocado pest. Avocado thrips is a sexually reproducing species, and fertilized eggs produce female thrips, whereas unfertilized eggs result in males. Full details on the developmental and reproductive biology of avocado thrips across five different temperatures are available (Hoddle 2002a). Combined field and laboratory studies have indicated that approximately 77% of *S. perseae* larvae drop from avocado trees to pupate in the upper 2" of leaf duff beneath the tree canopy before emerging as winged adults that fly back up into the canopy to commence feeding and reproduction. One strategy for increasing thrips pupation mortality rates beneath trees that was investigated was the use of composted organic yard waste used for avocado root rot (*Phytophthora cinnamomi*) control (Hoddle et al. 1999, 2002a). Data from replicated field trials indicated that coarse, composted mulch placed around trees and over existing leaf mulch to a depth of ~ 12 inches, and spread to the edge of the canopy, reduced peak emergence rates of adult *S. perseae* by approximately 50% in comparison to emergence rates from naturally occurring leaf duff under avocado trees that lacked mulch. Additionally, the cumulative emergence of adult thrips from mulched plots was significantly lower than under non-mulched trees. The exact mechanism causing reduced adult thrips emergence from mulch is unknown but may be due to antagonistic micro-arthropods associated with the mulch (especially generalist predators like small mites, Collembola, beetles, and spiders that colonize the mulch and opportunistically prey on thrips larvae and pupae when they find them) (Yee et al. 2001b, Hoddle et al. 2002a), release of secondary plant compounds from decaying yard waste, or a more favorable habitat for entomopathogens (i.e., pathogens causing disease in insects) such as fungi (e.g., *Beauveria* spp.) or nematodes (e.g., *Steinernema* spp.) that were recovered from the mulch. In addition to the potential for avocado thrips suppression, mulches offer other benefits including improved water retention, soil quality, weed suppression, and reduced erosion and aeration needed for root respiration (Hoddle et al. 1999, Hoddle et al. 2002a).

Numerous field surveys have clearly indicated that young fruit are vulnerable to avocado thrips feeding damage. As young foliage from the spring growth hardens in late May and early June during or after fruit set, adult female avocado thrips move from foliage to oviposit into young fruit. It is the feeding by emerged larvae that results in damage to the skin of developing fruit. Laboratory observation of field-collected fruit indicated that females lay eggs in fruit ranging from 0.16 - 3.0" in length. The majority of larvae (> 95%) emerged from fruit 0.6 - 2.5" in length. Once fruit exceed 2" in length, avocado thrips are found primarily on young leaves (Hoddle 2002b). These observations strongly suggest that fruit < 2" in length are quite vulnerable to attack by avocado thrips. This relationship between fruit size and attack by avocado thrips was investigated in commercial avocado orchards by Wee Yee in Ventura who was working with Phil Phillips and Ben Faber (Yee et al. 2001a).

Field biology studies conducted over three years at three sites with different temperatures in Ventura and Santa Barbara counties indicated that fruit may be most susceptible to damage over a two-week growing period just after fruit set, when fruit are 0.2 - 0.6" in length (Yee et al. 2001a). These studies also indicated that when approximately 3-5 thrips were consistently found per leaf during fruit set, feeding caused 6-15% economic scarring damage on fruit. Furthermore, young fruit 0.5" long or less infested with an average of 0.5-1.5 larvae per fruit in May and June resulted in 22-51% economic scarring. Over all years and sites, thrips were generally more abundant on young leaves than on fruit from early to mid June when fruit were setting. When leaves aged and hardened from late June through August (depending on region), equal or higher numbers of thrips were generally found on fruit, although overall numbers of thrips declined during this period with increasing summer temperatures (Yee et al. 2003). These results suggest that thrips numbers on leaves prior to or during fruit set may be used to predict scarring damage on fruit, and that the economic injury level may be less than 5 larvae/leaf during this time (Yee et al. 2001a). However as noted below (see the section "Making avocado thrips treatment decisions"), this relationship may not always be clear-cut and other factors may strongly influence treatment decisions

Evaluation of Augmentative Releases of Commercially Reared Biological Control Agents

As management plans were being developed for avocado thrips, the potential for augmentative releases of natural enemies was of great interest to growers and PCAs. Augmentative biological control is a simple concept, i.e., it is the release of mass reared, commercially available natural enemy species to augment or boost naturally-occurring populations of biological control agents. These supplemental releases may be desirable at critical times because the population density of the resident natural enemy fauna on leaves, fruit, and leaf litter are too low (Yee et al. 2001b) to respond in a timely manner to prevent the pest from causing economic damage. Augmentative biological control has been used most successfully in protected agriculture, especially greenhouses; success rates on outdoor crops is modest as (an exception is augmentative releases of *Aphytis melinus* for California red scale control on citrus in the San Joaquin Valley of California).

Research efforts on augmentative biological control of avocado thrips focused on two natural enemy species: (1) commercially available green lacewings (*Chrysoperla carnea* [Neuroptera: Chrysopidae]), and (2) a native natural enemy, the predatory thrips *Franklinothrips orizabensis* (Thysanoptera: Aeolothripidae), which was observed to respond to *S. perseae* outbreaks in avocado orchards. Before augmentative releases of *F. orizabensis* could be evaluated, significant obstacles in our understanding of the developmental and reproductive biology, diet requirements, predation behavior, and pupation biology of this natural enemy had to be overcome if it was to be mass reared (Hoddle 2003b, c, Hoddle et al. 2001a, b). Jake Blehm of Buena-Biosystems in Ventura undertook the mass rearing program for this natural enemy once UC Riverside researchers had figured out the rearing and harvesting system. The mass rearing turned out to be quite simple; irradiated *Ephestia* eggs (food) sprinkled on top of potted bean plants (oviposition substrate for the predator) resulted in the reliable production of large numbers of *F. orizabensis* and predators were harvested as pupae inside small plastic tubes. The plastic tubes were placed on the floor of the rearing cages and larvae would enter and spin their pupal cocoons inside these tubes. Empty tubes were separated from tubes with pupae using a venturi-airstream separation principle – an airstream delivered by an aquarium pump caused tubes with pupae to fly further than empty tubes when they entered the airstream and were collected in containers at distances greater than where empty tubes landed. Despite promising laboratory results, augmentative releases of *F. orizabensis* replicated across different field sites were unable to significantly reduce *S. perseae* densities in comparison to control sites not receiving predators (Hoddle et al. 2004).

Green lacewings are commercially available as eggs (either loose or attached to cards which are hung in trees) or larvae, which are packaged in ventilated hex-cell units to prevent cannibalism. Hex-cell units are opened in the field, attached to branches, and larvae are left to disperse naturally. Lacewing larvae are extremely aggressive predators and they have a very broad diet, consuming most soft bodied arthropods (i.e., insects and mites, and each other) that are smaller than the larva in size. To evaluate the efficacy of green lacewings for control of avocado thrips in commercial Hass orchards, two different field trials were run by two different research teams, in different years, and locations. Releases of lacewing larvae were evaluated by Silvers and Morse (UCR) in Fallbrook in 1999, and releases using lacewing eggs were evaluated by Hoddle and Robinson (UCR) in San Diego and Orange Counties in 2003.

Work by Silvers and Morse (Silvers 2000) clearly demonstrated that lacewing larvae provided no appreciable control of avocado thrips when compared to control plots not receiving predators. When this news was shared with the avocado community, several insectaries immediately challenged the results, declaring that the release program didn't accurately follow successful release strategies developed by PCAs. Their view was that most often, lacewing eggs, not larvae, were deployed in orchards because they are cheaper and larger numbers could be dispersed across trees needing treatment, thereby giving much better coverage which ultimately resulted in pest control. Additionally, Silvers' work was criticized by PCAs because release timings, release rates, and tree size (Silvers used top-worked Hass trees which had a lot of flush), differed from conditions under which PCAs reported control with augmentative releases of lacewings.

To address these criticisms, a meeting organized by Steve Peirce was held in the Old Entomology Building at UCR, which was attended by Insectary representatives, PCAs, and UCR researchers. It was decided that lacewing releases for avocado thrips control should be evaluated according to industry practices and two PCAs offered to assist with this. Consequently, with funding from the CAC, field evaluations of lacewing releases made by PCAs, deployed either as eggs on release cards, or as loose eggs (at 75% egg hatch) mixed with corn grits and sprayed onto trees with a motorized sprayer were evaluated by UCR researchers. Lacewing eggs were deployed by PCAs using these methods 7 to 8 times over a four-month period. Eggs on paper cards were deployed at a rate of 16,592 eggs per acre, while sprays of ~75% hatched lacewing eggs were around 208,216 eggs per acre. Avocado thrips in blocks treated with lacewing eggs were monitored every two weeks and densities were compared over the same time intervals to paired control blocks not receiving lacewing treatments. The results at the end of the trial were convincing and identical across sites and release strategies. There were no significant differences in avocado thrips populations (larvae or adults) when augmentative releases of lacewing eggs were made in commercial Hass avocado orchards using PCA release rates, methods, and timings, when compared to blocks that were not treated with lacewing eggs (Hoddle & Robinson 2004). Despite the results of this research, several PCAs believe that green lacewings contribute in a substantial way to avocado thrips biological control.

From these studies it was concluded that augmentative releases of lacewings as either larvae (Silvers 2000) or eggs (deployed in two different ways; Hoddle & Robinson 2004) failed to provide a significant reduction in densities of avocado thrips larvae or adults when population densities were compared through time to control blocks not receiving augmentative predator releases. Consequently, augmentative releases of lacewings cannot be recommended for biological control of avocado thrips in California.

Pages 11-17 above are essentially pages 137-152 of the Morse and Hoddle (2012) CAS article. Note that the CAS article also contains sections on (1) Making Avocado Thrips Treatment Decisions, (2) Chemical Control of Avocado Thrips, (3) Pesticide Resistance Management, and (4) Summary and Predictions.

OBJECTIVES

Throughout the 5 years of this project, our objective has been to provide solutions to the problems the avocado industry faces focusing largely on avocado thrips, persea mite, and pesticide resistance management but also addressing other issues when they arose.

The following objectives were listed in the 2007-08 project proposal that was approved for funding (Year 1):

We believe it is essential that work continue simultaneously on four fronts:

1. Rapidly introduce alternatives to Agri-Mek for persea mite control.

2. Find and introduce additional materials that can be rotated with Agri-Mek for avocado thrips control (Admire and other foliar applied materials with chemistry different from Agri-Mek such as Movento). Research with Movento is exciting both because this material is a new chemistry for avocado thrips control but also because it is systemic and has potential for control of armored scales should one of these species become problematic on avocado in California.

3. Monitor for avocado thrips resistance to Agri-Mek, Success, Admire, and other products.

4. Screen pesticides for efficacy against *Neohydatothrips burungae* should this insect become problematic on avocado.

The following objectives were listed in the 2009-10 project that was approved for funding (Year 3):

We believe it is essential that work continue simultaneously on four fronts:

1. Rapidly introduce alternatives to Agri-Mek for persea mite control (Envidor and Zeal).

2. Find and introduce additional materials that can be rotated with Agri-Mek for avocado thrips control (Danitol and possibly Movento, NNI-0101, and other new chemistries). Research with Movento is exciting both because this material is a new chemistry for avocado thrips control but also because it is systemic and has potential for control of armored scales should one of these species become problematic on avocado in California.

3. Monitor for avocado thrips resistance to Agri-Mek, Delegate, Veratran, and other products. In particular, keep an eye on possible evolution of resistance to Danitol once this material is introduced in 2010.

4. Screen pesticides for efficacy against *Neohydatothrips burungae* should this insect become problematic on avocado. Screen pesticides for efficacy against armored scale insects should one or more new species become established in the state.

The following objectives were listed in the 2011-12 project that was approved for funding (Year 5; Milestones were first instituted in 2010-11 = Year 4 of this project):

1. To rapidly introduce alternatives to abamectin (Agri-Mek, Epi-Mek, and generics) for persea mite control (Envidor, Zeal, and FujiMite).

2. To find, evaluate, and introduce additional materials that can be rotated with abamectin for avocado thrips control (Danitol, Movento, and other new chemistries).

3. To monitor for avocado thrips resistance to abamectin, Danitol, Delegate, and other products.

4. Screen pesticides for efficacy against armored scale insects should one or more new species become established in the state.

Specifically:

Objective 1: Conduct laboratory and field screening trials with new pesticides potentially useful against avocado thrips. Prioritize materials to be considered for registration on avocado and co-ordinate work being done on citrus thrips. Conduct field trials with new materials for efficacy against persea mite.

Objective 2: Monitor avocado thrips populations for resistance to abamectin, Danitol, and Delegate and obtain baseline resistance levels at several field sites before these materials are used extensively.

Comments regarding project objectives:

One can see that project objectives evolved only slightly over the 5 years of the project. Over time, we modified objectives somewhat based on which new products neared registration, the degree to which resistance appeared, downplayed *Neohydatothrips* when economic populations failed to appear on avocados (it is an occasional problem on lemons in Ventura Co.), and once we became more concerned about armored scales.

One comment should be added regarding evaluating pesticides that might be used should one or more species of problematic armored scale appear on avocados. When Esteem was registered for use on CA avocados, we became less concerned and decided to shift our attention to how we could make Movento work on avocados – it is a unique material in that although it is applied as a foliar spray, the product that is sprayed has little impact on mites and insects (thus, it would not be likely to cause secondary pest upsets or affect natural enemies negatively except those that feed on the plant) but it is highly systemic. In addition to impacts on avocado thrips and persea mite, based on research on citrus and other commodities, we believe it could be a quite effective scale material on avocados (might get much better control of scales with this highly systemic product in contrast to contact materials applied by helicopter).

A. 2007-08 RESEARCH

We list below the major research that was conducted each of the 5 years of this project, 2007-08 through 2011-12. Back when this project was funded, we did not have the "milestone" system wherein the CAC considers it essential we work only on what we say we are going to work on at the beginning of the project. Instead, we adjusted what was done each year to what we thought made sense at the time based on research progress and substantial feedback from the industry (from CAC research personnel such as Witney, PCAs, and growers).

A1. September 2007 persea mite screening trial in Goleta

Although the treatments were applied in FY2006-07, most of the post-treatment evaluations and all data analysis were done in 2007-08. The last usable field count was taken on day 111 = 1-15-08. After winter cold weather, we wanted to see if persea mite levels might rebound so a count was taken day 181 = 3-25-08 but persea mite levels had not rebounded and we discontinued the trial.

Materials and methods

A 2-year old (planted 8-06) Hass avocado grove on Dusa rootstock in Goleta, CA was used to evaluate the impact of 12 treatments on avocado persea mite. At the time of treatment, trees were 4-5 feet tall. Five mature leaves were randomly selected per tree and were returned to the laboratory where the total number of motile persea mites (larvae, protonymphs, deutonymps, and adults combined; i.e. all stages except eggs) on the bottom surface of the leaf were counted unless it was visually estimated that there were more than 50 motiles per leaf. In this case, the second half vein method of Machlitt (1998) was used - i.e. all motile mites were counted within one viewing field of a lab miscroscope as one proceeded down the second left half vein of the leaf. Total persea mites per leaf are estimated as = 11.35 multiplied by the number seen around the second half vein (Machiltt 1998).

Pre-count leaves were collected from 138 trees (5 leaves/tree) on 9/10/07. There were 12 experimental treatments so the 12 trees with the high pre-count level of mites were assigned to block 1, the next 12 to block 2, etc., until 8 blocks were assigned (i.e. 8 single tree replicates were used per treatment). One tree in each block was then randomly assigned to each treatment. Thus, the experimental design was based on 8 single-tree replicates for each of the 12 treaments.

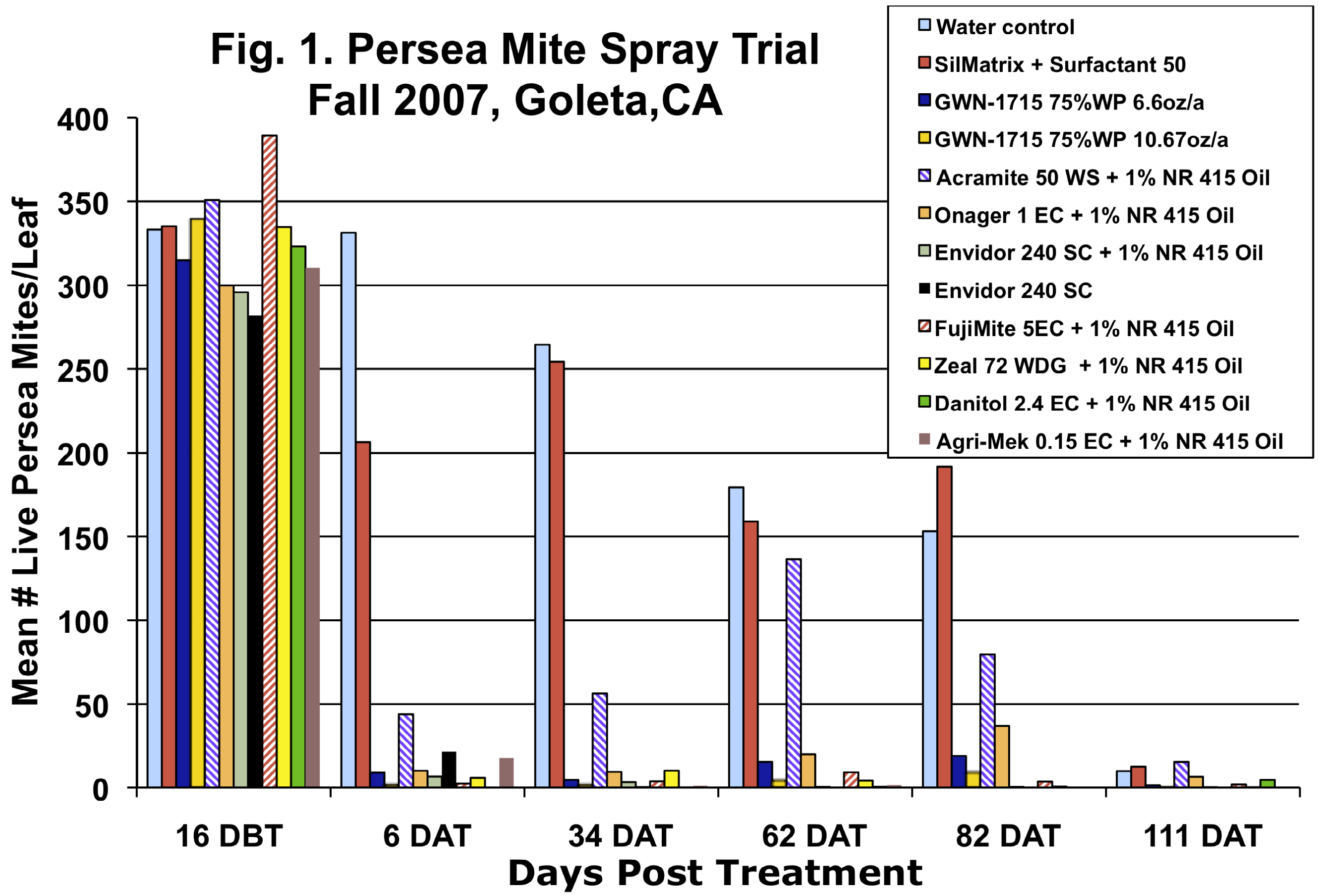
Treatments were applied on 9/26/07 or 9/27/07 using a Stihl SR-400 backpack mistblower using setting #3 (of 5 on the sprayer). A total of ca. 3 gallons of spray was used for the 8 trees in each of the twelve treatments. Sprays were applied starting early in the morning and continuing as long as conditions were calm (i.e. sprays were discontinued if sufficient wind was present to reduce spray coverage on the trees; this is why the applications took 2 days). Post-treatment counts were taken in the same way as pre-counts and data are expressed as the mean number of motile mites per leaf. Treatment rates were water control, Zeal 72WDG at 3 oz/a plus 1% NR-415 oil, Envidor 240SC at 20 fl oz/a without oil, Envidor at the same rate with 1% oil, FujiMite 5EC at 32 fl oz/a with 1% oil, Acramite 50WS at 1 lb/a plus 1% oil, Onager 1EC at 19 fl oz/a plus 1% oil, Danitol 2.4EC at 21.5 fl oz/a plus 1% oil, Agri-Mek 0.15EC at 10 fl oz/a plus 1% oil, Silmatrix at 1% plus 8 oz/a Surfactant 50 (Monterey Ag suggestion regarding the surfactant instead of oil), and GWN-1715 75%WP at 6.6 vs. 10.67 oz/a, both without oil (Gowan suggestion to leave out the oil). All per acre rates were calculated based on 100 gpa dilution.

Results

Data are shown in Fig. 1. Mean mite levels pre-treatment did not differ significantly between the 8 trees assigned to each of the various treatments. All treatments except Silmatrix were fairly effective in reducing mite levels up to 34 days post-treatment but based on mite levels (not consistently supported by statistical separation), Acramite and to a lesser extent, Onager (and perhaps the low rate of GWN-1715), appeared somewhat less effective later in the trial. Zeal, Agri-Mek, Envidor, the high rate of GWN-1715, FujiMite, and Danitol all appeared quite effective out to 111 days post-treatment (1/15/08) although mite levels on control trees had declined substantially by that date.

Discussion and conclusions

These field trial data are consistent with previous persea mite trials we have run but additional data were needed to support fruit residue trials being done to obtain labels for Envidor (by Bayer), Danitol (by Valent), and FujiMite (by IR-4; their field trials with this product began in 2008 and they had specifically requested additional field efficacy data). In addition, we had not evaluated SilMatrix, Acramite, or GWN-1715 previously against persea mite. The weak performance of SilMatrix suggests we will not continue to test this material. Acramite also does not appear as strong as alternatives and because Onager is in IRAC class 10A and Envidor in 10B, this also does not appear to be a material that should be prioritized for future trials. GWN-1715 is in IRAC Class 21, the same as FujiMite and registration for the former is expected in 2015. There have been reports from other crops that FujiMite can be hard on beneficial species so future trials (perhaps fall 2013) will attempt to compare the impact of these two class 21 materials on beneficial species such as the predaceous mite *Euseius hibisci*.



A2. Investigation of abamectin persea mite resistance in Ventura Co.

We have made it widely known that when a grower or PCA see a situation in which it appears abamectin may not be working as expected, we are willing to evaluate resistance in either avocado thrips or persea mite populations. A PCA reported less than expected efficacy of abamectin against persea mite late in 2006 in Ventura Co. and concern regarding resistance. The following test was done late during FY 2006-07 but analysis, graphing, and communication with the affected PCA was in FY 2007-08.

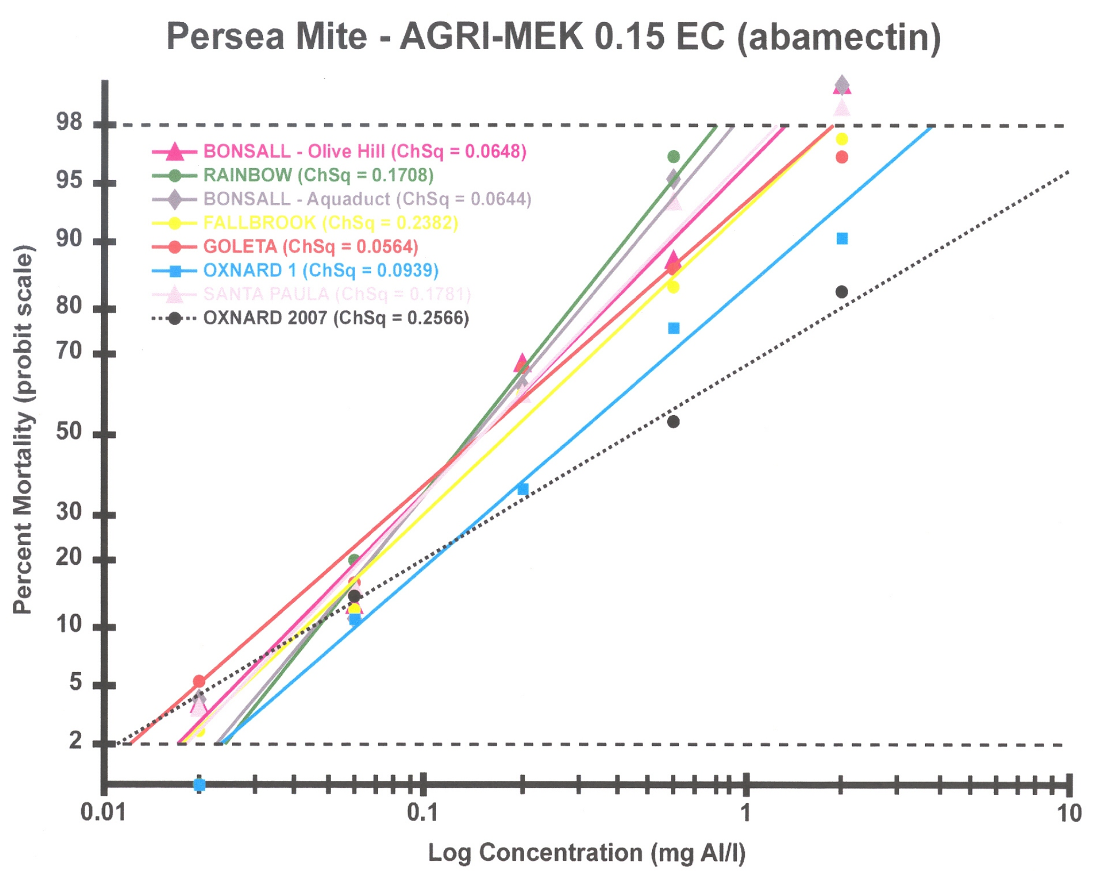
Material and methods

We have done many past field bioassays with abamectin and persea mite and we consistently try to use the same methods so that future data can be compared with past data to determine whether or not resistance is evolving and to what degree (see Humeres and Morse 2005 for details). Briefly, leaves are picked in the field containing adult persea mites and then we return these leaves to the lab where we do a bioassay using various rates of abamectin and a water control. Data are corrected for control mortality using Abbott's formula (1925) and then are subjected to probit analysis (chi-square value greater than 0.05 indicates a good regression) and on a probit (y axis) versus log abamectin concentration basis (x axis). Movement of the regression line to the right is indicative of resistance, which is typically accompanied by an initial flattening of the slope of the line.

When a PCA reports weak field efficacy with either avocado thrips or persea mite, this can be due to several causes other than resistance including unusually high pest populations, less than optimal timing of the treatment, less than optimal application, less material used than the recommendation specified (on occasion we suspect the full amount was not put in the spray tank and the product was stolen), etc. The best way to differentiate these other causes from resistance is to take a field bioassay and compare data against baseline data.

Results

The following graph shows the result of the persea mite bioassay. Oxnard 1 represents data from Humeres and Morse (2005; see Table 2 in that paper – last row, persea mite test done 8-3-03) and was an early warning of resistance to abamectin in a field population of persea mite. It is disappointing to see that persea mite abamectin resistance has proceeded somewhat further in this field population from Oxnard (Oxnard 2007 below; different grove in Oxnard than Oxnard 1).



Discussion and conclusions

Note the relatively flat slope of the Oxnard 2007 probit regression line. This is typical of the beginnings of resistance. We communicated our concern to the PCA and suggested that they use alternative methods for persea mite control at this site, trying as hard as possible to not use abamectin for either avocado thrips or persea mite control.

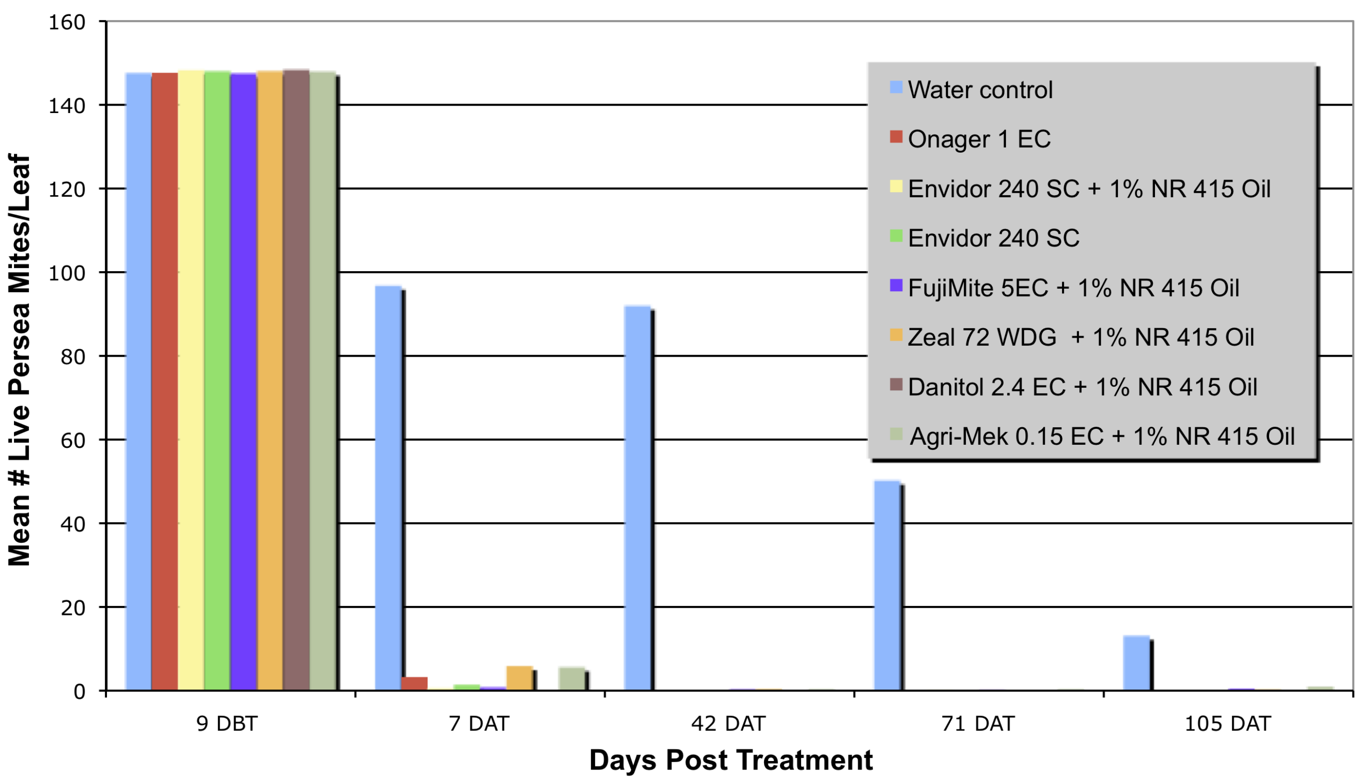
A3. October 2008 persea mite screening trial in Goleta

A persea mite spray trial was put on 10-9-08 in order to obtain additional efficacy data that could support registration registration efforts with Envidor, Zeal, FujiMite, and Danitol. We already knew that most of the tested treatments were effective but both IR-4 and the involved chemical companies had requested additional field efficacy data.

Material and methods

A fall 2008 persea mite trial in Goleta evaluated 8 treatments, i.e. Onager 1EC at 19 fl oz/a (no oil), Envidor 240SC at 20 fl oz/a both with and without 1% NR-415 oil, FujiMite 5EC at 32 fl oz/a with oil, Zeal 72WDG at 3 oz/a with oil, Danitol 2.4EC at 21.5 fl oz/a with oil, a water control, and Agri-Mek 0.15EC at 10 fl oz/a plus oil as a positive control. Pesticide rates were diluted on a 100 gpa basis. The field site has 1-year old Hass avocado trees on Dusa rootstock that were roughly 3 feet in height. Five mature leaves were randomly selected from each of 90 trees on 8-30-08 and were returned to the lab at UCR to count all motile mites (all life stages except eggs) per leaf. If it was estimated there were more than 50 mites per leaf then the Machlitt (1988) method was used to assess the number of mites in one field of the microscope along the center of the second left half vein and this number was multiplied by 11.35 to estimate the number of mites on that leaf. Based on these pre-counts, 64 trees with the highest mite levels were assigned to 8 blocks (trees with the top 8 counts were assigned to block 1, the next 8 to block 2, etc.) and then trees in each block were randomly assigned to each treatment. Pesticides were applied with a Stihl SR-400 backpack sprayed using setting #3 (of 5 on the sprayer) and a total of roughly 0.5 gallons of spray was applied to the 8 trees per treatment due to their small size. We like this sprayer for field applications of this type on small trees because it deposits small droplets mostly on the outside of a tree, somewhat similar to what a helicopter might apply. Post-treatment counts were taken in the same way on various days post-treamtment.

Fig. 2. Persea Mite Spray Trial Fall 2008, Goleta, CA



Results

Results are shown in Figure 2. We started with quite high persea mite counts (range of 147.5-148.4 motile mites per leaf, mean of 147.9) and the blocking resulted in similar pre-count levels across treatments. All treatments were effective in reducing persea mite levels as shown by data 7 days after treatment. Comparing pre-count levels 9 days before treatment to post-counts 7 days after treatment, water control mite levels declined by 34% (147.6 to 96.8 per leaf), which may have been due in part to the water application. At 7-days post-treatment, Zeal (5.9 motiles per leaf), Agri-Mek (5.6), and Onager (3.3) were somewhat slower in controlling persea mite levels than were the other treatments (high of 1.4 per leaf with Envidor without oil) but all levels were not separable statistically except from the water control, and by 42 days after treatment, mite levels in the water control were still at 92.0 mites per leaf whereas the highest levels with any of the chemical treatments were 0.3 per leaf with both Zeal and Agri-Mek. Mite levels had decreased to 50.2 per leaf in the water control at 71 days after treatment and were quite low at 105 days (13.1 per leaf) so the trial was discontinued. Total mite days from 7 to 105 days post-treatment were 6,441.1 for the water control, 129.5 Agri-Mek, 116.2 Zeal, 60.6 Onager, 30.5 FujiMite, 24.5 Envidor without oil, 11.6 Envidor with oil, and 0.0 Danitol.

Discussion and conclusions

Data were consistent with those from past persea mite field trials. All evaluated chemical treatments were effective and Onager is not being pursued for registration only because it is in the same class of chemistry (10A) as Zeal (10A). With excellent coverage (trees were quite small, ground application was used), all of these materials are extremely effective and the level of control with Danitol is quite high.

A4. Highlights of other activity during 2007-08 (partial list; I don't keep track of most PCA/grower calls)

When this project was initiated, there was substantial interest expressed by CAC personnel (e.g. research director Witney as well as Steve Peirce) that research and extension efforts by this project should deal with current industry concerns at the time. Thus, we list "other activity" each year of the project beyond the specific objectives identified at the very beginning of the project.

- 11 November 2007 presentation by Beth Grafton-Cardwell in Monterey, CA at the "Spinetoram Research Exchange" on Delegate research on citrus and avocados (avocado Delegate data provided by Morse);

- 12 Feb. 2008 presentation by Morse in San Luis Obispo, 13 Feb. in Santa Paula, and 14 Feb. in Temecula at spring CAC/CAS seminars titled "Research Update – Avocado Thrips, Persea Mite, New Pests, and Pesticide Resistance Management"; Poster also presented at each location with different content than the oral presentation (focused in more detail on pesticide resistance management; alternative chemistries that were available and were being developed);

- 19 Feb. 2008 email to Wayne Brydon of the CAC suggesting that the CAC push Valent to work on the registration of both Zeal and Danitol on avocados (we were unhappy with the the lack of effort); provided contacts within Valent who Wayne could contact, provided efficacy data, and suggested that as the EPA review of these materials was finalized, the CAC try to accelerate DPR review; similar email sent 5 August 2008 to Bob Coleman who was working for the CAC;

- Based on previous persea mite efficacy data and several years of lobbying the IR-4 program, IR-4 residue trials on FujiMite began in 2008, culminating in the expected registration on avocados mid 2013;

- March 2008 – substantial time spent informing avocado growers on citrus peelminer present in the San Joaquin Valley after it was observed on avocados shipped from the SJV to packinghouses in San Diego Co.;

- 26 June 2008 draft #7 of feedback on APHIS proposed rule changes dealing with movement of Hass avocados from areas where Mexican fruit fly or sapote fruit fly exist provided to Tom Bellamore of the CAC; spent considerable time late April – June working on this response after reviewing scientific literature, consulting with experts, sending earlier drafts to various scientists, etc.;

- "Integrated Pest Management for Avocados" (UC ANR Publication 3503; 222 pp.) was published by the UC IPM program in 2008 – this was a massive undertaking that involved substantial editing by Faber, Phillips, Morse, and Hoddle – the initial draft was written by a professional writer [Steve Dreistadt] with many of the sections (especially those on avocado thrips and persea mite) based on our past research; Morse is rather proud of the role he played in getting this publication started ca. 2004 – at the time, he was the statewide program leader for agricultural policy and pest management within UC and the IPM program was one of the programs that reported to him; at an annual meeting with IPM staff, there was a discussion of what new IPM manuals might be developed and it was noted that there was substantial grower and PCA interest in an avocado IPM manual; unfortunately, the IPM program did not have staff support to take on writing a new manual and instead, planned on updating previously published manuals dealing with other crops; Morse inquired about the cost to get an avocado manual started and suggested that the manuals director (Mary Louise Flint at the time) contact Steve Peirce to see if CAC might provide those funds; CAC was pleased to do so and as a result, this manual was started leading to publication in 2008;

- A year-round IPM program for avocados was made available on the UC IPM web site and pest management guidelines for most avocado pests were updated as of Aug. 2008.

- 26 September 2008 2-page letter sent by Morse to Cynthia Oshita, Office of Environmental Health Hazard Assessment (Prop 65 Implementation) at the request of the CAC dealing with the proposed listing of abamectin as a Reproductive Toxicant;

B. 2008-09 RESEARCH

B1. Six spring 2009 avocado field thrips trials with PCA co-operators

Delegate was registered for use on avocados in 2007 but growers and PCAs had not embraced this material perhaps because of poor results obtained previously with Success (a related chemistry from the same company) and/or because of their comfort with abamectin. Because a federal tolerance was established for Danitol use on avocado, we were first able to run field trials in 2009 including this product under a Research Authorization (RA), which negated the need for crop destruct. We believed it was critical to evaluate both Delegate and Danitol against avocado thrips. None of our past field trials had included aerial application of Danitol because of the cost of crop destruct. Based on citrus thrips research, we suspected both Delegate and Danitol would provide comparable efficacy as Agri-Mek and if so, it was critical they start being used to reduce abamectin selection for resistance.

Materials and methods

Our spring 2009 field trials were run with 6 different PCA cooperators with 3 field sites in the north and 3 in the south. We chose what we consider leading independent PCAs with an interest in evaluating Delegate and Danitol. We wanted to compare the performance of these three materials under a diversity of field situations. Two studies were run with pre-bloom application (Davis, Hand) 3 were timed at two-thirds leaf expansion (Holden, Machlitt, Roberts), and 1 was applied after fruit set (Barcinas). Two trials were run with ground speed-sprayer application (Barcinas, Holden) and the other 4 with helicopter application.

To plan these trials, we arranged donation of product and payment of PCAs for their time and effort from the involved chemical companies (no CAC funds went to any PCA from us and never have to date, i.e. as of when this report was submitted). We then set up separate meetings with the south and north PCAs to plan how to conduct the trials. It was agreed that the PCA would find a field site with high thrips levels (if at all possible), would decide how and when to treat, but that all treatments would go on the same way. If possible (if the grower was willing), they were asked to include an untreated control to assist in assessing thrips severity. The PCA agreed to take weekly thrips infestation counts of immature thrips (ignoring adults) on leaves or fruit (depending on how they normally took counts) and that Morse lab personnel would come in at the end of the season to take thrips scarring assessments at all sites in a standard way. All treatments were applied at the maximum label rate using 20 fl oz/a Agri-Mek 0.15EC, 7 oz/a Delegate WG, and 21.33 fl oz/a Danitol 2.4EC. In addition, at one of the trial sites (Hand), Agri-Mek was also applied at 15 oz/a for comparison. Generally, each location had 2 replicate plots of each treatment.

PCA David Holden of Holden Research and Consulting ran his trial on 15-17 foot high Hass avocado trees in Somis. Treatments were applied 5-21-09 using an FMC Airblast ground speed sprayer, 100 gallons per acre, with 1% NR-415 oil/a added to all 3 treatments. Immature thrips infestation counts were taken on 25 leaves per plot 6 days before treatment and on 8 dates post-treatment. Scar counts were taken 9-24-09 when fruit were 2-4 inches in diameter. At all 6 field sites, scar counts were taken near the center of each plot to minimize spray drift concerns and by walking around a number of trees, assessing avocado thrips scarring on outside fruit that one could reach from ground level (roughly knee to shoulder height) and a total of 1,000 fruit were assessed per treatment (500 per plot; 1-2 control plots were included at some sites).

PCA Dave Machlitt of Consulting Entomology Services ran his trial on 12-foot tall Hass avocado trees in Goleta. Treatments were applied by helicopter 6-9-09 at 60 gpa with 1 gallon/a NR-415 oil and 4 pints/a Phos Acid 0-28-26 added to all treatments. Immature thrips infestation counts were taken on 25 leaves per plot on the day of treatment but before it was applied and on 4 dates post-treatment.

PCA Tom Roberts of Integrated Consulting Entomology ran his trial on 12-14 foot tall Hass avocado trees in Somis. Treatments were applied by helicopter 6-4-09 at 50 gpa with 1% NR-415 oil, 2 quart/a Phosguard 0-28-25, 1 quart/a Zinc-All 7.7%, and 2 oz/a Slither added to all treatments. Immature thrips infestation counts were taken on 25 leaves per plot 3 days pre-treatment and on 5 dates post-treatment.

PCA Matt Hand of Southern California Entomology ran his trial on 15-25 foot tall Hass avocado trees in Valley Center. Treatments were applied by helicopter pre-bloom on 4-4-09 at 100 gpa with 4% NR-415 oil and 3 fl oz/a Slither added to all treatments. Immature thrips infestation counts were taken on 25 leaves per plot 1 day pre-treatment and on 8 dates post-treatment. Scar counts were taken 1-7-10 (Agri-Mek) and 1-25-10 (Delegate, Danitol) on 500 fruit per plot.

PCA Jim Davis of American Insectaries ran his trial on 25-30 foot tall Hass avocado trees in Escondido. Treatments were applied by helicopter pre-bloom on 4-8-09 at 100 gpa with 1% NR-415 oil and Phosguard 0-28-26 added to all treatments. Immature thrips infestation counts were taken on 25 leaves per plot 2 days pre-treatment and on 10 dates post-treatment.

PCA Joe Barcinas of Entomological Services, Inc. ran his trial on 25-30 foot tall Hass avocado trees in Irvine. Treatments were applied by a PTO driven low volume ground speed sprayer 6-23-09 at 100 gpa with 1% NR-415 oil added to all treatments. Immature thrips infestation counts were taken on 20 fruit per plot 1 day pre-treatment and on 8 dates post-treatment.

Results

Grading fruit for economic versus subeconomic avocado thrips scarring is inherently subjective. In doing fruit scarring evaluations, we considered both the percent of the fruit surface area scarred and the apparency (severity) of the scar and estimated to the best of our ability the level of scarring that would likely lead to downgrading fruit from first to second grade in the packing house. We realize this "threshold" level of scarring for downgrading can vary from year to year and we tried to be conservative in our ratings (i.e. list the scarring as economic if it was

Table 1. Leaf or fruit infestation counts - avocado thrips spray trial 2009
Mean number of immature avocado thrips/substrate on 20 fruit (Barcinas) or 25 leaves (other 5).

Treatment	Pre- or post-treatment counts (number of immature per fruit [Barcinas] or per leaf [other 5 co-operators])										
Holden	-6	+6	+12	+19	+25	+32	+39	+46	+55			+6 to +55
												thrips days/leaf
Control S	0.4	0.8	1.4	5.3	5.9	6.3	7.2	6.2	4.4			248.20
Control N	0.8	1.3	2.1	2.5	5.3	6.0	5.7	5.6	6.4			223.75
		Application date = 5-21-09										
Agri-Mek S	0.6	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1			1.15
Agri-Mek N	0.9	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0			1.45
Delegate S	2.1	0.0	0.1	0.0	0.0	0.2	0.1	0.0	0.1			3.20
Delegate N	1.6	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.0			2.15
Danitol S	0.7	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0			1.30
Danitol N	0.8	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1			1.15
Machlitt	0	+8	+15	+23	+34							+8 to +34
												thrips
		Application date = 6-9-09										days/leaf
Agri-Mek S	0.8	0.8	0.9	0.0	0.0							9.70
Agri-Mek N	1.6	0.3	0.9	0.1	0.0							8.70
Delegate S	1.0	0.0	0.2	0.0	0.3							3.04
Delegate N	0.8	0.0	0.1	0.0	0.1							1.40
Danitol S	1.5	0.0	0.0	0.0	0.0							0.30
Danitol N	2.0	0.0	0.1	0.0	0.0							0.60
Roberts	-3	+8	+15	+22	+29	+36						+8 to +36
												thrips
		Application date = 6-4-09										days/leaf
Agri-Mek E	1.6	1.4	0.7	0.7	0.3	0.2						17.64
Agri-Mek W	1.6	2.9	4.4	1.2	0.8	1.0						58.52
Delegate E	3.2	2.1	3.4	1.1	0.9	2.7						54.60
Delegate W	0.7	1.8	3.4	0.1	0.2	0.3						33.32
Danitol E	1.2	0.1	0.1	0.0	0.0	0.0						1.26
Danitol W	0.8	0.4	0.1	0.0	0.0	0.0						2.10
Hand	-1	+10	+22	+34	+48	+68	+83	+90	+98			+10 to +98
												thrips days/leaf
Control 1	0.4	0.0	0.4	0.0	0.0	0.0	2.0	3.0	1.5			55.50
		Application date = 4-4-09										
Agri-Mek 1	0.4	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0			15.20
Agri-Mek 2	0.0	0.0	0.0	0.0	0.4	0.4	0.0	1.0	1.5			27.38
15 oz A-M 1	0.4	0.2	0.0	0.0	0.2	1.0	2.0	4.0	2.0			82.60
15 oz A-M 2	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0			7.08
Delegate 1	0.4	0.0	0.0	0.0	0.0	0.0	1.0	1.0	2.5			28.70
Delegate 2	0	0.4	0	0	0.4	1	2	5	1			90.60
Danitol 1	0.4	0	0	0	0	0.4	1	2.5	1.5			43.03
Danitol 2	0	0	0	0	0.4	0.4	1	1	0.5			34.58
Davis	-2	+7	+14	+21	+28	+35	+42	+49	+56	+63	+70	+7 to +70
												thrips days/leaf
Control 1	0.6	0.7	0.7	1.3	1.2	0.6	0.2	1.6	0.8	1.0	1.0	29.54
Control 2	0.4	0.5	0.3	0.3	0.8	0.6	0.1	0.4	0.5	0.7	0.8	15.96

	Application date = 4-8-09											
Agri-Mek 1	0.8	0.1	0.0	0.0	0.1	0.2	0.0	0.1	0.3	0.1	0.0	2.24
Agri-Mek 2	0.7	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.2	0.84
Delegate 1	0.2	0.0	0.0	0.0	0.2	0.2	0.1	0.1	0.0	0.0	0.2	3.78
Delegate 2	0.6	0.0	0.2	0.3	0.0	0.4	0.0	0.2	0.2	0.2	0.2	6.72
Danitol 1	0.5	0.0	0.0	0.0	0.4	0.5	0.0	0.0	0.1	0.1	0.1	5.88
Danitol 2	0.3	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.1	0.2	0.1	2.80

Barcinas	-1	+7	+14	+21	+28	+35	+49	+63	+77	+7 to +77 thrips-days/fruit
Control 1	3.4	1.4	2.2	2.1	0.8	0.2	0.0	0.0	0.0	40.95
	Application date = 6-23-09									
Agri-Mek 1	0.6	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.88
Agri-Mek 2	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
Delegate 1	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.28
Delegate 2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
Danitol 1	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
Danitol 2	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00

Table 2. Summary of scar counts taken by UCR for the Spring 2009 avocado thrips cooperative research project

Cooperative project between Dow, Syngenta, Valent, 6 avocado PCAs, CAC, and UCR

	Date of									Agri-Mek	
	Scar	Control		Danitol		Delegate		Agri-Mek		15 fl oz	15 fl oz
Site	Counts	Plot 1	Plot 2	Plot 1	Plot 2	Plot 1	Plot 2	Plot 1	Plot 2	Plot 1	Plot 2
% Economic scarring by avocado thrips											
Holden	9/24/09	5.8%	2.6%	0.0%	0.0%	2.8%	2.2%	2.2%	1.2%		
Machlitt	9/21/09			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
Roberts	10/22/09			0.0%	0.0%	0.2%	0.0%	0.0%	0.0%		
Hand	1/7/10			0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Davis	3/11/10	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
Barcinas	4/20/10	0.0%		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
% Sub-economic avocado thrips scarring											
Holden	9/24/09	34.2%	18.8%	0.4%	0.2%	16.2%	13.6%	23.8%	12.0%		
Machlitt	9/21/09			0.2%	0.2%	0.6%	0.2%	2.6%	0.0%		
Roberts	10/22/09			0.0%	2.6%	17.4%	10.4%	8.8%	23.8%		
Hand	1/7/10			8.2%	3.6%	0.4%	5.0%	0.6%	0.6%	0.4%	0.2%
Davis	3/11/10	2.0%	2.8%	1.4%	0.4%	0.0%	0.0%	1.2%	0.0%		
Barcinas	4/20/10	27.2%		13.0%	5.6%	6.4%	7.6%	4.6%	8.0%		

close to this). We used a threshold for economic scarring of 10% of the fruit surface lightly scarred or 5% heavily scarred by avocado thrips.

We list avocado thrips fruit infestation counts in Table 1 and fruit scarring evaluations in Table 2 (above).

Discussion and conclusions

One of the greatest benefits of this study was getting Danitol and Delegate in the hands of 6 PCAs, getting them to use these products, and engendering discussion of data at meetings and with other PCAs. Although we learned a great deal in these trials, thrips pressure was not as high in spring 2009 as we would have liked so as to provide a strong test of these products.

At the two pre-bloom helicopter sites (Hand, Davis), performance of Delegate and Agri-Mek were similar but there was a bit more sub-economic fruit scarring at the Hand site with both Danitol reps and one Delegate replicate. With the treatments applied at 2/3 leaf expansion (Holden, Machlitt, Roberts), Danitol appeared extremely effective and based on sub-economic scarring, Delegate performance was similar to Agri-Mek. At the Barcinas site, it is difficult to separate the performance of the 3 materials.

One of the things we asked all PCAs to keep an eye out for were any signs of pest resurgence (thrips, mites, or other pest species) after treatments. They did so but none were reported (we asked).

<u>B2. August 2009 avocado thrips nursery screening trial</u>

Materials and methods

For nursery avocado thrips trials evaluating non-systemic chemicals, our standard screening methodology was used. 15-gallon potted Hass avocado plants were sprayed with candidate pesticides, pesticides were allowed to weather in the field, leaves tagged prior to the spray (identifying them as being fully expanded but tender at the time of pesticide application) were picked on various dates post-treatment, second instar avocado thrips collected from the field were placed on the leaves inside Munger cells (Morse et al. 1986) in the laboratory (6 Munger cells per treatment, 10-15 thrips per cell), and thrips mortality was evaluated after 48 hours.

The oil used in this trial was Helena's Omni Oil 6E (a 98% AI Narrow Range 415 spray oil). 120 individual leaves per treatment were tagged prior to spray applications. Chemicals were applied with a hand held sprayer (B&G T-100 stainless steel 1 gallon sprayer). Individual tagged leaves were sprayed within each treatment row, leaving a buffer row between treatments. The spray attempted to simulate a ground application (300 gpa); treated leaves were sprayed with a uniform droplet pattern, stopping prior to runoff. Such a trial is intended to be mainly comparative in nature.

Results

Data are shown in Table 3. Control second instar avocado thrips mortality was low until day 41 post-treatment (38.7%) when leaves tagged at the beginning of the trial started to harden off. After this date, leaves were quite tough resulting in unacceptably high control thrips mortality and the trial was discontinued. Due to a required confidentiality agreement, until recently, the identity of Experimental 1 could not be disclosed. This material was BYI-2960 200 SL (Sivanto) put on at 12.32 fl oz/a + 1 % oil.

Discussion and conclusions

During the first several bioassays, Mustang and Delegate provided the most effective control of avocado thrips. On day 20, the most effective treatments were Mustang, Delegate 5 oz/ac, and Delegate 2.5 oz/ac + Vintre. Note that this test does not evaluate the contact activity of treatments because the first bioassay was done 6 days after treatment by placing second instar thrips on treated leaves in the laboratory. We consider the 5 oz rate of Delegate + 1% oil to be the standard treatment and used the 2.5 oz rate of Delegate to see if the addition of Vintre as a surfactant might improve efficacy relative to to the use of oil. There is a suggestion this might be the case but perhaps we should have evaluated a lower rate of Delegate to tease this out - perhaps 1.25 oz of Delegate.

Table 3. Avocado thrips nursery trial summer 2009 (treatments applied 8-27-09)

		Percent thrips mortality (control) or corrected mortality				
		9/2/09	9/16/09	9/22/09	9/30/09	10/7/09
Treatment	Rate	+ 6 days	+ 20 days	+ 26 day	+ 34 days	+ 41 days
Water Control	--------	10.4	18.8	23.4	23.3	38.7
Experimental 1		41.6	61.4	26.3	11.9	0.0
NNI-0101 20 SC	6.4 fl oz + 1% oil	67.9	43.3	76.6	54.2	20.8
Diamond 0.83 EC	19.28 fl oz	76.7	40.3	31.0	64.4	0.0
HGW86 10 SE	20.5 fl oz + 1% oil	81.1	59.5	88.1	67.0	27.5
Delegate 25% WDG	2.5 oz + 1% oil	98.4	96.0	86.6	32.0	33.7
Delegate 25% WDG	2.5 oz + 20 fl oz Vintre	100.0	100.0	73.5	53.2	19.8
Delegate 25% WDG	5 oz + 1% oil	100.0	98.2	85.9	63.0	35.3
Delegate 25% WDG	2.5 oz + 64 fl oz Vintre	98.2	98.0	47.8	63.0	66.9
Mustang 1.5 EW	4.3 fl oz + 1% oil	100.0	100.0	100.0	92.2	67.4

B3. Highlights of other activity during 2008-09 (partial list; I don't keep track of most PCA/grower calls)

- 18 November 2008 presentation at the Entomological Society of America National meeting in Reno, NV by graduate student Deane Zahn – "Performance of Spinetoram on *Scirtothrips* species in California and Arizona" which among other things, summarized Delegate work on avocados;

- 29 November 2009 feedback provided to a grower upon hearing about a strain of *Xylella* attacking avocado trees in Costa Rica;

- Morse worked with Jim Davis and Guy Witney to organize a tour of UCR Entomology labs working on avocados by the Production Research Committee Pest subcommittee. On 10 March 2009, the group toured the Morse, Stouthamer, Byrne, Millar, and Hoddle labs (because of the size of the group, the group split in half and Morse took half of the group around the tour which had 8 "stops" (2 each for Morse, Stouthamer, and Millar projects);

- 24 March 2009 presentation by Morse at the Sixth International IPM Symposium in Portland, OR – "Invasion Biology of Thysanoptera" which focused a good deal on avocado thrips. This was an invited presentation to a large audience based on the 2006 Morse and Hoddle article in the Annual Review of Entomology "Invasion Biology of Thrips" – a large part of the motivation for that review article was avocado thrips' invasion of California;

- 31 March 2009 presentation by Morse at the Pacific Branch meeting of the Entomological Society of America annual meeting in San Diego, CA – "Evolution of IPM on Avocados in California in the Context of Invasive Arthropods" (much of the talk focused on avocado thrips and persea mite);

- 13 April 2009 – provided feedback to Guy Witney on his draft honey bee – avocado thrips publication prepared for DPR after the "abamectin incident" in San Diego Co.;

- 14 April 2009 presentation by Morse in San Luis Obispo, 15 April in Ventura, and 16 April in Temecula at spring CAC/CAS seminars titled "Research Update – Avocado Thrips, Persea Mite, and Pesticide Resistance Management";

- 1 May 2009 – further feedback on the abamectin – honey bee situation provided to Guy Witney prior to his meeting with San Diego Ag Commissioner Bob Atkins;

- A nursery avocado thrips field trial was run during August 2009 evaluating 10 different treatments.

- 10 August 2009 feedback provided to avocado farm advisor on a wax scale observed on avocados (submitted for identification and turned out to be *Ceroplastes cirripediformis* = barnacle scale);

- 24 October 2009 feedback provided to a PCA on avocado budwood treatments that might be used to reduce mite and thrips levels;

- This was the first year in recent years where we received no reports of abamectin field "failures" with either avocado thrips or persea mite treatments. Generally low thrips levels may be the cause in part.

C. 2009-10 RESEARCH

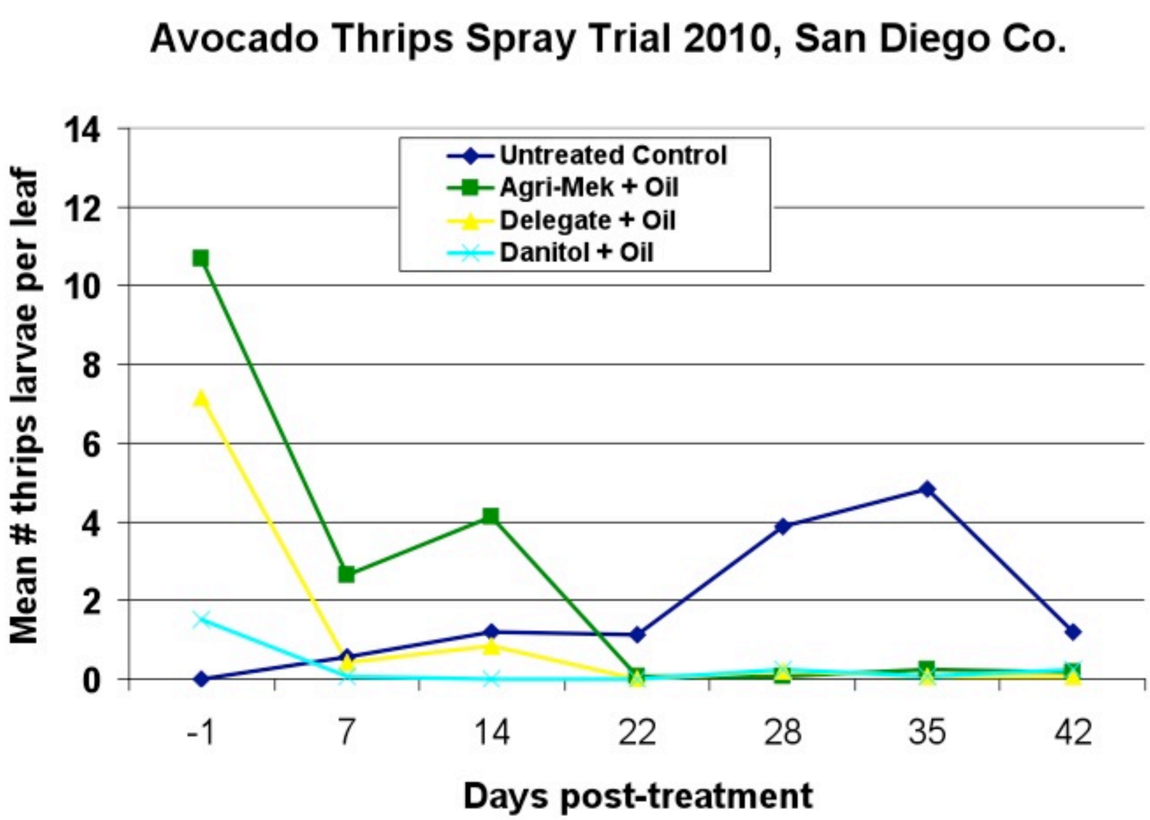
The 6 avocado thrips field trials run with PCAs in spring 2009 were a tremendous amount of work to coordinate (especially because of the Danitol Research Authorization required at each site), were expensive, and there was no way we would have been able to repeat the scope of those studies in 2010, even after Danitol was registered on avocados as of Feb. 2010. We were able to talk the involved chemical companies into supporting only 2 trials of a similar nature in 2010, one each in the north and south. As in 2009, no CAC money was provided to PCAs and their work was paid for by Bayer, Dow, and Valent, with donation of product from these companies along with Syngenta.

C1. Spring 2010 avocado thrips field trials in Escondido and Camarillo

Materials and methods

Treatments in Escondido were applied post-bloom (6-2-10) in cooperation with PCA Jim Davis using helicopter application at 100 gpa. Trees were large at this site, ranging from 20-30 feet tall. Two plots were sprayed with each of Agri-Mek 0.15EC 20 fl oz/a, Danitol 2.4 EC 21.33 fl oz/a, and Delegate WG 7 oz/a, and there were 2 untreated control plots. 2% NR-415 oil was added to all plots as well as Phos Acid 0-28-26. The number of immature avocado thrips per leaf was assessed by the PCA on 25 leaves in the center of each plot 1 day pre-treatment and on 6 dates post-treatment. We had enough trees in each plot at this site so that scar counts could be taken only on 300 randomly selected fruit per plot by Morse lab personnel on 11-18-10. Scar counts were taken near the center of each plot to minimize spray drift concerns and by walking around a number of trees, assessing avocado thrips scarring on outside fruit that one could reach from ground level (roughly knee to shoulder height).

Treatments in Camarillo were applied post-bloom (5-28-10) in cooperation with PCA David Holden using ground speed sprayer application at 100 gpa. Two plots were sprayed with each of Agri-Mek, Danitol, and Delegate, at the same rates as in Escondido except NR-415 oil was added at 1% with no other additives. There were 2 untreated but smaller control plots. In addition, Movento at 10 fl oz/a was evaluated on a crop destruct basis (paid for by Bayer) adding either 0.25% Destiny or 1% NR-415 spray oil to each of 5 replicated 2-tree plots (10 trees of each treatment total). The number of immature avocado thrips per leaf was assessed by the PCA on 25 leaves in the center of each plot 2 days pre-treatment and on 8 dates post-treatment. Trees at this site were 6-7 feet high and fruit set was rather low. Fruit scarring evaluations were taken over 3 dates, 10-7-10, 10-20-10, and 12-2-10 at Camarillo and were quite difficult because fruit set was very low. The Agri-Mek, Danitol, and Delegate plots were large enough so 150 fruit from the center of each plot were assessed for avocado thrips scarring (outside fruit, knee to shoulder level) but only 181 fruit were assessed on control trees and 62 and 142 on Movento + Destiny and Movento + oil trees, respectively.



Results

Leaf infestation counts are shown in the two figures (one above, one below) for Escondido (San Diego Co.) and Camarillo (Ventura Co.). Mean immature thrips days from +7 to +42 days-post-treatment for Escondido were Control 85.3, Agri-Mek + oil 41.4, Delegate + oil 9.8, Danitol + oil 3.5. Thrips days from +6 to 53 days post-treatment for Camarillo were Control 401.9, Movento + oil 240.9, Movento + Destiny 221.2, Danitol + oil 1.3, Agri-Mek + oil 0.3, Delegate + oil 0.0. These data reflect the inherent differences between helicopter control on large trees versus speed sprayer control on small trees.

Fruit scarring evaluations at both sites are shown in Tables 4 and 5 below. In doing fruit scarring evaluations, we considered both the percent of the fruit surface area scarred and the apparency (severity) of the scar and estimated to the best of our ability the level of scarring that would likely lead to downgrading fruit from first to second grade in the packinghouse. We realize this "threshold" level of scarring for downgrading can vary from year to year and we tried to be conservative in our ratings (i.e. list the scarring as economic if it was close to this). We used a threshold for economic scarring of 10% of the fruit surface lightly scarred or 5% heavily scarred by avocado thrips.

Discussion and conclusions

We had somewhat higher avocado thrips pressure in 2010 compared with most sites in 2009 and it is nice to see that each both Delegate and Danitol performed strongly under these conditions. In looking at the fruit scarring data in Camarillo, one must consider the unusual conditions of this study – moderately high thrips levels and very low fruit set (thus a large number of thrips concentrated their feeding on few fruit).

We still have work to do with Movento – the problem may likely be the material is not being moved into avocado leaf tissue. Results if taken alone would have been very discouraging and it is luck that at the same time, we conducted the following trial at UCR or we might have given up on Movento.

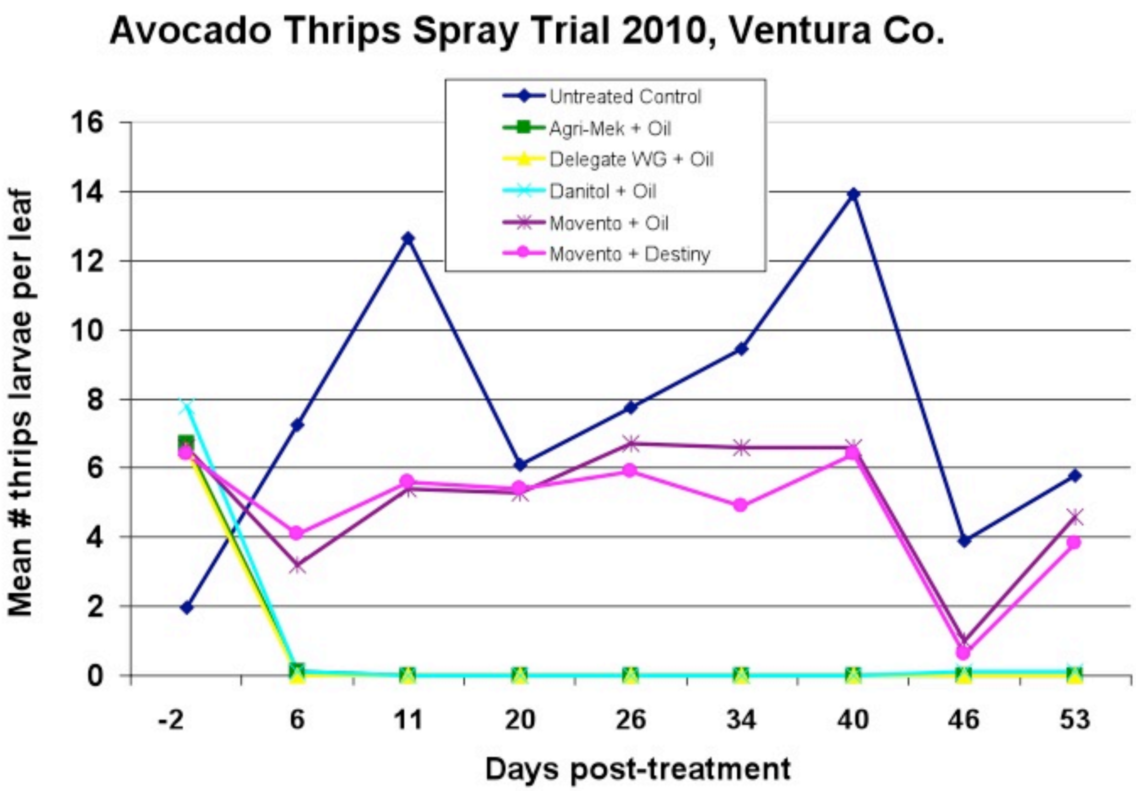


Table 4. Summary of scar counts taken by UCR for the Spring 2010 avocado thrips cooperative research project between Dow, Syngenta, Valent, Jim Davis, CAC, & UCR.

Site	Date of Scar Counts	Control		Danitol		Delegate		Agri-Mek	
		Plot 1	Plot 2	Plot 1	Plot 2	Plot 1	Plot 2	Plot 1	Plot 2
% Economic scarring by avocado thrips									
Davis, Escondido	11-18-10	5.3%	2.7%	0.0%	1.3%	1.0%	0.0%	0.0%	0.0%
Mean for 2 plots			4.0%		0.7%		0.5%		0.0%
% Sub-economic avocado thrips scarring (any scarring by avocado thrips)									
Davis, Escondido	11-18-10	38.0%	28.7%	0.3%	11.0%	3.7%	4.3%	2.3%	3.3%
Mean for 2 plots			33.3%		5.7%		4.0%		2.8%

Table 5. Summary of scar counts taken by UCR for the Spring 2010 avocado thrips cooperative project between Bayer, Dow, Syngenta, Valent, David Holden, CAC, and UCR.

Site	Control	Danitol	Delegate	Agri-Mek	Movento + Destiny	Movento + NR-415 Oil
% Economic scarring by avocado thrips						
Holden, Camarillo	68.5%	0.0%	0.0%	0.0%	1.6%	29.0%
% Sub-economic avocado thrips scarring (any scarring by avocado thrips)						
Holden, Camarillo	95.0%	0.0%	7.0%	8.0%	9.9%	37.3%

C2. April 2010 Movento trial on the UCR campus

Past field trials with Movento have shown quite variable results. Whereas this material has shown great promise on citrus for control of a diversity of pests, in only one prior field trial (by PCA Dave Machlitt) did it show good results on avocados. Conversations with Bayer, Ben Faber, and Carol Lovatt lead us to consider several new ideas that were tested in this spring 2010 trial: (1) see if we could get better plant uptake with bloom applications (idea from Lovatt was to try it during cauliflower bloom), (2) evaluate thrips mortality over an extended period of time (Bayer suggests the activity is very slow – we did not realize how slow until the spring 2011 trial), and (3) leaf uptake of nutritional materials is much more difficult on avocados than on citrus (several discussions with Faber which colored our thinking on foliar uptake of Movento).

Movento is an interesting material in that the formulation that is sprayed on the plant (spirotetramat itself) has no toxicity but is taken up into the plant and converted to the toxic enol derivative. Thus, only plant feeding species should be impacted by this pesticide, or possibly natural enemies that derive a toxic dose by feeding on poisoned prey or hosts. Three main reasons to continue to put so much effort in this material are (1) it likely has little impact on most natural enemies on avocados, (2) it has a broad spectrum of activity and might be useful against thrips, mites, scales, and other as yet exotic pests of avocado, and (3) because it is so highly systemic, it might perform very well using helicopter application, even if put on with low per acre gallonage (something PCAs are quite excited about so that the cost is more competitive with generic abamectin).

Materials and methods

Treatments were applied to 6-year old Hass avocado trees (Torro Canyon rootstock) on the UCR campus. Trees were sprayed to runoff using a 1-gallon B&G (Model F-100 stainless steel) hand sprayer. Two treatments were compared: 16 fl oz Movento (240 g ai/liter) on a 200 gpa dilution basis plus 0.5% NR-415 oil versus 16 fl oz

Movento with 0.25% Dynamic. Two timings for each treatment were compared -- trees sprayed to runoff at the cauliflower bloom stage (April 13) and two weeks later (April 27) when the trees were in full bloom. Leaves were picked various times post-treatment and ca. 10 second instar avocado thrips collected from an unsprayed field site were placed on each leaf. Thrips were confined on the leaves inside Munger cells (Morse et al. 1986). Five replicate Munger cells were used to evaluate each treatment.

In the first bioassay, done 24 days after the first spray and 10 days after the second spray, thrips mortality at 4 days after thrips were introduced into Munger cells was relatively high on control leaves (32%). Results appeared better with the second spray timing compared to the first -- thus, we dropped evaluation of the first timing. Thus, in the second and third bioassays (done only with the second spray timing), we placed thrips on treated leaves for two days, took a mortality assessment, and then transferred surviving thrips to a new set of field treated leaves (i.e. a new set of leaves were picked from the treated tree in the field and brought into the lab for the bioassay). The second bioassay was set up 21 days after the second spray and the third, 36 days after that spray.

Results

Bioassay 1 -- New leaves were not used – we just took readings on the same leaves over 10 days. Cumulative control mortality for cells set up May 7 (24 days after first spray timing, 10 days after the second) at 3, 4, 7, and 10 days was 11.2, 32.0, 39.0, and 42.4%, Corrected % mortality with with Movento + oil at the early timing, Movento + Dynamic early, Movento + oil late, and Movento + Dynamic late at the 10 day bioassay reading were 75.3, 63.6, 70.2, and 65.9%, respectively.

Bioassay 2 – Based on the results of the first bioassay, we decided to drop the early timing and moved the surviving thrips to new field treated leaves after 2 days (i.e. new leaves were picked from the field on day 2). Here control mortality was absent at both the 2 and 4 day reading. Mortality on leaves harvested 21 days after the late timing (cells set up May 18) at 2 and 4 days was 37.3% and 73.2% with Movento + oil late and 57.8% and 89.4% with Movento + Dynamic late.

Bioassay 3 – We used similar methods as in Bioassay 2 (thrips put on leaves 36 days after the second spray on June 2; surviving thrips transferred to new leaves on day 2). Unfortunately, leaves on the trees had started to harden off resulting in 9.3% control mortality at 2 days and 22.0% at 4 days. Corrected mortality at 4 days was 35.9% with Movento + oi late and 28.5% with Movento + Dynamic late.

Discussion and conclusions

Generally, there appeared to be only slight differences between results with 0.5% oil vs. 0.25% Dynamic. Some control was achieved but if 4 days is long enough for Movento to act on the thrips (based on spring 2011 data, we later realized it is not), the highest mortality obtained was 89% (second bioassay, Movento plus Dynamic). After seeing these data and discussing them with Bayer, in future trials we decided to change the leaves at 3 days and run each bioassay for 6-9 days total. This material could hold a lot of promise for use on avocados and additional research is needed to see how we can best make it work.

<u>C3. Two field trials by PhD student Deane Zahn aimed at evaluating the impact of pesticides used against avocado thrips on the predaceous mite *Euseius hibisci*</u>

The request for CAC Final Reports states the following "A graduate student thesis may be submitted in lieu of a Final Report if COMMISSION funds helped to support the graduate student's research." CAC funds did in fact help support part of PhD student Deane Zahn's research and we attach chapter 4 from her dissertation, which describes this study in substantial detail ("Zahn PhD dissertation chapter 4.doc"). We provide below only a brief summary.

Two field trials were run by PhD student Deane Zahn evaluating the impact of abamectin, Danitol, Delegate, Veratran D, and a water control against the major predaceous mite found on avocados, *Euseius hibisci*. This was a massive project involving field application of pesticides, allowing pesticide residues to weather in the field, and then picking leaves at various dates post-treatment to evaluate how long pesticides impacted the adult female mites. The first trial was run with treatments applied 9 November 2009 and it was intended mainly to work out trial protocols - abamectin and Danitol might be applied this time of year for persea mite control but the main intent was to compare these chemicals as used in the spring for avocado thrips control. The second trial was run 3 May 2010 and bioassays were done after leaves had weathered in the field for 1, 3, 7, 14, 21, 28, 49, 70, 90, 111, and 132 days. We obtained a substantial amount of data and some of it was not what we expected – Veratran D impacted the mites for longer than we would have expected (through 7 days), the Delegate was highly repellant to the mites (through 14 days), and the Danitol was quite toxic for an extended period of time (through 90 days). The results with Delegate were novel enough (mites avoided residues by running into the water moat where they drowned) that we ran an additional study evaluating whether or not exposure to high UV light affected impacts with abamectin and/or Delegate. High UV decreased the impacts of both materials, more so with abamectin than Delegate; but even with Delegate, high UV exposure shortened significant impacts on predaceous mites from 10 days to 3 days of field weathering.

C4. Dealing with an Envidor label problem

This label problem with Envidor was unexpected (supplemental label came out with a minimum of 100 gpa by air which some PCAs considered uneconomic with the increase in helicopter application costs and the lower cost of generic abamectins versus the market price of Envidor). Previous discussions with Bayer had identified 50 gpa as a good minimum helicopter gallonage but somehow this fact was lost during the process. Fortunately, with sufficient pressure (9-26-10 letter by Morse to Bayer, multiple phone calls), the company was receptive to producing a revised supplemental label allowing 50 gpa and this was approved at the federal level 10-20-10.

C5. Dealing with a Danitol dermatitis problem

Danitol was registered for use on CA avocados in Feb. 2010 and the label allows aerial application with as low as 50 gpa; partially because of concerns we expressed to Valent regarding thrips resistance to pyrethroids, the label also contains a Resistance Management warning and allows only a single application per year on avocados – based on experience on citrus, we believe this restriction is absolutely critical.

On 24 June 2010, Morse received a phone call about a worker re-entry (picker dermatitis) problem following a legal application of Danitol; luckily, UCR Extension toxicologist Dr. Robert Krieger had recently worked with Danitol residue analysis on strawberries and he was rapidly recruited to assist with an assessment of the situation; the ensuing discussions with the grower, packing house contact, and involved company (Valent) took up a substantial amount of both Morse and Krieger's time over the following 3 weeks; after a number of samples were analyzed following our protocol and the packinghouse contact and Valent were coerced into exchanging information (by both submitted it to Morse first and seemed unwilling to speak to each other), a crisis was averted when the grower was able to proceed with harvesting an early maturing crop before prices fell (80 acres, his estimate was $0.85 million in crop value); the grower wrote a letter 13 July 2010 to Dean Thomas Baldwin thanking Morse and Krieger for their assistance – this was appreciated but we are mainly glad the situation was dealt with without further incident.

We worked with Valent on follow-up studies to try and pin down why this happened. Valent provided us an advisory (also posted on web sites used by PCAs such as CDMS if one knows to look for it) that specifies field workers should wear chemical resistant gloves and face/eye protection if they will come in contact with foliage for up to 14 days after treatment. The advisory suggests the PHI will remain at 1 day but that in practice, avocado growers will probably not want to use this material if harvest will occur within 14 days of treatment.

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Camarillo, CA 93011
(805) 488-5639

July 13. 2010

Dr. Thomas O Baldwin. Dean
College of Natural & Agricultural Sciences
College Building North
University of California
Riverside, CA 92505

Dr. Baldwin,

Recently we had an issue with a pesticide residue that was exceeding all label requirements for reentry. We were not having much success with the chemical company solving the issue. We contracted Dr. Joseph Morse who jumped right into the issue. He teamed up with Dr. Robert Krieger and between the two of them we were able to push the chemical company forward and do significant leaf analysis to determine that residues had finally fallen to the point where it was safe for the workers to reenter the fields. I know both of these men are extremely busy and yet they were there on the spot for us. It was a great comfort for me to know that I had their support. Although very professional, both men were extremely approachable and patient with me as I tried to understand the processes they needed to go through to get data that was appropriate to understanding and resolving our dilemma. As an avocado grower I have always been appreciative of the work the University does for our industry. I am now, also appreciative of the extra effort that goes into work that may or may not get any publicity.

We were waiting to harvest between 600,000 and 800,000 pounds of avocados so this was a very nerve wracking time. We are now on our way to a successful harvest. We owe a debt of gratitude to these men.

Thank you.

Mark McKee

Mark McKee,
Ranch Manager

Cc. Dr. Donald A. Cooksey
Dr. Richard Redak
Dr. Jonathan Dixon

This not a fully satifactory resolution of the problem as the Danitol advisory is not a binding document (i.e. it is only an advisory). This is something the CAC probably should continue to work with Valent on. Valent requires additional PPE 3 days after application on grapes, and 5 days after application on apples and pears. However, the avocado PPE advisory is only that – we probably ought to push for more education of avocado growers and/or label revisions. Note, however, that in the list of pesticides one might use for control of either avocado thrips or persea mite in Morse and Hoddle (2012) and Hoddle and Morse (2013), we make it very clear that we suggest avocado growers follow this advisory.

The bottom line of this experience is that both the grower and the packing house were extremely thankful for what was done in response to their field situation (see the 7-13-10 letter from Mark McKee above).

<u>C6. Fall 2010 Saticoy persea mite trial</u>

Materials and methods

A persea mite field trial was put on in cooperation with PCA Dave Machlitt in Saticoy during fall 2010. Trees were 15-25 feet high, row spacing was 33' x 20' (66 trees per acre), and treatments were applied with a helicopter on 8-12-10 using 100 gpa. The grove was 5.25 acres in size and the south 2.25 acres was treated wth 20 fl oz/a Envidor 240 SC and the north 3 acres with 15 fl oz/a Epi-Mek 0.15 EC plus 3 gal/a NR-415 oil. An immediately adjacent untreated block served as a control.

Each Saticoy plot was split in half and for each of the two plots for each treatment, 10 leaves were randomly selected from each of 5 trees and motile persea mite levels on the undersurface counted using the second half vein method in the field (Machlitt 1988; one width of a hand lens, all motile mites) and then converted to whole leaf levels by multiplying by 11.35.

Results

Data for the Saticoy trial are shown in Table 6. Note that there was a major heat event (>105°F) on Sept. 27 and this is likely why levels in the untreated control plot were lower as of Oct. 7.

Table 6. Results from the fall 2010 Saticoy persea mite trial

	Mean motile persea mites per leaf (half-vein method)						
	9/8	9/20	9/28	10/7	10/22	11/5	Mean mite-days 8-54
Treatments	Precount	8 DAT	16 DAT	25 DAT	40 DAT	54 DAT	DAT
UTC	38.2	69.1	35.7	17.9	26.3	3.6	1,200.8
Epi-Mek	57.2	22.4	8.2	2.1	0.4	0.0	188.8
Envidor	49.0	26.7	2.3	0.6	0.0	0.0	133.4

Discussion and conclusions

Percent reduction in total mite days in comparison to the untreated control was 15.7% with Epi-Mek and 11.1% with Envidor. This suggests pretty clearly that at 100 gpa by helicopter, Envidor can give similar results as does Epi-Mek.

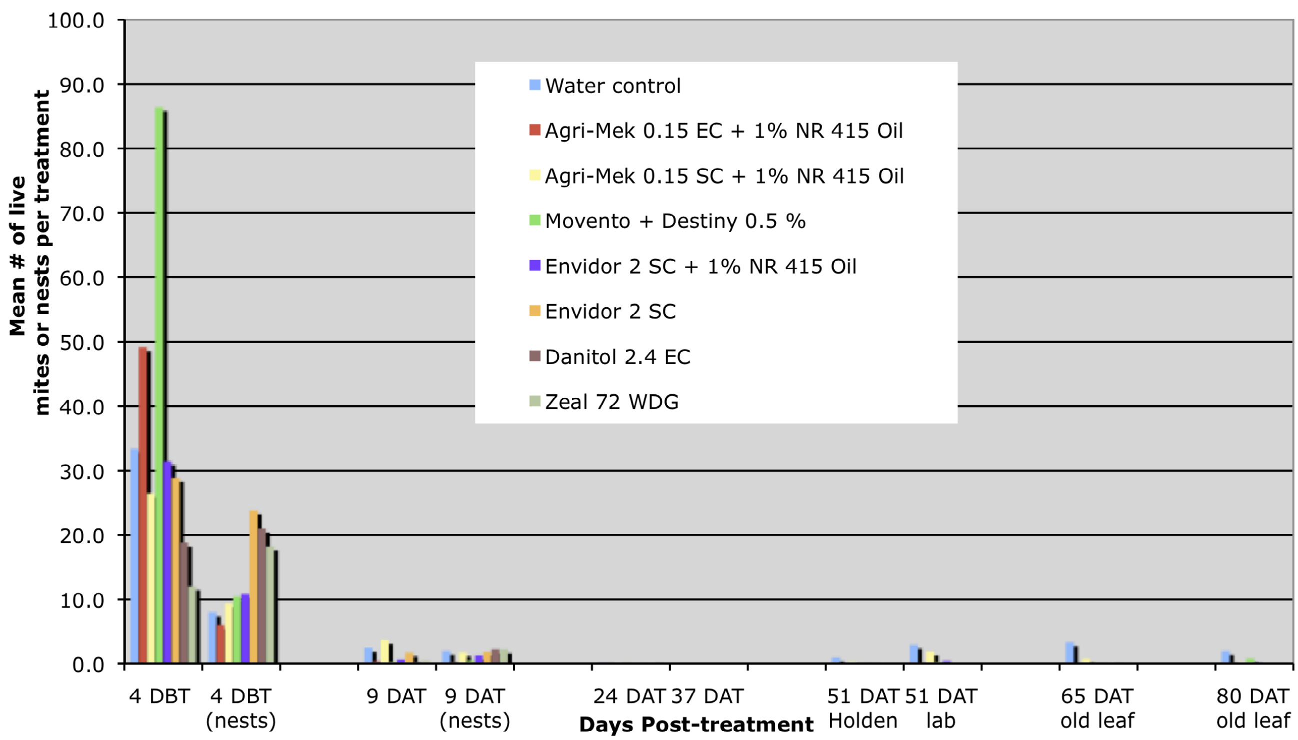
C7. Fall 2010 Somis persea mite trial

Materials and methods

A field trial was run on 1-year old Hass avocado trees in Somis with the cooperation of PCA David Holden. Trees were sprayed 9-13-10 by hand-gun using 4 replicates of 3-tree plots in a row (12 trees per treatment). Eight treatments were compared including a water control, Agri-Mek 0.15 EC 15 fl oz/a + 1% NR-415 oil, Agri-Mek SC at the same AI plus oil, Movento 16 fl oz/a + Destiny 0.5%, Envidor 2SC 20 fl oz/a + oil, Envidor at the same rate without oil, Danitol 2.4EC 21.33 fl oz/a without oil, and Zeal 72 WDG 3 oz/a without oil. Spray dilution was calculated on a basis of 400 gpa and trees were sprayed to runoff (0.5-1 gal per tree because they were quite small).

Holden's technician counted the number of persea mite nests per leaf on 5 leaves per tree and then shipped these leaves to UC Riverside where Morse lab personnel tore the nests apart and counted the number of motile persea mites per leaf to see if we could obtain a correlation between the two types of counts. In Riverside, if it was estimated there were more than 50 mites per leaf, the Machiltt (1988) second half vein method was used and the number of mites per one view of the microscope was multiplied by 11.35 to obtain an estimate of the total number of mites per leaf. Pre-counts were taken -25 days before treatment (nests only), and then on 7 dates using both methods (-4, +9, 24, 37, 51, 65, 80 DAT = days after treatment).

Fig. 3. Persea mite pesticide trial
Comparison of motile mite counts vs. nest counts (for some dates)
Somis, CA; Sept. 2010



Results

This study was a great deal of work but was largely a waste of time. Although we started with good levels pre-treatment, based on the 9 day post-count (Sept. 22), the water control treatment drastically reduced levels (see Fig. 3 above). In addition, a strong heat wave occurred Sept. 26-28 (112°F on Sept. 27 at this site) and mite levels never rebounded to a significant degree.

Discussion and conclusions

Usuable data were not obtained in this study other than to suggest based on the 4 day pre-count that there does not appear to be a good correlation between nest counts and number of motile mites per leaf.

C8. Highlights of other activity during 2009-10 (partial list; I don't keep track of most PCA/grower calls)

- 13 December 2009 presentation by graduate student Deane Zahn at the Entomological Society of America National meeting in Reno, NV – "Insecticide Resistance Management on Citrus and Avocados in California" based on Morse lab research data;

- 20 January 2010 presentation by Morse at a DuPont Thrips Expert Workshop in San Diego, CA – "Possible Uses of Cyazypyr on Citrus and Avocado in California"; this was an outstanding meeting because it brought together key thrips researchers together from all over the U.S. and Europe – some very interesting research on thrips on other crops influenced my thinking on avocado thrips research;

- April 2010 – review and update of all avocado insect and mite pest management guidelines posted on the IPM web site;

- 6 April 2010 presentation by Morse in San Luis Obispo, 7 April in Ventura, and 8 April in Temecula at spring CAC/CAS seminars titled "Research Update – Avocado Thrips, Persea Mite, and Pesticide Resistance Management"; this was a good opportunity to get PCAs and growers thinking about using Danitol and Delegate as an alternative to abamectin – it is disappointing how little they have followed through on this given how strong both products looked in the spring 2009 field trials – these data were shown to them in detail;

- 25 July 2010 response to grower noticing high levels of a planthopper on avocados; arranged for identification by Muesum scientist Doug Yanega at UCR- the planthopper was identified as *Ormenis savcia* based on similar specimens collected in Santa Barbara and San Diego counties in the 1980's;

- 3 September 2010 response on high levels of peelminers seen damaging the surface of avocados; unfortunately, mining damage did not yield live insects which could be subjected to molecular examination to see if the dangerous SJV strain had made its way to southern California;

- 12 September 2010 report sent to a PCA in Ventura Co. reporting poor persea mite control with abamectin; information provided on possibly using Envidor as a treatment alternative;

D. 2010-11 RESEARCH

D1. April 2011 Movento trial on the UCR campus

Based on results from the Spring 2010 Movento trials on campus we decided to evaluate avocado thrips mortlity over a longer period of time once the thrips were exposed to treated leaves. Surviving thrips were moved to new leaves (newly picked leaves from the treated trees) every 3-4 days and trials were continued through 2 or 3 leaf changes depending on results (terminated after 6-7 days if mortality was high).

Materials and methods

Treatments were applied to 7-year old Hass avocado trees (Torro Canyon rootstock) on the UCR campus at a single timing of 4-22-11 (peak bloom). Tagged leaves were sprayed just prior to runoff using a 1-gallon B & G (Model F100 stainless steel) hand sprayer using 10 fl oz/a Movento (200 gpa dilution basis) plut 1% NR-415 oil.

Leaves were picked various times post-treatment and ca. 10-14 first instar avocado thrips collected from an unsprayed field site (SCFS) were placed on each leaf. Thrips were confined on the leaves inside Munger cells (Morse et al. 1986). Ten replicate Munger cells were used to evaluate each treatment with the same number of control cells (leaves from untreated trees).

Results

Bioassay 1 – Thrips were placed into Munger cells on May 6, 14 days after treatment and surviving thrips were moved to new leaves at 3 days. Control mortality of 157 thrips was 5.1% at 3 d and 6.2% at 6 days. Corrected Movento + oil mortality of 162 thrips was 75.0% at 3 days and 100% at 6 days.

Bioassay 2 – Thrips were placed into Munger cells on May 13, 21 days after treatment and surviving thrips were moved to new leaves at 3 days. Control mortality of 126 thrips was 3.2% at 3 d and 3.2% at 7 days. Corrected Movento + oil mortality of 128 thrips was 70.0% at 3 days and 99.2% at 7 days.

Bioassay 3 – Thrips were placed into Munger cells on May 20, 28 days after treatment and surviving thrips were moved to new leaves at 3 and 7 days. Control mortality of 132 thrips was 0% at 3 d, 0% at 7 d, and 6.3% at 9 days. Corrected Movento + oil mortality of 134 thrips was 56.7% at 3 d, 75.9% at 7 d, and 91.8% at 9 days.

Bioassay 4 – Thrips were placed into Munger cells on May 27, 35 days after treatment and surviving thrips were moved to new leaves at 4, 7, and 10 days. Control mortality of 113 thrips was 0% at 4 d, 4.0% at 7 d, 4.3% at 10 d, and 9.6% at 12 days. Corrected Movento + oil mortality of 117 thrips was 36.8% at 4 days, 44.2% at 7 d, 49.8% at 10 d, and 72.4% at 12 days.

Discussion and conclusions

Finally a test that justified all the work we have put into Movento. The key appears to be that thrips mortality can be quite slow, especially when levels in leaves have declined somewhat (i.e. Bioassays 3 and 4 at 28 and 35 days after treatment). The amount of avocado thrips mortality obtained, however, was impressive.

D2. Two Somis persea mite trials conducted in 2011

Materials and methods

Two persea mite pesticide efficacy trials were conducted in Somis, Ventura County, during 2011 using the same trees (with re-assignment of treatments to different trees after Trial 1, see below) for both trials. Treatments were applied to 2-year old Hass avocado trees planted on berms with tree spacing of 16’ between trees within a row and 20’ between rows (thus, 136 trees per acre). Treatments evaluated were Agri-Mek SC (0.7 lb ai/gal) at 3.214 fl oz/a + 1% IAP NR-415 oil (denoted as “oil” below unless otherwise noted), Agri-Mek SC at the same rate with 1% Saf-T-Side oil, Envidor 240SC at 20 fl oz/a, the same rate of Envidor with oil, Agri-Mek 0.15EC at 15 fl oz/a (same AI as used with the SC version to compare them) + oil, Zeal 72WDG at 2 oz/a + oil, Saf-T-Side (435) oil alone at 2%, oil alone at 2%, Trilogy (70% Neem oil extract) at 1%, and an untreated control.

Treatments were applied in the first trial on 29 June 2011 and in the second study on 26 October 2011. In both cases, single tree replicates were sprayed to runoff using a Hypro hand sprayer set at 200 psi and per acre dilution rates were calculated based on 300 gpa, although because of the size of the trees, much less spray than this was used per acre. Seven leaves per data tree were picked in the field by Holden and/or his assistant, placed in a labeled paper bag, and shipped by FedEx to Riverside where Morse's lab counted all motile persea mites per leaf with a microscope (i.e. all life stages except eggs).

Table 7. Mean motile persea mite levels per leaf various days after the first treatment, 6-29-11.

	Date picked	7/5/11	7/19/11	8/2/11	8/16/11	8/30/11	9/13/11	9/29/11	10/11/11		% of
	Days post trmt	6	20	34	48	62	76	92	104	Mite	control
Treatment	Date Rcvd	7/7/11	7/21/11	8/4/11	8/17/11	8/31/11	9/14/11	9/30/11	10/13/11	days	mite-d
Control	tree mean	4.3	10.4	9.8	24.3	37.4	71.5	47.2	13.6	2,991.1	
	min	0	0	0	0	0	0	0	0		
	max	43	137	158	214	423	396	263	97		
Trilogy	tree mean	14.8	6.4	0.2	2.1	4.0	1.5	28.1	22.3	831.0	27.8%
	min	0	0	0	0	0	0	0	0		
	max	174	86	8	89	57	33	178	105		
Envidor	tree mean	0.1	0.0	0.1	0.3	1.8	9.4	14.5	9.8	434.6	14.5%
	min	0	0	0	0	0	0	0	0		
	max	2	1	1	7	21	194	161	115		
Agri-Mek	tree mean	2.1	1.0	0.1	0.2	1.4	8.8	10.8	9.5	392.0	13.1%
SC + oil	min	0	0	0	0	0	0	0	0		
	max	28	28	2	2	16	158	84	65		
Envidor	tree mean	0.1	0.0	0.1	0.2	4.1	5.3	12.6	6.2	353.7	11.8%
+ oil	min	0	0	0	0	0	0	0	0		
	max	3	1	2	2	25	85	157	86		
Zeal + oil	tree mean	0.1	0.1	0.0	0.0	0.1	0.3	6.6	12.0	174.2	5.8%
	min	0	0	0	0	0	0	0	0		
	max	5	4	1	1	1	11	83	64		
oil alone	tree mean	0.1	0.0	0.1	0.1	0.3	0.1	4.2	4.6	95.6	3.2%
	min	0	0	0	0	0	0	0	0		
	max	2	0	3	4	5	1	74	42		
Saf-T-Side	tree mean	0.0	0.0	0.0	0.1	0.6	0.2	0.2	11.0	82.5	2.8%
oil	min	0	0	0	0	0	0	0	0		
	max	0	1	0	2	15	3	4	79		
Agri-Mek	tree mean	0.0	0.0	0.0	0.1	0.2	0.2	2.2	2.1	51.1	1.7%
EC + oil	min	0	0	0	0	0	0	0	0		
	max	0	0	0	2	8	4	32	31		
Agri-Mek SC	tree mean	0.4	0.0	0.0	0.0	0.2	0.2	0.0	2.2	22.4	0.7%
+ Saf-T-Side	min	0	0	0	0	0	0	0	0		
oil	max	11	0	0	1	3	5	1	29		

We planned on applying treatments in the first trial to 8 single tree replicates spaced around the plot and randomly chosen from blocks based on pre-counts (see how treatments were assigned in Trial 2 – this was the original plan). When Dave arrived at the field site on 29 June, he found to his surprise that the grower had planted pumpkins in between the rows. Had he dragged the spray host around the plot when applying each treatment as was planned, he would have destroyed the grower's pumpkins. In order to do the best he could, he selected 4 data trees in each of two adjacent rows for one treatment, another two adjacent rows (8 trees total) for the second, etc. Thus, treatment trees were not scattered around the field and were not based on pre-counts as had been planned. Post-counts were taken in the same way as precounts on each of the 8 single replicates at 6, 20, 34, 48, 62, 76, 92, and 104 days post-treatment. Mite-days were calculated in Trial 1 based on all counts except the last count on 104 days post-treatment.

We decided to repeat the trial at the same site using some of the same trees (6 single tree reps per treatment instead of 8). Persea mite levels at 104 days post-treatment (leaves picked 10-11-12) were used to set up Trial 2 and different trees (although used in the first trial) were assigned to each treatment. The 10 data trees with the highest levels were assigned to Block 1, the next 10 to Block 2, etc. Then one tree in each block was randomly selected and assigned to each treatment. In this second trial, there were 6 data trees per treatment and they were randomly scattered around the field. Treatments were applied in the same way as in Trial 1 on 26 October 2011 and post-treatment counts were taken as before on 10 leaves per tree.

Table 8. Mean motile persea mite levels per leaf after the second treatment, 10-26-11.

		Dates leaves were received in Riverside							% reduction
	Pre-count	11/3/11	11/16/11	11/30/11	12/15/11	1/4/12	1/27/12	mite	of control
Treatment	Days post-treatment	8	21	35	50	70	93	days	mite days
Control	10.4	16.0	23.5	14.2	11.3	13.2	22.9	1,371.0	
Trilogy	11.0	2.4	9.0	1.5	1.0	1.1	1.5	216.9	15.8%
Envidor	10.3	1.1	4.0	4.6	1.9	0.0	1.4	179.4	13.1%
Agri-Mek EC + oil	10.3	0.7	1.2	0.5	0.5	0.3	0.1	46.5	3.4%
Saf-T-Side oil	10.2	0.8	0.8	0.1	0.1	0.8	0.1	38.2	2.8%
Oil alone	10.5	0.3	0.4	0.7	0.2	0.4	0.3	32.2	2.3%
Agri-Mek SC + oil	10.6	3.2	0.3	0.0	0.0	0.0	0.0	25.9	1.9%
Zeal + oil	10.8	1.3	0.3	0.1	0.1	0.0	0.0	17.3	1.3%
Agri-Mek SC + oil	10.7	1.2	0.3	0.0	0.3	0.0	0.0	16.7	1.2%
Envidor + oil	10.5	0.6	0.2	0.2	0.0	0.0	0.0	10.1	0.7%

Results

One must remember the avocado trees used in this study were only 2 years old, i.e. they were quite small, and were sprayed to run-off at 200 psi. Thus, coverage was excellent, especially in contrast to what a large tree would receive with helicopter application at 50-100 gpa. Under such conditions, one would expect that materials such as oil, that rely heavily on coverage, would perform extremely with respect to initial knockdown.

In the first trial (Table 7 above), mite levels built slowly on the untreated control trees, reaching a peak on 13 September and declining somewhat after that on the type of mature leaves that were picked in the field. All treatments appeared relatively effective under the conditions of this study (very small trees, very good ground hand-gun spray coverage). Recall, however, that this study was conducted without data trees assigned to a particular treatment scattered throughout the block as had been intended, because of the pumpkins.

The experimental design of Trial #2 was more solid (Table 8 above), as treatments were assigned to data trees based on pre-counts and these trees were scattered around the field. Mite levels on untreated control trees increased somewhat in the first two post-treatment counts, then declined somewhat, and increased again at the end of the trial (although this was somewhat an artifact of one tree having very high levels – mean of 106 mites per leaf; next highest tree mean on 1-27-12 was 19).

Discussion and conclusions

Results of the two trials were similar. All treatments appeared relatively effective although there is a suggestion of relatively slow knockdown with Trilogy (organic oil at 2% appears somewhat more effective than Trilogy at 1%). There is also a suggestion that Envidor performed better with 1% oil than without oil under the conditions of this study. In retrospect, this was a somewhat biased trial given the very small tree size and excellent spray coverage with a hand gun. Thus, results with contact materials such as various oils were unrealistically strong.

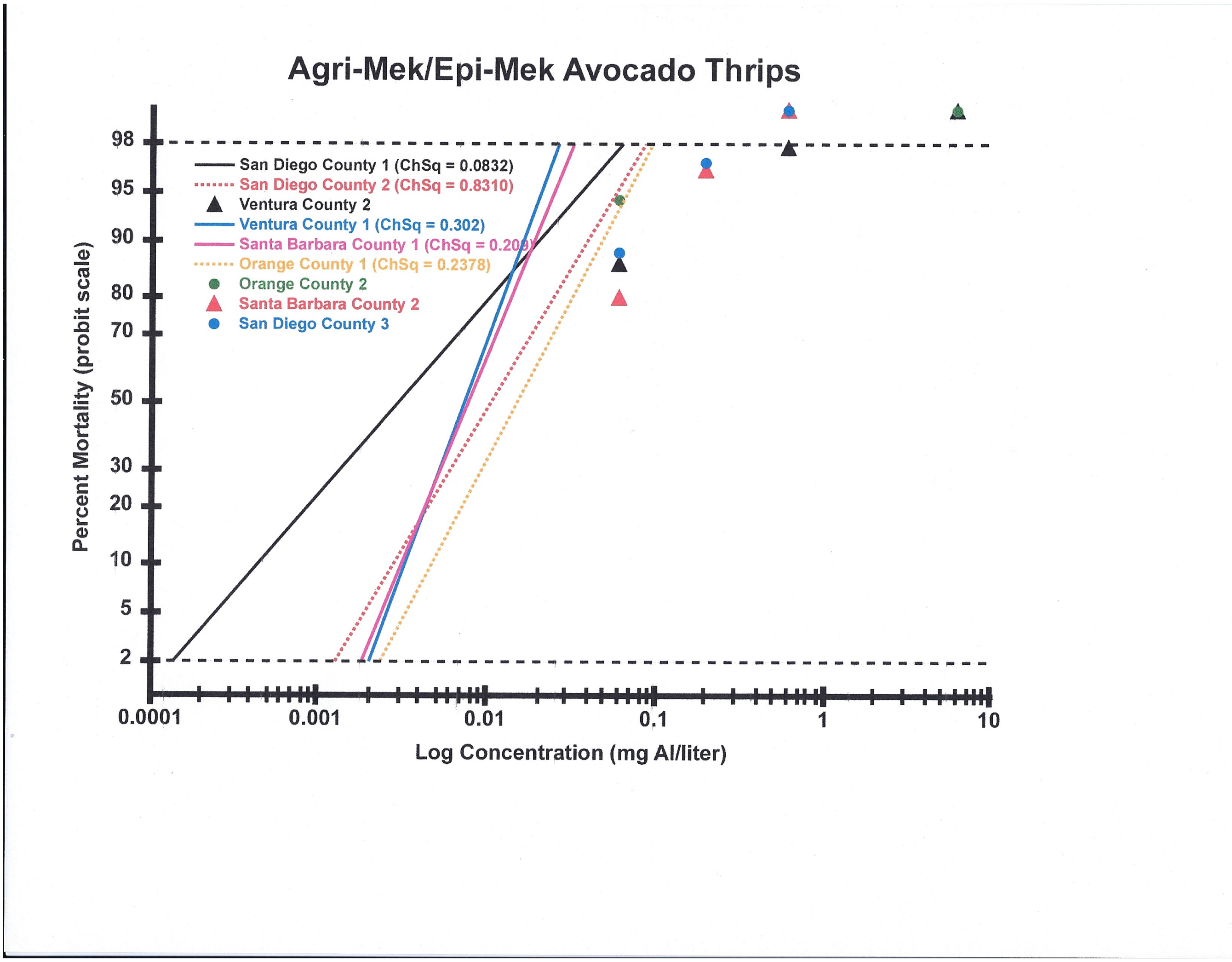
<u>D3. Field avocado thrips resistance evaluations</u>

Four reports of poor avocado thrips field control with abamectin during spring 2011 applications were investigated. In all 4 cases, we were unable to document abamectin resistance based on baseline data obtained in previous years in groves prior to significant use of abamectin. Results were discussed with PCAs and it was concluded that the observed lack of control was likely due to a combination of several factors: high avocado thrips pressure during spring 2011, perhaps less than optimal timing and application of the treatment, and/or the beginnings of abamectin resistance that our bioassay methodology was insufficiently sensitive to detect. In part, this lead to our ideas about developing more sensitive methods of detecting the beginnings of abamectin resistance using biochemical and/or molecular methods. This was one reason why we included this type of research in our new project proposal that was funded starting 11-1-12.

Materials and methods

At field sites reporting concerns over abamectin performance against avocado thrips, we visit the site and collect leaves infested with second instar thrips. These are placed in plastic Ziploc bags and are transported to UCR in an ice chest where they are held in a refrigerator until use in a bioassay, which is typically done the following day (although the thrips do fine in the refrigerator for several days if needed). Based on past abamectin resistance work, we used 3 diagnostic doses in our abamectin resistance bioassays: initially, 0.06, 0.6, and 6.0 mg AI per liter abamectin. Each concentration of pesticide is made up in a 1 liter Kimax glass container placed on a magnetic stirring plate to keep the material in solution while leaves are dipped in the solution. Fully expanded but tender avocado leaves (of the type thrips prefer) are picked from untreated trees from Field 13F on the UCR campus, are washed to removed dirt and dust, and are then dipped for 8 seconds in each pesticide solution (controls use water; no Triton added as a surfactant like with persea mite resistance assays). Leaves are held on paper towels to dry and are then positioned within a Munger cell with 5 cells used at each concentration. 8-15 second instar avocado thrips are hand transferred from the field leaves to each treated leaf. Mortality is evaluated 48 hours later and corrected percent mortality data (using Abbott's [1925] formula) are plotted on log dose – probit paper in comparison to past avocado thrips bioassay data with abamectin (see the following figure which shows these data).

Based on results from the 6-21 and 7-8 bioassays, we revised bioassay rates to be 0.06, 0.2, and 6.0 mg AI/liter in the third and fourth bioassay done in 2011.



Results

In a bioassay of avocado thrips collected 6-21-11 from Ventura Co., control mortality was 0.0% (63 thrips total in 5 Munger cells) and mortality at 0.06, 0.6, and 6.0 mg AI/liter were 86.2, 97.8, and 100% with 47, 48, and 47 thrips, respectively.

In a bioassay of avocado thrips collected 7-8-11 from Orange Co., control mortality was 3.5% (57) and mortality at 0.06, 0.6, and 6.0 mg AI/liter were 94.7, 100, and 100% with 56, 56, and 53 thrips, respectively.

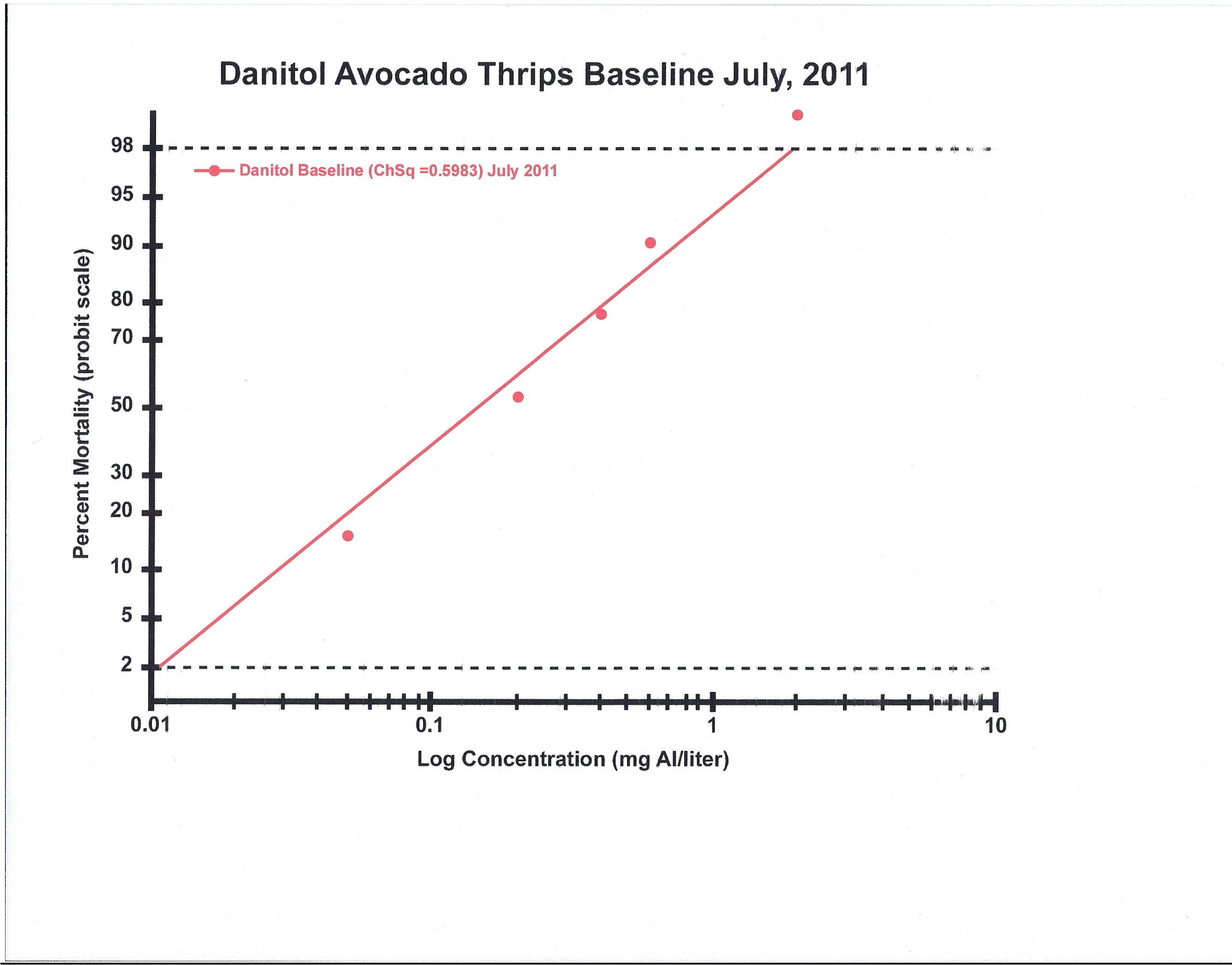
In a bioassay of avocado thrips collected 7-15-11 from Santa Barbara Co., control mortality was 0.0% (59) and mortality at 0.06, 0.2, and 0.6 mg AI/liter were 77.1, 96.4, and 100% with 63, 59, and 59 thrips, respectively.

In a bioassay of avocado thrips collected 7-22-11 from San Diego Co., control mortality was 1.7% (60) and mortality at 0.06, 0.6, and 6.0 mg AI/liter were 88.5, 97.2, and 100% with 59, 69, and 59 thrips, respectively.

Discussion and conclusions

It is easiest to evaluate these data by looking at the following graph of diagnostic dose data (individual points) versus past log dose – probit regression lines (above). It helps to have experience with such data and to realize that the probit regression turns an S-shaped curve with quite long tails into a straight line (thus, although we plot points for 100% mortality a bit above 98% probit mortality, if fact, they much, much higher (theoretically, at infinity).

Our analysis of these data is that we had very good tests (as good as is possible using this type of method) and there is no clear evidence of abamectin resistance although one has a suspicion it may be in the early stages. Thus, again the need is suggested to develop more highly diagnostic biochemical and/or molecular methods.



<u>**D4. Baseline avocado thrips susceptibility to Delegate and Danitol**</u>

Materials and methods

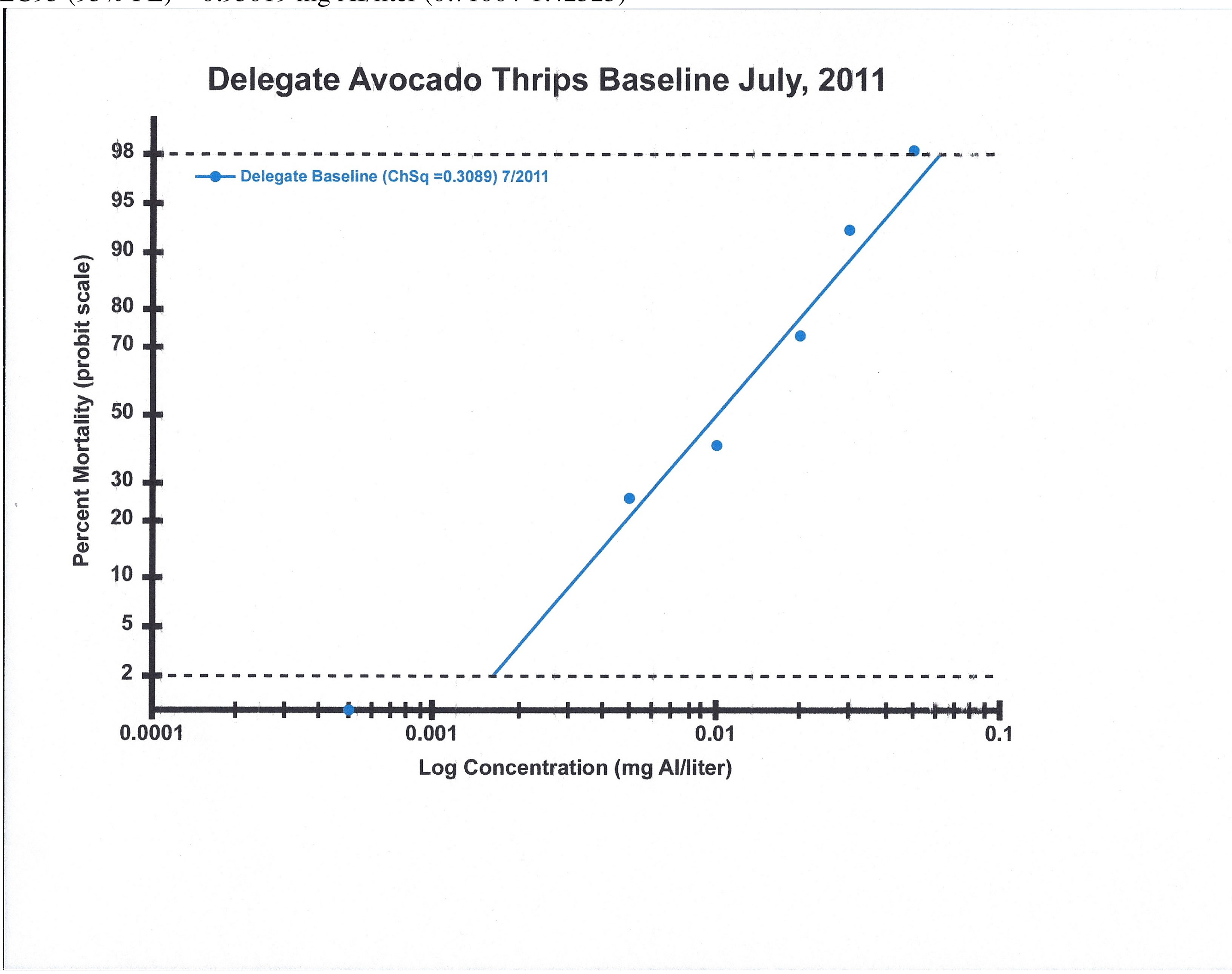
Methods were identical to those described in detail for study D3 with abamectin, above. A difference is one must run trials at a number of widely spaced rates initially and based on the results, modify rates used in later tests so that one ends up with at least 4-5 data points yielding more than 0 and less than 100% mortality.

Delegate bioassays were done on 5-27-11, 6-8-11, 6-15-11, and 6-29-11 using second instar avocado thrips collected from the South Coast Field Station Field 2. Danitol bioassays were done on 6-21-11 and 6-29-11 also using thrips from SCFS #2. Control mortality was 0.0, 1.1, 0.0, 0.0, and 0.0% using a total of 53, 75, 63, 63, and 56 second instar avocado thrips on the 5 trial dates, respectively (the same control data were used for both pesticides on 6-29). As far as we know, Danitol and Delegate have never been used on avocados at the SCFS and we doubt if avocado thrips would spend much time on other crops where these pesticides might have been used.

Results

A "good" bioassay has a chi-square probability greater than 0.05. The results of the Danitol and Delegate bioassays are shown in the figures above and below, respectively.

For Danitol raw data (mg AI/ liter, total test thrips numbers, test dead, control total, control dead) were:
0.05, 65, 10, 63, 0
0.20, 62, 33, 63, 0
0.40, 60, 46, 56, 0
0.60, 64, 58, 63, 0
2.0, 63, 63, 63, 0
Slope of the regression line (± SE) = 2.169 ± 0.695
Pearson chi-square value = 1.8769, df=3, chi-square probability = 0.5983
LC50 (95% FL [fiducial limits]) = 0.16575 mg AI/liter (0.13333-0.20047)
LC95 (95% FL) = 0.95019 mg AI/liter (0.71064-1.42525)



For Delegate raw data (mg AI/ liter, total test thrips numbers, test dead, control total, control dead) were:
0.0005, 70, 1, 75, 1
0.005, 70, 19, 75, 1
0.01, 61, 25, 56, 0
0.02, 64, 47, 63, 0
0.03, 56, 52, 56, 0
0.05, 52, 51, 53, 0
Slope of the regression line (± SE) = 2.598 ± 0.546
Pearson chi-square value = 4.7960, df=4, chi-square probability = 0.3089
LC50 (95% FL) = 0.01019 mg AI/liter (0.00862-0.01182)
LC95 (95% FL) = 0.04377 mg AI/liter (0.03416-0.06221)

Discussion and conclusions

Once Delegate and Danitol start being used more on avocados, it will be important to have these baseline data showing the inherent susceptibility of avocado thrips to these two products. If one suspects resistance, once can compare field data to these baseline data (see for example how this was done with abamectin under D3 above).

D5. Summer 2011 persea mite trial in San Marcos

In contrast to the first two 2011 persea mite studies that failed to yield interesting data (but were a lot of work), the third study was one of the best field trials (on either citrus or avocados) we have ever been involved in. Part of this was due to excellent collaboration with Matt Hand (local PCA) and high persea mite pressure – 6 nearby groves of similar size were treated for persea mite control on 25 August 2011, 3 with abamectin, Zeal, or Envidor at 50 gpa by helicopter and one each with the same 3 products using 100 gpa by helicopter. The data are the type of data one is always shooting for (but rarely achieves) in a field trial – they very convincingly showed how much more effective the higher gallonage helicopter treatments can be.

In this study, we worked with PCA Matt Hand of Southern California Entomology and he did a great job in doing much of the work on this project. Our role was to design the study with him, arrange for the donation of chemical and funding to support his work (no CAC funds), visit the field site to discuss details and sampling methods, and enter and analyze all data.

Materials and methods

The 3 treatments compared via helicopter application were 50 vs 100 gpa of each of (1) Envidor 2SC at 20 fl oz/a with no added oil, (2) Agri-Mek 0.7SC at 4.25 fl oz/a with 4% Omni 6E oil, and (3) Zeal 72WDG at 3 oz/a with the same rate of oil. All 6 treatments included Phosgard 0-28-25 at 64 fl oz/a.

Six adjacent avocado groves were chosen for this study. All trees were planted at the same time (with the exception of replants – see especially Zeal-50) and were later divided into separate lots, each near a house. 10 trees were chosen throughout each grove for persea mite pre-counts and the same 10 trees were assessed on various dates post-treatment. In both cases, there were 10 data trees per block, 5 leaves per tree were picked, and all motile mites (all stages except eggs) were counted on the entire under surface of the leaf. Matt also recorded any natural enemies seen.

Trees in the Agr-50 (Agri-Mek at 50 gpa) plot were 16-30’ high; data trees 9 and 10 might have not received good spray coverage because they were near the road and houses; the rest should have been fine. Env-50 trees were 20-30’ tall; data trees 2 and 5 were quite large at 30’. Zeal-50 was a very open grove with smaller trees, and many were near a homes; data trees 1-3 near a home, tree sizes for data tree 4 (15’), 5 (6’), 7 (25’), 10 (25’), trees 4-7 also near a house; much more open space between most trees (many replants). Agr-100 was the most difficult spray coverage of the 6 groves – tight tree spacing, full and thick canopy. Env-100 trees were 20-30’ in heigh.

Zeal-100 trees were pretty tight and large, 25-35' high; trees 1-4 should have been sprayed well; #5 near a gully – probably not as good coverage.

After the treatment, Matt realized that some of the pre-count trees at the Zeal-100 site were not sprayed because they were too near a gully and a home. We call these a "semi-control" because there could have been some drift from the treatment. 3-5 trees were assessed in this area each date as "semi-controls". Because some of the Zeal-100 trees were assumed to be semi-controls, there were only 7 data trees for that treament (all with good evidence of oil residue from the spray).

Table 9. Number of motile persea mite per leaf (all stages except eggs)

		8/23/11	8/30/11	9/6/11	9/22/11	10/11/11	11/1/11	11/29/11	1/5/12	Cumul.	% mite-	# of
		Pre-count	Days Post-Treatment							mite-	days of	trees
		-2	5	12	28	47	68	96	133	days	Semi-C	n
mean	Agr-50	15.60	17.82	17.50	19.70	18.32	4.86	2.02	1.23			
mite-days				123.6	297.6	361.2	243.4	96.3	60.1	1,182.2	66.1%	10
min		0	3	0	2	0	0	0	0			
max		75	55	62	47	65	18	15	15			
mean	Env-50	8.38	9.22	10.04	23.30	12.94	11.88	5.90	0.88			
mite-days				67.4	266.7	344.3	260.6	248.9	125.4	1,313.4	73.4%	10
min		0	0	0	0	0	0	0	0			
max		46	40	38	80	65	75	40	12			
mean	Zeal-50	27.92	21.18	3.94	2.66	1.72	1.92	0.92	0.36			
mite-days				87.9	52.8	41.6	38.2	39.8	23.7	284.0	15.9%	10
min		0	0	0	0	0	0	0	0			
max		53	50	55	40	75	12	8	6			
mean	Agr-100	30.60	18.66	7.68	8.28	4.68	1.64	1.06	0.86			
mite-days				92.2	127.7	123.1	66.4	37.8	35.5	482.7	27.0%	10
min		5	4	0	0	0	0	0	0			
max		75	45	75	40	41	12	19	9			
mean	Env-100	31.95	22.25	12.15	5.35	1.85	4.22	1.87	2.33			
mite-days				120.4	139.9	68.4	63.8	85.3	77.8	555.5	31.1%	11
min		3	0	0	0	0	0	0	0			
max		75	46	75	19	15	45	17	19			
mean	Ze-100	3.00	3.31	1.83	1.86	7.86	6.69	5.89	3.03			
mite-days				18.0	29.5	92.3	152.7	176.0	164.9	633.4	35.4%	7
min		0	0	0	0	0	0	0	0			
max		14	15	16	15	71	40	22	35			
mean	Semi-C	24.13	20.50	17.04	17.56	32.36	7.64	9.20	4.36			3 to 5
				131.4	276.8	474.2	420.0	235.8	250.9	1,789.1		
min		7	7	0	5	4	0	0	0			
max		53	50	55	40	75	18	32	33			

Note that some data trees were stumped on day 133 of the trial (5 in Agri-50). Also, because of concerns regarding high levels of persea mite, the Agri-50 grove was re-sprayed between the day 68 and 96 counts with 1.67 gallons of oil per 100 gpa with added zinc and phos-acid 0-60-0 -- not great coverage but a fair amount of leaf burn (Matt thinks they used unbuffered phos-acid)

Note the different levels of persea mite in the 6 groves before treatments were applied. Because Matt had no experience with Zeal, he chose a grove he was not too worried about for treatment with that material -- Zeal-50 had quite high levels of persea mite pre-treatment but it was a very open grove with a lot of young, replant trees. Zeal-100 had large trees and a very tight canopy but persea mite levels pre-treatment were quite low.

The two groves he was most concerned about (especially Agri-100 but also Env-100), because of large trees, tight canopies, and high pre-count persea mite levels were chosen for 100 gpa treatment with the two materials he was more familiar with (Agri-Mek a great deal; Envidor somewhat).

Results

Data from the trial are shown in Table 9 above. Data comparing the performance of Agri-Mek at 50 vs. 100 gpa and Envidor at 50 vs. 100 gpa are shown in the two figures below.

With persea mite trials, a good summary statistic for how well treatments perform is the cumulative number of mite-days post treatment (calculated as the mean number of mites per leaf based on averaging two successive counts * the number of days between those two counts. We believe this is a good method for persea mite because leaf damage is cumulative over time. As a single summary statistic, we calculated the cumulative number of mite-days post-treatment as a percentage of those observed on the semi-control trees.

Discussion and conclusions

What did we learn from this trial? First, because of differing pre-count levels and differing tree canopies in the various groves, one should be careful in interpreting these data (for example the performance of Zeal should not be exaggerated given the much more open Zeal-50 site and the lower pre-count levels in Zeal-100). Second, both Agri-Mek and Envidor appeared to perform much better at 100 gpa than at 50 gpa – these are likely the most valid comparisons that should be looked at in this trial, i.e. despite much higher levels in Agri-100 pre-treatment and a tighter grove than Agri-50, results with Agr-Mek at 100 gpa were much better than at 50 gpa. Similarly, Envidor at 100 gpa appeared to outperform the same material at 50 gpa.

There were not enough pests other than persea mite (occasional avocado brown mite, sixspotted mite, or avocado thrips) to say much about the possible impact of these treatments on these pests. Similarly, with the various predators observed (mostly *Euseius hibisci* but also some *Franklinothrips orizabensis*, larva of an unidentified dipteran, and predaceous staphylinid beetles), there were not enough consistently seen pre-treatment to say any of the treatments had a large impact on their populations. These were large trees and even with 100 gpa by air, none of Agri-Mek, Envidor, or Zeal appeared to prevent at least some natural enemies from showing up post-treatment.

Fig. 1. Agri-Mek 0.7 SC at 4.25 fl oz/acre + 4% Omni 6E Oil applied by helicopter at 50 vs. 100 gpa

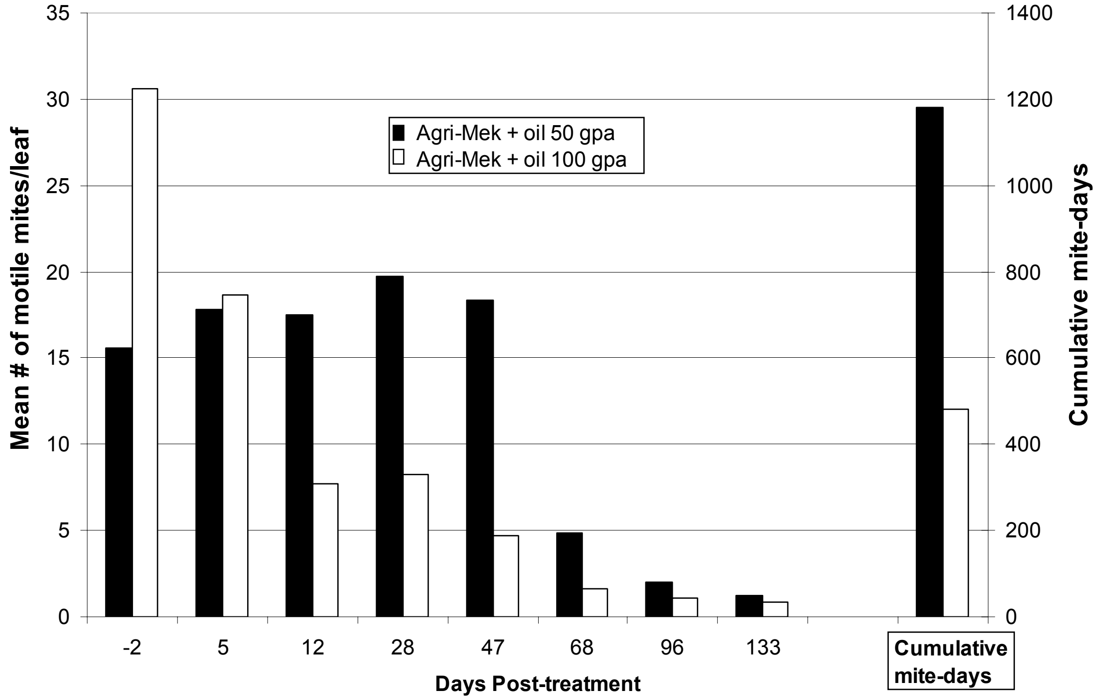
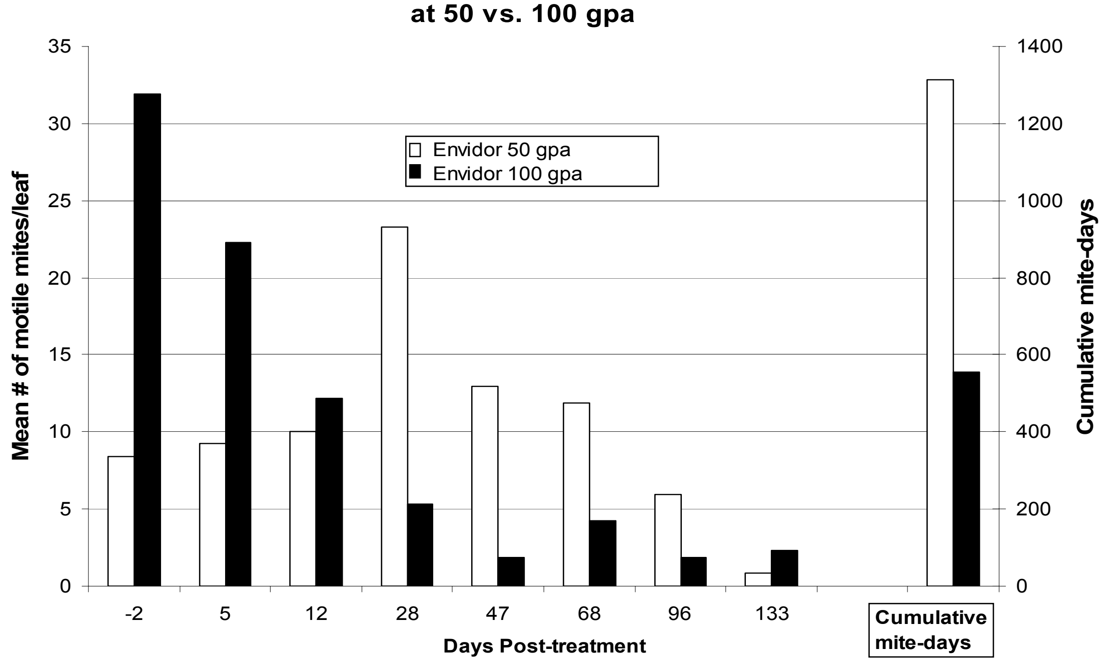


Fig 2. Envidor 2SC at 20 fl oz/acre (no oil) applied by helicopter at 50 vs. 100 gpa



D6. Highlights of other activity during 2010-11 (partial list)

- 13 December 2010 presentation at the Entomological Society of America National meeting in San Diego, CA by graduate student Deane Zahn – "Impacts on Thrips Treatments on *Euseius hibisci* in southern California Avocados";

- 24 March 2011 request for information (referral from J. Dixon) – provided information on the key arthropod pest and diseases on avocados in CA;

- 28 March 2011 presentation at the Pacific Branch of the Entomological Society of America annual meeting in Waikoloa, HI by graduate student Deane Zahn – "Insecticide Impacts on the Native Predaceous Mite *Euseius hibisci* in southern California Avocados";

- Morse asked by Tom Bellamore to provide a review of 3 documents dealing with the supposed non-host status of Hass avocados to various species of fruit flies in relation to proposed Peruvian imports; 4-page review of these documents provided by Morse on 8 May 2011;

- 19 August 2011 – response to Ken Melban regarding possible IR-4 work on clofentezine for use on avocados against persea mite;

- 31 August 2011 – response to PCA request on how to control avocado brown mite via helicopter application.

E. 2011-12 RESEARCH

Because our spring 2011 Movento work showed strong results and this material was recently registered for use on CA avocados, two avocado thrips field trials were run during spring 2012 (E1, E2).

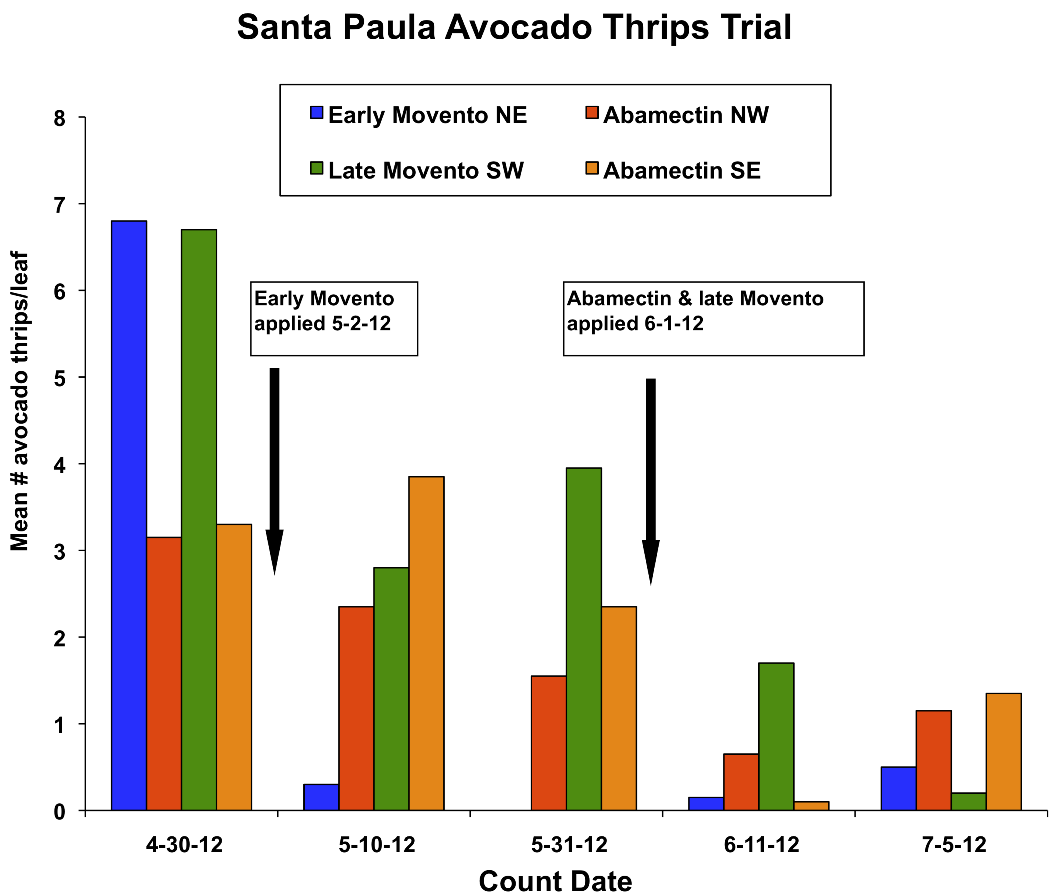
E1. Santa Paula avocado thrips Movento trial

Materials and methods

An avocado thrips trial was run during the spring 2012 in Santa Paula, CA to evaluate both an early (May 2) and late (June 1) speed-sprayer ground treatment with Movento versus a late treatment (June 1) with Epi-Mek (2 plots). PCA Tom Roberts ran the study, decided on treatment timing, added material to the spray tank, supervised the applications, and took fruit infestation counts pre-treatment and on 4 dates post-treatment. Treatments were applied with an FMC Silver Master speed sprayer equipped with a stainless steel 300-gallon tank using 240 gpa. Four gallons per acre NR-415 oil (thus 1.7%) and 4 pints per acre Fosphite were added to all treatments.

This was a grove of 20-year old Hass avocados planted at 21' between rows and 18' between trees within a row (ca. 115 trees per acre; approximately 18' in height). The field was divided in half (67 trees to the north and 70 to the south). 8.5 rows by 67 trees (5 acres) on the northeast of the block were treated on May 2 (early Movento) and 8.5 rows near the south center of the block were treated with the late Movento treatment 4.5 weeks later on June 1. The rest of the field was treated at the late timing with Epi-Mek.

Morse lab personnel took scar counts of the percent of the surface area (10% increments) of 500 randomly selected fruit scarred by avocado thrips in the center of each of the 4 plots (this was done by weaving back and forth between the two center rows and randomly selecting fruit that could be reached for examination from the ground).



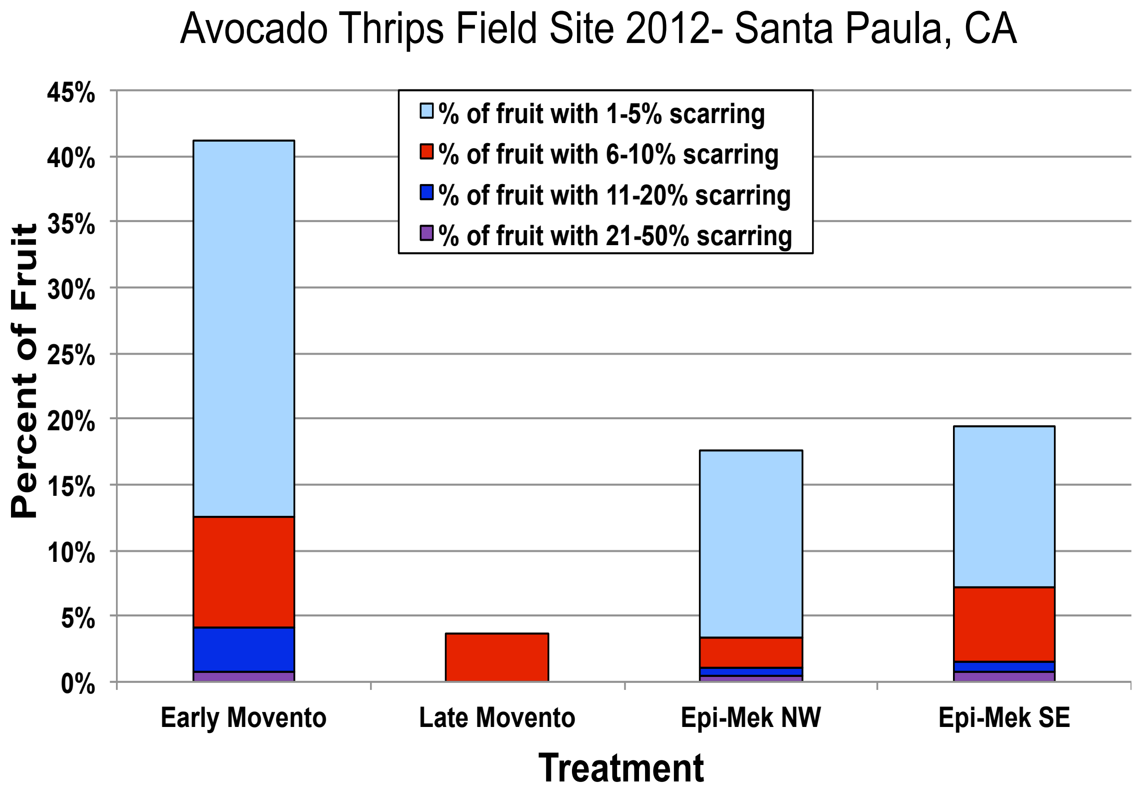
Results

Take a look at thrips infestation level graph above – probably just by chance, thrips levels on April 30 in the two Movento plots were about double those counted in the two abamectin plots before any treatments went on. The only spray applied May 2 was the 5 acres of "early Movento" and thrips levels as measured May 10 (8 days after treatment) dropped quite a bit in this plot and remained low through the last count on July 5. The other 3 plots were treated on June 1, the day after the May 31 counts. Immature thrips levels assessed on June 11 were somewhat higher in the late Movento plot compared with other plots but based on the fruit scarring data, it appears likely these thrips were not feeding and were in the process of dying (Movento is quite slow acting).

See the fruit scarring figure below. Percent of fruit scarred by avocado thrips were 41.2% with the early Movento treatment (4.2% of this was severe [economic] scarring), 3.6% with the late Movento treatment (1.0% severe), and 17.6 and 19.4% with the late abamectin treatment (1.0 and 1.4% severe).

Discussion and conclusions

In past years, we have used 10% of the fruit surface area scarred by avocado thrips (the 1 to 10% scarring category) as the threshold for what might typically be ignored in the packing house and lead to the fruit still being marketed as first grade. With the increase in volume of fruit available in the marketplace due to imports from Mexico and Chile (and perhaps in 2012 in part because of the very large CA crop), this threshold might be 3-5% of the surface area at the time. Based on the 10% threshold, all treatments were fairly effective in reducing economic scarring. Based on fruit scarring, it appears the early Movento treatment might have gone on too early (we are still learning how to best time Movento applications).



E2. Fallbrook avocado thrips field trial

The second field trial during spring 2012 was done near Fallbrook with hand gun application to 11 plots; 2 plots each were used for the abamectin standard, untreated control, and Movento application and 1 plot each was treated with Sivanto, Bexar, Closer, NNI-0101, and NR-415 oil alone; Morse lab personnel took leaf infestation counts both pre-treatment and on 7 dates post-treatment as well as fruit scarring evaluations; consistent with earlier studies, Movento impact on thrips was slow, taking several weeks for tree uptake and depression of thrips levels; thrips recovered to higher than control plot levels in both the abamectin and NNI-0101 plots by 49 days post-treatment; results with Sivanto, Bexar, and Closer were all quite impressive (this is the first field trial with all 3 of these new products on avocados);

We had planned the above field trial mainly as a Movento study and only included NNI-0101, Sivanto, Bexar, and Closer at the last minute; it is fortunate we did this – results with Bexar and Closer were encouraging and suggest we need to make both a high priority for further study so that one of them might be selected for submission to IR-4; the strong results with Sivanto may make it possible to make this product available for use on avocados whereas it otherwise might have missed a one-time opportunity to accomplish this; Bayer ran into an unfortunate situation with their submission of Tier 3 Movento label requests – this entailed re-review of all Tier 1 and 2 submissions and the temporary cancelling of all Movento labels in the U.S.; as a result of this experience, they plan only 2 Sivanto submissions to EPA – Tier 1 label requests were submitted late 2012 (anticipated registration Quarter 2 of 2014 if all goes well) and their final and last package of submissions is scheduled for Quarter 1 of 2015 – avocados either make it into this package or they do not; it is thus too late to get Sivanto into the IR-4 program; however, our data may have convinced Bayer to start work on Sivanto – this is their preliminary assessment and we plan spring 2013 avocado thrips field trials to cement this assessment; it is notable that as of November 2011, Sivanto was not on our radar for avocados and it has now moved to near the top of our priorities for spring 2013 research – this is a good example of the need to modify future research plan based on research results.

Materials and methods

An avocado thrips (*Scirtothrips perseae* Nakahara) trial was run during spring 2012 in Fallbrook, CA to evaluate six chemical treatments as well as an untreated control and oil treatment (see the following table for treatments and rates). Pre-treatment counts of immature avocado thrips were taken on 8 single tree replicates, 4 leaves per tree in the center of each plot and in the same way 11, 18, 26, 35, 49 and 67 days post-treatment.

This was a grove of 25-year old top-worked (in March 2011) Hass avocados planted in 15' by 20' rows on steep hillsides (ca. 145 trees per acre). Trees were about 6'-8' high and 5'-6' wide. There were 11 plots of differing sizes (ca. 30-60 trees per plot) spread over 2-4 acres blocks on the ranch. Plots for treatments that required crop destruct (Bexar, Closer, NNI-0101, Sivanto) were intentionally made smaller to avoid excess fruit drop in order to hold the cost of crop destruct down. Trees were flushing throughout the study due to vigorous regrowth following top working and mild weather.

We had two plots per treatment with 3 treatments (Movento, Untreated control, Epi-Mek standard) and a single plot with the remaining 5 treatments. All trees in each plot were treated, i.e. there were a number of treated buffer trees around the center 8 data trees. All treatments (except the untreated control) included 0.5% NR-415 spray oil. Spray dilution rates were calculated based on per acre use rates with a dilution of 300 gpa. Treatments were applied April 5-6 using a 4-gallon SP Systems Professional backpack sprayer. This applied a light mist spray to all trees.

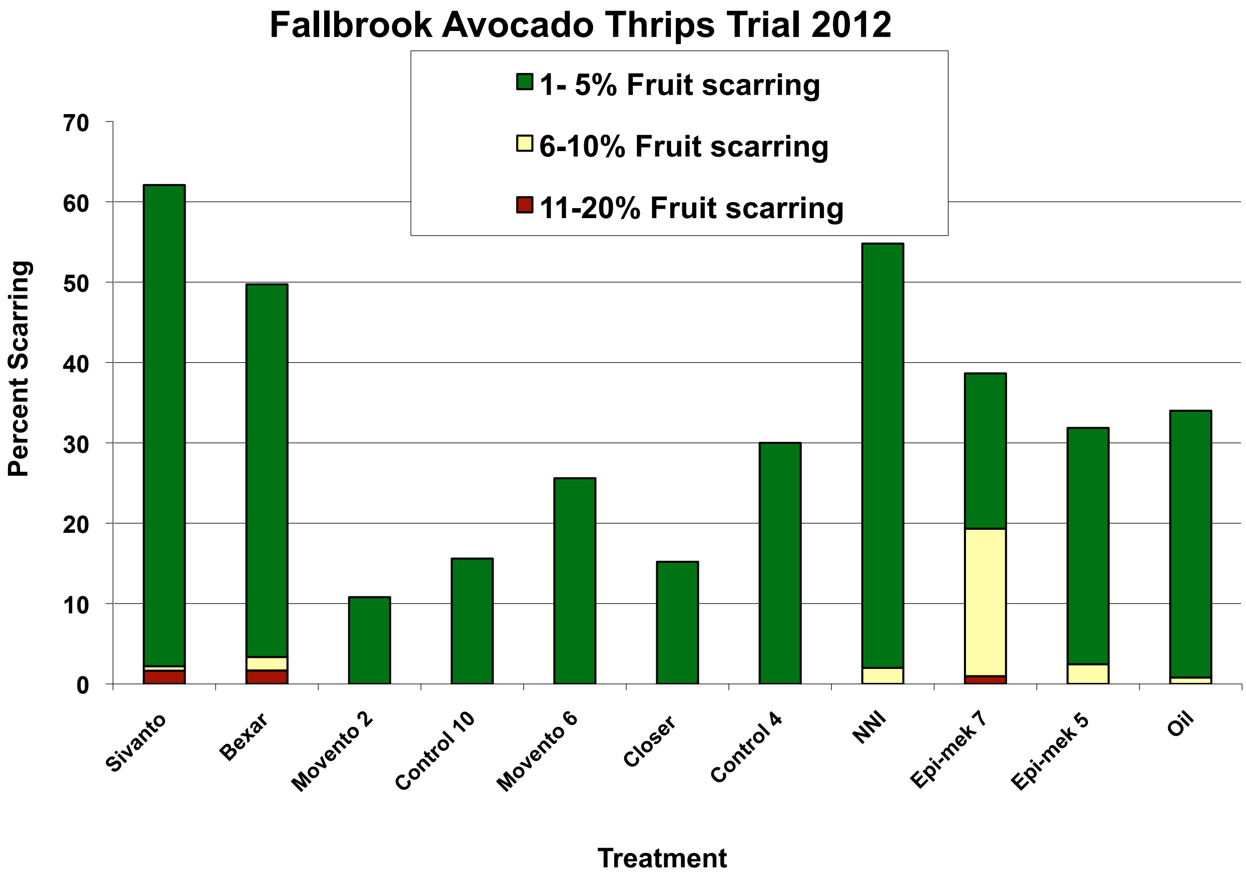
Results

In the following table, data are shown separately for each field plot (i.e. treatments with two plots are shown twice) and there were differences between thrips levels in various plots receiving the same treatment. For example, the control plot 10 had lower initial levels, which never seemed to build like levels in control 4. All treatments showed good control of immature avocado thrips out through day 35 post-treatment. Movento appeared to take slightly longer to knock the thrips down in plot 6, but starting with day 26, levels in that plot were quite low until day 67. We have no good explanation for why the 0.5% NR-415 oil by itself appeared to be so effective (but remember these were small trees, hand application by ground). One explanation is that thrips levels never built in that plot throughout the trial – one certainly would not expect to see much impact from oil beyond 3-4 weeks. A second possibility is because this plot was large (ca. 60 trees), initial knockdown was quite good and little immigration occurred into the center 8 data trees because of the abundance of flush on most trees.

	Date counted	spray on 4/5/12	4/3/12	4/16/12	4/23/12	5/1/12	5/10/12	5/24/12	6/11/12	
	Days pre or post Apr 5		-2	11	18	26	35	49	67	Thrips days[a]
			Mean number of immature avocado thrips per leaf							
Plot 11	NR-415 Oil	0.5%	2.3	0.8	0.9	0.1	0.2	0.0	1.8	29.0
Plot 2	Movento	10 fl oz/a	4.7	1.6	1.8	0.1	0.2	0.1	1.6	38.3
Plot 1	Sivanto	14 fl oz/a	2.7	0.0	1.8	0.2	0.7	0.3	3.3	57.4
Plot 9	Bexar 15 SC	27 fl oz/a	10.2	0.7	1.9	0.7	0.5	0.8	2.8	65.7
Plot 10	Untreated control	---	2.2	1.5	1.1	0.9	0.5	0.3	4.0	67.7
Plot 3	Closer 2 SC	8.5 oz/a	6.7	0.5	1.3	0.1	1.4	2.6	4.6	110.4
Plot 6	Movento	10 fl oz/a	4.7	2.6	6.0	0.5	0.4	0.3	5.2	114.6
Plot 7	Epi-Mek 0.15 EC	10 fl oz/a	12.2	0.7	2.1	0.2	0.1	5.0	11.7	206.4
Plot 8	NNI-0101 20 SC	6.4 fl oz/a	4.0	1.1	1.8	2.1	1.6	9.6	12.1	315.5
Plot 4	Untreated control	---	8.9	7.0	8.7	8.7	5.2	7.7	7.3	412.4
Plot 5	Epi-Mek 0.15 EC	10 fl oz/a	3.9	0.3	0.8	0.2	0.1	22.8	14.6	506.1

[a] Thrips-days calculated from 4-16-12 to 6-11-12.

Morse lab personnel took scar counts of the percent of the fruit surface area that was scarred by avocado thrips on up to 250 fruit, concentrating on the 8 data trees in the center of each plot (in some cases, there were not enough fruit on those trees and fruit on trees out to the border of the plot were assessed). The following graph shows the percent of fruit that had 1-5% of the surface area scarred, the percent with 6-10% scarred, and the percent with 11-20% (only 3 fruit had 20% and none more than this). If there were not 250 fruit on the 8 data trees, additional fruit were located on trees throughout the plot (some trees had very few fruit). Small tree size and smaller plots with unregistered products made it difficult to locate 250 fruit in all plots (all had 250 fruit rated except #9-Bexar 179, #1-Sivanto 182, #5-Epi-Mek 204, and #7-Epi-Mek 207).



Discussion and conclusions

In past years, we have used 10% or more of the fruit surface area scarred by avocado thrips (the 11 to 20% scarring category in this case) as the threshold for what might typically be ignored in the packinghouse and lead to the fruit being marketed as first grade fruit. With the increase in volume of fruit available in the marketplace due to imports from Mexico and Chile as well as the large 2012 CA crop, we lowered the economic threshold to 5% or more of the surface area. Based on the 5% threshold, all treatments were fairly effective in reducing economic scarring with the exception of one of the Epi-Mek plots (#7).

E3. Investigation of poor abamectin control of persea mite, Ventura Co.

A PCA contacted us during the summer of 2012 and asked that we check for abamectin resistance at a field site where less than expected persea mite control was achieved. Unfortunately, a heat spell prior to mite collection knocked down field levels so we were able to do only a limited test. Whenever testing for persea mite abamectin resistance, we use data from Humeres and Morse (2005) for comparison.

Materials and methods

Several diagnostic rates of abamectin were mixed in a 1-liter glass container placed on a magnetic stirring plate to keep the solution dissolved. Commercial Agri-Mek 0.15 EC was used and Triton X-100 was added to all treatments including the water control at 0.1% (only because this is how it was done in Humeres and Morse 2005). Our normal method is to test 4-5 rates and a control with 5 leaves per rate with 20-30 adult persea mites transferred to each leaf using a small brush. Due to a shortage of mites to test, we had to cut back this test to 2 leaves per rate for 2 rates and the control. Fully expanded but dark green (recently mature) leaves were selected from untreated trees in Field 13F on the UCR campus. They were picked and washed to remove dust and then after drying, dipped for 8 seconds in the pesticide solution. After allowing them to dry on paper towels, they were placed abaxial surface up (under surface) on a wet sponge in a plastic sandwich container. Strips of felt held both end of the leaf on the wet sponge and Tree Tanglefoot Pest Barrier was used to ring the leaf to contain the mites inside the ring. The lid of the tray had 4 holes for ventilation. 20-30 adult female persea mites were transferred to each leaf and mortality was assessed after 72 hours by lack of normal mite movement after it was prodded with a brush. Data are corrected for control mortality using Abbott's (1925) formula and are plotted in comparison to previous baseline abamectin data (see Humeres and Morse 2005).

Results

Mite infested leaves were picked from the field on 7 August 2012 and the test was done on 10 August. Control mortality on two leaves was 7.85% (4/51 mites dead) and corrected percent test mortality at 1.0 and 5.0 mg AI/liter abamectin was 92.60 and 100% (43/46 and 47/47), respectively. No mites were found trapped in the Tanglefoot.

Discussion and conclusions

Data were consistent with those from susceptible populations of persea mite from Humeres and Morse (2005). We communicated this to the PCA and offered to do a follow-up bioassay once persea mite levels recovered from the heat but he did not take us up on that offer.

<u>E4. Highlights of other activity during 2011-12 (partial list)</u>

- 5 March 2012 presentation by Morse at the PRC meeting at CAC headquarters in Irvine; Made a Powerpoint presentation summarizing research being done by 4 research teams: Byrne and Morse (Systemic research, Pest Management Alliance proposal), Millar (Pheromone research), Stouthamer and Morse (armored scale research), and Morse (avocado thrips and persea mite research);

- 8 March 2012 – series of 5 emails with an avocado grower interested in trying aerial applications of Movento for control of avocado thrips; arranged for Bayer to donate product so that he could try this material and provided recommendations on gallonage, timing, and addition of surfactants;

- March 2012 input provided on tydeid mites found infesting avocado budwood shipped overseas (5 emails over time provided in response);

- March 2012 response to request from the Santa Barbara Ag Commissioner's office for information on avocado shot hole borer;

- 20 March 2012 – response to grower who was concerned about scarab beetles seen in his avocado grove after he had spread cured horse manure for fertilization; suggested there was no likely reason for concern as these were likely common dung beetles (clear from pictures he sent) but if he put some with manure in a jar for a month, we could identify the adults that emerged (he chose not to bother);

- Presentation by Morse, 27 March 2012 at the Bayer Research Exchange in San Diego, CA – "Management of Persea Mite and Avocado Thrips on Avocados" (an important meeting based on a meeting with John Bell of Bayer to map out Sivanto registration on avocados – see below);

- 2 April 2012 field meeting (commercial avocado grove in San Diego Co.) with Bayer product manager John Bell and research specialist McNally – discussed what was needed to get Sivanto registered for use on avocados (material that can be used <u>during bloom</u> by heliocopter with no reservations regarding honey bees);

- Presentation by Morse at a UC Davis Workshop (Re-Conceiving Policies for Invasive Insect Pests), 14 May 2012 on "A New Paradigm for Intervention Strategies with Invasive Species". This talk focused on the need to change how U.S. commodities are protected from invasive species entering the U.S. – the consensus is the present system is broken and new strategies need to be explored; an article for the high visibility journal Science is planned but should have been further along by now;

- 15 May 2012 response on defect seen on avocados supposedly caused by insect feeding;

- 20 June 2012 presentation by PCA Tom Roberts (PowerPoint file provided by Morse) in Santa Paula, CA -- "Management of Persea Mite to Reduce the Potential for Miticide Resistance";

- 27 June 2012 presentation by Morse (modified above ppt somewhat) in Irvine, CA -- "Management of Persea Mite to Reduce the Potential for Miticide Resistance";

- 15 July 2012 response to grower request for information on high levels of avocado looper;

- 22 July 2012 response to PCA about aphids seen on avocado; arranged for specimens to be sent to the CDFA Plant Pest Diagnostic lab for identification;

- 27 August 2012 presentation to the PRC in Irvine on the new 5-year project proposed by Morse and Byrne (Sustained Chemical Control of Avocado Arthropod Pests - project ended up being funded);

- 31 August 2012 response to PCA on high levels of torpedo bug (presumed *Siphanta acuta*) seen on avocados;

- 22 September 2012 – 4 changes submitted to avocado pest management guidelines;

- 26 September 2012 response on grower question about a greenhouse thrips problem on avocados;

- Publication accepted by the Journal of Economic Entomology by Zahn and Morse titled "Investigating Alternatives to Traditional Insecticides: the Effectiveness of Entomopathogenic Fungi and *Bacillus thuringiensis* against Citrus Thrips and Avocado Thrips". The study evaluated both inactivated and activated forms of two Bt endotoxins (Cyt1Aa and Cry11Aa) as well as 6 strains of *Beauveria bassiana* (Bb) against both species of thrips; the Bt endotoxins showed little activity against either thrips species; none of the Bb strains were sufficiently efficacious against avocado thrips to pursue further but were against citrus thrips;

- Presentation by Morse, 14 November 2012 in Santa Paula, CA at a CAPCA meeting – "Best Practices for Pesticide Use with Avocado Thrips and Persea Mite / Resistance Management in Avocados".

OVERALL PROJECT SUMMARY

A major accomplishment of this project were to help support the registration of new products for control of avocado thrips and persea mite on avocados and then once materials were registered, to work with PCAs and growers to evaluate these materials. This project ran 5 years 11-1-07 through 10-31-12. Materials registered just prior to (Delegate) or during this project included Delegate (2007), Danitol (2010), Envidor (2010), Movento (2011), and Zeal (2012).

A good question is whether some or all of these products would have been registered without our project. Some certainly would. If we hadn't done the work, perhaps CAC would have arranged for someone else to do it. However, Morse has worked with the involved chemical companies for 30 years on citrus, often evaluating the same products against citrus thrips or mites several years prior to when they were evaluated on avocados, we can conservatively say that without our efforts, registrations would not have occurred as quickly as they did.

Over the 5 years of this project, new and recently registered products were evaluated against persea mite in 7 trials (counting the 6 San Marcos groves treated in summer 2011 as 1 trial) and against avocado thrips in 15 trials.

Based on the results from these field trials, two recent publications were produced for the CAS Yearbook that summarize much of the history of research on avocado thrips (Morse and Hoddle 2012) and persea mite (Hoddle and Morse 2013). **These include a tabular summary of all of the products that are registered or nearing registration for control of avocado thrips and persea mite as well as our recommendations regarding how growers and pest control advisors should best use these products.**

We have done our best to inform growers regarding the dangers of abamectin resistance. A good question is whether growers and PCAs will show enough restraint so this does not occur soon. Certainly we would be receptive to working with the CAC to get the word out further.

The spring 2012 Fallbrook field trial has identified 3 new products that show good potential for control of avocado thrips (Bexar, Closer, and Sivanto). Based on this trial, discussions with Bayer personnel 3-27-12 in San Diego, and the avocado grove visit by Bayer product manager John Bell 4-2-12 (and the releationship we have developed with him over the past 10 years), we can take credit for moving this material toward registration on avocados. It was a near thing – at first, we were told that Sivanto would not be included in the Tier 2 (final) registration package planned for submission to EPA in 2015. If so, this product would likely **never** be registered for use on avocados (unless Bayer were to relent from their stated position – IR-4 will generally not support a registration if the company is opposed and Bayer insists there will be no Sivanto submissions after Tier 2). Recently, Bayer agreed to start residue work with Sivanto on avocados and they indicate avocados will be included in the Tier 2 package.

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