Insect and Mite Research

Project No.: **10-ENTO7-Zalom**

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Interpretive Summary:

This project continues to address the most significant chronic pest of almonds with a long-term production perspective. In this year, our focus remained evaluating efficacy and treatment timing for the navel orangeworm (NOW) and the peach twig borer (PTB) at the May spray timing, with emphasis on products with more specificity that we assume will be less disruptive of naturally occurring biological contro agents. Two field studies were conducted that indicated a number of products can control either or both insects at this time. The recommended May spray timing overlaps sufficiently such that a well-timed spray using a degree-day model for both insects can render control of the first generation larvae. If NOW is the primary pest targeted, the earliest treatment timing we evaluated (NOW biofix) with either Altacor or Intrepid might be better than the traditional 100 degree-days timing, although significant control was achieved at all treament timings. A study of 11 almond varieties indicated that NOW generally show improved survivorship and earlier emergence in almonds with both pedicel and shell damage, and have decreased survivorship and later emergence in almonds with undamaged shells. However, almond variety impacts the responses and performance of NOW, and interactions between variety and almond damage are also important. A laboratory study intended to determine comparative impacts among pyrethroid insecticides on female *Galendromus occidentalis* survivorship indicated that all of the pyrethroids applied by direct contact to *G. occidentalis* caused a significant decline in survivorship. A field study of *G. occidentalis* survivorship on twigs collected from trees treated at hullsplit with either bifenthrin (Brigade) or λ-cyhalothrin (Warrior) showed reduced survivorhsip relative to untreated control trees on both November 25 and February 16 sampling dates. Survivorship was not significantly reduced on twigs from the bifenthrin treated trees collected on the day following treatment, but it was significantly lower on twigs from the λ-cyhalothrin treated trees.

Objectives:

1. Purchase pheromone traps, navel orangeworm (NOW) bait traps, and lures for UC Cooperative Extension Farm Advisors for their ongoing monitoring and extension efforts.
2. Evaluate efficacy and May treatment timing for newly registered and candidate insecticides against peach twig borer (PTB).
3. Evaluate efficacy and May treatment timing for newly registered and candidate insecticides against navel orangeworm; Conduct associated research on NOW development on selected varieties.
4. Determine direct and residual effects of 4 pyrethroid insecticides on *Galendromus occidentalis.*

Materials and Methods:

Objective 1. Monitoring. Each year through this project, trapping supplies are purchased for use by UC Cooperative Extension Farm Advisors to help them monitor the phenological activity of almond insect pests in their counties. The Advisors use the data gathered from these traps to update pest status for local growers and PCA's. Continuing to coordinate regional insect trapping and collaborating with new monitoring research allows for consistency and improvements in this important component of almond IPM.

Objective 2. Peach twig borer. May sprays offer the potential to obtain some level of control of NOW, which has flights that overlap somewhat with PTB flights in many years. May sprays also have an advantage over hullsplit sprays in that there will be less overlapping of generations earlier in the season, making May spray timing (and therefore efficacy) more precise. The current May spray timing recommendation (400 degree-days after the start of the spring flight is based on research developed for organophosphates that cause direct mortality to the PTB larvae. Many of the newer insecticide products have different modes of action, so spray timing may need to be earlier (or later) relative to products that kill larvae directly. For the third year, in Spring, 2011, we evaluated products that could be used at the May spray timing and multiple timing for selective products.

This year's study was conducted on second leaf almonds in collaboration with Sutter County CE Farm Advisor, Franz Neiderholzer at a site east of the Sutter Buttes and northwest of Yuba City. Treatments were applied to Nonpariel, Monterey and Wood Colony varieties that were grafted on Krymsk rootstock. The treatments were blocked by variety with 2 replicates of each insecticide treatment for each variety (6 replicates in all). The PTB biofix for the site was determined to be April 23, and the navel orangeworm biofix May 13. PTB pheromone traps and navel orangeworm (NOW) egg traps were deployed to determine biofix for the first flights of both species so that degree-days could be calculated to time treatments. It was our intention to base the treatments on degree-days (DD), so most applications were applied at a timing intended to be about 400 DD, the treatment timing for PTB recommended in the *UC Pest Management Guidelines for Almonds*. The actual application date was May 24, 2011, at 383 PTB DD. One Bacillus thuringiensis product, Dipel, was applied twice, on May 9 (211 PTB DD) and on May 24. Two products, Intrepid and Altacor were applied once on May 24 and separate trees at earlier (May 13, 0 NOW DD) and later (May 26, 91 NOW DD) treatment timings as well. All sprays were applied at the equivalent of 100 gal of water per acre with an Echo Duster-Mister Air Assist Sprayer. PTB shoot strikes were evaluated on June 22, 2011, at 870 PTB DD following biofix. As in 2010, unusual rainy periods and cool temperatures occurred in May following biofix of both PTB and NOW, so it is possible that the rains may have killed some of the early emerging moths or their eggs, creating the equivalent of a later moth emergence. Data were anlyyzed by one way ANOVA and treatment means separated from the untreated control by Student's t-test.

Objective 3. Navel orangeworm. As mentioned for PTB, the 'May spray' timing offers the potential to obtain some level of control of both NOW and PTB as these insects have flights that overlap somewhat in many years. The current May spray timing recommendation for NOW in the *UC Pest Management Guidelines for Almonds* is 100 degree-days after the first eggs are laid for 2 consecutive sampling periods on egg traps. The site of our May navel orangeworm control study was a mature almond orchard near Ripon, but in San Joaquin Co. The block had not been treated by the grower and had a mummy load recorded on April 13, 2010, averaging 3.1 per tree on the Nonpariel trees and 22.5 on the Fritz trees, when NOW egg traps and PTB pheromone traps were hung to establish the biofix for each species. Ten black navel orangeworm eggs traps were hung for better resolution of a biofix. The first eggs were found on April 19, 2010, and we set the biofix at May 1 at which time 5 of the 10 traps had eggs (avg. 4.6 eggs for the 10 treaps. PTB biofix was established as April 19.

All products were applied as close to the treatment timing for NOW as practical. Three products, Intrepid, Altacor and Delegate were applied at earlier and later treatment timings as well. Uninfested nonpareil mummy nuts with hulls intact collected in Fall, 2009, were hot glued to the outside of strands of vegetable mesh during April, 2010, and 236 strands were prepared in all. These sentinel mummies were hung at mid-canopy in Nonpareil trees on April 30, 2010, the day before the May 1 biofix date, as close as possible to the first date for exposure to navel orangeworm egg laying. There were 19 treatments (**Table 1**) in all, with 11 mummy strands allocated for each treatment plus 22 strands for a water-only control. Treatments of Intrepid, Altacor and Delegate were applied directly to the strands at 3 timings, April 30 (0 NOW DD), May 13 (99 NOW DD), and May 31 (equivalent to 441 PTB DD). The equivalent spray volume was 100 gpa. The mummies were removed from the trees on July 16, 2010 when 976 NOW DD had been accumulated, and hand-cracked for identification of larvae or evidence of NOW feeding. Data were analyzed by one-way analysis of varience (ANOVA) and treatment means compared by Student's t-test.

We are repeating the 2010 experiment on efficacy of products at the May spray timing for NOW in 2011 at another site near Ripon. Biofix dates were May 10 for NOW and April 22 for PTB. Treatments with all products were made on May 25 at 96 NOW degree-days (as near to the recommended 100 NOW DD as practical). In addition, treatments with Altacor, Delegate and Intrepid were made at the biofix for NOW (May

10) and near the recommended PTB DD treatment timing May 27 at 360 PTB DD). The sentinel mummies that we deployed were collected July 11, and are being evaluated for presence of NOW and damage at this time and data will be presented in next year's annual report.

Table 1. Products evaluated for navel orangeworm control at 'May Spray' timings, San Joaquin County, 2010.

Product	Chemical name	IRAC #	Rate (form/ac.)	Date	DD
Control (water)					
Belt[1]	flubendiamide	28	4.0 oz	5/13/10	99 NOW
Tourismo[1]	flubendiamide, buprofezin	28,16	14.0 oz	5/13/10	99 NOW
Tourismo[1]+ Warrior	flubendiamide+ buprofezin	28+16	14.0 oz+ 5 oz	5/13/10	99 NOW
Athena EW[2]	bifenthrin+abamectin	3/6	27.2 oz	5/13/10	99 NOW
Brigade 10WP	bifenthrin	3	0.5 lb	5/13/10	99 NOW
Assail 30SG[2]	acetamiprid	4A	6.4 oz	5/13/10	99 NOW
Bifenture 10DF[2]	bifenthrin	3	16.0 oz	5/13/10	99 NOW
Lambda-Cy 1EC	lambda cyhalothrin	3	5.0 oz	5/13/10	99 NOW
Intrepid 2F[3]	methoxyfenozide	18	16.0 oz	5/31/10	441 PTB
Intrepid 2F[3]	methoxyfenozide	18	16.0 oz	4/30/10	0 NOW
Intrepid 2F[3]	methoxyfenozide	18	16.0 oz	5/13/10	99 NOW
Delegate[3]	spinetoram	5	6.4 oz	5/31/10	441 PTB
Delegate[3]	spinetoram	5	6.4 oz	4/30/10	0 NOW
Delegate[3]	spinetoram	5	6.4 oz	5/13/10	99 NOW
Altacor 35WG[3]	chlorantraniliprole	28	4.0 oz	5/31/10	441 PTB
Altacor 35WG[3]	chlorantraniliprole	28	4.0 oz	4/30/10	0 NOW
Altacor 35WG[3]	chlorantraniliprole	28	4.0 oz	5/13/10	99 NOW
Proclaim	emamectin benzoate	6	4.0 oz	5/13/10	99 NOW
Voliam Xpress	lambda-cyhalothrin, chlorantraniliprole	28/3	7.0 oz	5/13/10	99 NOW

[1] Mixed with a NIS surfactant at 0.25% v/v.
[2] Mixed with Dyne-amic at 0.25% v/v.
[3] Mixed with Induce at 1.0% v/v.

A study of NOW infestation from the 3 almond variety trials - Chico, Kern County, and Manteca - with regard to hullsplit date and shell seal that was conducted in part by a visiting scholar to my lab from China Agricultural University in Beijing and in collaboration with Bruce Lampinen and Tom Gradziel was published in 2011 (Hamby et al., 2011). Results of that study showed that hullsplit date and shell seal were significantly related to damage across varieties as expected, but there were a few varieties in those trials (some of which are not grown commercially) that seemed to have more or less damage than the average as measured by hullsplit date or shell seal alone. As a follow up to that study, we initiated a study to determine NOW development on several of those varieties. Jim Burkhard, who manages the planting at Delta College, has allowed us to collect nuts at harvest from the varieties of interest that remain at the Manteca site. The varieties we chose were based on their economic significance, or had higher or lower than expected NOW infestation based on regression analysis across years for hullsplit date or lower than expected infestation based on shell seal. To ensure uniform nut maturity, almonds of each variety were collected immediately after being shaken from trees on the following dates: Nonpareil (August 31, 2009), Johlyn, Livingston, Wood Colony, Padre, Price, Sonora, Plateau, and Aldrich (September 21, 2009), Monterey and Carmel (October 5, 2009). The nuts were returned to UC Davis for several experiments. Ten nuts of each variety were placed wide mouth tapered pint canning jars covered with stainless steel wire mesh and twenty mated female moths transferred to each container. Treatments included 4 replicates of each variety for the following treatments: nuts in shells, shelled nuts with skin intact, and shelled nuts scratched with a sterile paper clip. There were 66 jats total. These nuts were then held within an environmental chamber at 16:8 (L:D) photoperiod at (27^{o}C). Once pupae were observed, arenas were examined at approximately 1:00 pm daily to standardize the post-eclosion drying time for weight measurements. Emerged moths were removed and weighed. Individual moths were captured in 20-ml disposable glass scintillation vials (Fisher Scientific, Pittsburgh, PA) and mg weight measurements were obtained by weighing individual moths in vials using a Mettler Toledo AB104-S balance (Mettler Toledo, Columbus, OH). Gender was determined by visual inspection, after which moths were removed and the weight of the glass vial was recorded in order to obtain the moth weight. Emergence dates were recorded and days to emergence were used to determine thermal summation expressed as Fahrenheit degree days. The experiment was considered complete after two successive days with no moth emergence. A Cox proportional hazard model was used for survival analysis in the form of a hazard function that includes an interaction between treatment and variety: $h(t{:}\mathrm{X}) = h_0(t) \exp \{\mu+\alpha_i+\beta_j+ (\alpha\beta)_{ij}\}$. Comparisons between each variety and Nonpareil were generated using parameter estimates and standard errors with Nonpareil as the reference variety. A Z-statistic and corresponding 2-tailed *P*-value was subsequently calculated. ANOVA was used to compare moth weights using a general linear model. A third experiment to consider preferenceis has been set up in the field, but is still underway. Data from the preference study will be reported in next year's annual report.

Objective 4. Predator mite and spider mite research. As an extension of our 2009 studies on direct and/or residual effects on *G. occidentalis* of the reduced-risk insecticides being evaluated in our PTB and NOW experiments, we proposed to determine direct and residual effects of 4 pyrethroid insecticides on this predator mite. The reason for doing this study was that some of these registered pyrethroid insecticide represent somewhat different chemistry and may therefore have somewhat different effect than we had showed in previous studies of esfenvalerate (Asana) and permethrin (Ambush or Pounce) that proved devastating to *G. occidentalis*.

For the laboratory study, we exposed the female predators by treating them on leaf surfaces with the same concentration of each product that would be used in the field (contact assay) or by transferring females to previously treated and air dried leaves (residual assay), then determined female adult survival, number of eggs laid and percent eggs from which live offspring emerged. This enabled us to calculate the total effects (*E*) of each pesticide for *G. occidentalis* exposed directly to sprays and by contact with recently dried residues. Pacific mite, *Tetranychus pacificus*, which were used as prey for the predator mites, and *G. occidentalis* colonies were maintained on cotton seedlings in growth chambers at 24±1ºC, 75-85% RH and 16:8 photoperiod. The source of our *G. occidentalis* colony is Sterling Insectary (McFarland, CA). The bioassay unit consisted of three leaf discs placed on wet filter paper inside of a covered 90 mm diameter Petri dish. The Petri dish cover had three 6 mm diameter holes covered with fine nylon mesh to prevent excessive humidity, provide ventilation and prevent escape. Bioassays were conducted at 27±1ºC, 50-60% RH and 16:8 photoperiod. Five adult *G. occidentalis* females eclosed on the same day that were allowed to mate were transferred onto each leaf using a fine camel hair brush. An excess of spider mite active stages and eggs were transferred to each leaf daily as needed for food for the predators and to discourage cannibalism. Mortality and fecundity were recorded on the third day, and the *G. occidentalis* females were then removed. Fertility (number of offspring produced from the eggs that were laid) was determined 3 days after the females were removed. There were seven replicates of the bioassay units representing each insecticide treatment and the untreated control.

The field study was conducted at Nickel's Estate in Colusa County. Nonpareil and Butte variety almond trees were treated at hullsplit (August 5) by handgun sprayer to runoff with the pyrethroids bifenthrin (Brigade) at 94.64 ppm or lambda-cyhalothrin (Warrior) at 44.53 ppm with 4 additional trees of each variety remaining untreated as controls. There were 4 single tree replicates of each treatment with one tree left untreated between each treated tree as a buffer. Treatments and varieties were assigned in a completely randomized design. Twigs were sampled from the trees the day following application, before leaf fall on November November 25 to coincide with the timing of natural predator movement off of the foliage and onto the bark where they would normally overwinter, and after bloom on February 16. Twigs were placed into washed glass jars, and frozen at -20˚C within 4 hours of collection. Half of the twigs collected were randomly selected and sent to Environmental Micro Analysis Inc. (Woodland, CA) for analysis of surface residues of both products, and half were used for laboratory bioassays to determine the effect of remaining residue on *G. occidentalis* females which would normally be overwintering on bark. The twigs used for the bioassays were cut into 3.0 cm lengths and split in half lengthwise. Five twigs from a single treatment were placed in a Petri dish on top of moistened filter paper. One replicate of each treatment consisted of 4 dishes (20 twigs) and each treatment was replicated four times. Two-spotted spider mite eggs were transferred to these twigs as food, and then 2 adult female *G. occidentalis* were transferred onto each twig. Female survival and fecundity (number of eggs laid) were determined every 24 hours for 3 days. Eggs laid were transferred to an untreated cowpea leaf and observed for 6 days to determine fertility (percent of eggs that hatched). For residue analysis, measured branch segments were placed into a 236.6 ml amber glass jar with a Teflon-lined screw cap, and 100 ml of acetone were added. Contents were swirled for 1 hr, then left to sit overnight. A 50 ml aliquot was removed from the jar into a 50 ml graduated test tube. Its contents were concentrated to dryness on a 45° C N-evaporator and then reconstituted with hexane. The extract was cleaned using a 500 mg florisil SPE column followed by a carbon/amino SPE column. The eluant was concentrated just to dryness and increased back to 1 ml with toluene. The extracts were analyzed on a Varian 3400 gas chromatograph (Agilent Technologies, Folsom CA) equipped with dual columns and dual electron capture detectors. The amount of pyrethroid was calculated based on external standards, and the amount per unit area reported. Dibutyl chlorendate served as the surrogate for this experiment.

Statistical analysis. Mortality was analyzed using a generalized linear model with a binomial response function (adjusted for over-dispersion). Treatment effects were further analyzed using Dunnett's adjustment for multiple comparisons. The analysis of fecundity used the response variable number of eggs per surviving female in a generalized linear model with a Poisson response function that was adjusted for over-dispersion. Treatment effects were further analyzed using Dunnett's adjustment for multiple comparisons. Mortality and fecundity for the twig residue bioassays were analyzed in much the same way employing Tukey's W-test for multiple comparisons.

Results and Discussion:

Objective 1. Monitoring. Each year through this project, trapping supplies are purchased for use by UC Cooperative Extension Farm Advisors to help them monitor the phenological activity of almond insect pests in their counties to update pest status for local growers and PCA's. The trapping supplies are standardized to insure consistency in data collected over years. For the 2011 season, supplies purchased and distributed included 220 traps of various kinds, 250 pheromone lures for peach twig borer (PTB), San Jose scale (SJS), and oriental fruit moth (OFM), and 8 lbs of NOW bait. Six Farm Advisors received these supplies.

Objective 2. Peach twig borer. This is the third year that we attempted to determine the best use of new products for control of PTB as a May spray. UC researchers have not promoted the use of May sprays for many years because of the potential for disrupting natural enemies in the orchards. When disrupted early season, it is likely for flare ups of spider mites and secondary almond pests to occur requiring repeated subsequent applications targeting these pests to achieve control. Some of the newer reduced-risk insecticides being registered for Lepidoptera pest control are potentially less disruptive of natural enemies. The May spray timing also affords the potential to obtain some level of control of NOW which has flights that will overlap somewhat with PTB flights in many years. May sprays have an advantage over hullsplit sprays for PTB control in that there will be less overlapping of generations earlier in the season that could make May spray timing (and therefore efficacy) more precise. The current May spray timing recommendation (400 degree-days after the start of the spring flight is based on research developed for organophosphates that caused direct mortality to the PTB larvae. Many of the newer insecticide products such as th insect growth regulators have different modes of action, so spray timing may need to be earlier (or later) relative to products that kill larvae directly.

ANOVA results from our 2011 study revealed significant differences between treatments (F=4.1015, df=17,113, P<0.0001). Means were separated by Student's t-test. The analysis revealed that all treatments except for the diflubenzuron (Dimilin and generic version) significantly reduced the number of peach twig borer shoot strikes relative to the untreated check (**Table 2**). None of the other treatments differed significantly from one another.

Table 2. Mean (± SD) peach twig borer shoot strikes per tree, 2011.

Treatment	Rate	Application date	PTB strikes/tree* Mean ± SD			
untreated	na	na	5.4	±	4.8	A
Dipel[1]	1 lb	5/9 & 5/24/11	2.3	±	2.9	CDE
Dimilin 2L	12 oz	5/24/11	3.5	±	3.0	ABCD
diflubenzuron 2L (generic)	12 oz	5/24/11	5.2	±	3.3	AB
Dimilin 2L + Lorsban	12 oz + 4 pt	5/24/11	3.8	±	3.5	ABC
Lorsban	4 pt	5/24/11	2.0	±	1.7	CDE
Intrepid 2F[3]	16 oz	5/13/11	2.5	±	2.0	BCDE
Intrepid 2F[3]	16 oz	5/24/11	2.0	±	1.5	CDE
Intrepid 2F[3]	16 oz	5/26/11	2.3	±	1.8	CDE
Delegate WG[3]	4.5 oz	5/24/11	0.5	±	0.5	E
Delegate WG[3]	7.0 oz	5/24/11	0.3	±	0.5	E
Altacor[2]	4.0 oz	5/13/11	0.2	±	0.4	E
Altacor[2]	4.0 oz	5/24/11	0.2	±	0.4	E
Altacor[2]	4.0 oz	5/26/11	0.3	±	0.5*	E
Assail 70WP + Lamda-Cy EC	4.1 oz + 2.56 oz	5/24/11	0.8	±	0.8	DE
Assail 70WP + Lamda-Cy EC	2.3 oz + 5.12 oz	5/24/11	0.5	±	0.5	E
Belt SC[2]	4 oz	5/24/11	0.3	±	0.8	E
cyazypyr 10SE[2]	16.9 oz	5/26/11	0.0	±	0.0	E

*Means followed by the same letter do not differ significantly at $P<0.05$ by Student's t-test.
[1] LI-700 added @ 0.5% v/v
[2] Dyne-Amic added @ 0.25%% v/v
[3] Induce added @ 0.25% v/v

The comparison of treatment timings of Altacor and Intrepid indicated that in 2011 all treatment timings were statistically equavalent for both products and significantly different than the untreated (**Table 3**). ANOVA statistics among treatment timings and in comparison to the utreated control for each product were Altacor (F=6.5318, df=3,29, P<0.0019) and Intrepid (F=2.0598, df=3,29, P<0.1301). In 2009, the earlier treatment timing was as good as or better than the treatment timing currently recommended in the *UC Pest Management Guidelines for Almonds* in all cases and in each case, and the later treatment timing was not as effective. Results for 2011 support results from 2010, which also had period of rain and cool temperatures occurring during much of mid-May, following the first application. Our PTB and NOW trap captures from the site indicate a surppression in activity during this period, much as we observed in 2010. It is possible that there was significant PTB mortality during tht period, and under such conditions perhaps resetting the biofix should have been considered.

Table 3. Effects of treatment timing for peach twig borer control when using Altacor and Intrepid, 2011.

Treatment	Rate (form./ac.)	Degree-days	Application date	PTB strikes/tree Mean ± SD
untreated	na		na	5.4 ± 4.8
Intrepid 2F[1]	16 oz	0 NOW	5/13/11	2.5 ± 2.0*
Intrepid 2F[1]	16 oz	383 PTB	5/24/11	2.0 ± 1.5*
Intrepid 2F[1]	16 oz	91 NOW	5/26/11	2.3 ± 1.8*
Altacor[2]	4 oz	0 NOW	5/13/11	0.2 ± 0.4*
Altacor[2]	4 oz	383 PTB	5/24/11	0.2 ± 0.4*
Altacor[2]	4 oz	91 NOW	5/26/11	0.3 ± 0.5*

*Means significantly different from untreated control at *P*<0.05 by Student's t-test.
[1] Induce added @ 0.25% v/v
[2] Dyne-Amic added @ 0.25%% v/v

Objective 3. Navel orangeworm. **Figure 1** presents accumulated NOW and PTB degree-days for the site, optimal treatment timings for each insect (arrows), and actual treatment timing (vertical lines). **Figure 2** shows the trap catches in comparison to accumulated degree-days. Our actual treatment timings bracketed the recommended times for both insects. ANOVA statistics revealed significant treatment differences for NOW infestation (F=7.5143, df=19,223, P<0.0001). Means were separated using Student's t-test. The analysis revealed that all treatments except for the Assail treatment significantly reduced the proportion of infested mummies (**Table 4**).

Figure 1. Navel orangeworm and peach twig borer degree-days, UC recommended treatment timings (arrows), and actual treatment dates (vertical lines).

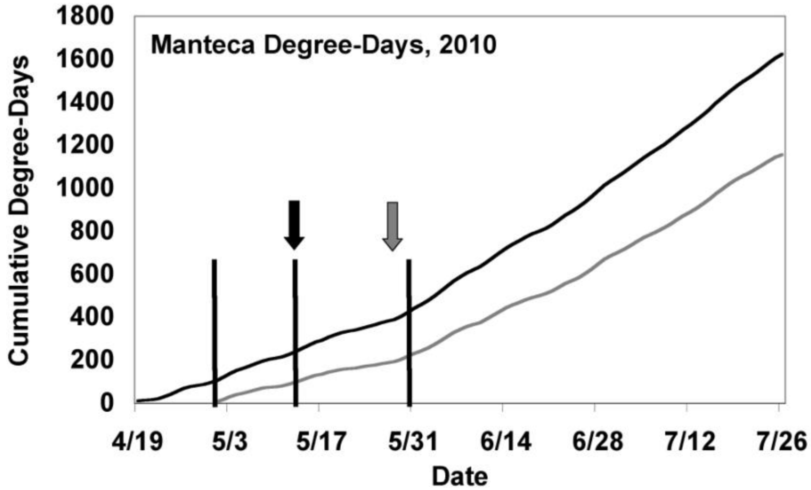
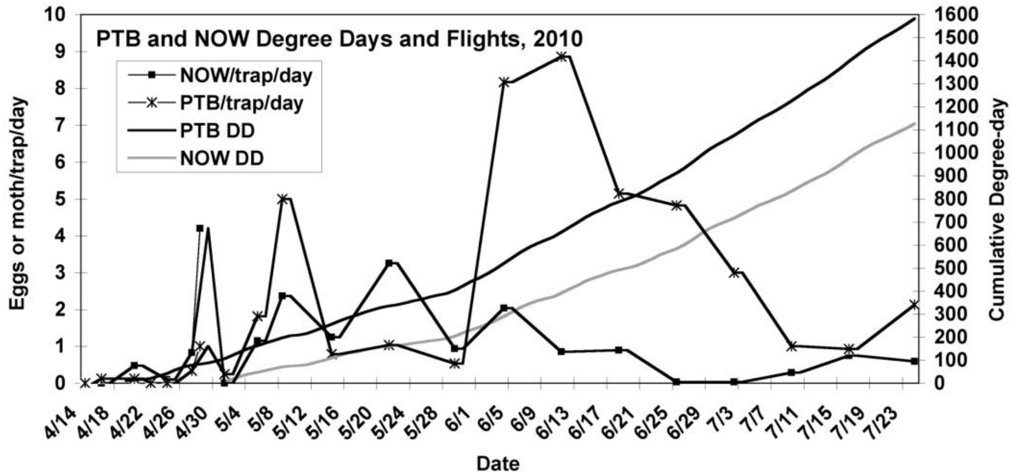


Table 4. Mean (± SD) proportion of NOW infested mummies, San Joaquin Co., 2010.

Treatment	Application date	Degree-days	n=	Proportion of nuts damaged* Mean ± SD			
Control (water)	5/13/10		26	0.14	±	0.1	A
Belt[1]	5/13/10	99 NOW	10	0.01	±	0.0	B
Tourismo[1]	5/13/10	99 NOW	11	0.01	±	0.0	B
Tourismo[1] + Warrior	5/13/10	99 NOW	10	0.00	±	0.0	B
Athena EW[2]	5/13/10	99 NOW	11	0.01	±	0.0	B
Voliam Xpress	5/13/10	99 NOW	11	0.01	±	0.0	B
Brigade 10WP	5/13/10	99 NOW	11	0.01	±	0.0	B
Assail 30SG[2]	5/13/10	99 NOW	11	0.10	±	0.1	A
Bifenture 10DF[2]	5/13/10	99 NOW	10	0.00	±	0.0	B
Lambda-Cy 1EC	5/13/10	99 NOW	11	0.00	±	0.0	B
Intrepid 2F[3]	4/30/10	0 NOW	10	0.00	±	0.0	B
Intrepid 2F[3]	5/13/10	99 NOW	11	0.03	±	0.1	B
Intrepid 2F[3]	5/31/10	441 PTB	10	0.02	±	0.0	B
Delegate[3]	4/30/10	0 NOW	10	0.01	±	0.0	B
Delegate[3]	5/13/10	99 NOW	11	0.01	±	0.0	B
Delegate[3]	5/31/10	441 PTB	9	0.01	±	0.0	B
Altacor 35WG[3]	4/30/10	0 NOW	10	0.00	±	0.0	B
Altacor 35WG[3]	5/13/10	99 NOW	11	0.02	±	0.0	B
Altacor 35WG[3]	5/31/10	441 PTB	10	0.02	±	0.0	B
Proclaim	5/13/10	99 NOW	10	0.01	±	0.0	B

*Means followed by the same letter do not differ significantly at *P*<0.05 by Student's t-test.
[1] Mixed with a NIS surfactant at 0.25% v/v.
[2] Mixed with Dyne-amic at 0.25% v/v.
[3] Mixed with Induce at 1.0% v/v.

Figure 2. Peach twig borer males and navel orangeworm eggs collected per trap per week and associated degree-day accumulations for the Manteca site, 2011.



Performance of NOW in the laboratory on 11 almond varieties collected at their respective harvest timings from the Delta College Regional Almond Variety Trial site, and with intact nutmeats, slightly scratched nutmeats or unhulled treatments indicated significant differences in emergence time due to variety (χ^2=79.810, df=10, *P*<0.0001, *n*= 663), treatment (χ^2=435.838, df=2, *P*<0.0001, *n*= 663), and the variety*treatment interaction (χ^2=111.530, df= 20, *P*<0.0001, *n*= 663). For intact nutmeats, NOW reared on Monterey (*Z*=0.996, *P*=0.008) showed significantly earlier emergence and higher probability of emergence compared to those on Nonpareil, though the effect of variety on probability of emergence was not quite significant in the overall analysis (χ^2 =16.847, df=10, *P*=0.0778, *n* = 258 (**Table 5)**. Scratching the nutmeats resulted in a significant overall separation by variety (χ^2=20.912, df=0, *P*=0.0217, *n*=325) (**Table 5**) with moths reared on Johlyn (*Z*=0.872, *P*=0.0550) and Plateau (*Z*=0.992, *P*=0.0163) showing earlier emergence and increased probability of emergence compared to Nonpareil. By contrast, those reared on Carmel (*Z*=0.0126, *P*=0.0251) (**Table 5**) and Price (*Z*=0.0148, *P*=0.0296) emerged significantly later and were less likely to emerge. Unshelled nuts (χ^2=120.221, df=10, *P*<0.0001, *n*=80) resulted in significant differences in hazard by variety, although none of the varieties from which moths emerged were significantly different from Nonpareil in emergence time or probability of survival (**Table 5**). On average, NOW emerged earlier in the scratched nutmeat treatment, and later in the unshelled treatment than in the intact nutmeat treatment.

Moth weights from the intact nutmeat treatment were significantly different by variety (*F*=6.185 df=10,245, *P*=<0.0001) and gender (*F*= 298.466, df=1,245, *P*=<0.0001. Monterey (*t*(10)=2.83, *P*=0.0050), Plateau (*t*(10)=2.70, *P*=0.0075), Sonora (*t* (10)=5.72, *P*=<0.0001), and Livingston (*t*(10) = 2.26, *P*=0.0244) (**Table 6**) generated significantly heavier moths than the Nonpareil, whereas Padre (*t*(10)=-3.11, *P*=0.0021) moths were significantly lighter. Wood Colony moths were not significantly lighter than Nonpareil in the intact nutmeat treatment (*t*(10)=-1.74, *P*=0.0838) (**Table 6**), but moths were significantly lighter in the scratched treatment (*t*(10)=-2.09, *P*=0.0372). Scratched nutmeats were analyzed similarly with variety (F=11.098, df=10,311, P=<0.0001) and gender (F=436.732, df=1,311, P=<0.0001) effects being significant. In the scratched nutmeat treatment, moths from the Johlyn ($t(10)$=5.84, P=<0.0001) (**Table 6**) treatment were significantly heavier than Nonpareil and moths from the Aldrich ($t(10)$=-4.12, P=<0.0001) treatment were significantly lighter than Nonpareil. Similar to the intact nutmeat treatment, Sonora ($t(10)$=5.65, P=<0.0001) and Monterey ($t(10)$=5.13, P=<0.0001) moths were significantly heavier. Analyses of the unshelled nut treatment indicated a very nearly significant difference by variety (F=2.148, df=6,69, P=0.0587) and significant by gender (F=83.062, df=1,69 , P=<0.0001) effects in the varieties that resulted in moth emergence (Johlyn, Livingston, Monterey, Price, Sonora, Wood Colony). Only Wood Colony ($t(6)$=-2.28, P=0.0256) (**Table 6**) generated significant differences in moth weights compared to the Nonpareil; moths emerging from Wood Colony almonds were lighter than those emerging from Nonpareils. For all treatments, gender was a significant factor, and females were significantly heavier than males.

Table 5. Cox proportional hazard analysis of navel orangeworm emergence time and probability of emergence compared to Nonpareil for each treatment and variety combination.

Damage treatment	Variety	Moths emerged	Mean (± SE) degree days (F°)	Hazard coefficient[1]	P^2
Intact nutmeat	Aldrich	24	926.75 ± 79.00	-0.11	0.586
	Carmel	23	887.65 ± 92.77	-0.06	0.763
	Johlyn	22	898.00 ± 103.33	-0.13	0.508
	Livingston	20	872.30 ± 74.61	-0.21	0.327
	Monterey	31	870.06 ± 67.17	0.47	0.008**
	Nonpareil	18	936.22 ± 133.12	0.00	NA
	Padre	28	905.93 ± 90.22	0.16	0.378
	Plateau	23	786.26 ± 50.18	0.26	0.196
	Price	19	841.50 ± 47.81	-0.14	0.516
	Sonora	27	847.41 ± 79.88	0.32	0.081
	Wood Colony	22	893.00 ± 100.62	-0.12	0.561
Scratched nutmeat	Aldrich	28	844.64 ± 65.41	-0.20	0.278
	Carmel	23	835.04 ± 76.64	-0.44	0.0251**
	Johlyn	32	792.69 ± 59.27	0.33	0.0550*
	Livingston	30	832.33 ± 72.41	-0.010	0.955
	Monterey	34	832.12 ± 61.40	0.20	0.217
	Nonpareil	33	856.71 ± 109.39	0.00	NA
	Padre	31	826.77 ± 71.80	0.070	0.685
	Plateau	33	791.33 ± 73.27	0.40	0.0163**
	Price	23	829.30 ± 86.85	-0.43	0.0296**
	Sonora	26	800.96 ± 73.79	-0.045	0.808
	Wood Colony	30	848.47 ± 110.63	-0.018	0.917
Unshelled	Aldrich	0	-------	-9.57	0.985
	Carmel	0	-------	-9.57	0.985
	Johlyn	15	985.60 ± 111.31	5.95	0.952
	Livingston	9	1041.33 ± 98.37	5.30	0.957
	Monterey	8	924.00 ± 99.09	5.23	0.958
	Nonpareil	25	952.16 ± 92.37	0.00	NA
	Padre	0	--------	-9.57	0.985
	Plateau	0	-------	-9.57	0.985
	Price	4	995.50 ± 21.06	4.45	0.964
	Sonora	13	961.23 ± 82.01	5.78	0.953
	Wood Colony	6	1118.33 ± 50.97	4.84	0.961

[1]Hazard coefficients (negative coefficients indicating later emergence and higher probability of non-emergence than Nonpareil, positive coefficients indicating earlier emergence and higher probability of emergence were estimated using a Cox proportional hazards model for each treatment individually due to the significant treatment*variety

[2]*P*-values determine the significance using the hazard coefficients generated in the Cox proportional hazards model; ** indicates significant difference at $P<0.05$.

Table 6. Mean mg adult moth weights (± SE) for eleven almond varieties and three damage treatments compared to the Nonpareil variety.

Damage treatment	Variety	Mean (± SE) moth weight (mg)	*P*[1]
Intact nutmeat	Aldrich	18.88 ± 6.12	0.521
	Carmel	18.61 ± 4.75	0.986
	Johlyn	19.35 ± 5.66	0.970
	Livingston	22.52 ± 5.02	0.0244**
	Monterey	20.13 ± 4.99	0.005**
	Nonpareil	16.38 ± 5.08	NA
	Padre	17.56 ± 4.92	0.0021**
	Plateau	21.20 ± 5.62	0.0075**
	Price	20.33 ± 4.50	0.842
	Sonora	22.23 ± 5.49	<0.0001***
	Wood Colony	16.81 ± 4.98	0.0838
Scratched nutmeat	Aldrich	16.86 ± 5.14	<0.0001***
	Carmel	18.22 ± 4.96	0.127
	Johlyn	24.89 ± 5.66	<0.0001***
	Livingston	19.44 ± 5.21	0.106
	Monterey	21.33 ± 6.17	<0.0001***
	Nonpareil	17.17 ± 5.80	NA
	Padre	19.82 ± 4.83	0.452
	Plateau	20.47 ± 4.17	0.138
	Price	18.03 ± 4.51	0.672
	Sonora	22.05 ± 6.06	<0.0001***
	Wood Colony	14.02 ± 5.39	0.0372**
Unshelled	Aldrich	-------	-------
	Carmel	-------	-------
	Johlyn	19.19 ± 5.92	0.147
	Livingston	21.97 ± 5.38	0.525
	Monterey	19.93 ± 5.36	0.412
	Nonpareil	18.72 ± 5.40	
	Padre	-------	-------
	Plateau	-------	-------
	Price	25.08 ± 6.55	0.101
	Sonora	23.17 ± 4.46	0.0664
	Wood Colony	14.02 ± 4.66	0.0256**

[1]*P*-values based on ANOVA of each damage treatment-variety combination compared to the Nonpareil variety; ** indicates significant difference at $P<0.05$.

This study indicates that NOW generally show improved survivorship and earlier emergence in almonds with both pedicel and shell damage, and have decreased survivorship and later emergence in almonds with undamaged shells. However, almond variety impacts the responses and performance of NOW, and interactions between variety and almond damage are also important.

Objective 4. Predator mite and spider mite research. *Laboratory studies*. **Table 7** shows female *G. occidentalis* survivorship for the laboratory study. All of the pyrethroids applied by direct contact to *G. occidentalis* caused a significant decline in survivorship (F=3.26, df=4,30, P=0.0246) with the possible exception of λ-cyhalothrin (Warrior). Fewer survived the permethrin (Pounce or Ambush) treatment than the other treatments. Most of the mortality occurred on the first day following treatment. There was no significant difference in *G. occidentalis* fecundity (F=2.19, df=4,22, P=0.1031) between the pyrethroid treatments and untreated control for the surviving females during the 3 day period (**Table 8**). The greatest effect on fecundity from exposure to all pyrethroids except bifenthrin (Brigade) occurred on the first day after exposure, with egg-laying by surviving females recovering on days 2 and 3. The bifenthrin treated females on average laid only 0.11 eggs on each of the 3 days with no apparent recovery during this period. There was no significant effect on fertility for any of the pyrethroid treatments or untreated control (P>0.05). Eggs produced by λ-cyhalothrin treated females had the lowest hatch rate (72%) compared to that of eggs laid by untreated females.

Table 7. Mean (± SD) surviving *Galendromus occidentalis* females on each of the 3 days following treatment with permethrin (pounce or Ambush), esfenvalerate (Asana), λ-cyhalothrin (Warrior), or bifenthrin (Brigade).

	Mean ± SD surviving females								
Treatment	Day 1			Day 2			Day 3		
Control	2.86	±	0.38	2.71	±	0.76	2.71	±	0.76
Permethrin	0.57	±	0.79	0.43	±	0.53	0.43	±	0.53
Esfenvalerate	1.29	±	0.79	1.14	±	0.95	1.29	±	0.95
λ-cyhalothrin	1.71	±	1.25	1.43	±	1.13	1.43	±	1.13
Bifenthrin	1.29	±	0.76	1.43	±	0.76	1.29	±	0.76

Table 8. Mean eggs (± SD) laid per surviving *Galendromus occidentalis* female on each of the 3 days of the laboratory study for the four pyrethroids used and untreated control.

	Mean ± SD eggs laid per female								
Treatment	Day 1			Day 2			Day 3		
Control	1.05	±	0.60	0.68	±	0.86	0.70	±	0.76
Permethrin	0.00	±	0.00	0.33	±	0.58	0.67	±	0.58
Esfenvalerate	0.10	±	0.32	0.56	±	0.73	0.89	±	0.33
λ-cyhalothrin	0.17	±	0.39	0.50	±	0.53	0.40	±	0.70
Bifenthrin	0.11	±	0.33	0.11	±	0.33	0.11	±	0.33

Field study. *G. occidentalis* survivorship on twigs collected from pyrethroid treated trees was reduced relative to the untreated control on both the November 25 and February 16 sampling dates (**Table 9**). Survivorship was not significantly reduced (*P*>0.05) on twigs from the bifenthrin treated trees collected on the day following treatment, but it was significantly lower on twigs from the λ-cyhalothrin treated trees. Lambda-cyhalothrin significantly (*P*<0.05) reduced fecundity of females exposed to twig residues on both the day following application and the November 25 sample dates, while bifenthrin reduced fecundity on only the date following treatment. There was no significant effect (*P*>0.05) of almond variety on either the fecundity or survivorship of *G. occidentalis* females placed on the bifenthrin, λ-cyhalothrin or untreated twigs collected on any of the sampling dates.

Mean (± SD) residues recovered (ng/cm^2) for bifenthrin on each of the 3 sampling dates (August 6, November 24, and February 16) were: 109.58±34.59, 46.38±16.16, and 16.99±10.34, respectively, while mean (± SD) residues recovered for λ-cyhalothrin were: 51.22±16.47, 7.24±4.33, and 8.49±3.18 respectively (**Table 10**). The reporting limit was 0.1 µg. As expected, bifenthrin and λ-cyhalothrin residues declined following the post-treatment sample. This correlates with observed survival in the twig bioassays (**Table 9**) except for bifenthrin on the day following application. Both residues and survivorship on samples collected in November and February did not differ statistically from one another (*P*>0.05) for either bifenthrin or λ-cyhalothrin. There was no residue found on control twigs.

Table 9. Adjusted mean fecundity and survival for *Galendromus occidentalis* females placed on twigs collected from treated or untreated almond trees on all three sample dates.

		August 6		November 25		February 16	
Treatment		Mean ± SE	*P*	Mean ± SE	*P*	Mean ± SE	*P*
Control	Fecundity	2.32 ± 0.18	-	1.52 ± 0.38	-	2.34 ± 0.12	-
	Survival	0.71 ± 0.04	-	0.76 ± 0.04	-	0.63 ± 0.03	-
λ-cyhalothrin	Fecundity	1.66 ± 0.17	0.0373*	3.22 ± 0.56	0.0452*	2.19 ± 0.12	0.66
	Survival	0.19 ± 0.03	<0.0001*	0.39 ± 0.04	<0.0001*	0.49 ± 0.03	0.0117*
Bifenthrin	Fecundity	0.41 ± 0.04	<0.0001*	1.86 ± 0.42	0.830	2.32 ± 0.12	0.99
	Survival	2.18 ± 0.18	0.860	0.54 ± 0.04	0.003*	0.49 ± 0.03	0.0117*

*Means significantly different from untreated control at *P*<0.05 by Student's t-test.

Table 10. Mean (± SD) pyrethroid residue (ng/cm^2) remaining on twigs collected from almond trees from the field study on all three sample dates.

Treatment	Collection date	Mean ± SD (ng/cm2)		
Bifenthrin	August 6	109.58	±	34.59
	November 25	46.38	±	16.16
	February 16	16.99	±	10.34
λ-cyhalothrin	August 6	51.22	±	16.47
	November 25	7.24	±	4.33
	February 16	8.49	±	3.18

Research Effort Recent Publications:

Hamby, K.A., Gao, L.W., Lampinen, B., Gradziel, T., and F.G. Zalom. 2011. Hullsplit date and shell seal in relation to navel orangeworm (Lepidoptera: Pyralidae) infestation of almonds. J. Econ. Entomol. 104(3): 965-969.