Insect and Mite Research

Project No.: **09-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 was largely on evaluating efficacy and treatment timing for the navel orangeworm (NOW) and the peach twig borer (PTB) at the May spray timing. Two field studies were conducted that indicated a number of registered and soon-to-be registered 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. An associated laboratory study provided evidence that NOW eggs can be somewhat controlled by either Altacor or Intrepid when laid on residue of either product. There was little control afforded by treating older eggs with either product, indicating that perhaps only newly laid eggs will only be affected. There was also evidence of ovi-larvicidal activity caused when the eclosing larvae chew out of the egg. Some modes of action of these newer products are thought to be 'safe' to beneficial arthropods such as predatory mites. We exposed gravid female predator mites (*Galendromus occidentalis*) to direct contact and residues of six products representing different mode of action classifications to determine if there were direct or indirect effects. Indeed we did find that some products affected the predatory mite females more than did others, and results are presented.

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. Collaborate in evaluating NOW pheromone blends and formulations and collecting ten lined June beetle for pheromone research as necessary in collaboration with other UC researchers (See Project No. 09-ENTO5-Leal).

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 applications and NOW biology.
4. Determine insecticide side effects on *Galendromus occidentalis.*

Materials and Methods:

Objective 1. Monitoring and collaboration. 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.

An experiment to determine efficacy of registered and candidate insecticides for control of PTB at the 'May' spray timing was conducted on third leaf almonds in collaboration with Sutter County Cooperative Extension Farm Advisor, Franz Neiderholzer at a site east of the Sutter Buttes and northwest of Yuba City. Treatments were applied to Price, Sonora and Peerless varieties that were grafted on plum 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 19, and the navel orangeworm biofix April 24. 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 of about 400 DD, the treatment timing for PTB recommended in the *UC Pest Management Guidelines for Almonds*. The actual application date was May 28, 2010, at 376 DD. Three products, Intrepid, Altacor and Delegate were applied at earlier (May 12, 211 DD) and later (June 4, 507 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 25, 2010, at 944 DD following biofix. This was later than we would normally evaluate shoot strikes ('normal' is about 750 DD), but when we attempted to take the shoot strike counts at that timing only very small strikes were seen. It is possible that the unusual May rains may have killed some of the early emerging moth or their eggs, creating the equivalent of a later moth emergence.

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 20 acre almond orchard on E. Clinton South Ave, near Ripon, San Joaquin Co. The block had not been treated by the grower and had a mummy load recorded on January 31, 2009, averaging 7 per tree. Mummies could still be found in trees when this study was initiated in late April, 2009, 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 May 1, 2009, and eggs were also recorded on May 6 and May 8 at which time 5 of the 10 traps had eggs. We selected May 4 as the NOW biofix date. PTB biofix was established as April 20.

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, 2008, were hot glued to the outside of strands of vegetable mesh during April, 2009, and 220 strands were prepared in all. These sentinel mummies were hung at mid-canopy in Nonpareil trees on May 6, 49 DD after the May 1 biofix date, which would have been close to the first possible date for exposure to navel orangeworm egg laying.. There were 20 treatments (**Table 1**) in all, with 10 mummy strands allocated for each treatment plus 20 strands for water-only controls. Treatments of Intrepid, Altacor and Delegate were applied directly to the strands at 3 timings, May 6 (49 DD), May 14 (128 DD and equivalent to 324 PTB DD), and May 19 (234 DD and equivalent to 449 PTB DD). The mummies were removed from the trees on June 29, 2009 when 783 NOW DD had been accumulated, and hand-cracked for identification of larvae or evidence of NOW feeding. The equivalent spray volume was 100 gpa.

We are repeating the 2009 experiment on efficacy of products at the May spray timing for NOW in 2010 at another site near Ripon in San Joaquin County. Biofix dates were April 30 for NOW and April 19 for PTB. Treatments with most all products were made at 99 NOW degree-days (May 13). In addition, treatments with Altacor, Delegate and Intrepid were made at the biofix (April 30) and near the recommended PTB DD treatment timing May 31 at 441 PTB DD). Mummies per tree when traps were deployed in the orchard were 3.1 in the Nonpareil trees and 22.5 in the Fritz trees. The mummies that we deployed were collected July 16, and are being evaluated for presence of NOW and damage at this present so data will be available at the Almond Board Research Conference and in next year’s annual report.

Table 1. Products evaluated for navel orangeworm control at 'May Spry' timings, Manteca, 2009.

Treatment	Chemical	Rate (form/ac)	Date	DD
Control (water)			5/14/09	
Belt	Flubendiamide	4.0 oz	5/14/09	128
Belt[1]	Flubendiamide	4.0 oz	5/14/09	128
Dimilin 2L	Diflubenzuron	12 oz	5/14/09	128
Dimilin 2L+Lorsban	diflubenzuron+chlorpyrifos	12 oz+4 pt	5/14/09	128
Athena EW[2]	bifenthrin+abamectin	805.7 ml	5/14/09	128
Danitol 2.4EC	Fenpropathrin	16 oz	5/14/09	128
Assail 30SG[3]	Acetamiprid	6.4 oz	5/14/09	128
Assail 70WP[3]	Acetamiprid	2.7 oz	5/14/09	128
Bifenture 10DF[3]	Bifenthrin	16 oz	5/14/09	128
Intrepid 2F	methoxyfenozide	16 oz	5/6/09	49
Intrepid 2F	methoxyfenozide	16 oz	5/14/09	128
Intrepid 2F	methoxyfenozide	16 oz	5/20/09	234
Delegate	Spinetoram	7 oz	5/6/09	49
Delegate	Spinetoram	7 oz	5/14/09	128
Delegate	Spinetoram	7 oz	5/20/09	234
Altacor 35WG[4]	chlornitraniliprone	4.5 oz	5/6/09	49
Altacor 35WG[4]	chlornitraniliprone	4.5 oz	5/14/09	128
Altacor 35WG[4]	chlornitraniliprone	4.5 oz	5/20/09	234
Altacor 35WG+Asana XL[4]	chlornitraniliprone+esfenvalerate	4.5 oz+10 oz	5/14/09	128
Proclaim	emamectin benzoate	4.0 oz	5/14/09	128

[1] Mixed with a NIS surfactant at 0.25% v/v.
[2] Mixed with summer oil at 1.0% v/v.
[3] Mixed with a silicone surfactant at 1.0% v/v.
[4] Mixed with Induce at 1.0% v/v.

In a related study, my lab conducted a detailed study of both Altacor and Intrepid to determine the exact manner by which both affect NOW, especially whether either has ovicidal activity. This knowledge could impact our thinking about treatment timing and coverage issues. NOW eggs and adults from a laboratory colony were used for all experiments comprising this study. Our NOW colony was maintained on wheat bran diet in 1 gallon glass jars at 27° C, 16:8 h [L:D] photoperiod, and 60-70% relative humidity. Treatments for were applied at the field equivalent application volume of 100 gallons/acre.

Insecticide applied directly to eggs. This experiment was conducted on eggs deposited on filter paper placed into colonies prior to treatment, and the eggs were between 3 to 5 days old at the time of treatment. Strips cut from the filter paper containing 5 to 10 eggs per replicate were dipped into solutions of each treatment and allowed to air dry in a fume hood before placing the strips into Petri dishes. Treatments, replicated 5 times each, were:

1. Altacor at 2.0 oz/acre (0.044 lb ai/acre; 200 ppm)
2. Altacor at 4.0 oz/acre (0.088 lb ai/acre; 400 ppm)
3. Altacor at 2.0 oz/acre (0.044 lb ai/acre; 200 ppm) plus Sunspray 11E (summer) horticultural mineral oil at 1% v/v

4. Altacor 4.0 oz/acre (0.088 lb ai/acre; 400 ppm) plus Sunspray 11E (summer) horticultural mineral oil at 1% v/v
5. Sunspray 11E (summer) horticultural mineral oil at 1% v/v
6. Intrepid at 16.0 oz/acre (0.25 lb ai/acre; 46 ppm)
7. Deionized water control

These treatments were repeated with and without the addition of a nonionic spreader-activator surfactant (Induce) at 1% by volume. The eggs were evaluated daily after treatment until all eggs from the control treatment had eclosed. Any emerging larvae were removed at this time to prevent cannibalism and pieces of nonpareil almonds were also placed in the Petri dishes to reduce cannibalism from newly emerged larvae. Remaining eggs that had not hatched were observed under a dissecting microscope for any evidence of eclosion to determine if the effect was ovicidal activity or ovi-larvicidal activity (larva dies immediately after hatching, presumably from ingestion of residue on egg chorion). Percent NOW larvae emerging from each treatment replicate was determined.

Insecticide applied to treated surface before oviposition. This experiment was conducted using previously treated paper toweling onto which mated female NOW were allowed to oviposit to determine residual activity and potential avoidance by female moths. The treatments were the same as in the previous experiment and included the nonionic spreader activator. The paper toweling was dipped into each of the treatments and allowed to air dry in a fume hood. The treated paper toweling was then used to line surfaces of an oviposition chamber. Ovipositional chambers were polyethylene containers measuring 120 cm diameter and 175 cm high. During a preliminary experiment, we observed that virgin females in oviposition chambers lined with untreated paper toweling did not readily mate or lay fertile eggs when provided with a single male. To improve mating success, NOW were first placed *en masse* into a coffee can mating chamber measuring 175 cm diameter by 175 cm high and containing the almonds and honey water as a nectar source, and the females were allowed to deposit eggs for 48 hours. After 48 hours, the almond for 24 hours after their emergence from pupal cases prior to being placed in the paper towel-lined oviposition chambers. Ten NOW females and 5 males from the mating chamber were placed in each of the oviposition chambers, provided with a honey water wick, and allowed to deposit eggs for 72 hours. The paper toweling was removed and the number of NOW eggs deposited was counted to establish if there might be behavioral effects that affect female oviposition. The number of live moths was recorded at this time. The paper toweling from each oviposition chamber were cut into pieces containing all of the eggs from the treatment replicate, and placed into a Petri dish. The eggs were evaluated daily for eclosion until all eggs from the control treatment had eclosed, and any larvae emerging were removed to prevent cannibalism. Eggs that had not hatched were observed under a dissecting microscope for any evidence of eclosion. Percent NOW larvae emerging from each treatment replicate was determined.

Insecticide applied to eggs laid on almonds. This experiment was conducted on eggs deposited on harvested unhulled almonds prior to treatment to determine contact activity. Unhulled almonds (var. Nonpareil) were obtained from an untreated almond orchard after the initiation of hullsplit. Seventy-five mated NOW females were placed in a mating chamber as described earlier were removed from the chamber, examined for NOW eggs, and number of eggs on each almond recorded. The location of each egg on the almond was marked with a Sharpie pen. Five almonds containing NOW eggs were dipped into each of the treatment solutions, air dried in a fume hood, and then placed into a growth chamber. Treatments, all contained the nonionic surfactant, replicated 5 times were:

1. Altacor at 4.0 oz/acre (0.088 lb ai/acre; 400 ppm)
2. Altacor at 4.0 oz/acre (0.088 lb ai/acre; 400 ppm) plus Sunspray 11E (summer) horticultural mineral oil at 1% v/v
3. Sunspray 11E (summer) horticultural mineral oil at 1% v/v
4. Intrepid at 16.0 oz/acre (0.25 lb ai/acre; 46 ppm)
5. Deionized water control

The eggs were evaluated daily after treatment until all eggs from the control treatment had eclosed, and emerging larvae were removed to prevent cannibalism. Number of NOW eggs laid and percent of emerging larvae were determined for each treatment replicate.

Insecticide applied to uninfested almonds before oviposition. This experiment was conducted similar to the previous experiment and included the same treatments, but the almonds were treated prior to exposure to mated females to determine potential avoidance behavior by NOW females and effects of residue on eggs. Ten unhulled almonds were dipped into each of the experimental treatments and allowed to air dry in a fume hood before being transferred to a cage sufficiently large enough for the treatments to be separated (16”L x 8”W x 14” H). The position of treatment almonds was randomized within the cage and the almonds were not in contact with other almonds. Seventy-five mated NOW females were transferred into a mating chamber and allowed to deposit eggs for 48 hours. After 48 hours the almonds were removed from the chamber, examined for NOW eggs, and number of eggs on each almond recorded. The location of each egg on an almond was marked with a Sharpie pen. The eggs were evaluated daily after treatment until all eggs from the control treatment had eclosed, and all emerging larvae were removed to prevent cannibalism. Number of NOW eggs laid and percent larvae emerging from each treatment replicate were determined.

Adult NOW survival. This experiment was intended to determine the number of days that newly eclosed adult NOW survived in containers when exposed to experimental treatments. NOW larvae were removed from the colony and sexed, then placed individually in rearing cups with diet until adult eclosion. The insecticide treatments, all containing the nonionic spreader activator, were sprayed on the inner surfaces of 475 ml plastic cups and their lids until completely covered, then allowed to dry in a fume hood. Treatments, replicated 20 times, were:

1. Altacor at 2.0 oz/acre (0.044 lb ai/acre; 400 ppm)
2. Altacor at 4.0 oz/acre (0.088 lb ai/acre; 400 ppm)
3. Avaunt at 6.0 oz/acre (0.011 lb ai/acre; 13.2 ppm)

4. Intrepid at 16.0 oz/acre (0.25 lb ai/acre; 46 ppm)
5. Deionized water control

A male + female pair of virgin moths were placed into each cup and provided with a honey water wick through the lip of the cup. The cups were placed into an environmental chamber at 27^{o}C constant temperature and 16:8 h [L:D] photophase. Adults were observed daily for mortality. Data collection was terminated after day 6.

Objective 4. Predator mite and spider mite research. As indicated in Objectives 2 and 3, a number of products have been or are becoming available for NOW and PTB control. The *UC Pest Management Guidelines for Almonds* have not recommended May sprays for these Lepidopterans because of concern for disruption of beneficial arthropods when broad spectrum insecticides such as organophosphates, carbamates and pyrethroids are applied early season. Many of the new products are being thought of as 'reduced-risk' or less harmful for beneficials. Using methods we have developed to study direct and side-effects of acaricides, we initiated a laboratory study to determine total effects of these products on *G. occidentalis*. Because it would be very costly and time consuming to test all possible products, we selected products that share similar modes of action in anticipation that others with similar activity would also have similar effects on non-target species. Products and IRAC category numbers of products being tested are Altacor (chlorantraniliprole, #28, Dupont), Avaunt (indoxacarb, #22, Dupont), Brigade WSB (bifenthrin, #3A, FMC), Delegate (spinetoram, #5, Dow), Dimilin 2L (diflubenzuron, #15, Chemtura), and Intrepid (methoxyfenozide, #18).

The *Galendromus occidentalis* used in this study were supplied by Sterling Insectary (Delano, CA). Insecticides and concentrations applied were clorantraniliprole at 164.06 ppm, bifenthrin at 94.64 ppm, diflubenzuron at 275.00 ppm, indoxacarb at 105.47 ppm, methoxyfenozide at 282.50 ppm, and spinetoram at 136.72 ppm. Contact treatments were applied to runoff using a 200 ml hand sprayer held 30 cm away from whole cowpea (*Vigna* unguiculata) leaves that were inhabited by gravid female *G. occidentalis.* Deionized water applied in the same manner to cowpea leaves with *G. occidentalis* served as a control for these treatments. The leaves were then allowed to air dry for 5 min. A gravid female from the treated leaves was then transferred to each untreated cowpea leaf disk with no fewer than 10 untreated *T. urticae* eggs provisioned on each disk as food for the predator. There were 7 replicates of each treatment and control. Residual treatments and the deionized water control were applied to whole cowpea leaves in the same manner as for the contact treatments, but the leaves did not harbor *G. occidentalis*. After the leaves were air-dried, leaf discs were cut from them and untreated *T. urticae* eggs and a gravid female *G. occidentalis* was transferred onto them. There were 7 replicates of each insecticide treatment, and 21 of the control. *G. occidentalis* were transferred to 20 mm cowpea (*Vigna unguiculata*) leaf disks cut from whole leaves using a cork borer. The cowpea leaves were collected from uninfested plants grown in a growth chamber in our lab, and 20 mm leaf disks were cut from them using a cork borer. The disks were placed on moistened filter paper lining a 90 mm diameter Petri dish. Three leaf disks placed into each Petri dish constituted one replicate. The cover of the Petri dish had three 10 mm holes to provide ventilation and control humidity. Each hole was covered with thrips mesh to prevent escape of the mites.

Both experiments were conducted in a growth chamber at 24 ± 1˚C and a 16:8 (L:D) photoperiod. Survivorship and fecundity of the *G. occidentalis* females was monitored every 24 hrs for the first three days. Any eggs they laid were transferred to an untreated cowpea leaf disk and monitored for eclosion. After the third day, the remaining females were removed. The eggs were observed for eclosion daily for an additional 3 days given that at 25˚C, *G. occidentalis* are known to mature and hatch in about 62 hours.

The analysis of fertility, using the response variable number of eggs per surviving female, used 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 at $p= 0.05$. Mortality was analyzed using a generalized linear model with a binomial response function (adjusted for over-dispersion) and treatment effects were further analyzed using Dunnett's adjustment as previously described. Due to the asymptotic nature of the approximation used by the fitting software, it was not possible to include bifenthrin in the model since 100percent mortality was observed.

Results and Discussion:

Objective 1. Monitoring and collaboration. 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 2010 season, supplies purchased and distributed included 250 traps of various kinds, 300 pheromone lures for peach twig borer (PTB), San Jose scale (SJS), and oriental fruit moth (OFM), and 8 lbs of NOW bait. Seven Farm Advisors received these supplies.

Objective 2. Peach twig borer. This is the second 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 which 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 the 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 2010 study revealed significant differences between treatments (F=9.027; df=21, 143; p<0.0001. Means were separated by Student's t-test. The analysis revealed that all treatments except for the middle treatment timing of Intrepid significantly reduced the number of peach twig borer shoot strikes relative to the untreated check (**Table 2**). Interestingly, in 2009, the middle treatment timing of Intrepid the low rate of the experimental product NAI-3202 EC from Nichino was the only 2 treatments that did not significantly reduce the number of shoot stikes.

Table 2. Mean (± SD) peach twig borer shoot strikes per tree, 2010.

Treatment	Rate	IRAQ MOA	Application Date	PTB strikes/tree Mean ± SD	
untreated	na		na	10.4 ± 2.6	A
Belt[1]	4.0 oz	28	5/28/10	3.0 ± 2.4*	EFG
Tourismo[1]	10 oz	28/16	5/28/10	3.8 ± 1.5*	DEFG
Tourismo[1]	14 oz	28/16	5/28/10	2.5 ± 1.6*	EFG
NAI-2302 EC[1]	14 oz	21	5/28/10	7.5 ± 4.5*	BC
NAI-2302 EC[1]	21 oz	21	5/28/10	5.2 ± 1.8*	CDE
Athena EW[2]	27.2 oz	3/6	5/28/10	5.3 ± 2.8*	CDE
Brigade 10 WP	0.5 lb	3	5/28/10	1.0 ± 1.3*	G
Assail 30SG[2]	6.4 oz		5/28/10	2.7 ± 2.8*	EFG
Bifenture 10DF[2]	16 oz	3	5/28/10	1.7 ± 1.5*	FG
Lambda-Cy 1EC[2]	5.0 oz	3	5/28/10	4.7 ± 3.1*	CDEF
Intrepid 2F[3]	16 oz	18	5/12/10	8.1 ± 3.8*	B
Intrepid 2F[3]	16 oz	18	5/28/10	8.7 ± 5.1	AB
Intrepid 2F[3]	16 oz	18	6/4/10	6.8 ± 4.3*	BCD
Delegate[3]	6.4 oz	5	5/12/10	1.5 ± 1.4*	G
Delegate[3]	6.4 oz	5	5/28/10	1.7 ± 2.3*	FG
Delegate[3]	6.4 oz	5	6/4/10	1.2 ± 1.0*	G
Altacor 35WG[3]	4.0 oz	28	5/12/10	2.0 ± 1.1*	FG
Altacor 35WG[3]	4.0 oz	28	5/28/10	1.7 ± 1.9*	FG
Altacor 35WG[3]	4.0 oz	28	6/4/10	1.3 ± 1.4*	G
Proclaim	4.0 oz	6	5/28/10	3.7 ± 2.6*	EFG
Voliam Xpress	7.0 oz	28/3	5/28/10	1.5 ± 1.5*	G

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

[1] NIS (nonionic) surfactant added @ 0.25% v/v

[2] Dyne-Amic added @ 0.25%% v/v

[3] Latron B-1956 or Induce NIS @ 1.0 v/v

The comparison of treatment timings of Altacor, Delegate and Intrepid indicated that in 2010 all treatment timings were statistically equivalent (**Table 3**). ANOV statistics for the treatment timing for each product were Altacor (F= 45.6469, df=3, 35, p<0.0001), Delegate (F= 45.3583, df=3, 35, p<0.0001), and Intrepid (F= 1.4959, df=3, 35, p<0. 2344). 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. That these results are somewhat contradictory may be due to the rain and cool temperatures that occurred during much of mid-May, following the first application. Our PTB and NOW trap captures from the site indicate suppression in activity during this period (**Figure 1**). It is possible that there was significant PTB mortality during this period, and under

Table 3. Effects of treatment timing for peach twig borer control when using Altacor, Delegate and Intrepid, 2010.

Treatment	Rate (form./ac.)	Degree days	Application Date	PTB strikes/tree Mean ± SD
untreated	na		na	10.4 ± 2.6
Altacor 35WG*	4.5 oz	211	5/12/10	2.0 ± 1.1*
Altacor 35WG*	4.5 oz	376	5/28/10	1.7 ± 1.9*
Altacor 35WG*	4.5 oz	507	6/4/10	1.3 ± 1.4*
Delegate	7 oz	211	5/12/10	1.5 ± 1.4*
Delegate	7 oz	376	5/28/10	1.7 ± 2.3*
Delegate	7 oz	507	6/4/10	1.2 ± 1.0*
Intrepid 2F	16 oz	211	5/12/10	8.1 ± 3.8
Intrepid 2F	16 oz	376	5/28/10	8.7 ± 5.1
Intrepid 2F	16 oz	507	6/4/10	6.8 ± 4.3

Induce (Latron) was added to all treatments @ 1.0 v/v

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

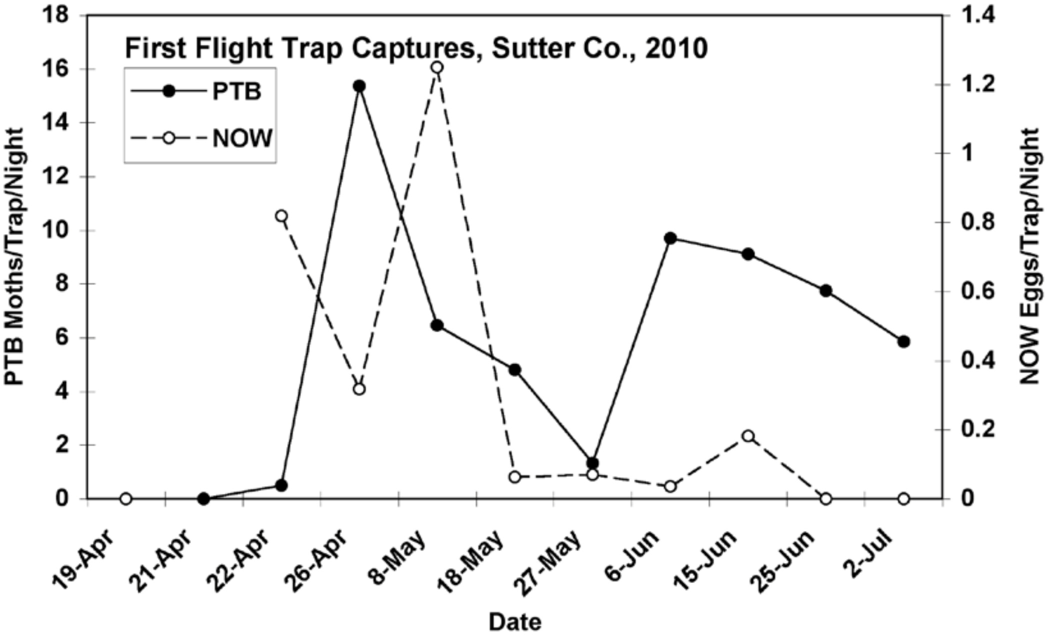

Figure 1. PTB and NOW trap captures during the first flight, Sutter Co., 2010

such conditions perhaps resetting the biofix should have been considered. In both years, ANOV did not indicate significant differences between the Intrepid treatments and the untreated control. The treatment timing for navel orangeworm in the *UC Pest Management Guidelines for Almonds* (100 DD using navel orangeworm degree-day developmental thresholds) predicted the optimum timing on May 8, which was 4 days before our first and second treatment timing. In 2009, the 100 NOW DD Timing was between our first and second treatment timing. It is likely that Altacor or Delagate could have been successfully applied for NOW control in this experiment and also achieved control of PTB similar to what was observed at the early treatment timing of either product.

Objective 3. Navel orangeworm. **Figure 2** presents accumulated NOW and PTB degree-days for the site, optimal treatment timings for each insects (arrows), and actual treatment timing (vertical lines). Our actual treatment timings bracketed the recommended times for both insects. ANOV statistics revealed significant treatment differences for both total NOW infestation (includes live or dead larvae or frass in the meats or hulls (ANOVA statistics, *F*=7.2826, df=20, 193, *p*<0.0001) and live NOW only (ANOVA statistics, *F*=6.6166, df=20, 193, p<0.0001). Means were separated using Student's t-test. The analysis revealed that all treatments except for the Dimilin alone treatment significantly reduced the proportion of infested mummies by both methods of evaluation (**Table 4**).

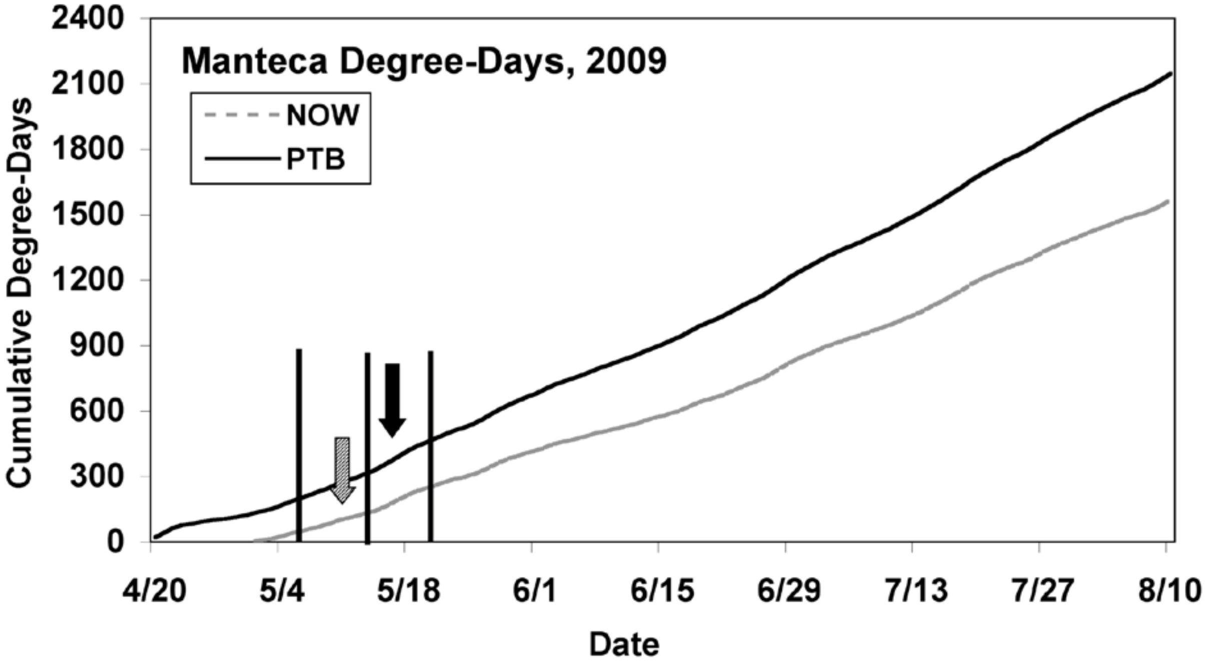

Figure 2. Navel orangeworm and peach twig borer degree-days, UC recommended treatment timings (arrows), and actual treatment dates (vertical lines).

Table 4. Mean (± SD) proportion of NOW infested mummies, Manteca, 2009.

			Proportion of infested mummies			
			All NOW		Live NOW	
Treatment	Rate (form/ac)	DD	Mean ± SD[1]		Mean ± SD[1]	
Control (water)			0.147 ± 0.12	A	0.097 ± 0.10	A
Belt	4.0 oz	128	0.018 ± 0.04	B	0.018 ± 0.04	B
Belt[2]	4.0 oz	128	0.000 ± 0.00	B	0.000 ± 0.00	B
Dimilin 2L	12 oz	128	0.122 ± 0.07	A	0.096 ± 0.06	A
Dimilin 2L+Lorsban	12 oz+4 pt	128	0.000 ± 0.00	B	0.000 ± 0.00	B
Athena EW	805.7 ml	128	0.000 ± 0.00	B	0.000 ± 0.00	B
Danitol 2.4EC	16 oz	128	0.024 ± 0.03	B	0.000 ± 0.00	B
Assail 30SG	6.4 oz	128	0.048 ± 0.05	B	0.016 ± 0.03	B
Assail 70WP	2.7 oz	128	0.056 ± 0.10	B	0.017 ± 0.03	B
Bifenture 10DF	16 oz	128	0.010 ± 0.02	B	0.005 ± 0.02	B
Intrepid 2F	16 oz	49	0.025 ± 0.05	B	0.010 ± 0.03	B
Intrepid 2F	16 oz	128	0.023 ± 0.04	B	0.012 ± 0.02	B
Intrepid 2F	16 oz	234	0.017 ± 0.03	B	0.011 ± 0.02	B
Delegate	7 oz	49	0.027 ± 0.04	B	0.015 ± 0.03	B
Delegate	7 oz	128	0.029 ± 0.05	B	0.007 ± 0.02	B
Delegate	7 oz	234	0.017 ± 0.03	B	0.017 ± 0.03	B
Altacor 35WG	4.5 oz	49	0.006 ± 0.02	B	0.006 ± 0.02	B
Altacor 35WG	4.5 oz	128	0.005 ± 0.02	B	0.005 ± 0.02	B
Altacor 35WG	4.5 oz	234	0.007 ± 0.02	B	0.000 ± 0.00	B
Altacor 35WG+Asana	4.5 oz+10 oz	128	0.006 ± 0.02	B	0.006 ± 0.02	B
Proclaim	4.0 oz	128	0.011 ± 0.02	B	0.006 ± 0.02	B

[1] Means followed by the same letter do not differ significantly at *P*=0.05 by Student's t-test.

While cracking nuts, we found a considerable number of green lacewing larvae and pupae in the hulls and split nuts, so we recorded these data. **Table 5** presents the mean proportion of mummies in each treatment that had a lacewing larva or pupa. Treatment differences approached significance (p<0.0706). The most notable observations were that no lacewing larvae or pupae were found in treatments with diflubenzuron + chlorpyrifos, bifenthrin alone, spinetoram at the late treatment timing. Other treatments also appeared to have reduced numbers of lacewings relative to untreated. It must be noted that reduced numbers of green lacewings may not be the result of direct mortality from application of a given product, but it may reflect a lack of prey for the predator due instead to efficacy of the product on the target pest or an alternative prey that we are not aware of. Further study of these compounds seems warranted if the total impact of applying a given pesticide is of interest as it should be in an IPM Program.

Our results of the series of the series of laboratory experiments intended to more closely determine how Altacor and Intrepid affect NOW produced some evidence for reduced NOW egg viability in the Altacor and Intrepid treatments. The greatest effect was observed when NOW were allowed to oviposit on treated and air-dried paper towels.

Table 5. Mean (± SD) proportion of mummies with lacewing larvae or pupae, Manteca, 2009.

Treatment	Rate (form/ac)	DD	Proportion with lacewings Mean ± SD[1]		
Control (water)			0.025	±	0.03
Belt	4.0 oz	128	0.021	±	0.04
Belt[2]	4.0 oz	128	0.007	±	0.02
Dimilin 2L	12 oz	128	0.017	±	0.04
Dimilin 2L+Lorsban	12 oz+4 pt	128	0.000	±	0.00
Athena EW	805.7 ml	128	0.022	±	0.03
Danitol 2.4EC	16 oz	128	0.008	±	0.02
Assail 30SG	6.4 oz	128	0.016	±	0.04
Assail 70WP	2.7 oz	128	0.011	±	0.02
Bifenture 10DF	16 oz	128	0.000	±	0.00
Intrepid 2F	16 oz	49	0.034	±	0.04
Intrepid 2F	16 oz	128	0.030	±	0.04
Intrepid 2F	16 oz	234	0.012	±	0.02
Delegate	7 oz	49	0.031	±	0.04
Delegate	7 oz	128	0.006	±	0.02
Delegate	7 oz	234	0.000	±	0.00
Altacor 35WG	4.5 oz	49	0.011	±	0.02
Altacor 35WG	4.5 oz	128	0.005	±	0.02
Altacor 35WG	4.5 oz	234	0.011	±	0.02
Altacor 35WG+Asana XL	4.5 oz+10 oz	128	0.006	±	0.02
Proclaim	4.0 oz	128	0.006	±	0.02

[1] ANOV statistics: F=1.5442, df=20, 213, p<0.0706.

Insecticide applied to eggs. No significant treatment differences were found either with ($F = 1.81$; df = 6, 28; $p=0.12$) or without the nonionic surfactant [NIS]($F = 1.88$; df = 6, 28; $p=0.13$) were detected following direct application to NOW eggs that had been laid on filter paper (**Table 6**). We observed that in the Altacor 2.0 oz/acre plus horticultural mineral oil and in the Altacor 4.0 oz/acre treatment some larvae died, but they did not die immediately following eclosion or in close proximity to the egg. These data were too few in number and patchy to analyze statistically, but may support the occurrence of ovi-larvicidal activity.

Table 6. Mean (± SE) proportion of navel orangeworm eggs laid on paper towel hatching after treatment (n=5).

	Mean ± SE proportion hatched	
Treatment	With NIS	Without NIS
Sunspray Horticultural Oil @ 1% v/v	0.896 ± 0.073	0.773 ± 0.084
Altacor @ 2.0 oz/acre	0.686 ± 0.098	0.843 ± 0.055
Altacor @ 2.0 oz/acre + Sunspray @ 1%	0.887 ± 0.079	0.843 ± 0.070
Altacor @ 4.0 oz/acre	0.750 ± 0.039	0.750 ± 0.154
Altacor @ 4.0 oz/acre + Sunspray @ 1%	0.820 ± 0.053	0.762 ± 0.084
Intrepid @ 16.0 oz/acre	0.813 ± 0.083	0.624 ± 0.089
Control	0.960 ± 0.040	0.975 ± 0.025

Insecticide applied to treated surface before oviposition. When the paper was treated and air-dried prior to lining an oviposition chamber, there appeared to be treatment differences both in the number of eggs laid and in the proportion of the eggs that hatched (**Table 7**). For total eggs laid by treatment, means differed significantly by ANOV following sqrt transformation ($F = 8.64$; df = 6, 14; $p=0.0005$). Tukey post-hoc comparison revealed the source of significance as the number of eggs laid in the Altacor at 4.0 oz+Sunspray, Altacor at 4.0 oz, and Intrepid at 16.0 oz treatments. For proportion egg hatch, means differed significantly following arcsine transformation by ANOV ($F = 8.02$; df = 6, 14; $p=0.0007$). Tukey post-hoc comparison revealed that all Altacor treatments and the Intrepid treatment differed significantly from the control, but there was no significant difference between 1% Sunspray and the control treatment. Number of eggs laid was reduced by more than 75% in both the Intrepid and Altacor 4.0 oz/acre treatments, and by 64% in the Altacor 4.0 oz/acre plus horticultural mineral oil treatments. The total effect (E) on oviposition and egg hatch combined for each treatment was calculated by the formula:

$$E = (\text{eggs}_c - \text{eggs}_t)/\ \text{eggs}_c * P_t$$

Where:

eggs_c = average eggs laid by the control females
eggs_t = average eggs laid by the treated females
P_t = proportion of eggs eclosed

By this measure, the greatest total effect (0.48) was achieved by Intrepid, followed by Altacor 4.0 oz/acre (0.37) and Altacor 4.0 oz/acre (0.32) plus horticultural mineral oil.

Table 7. Mean (+ SE) number of navel orangeworm eggs that were laid on treated, air-dried paper towels lining oviposition chambers, proportion of those eggs that hatched and total effect (*E*) of each treatment (n=3).

Treatment	Mean + SE eggs laid			Mean + SE proportion hatched			*E*
Sunspray Horticultural Oil @ 1% v/v	251.67	±	58.67	0.96	+	0.01	0.21
Altacor @ 2.0 oz/ac	180.33	±	17.46	0.33	+	0.15	0.15
Altacor @ 2.0 oz/ac + Sunspray @ 1%	181.33	±	40.70	0.38	+	0.12	0.17
Altacor @ 4.0 oz/ac	77.00	±	7.23	0.48	+	0.08	0.37
Altacor @ 4.0 oz/ac + Sunspray @ 1%	117.33	±	35.80	0.51	+	0.15	0.32
Intrepid @ 16.0 oz/ac	66.33	±	20.69	0.60	+	0.15	0.48
Control	322.67	±	7.27	1.00	+	0.00	0.00

Insecticide applied to eggs laid on almonds. On average, 30.5+3.24 eggs were laid on each unhulled almond used in this study. Significant treatment differences were detected following direct application of treatments to NOW eggs laid on the unhulled almonds, after arcsine transformation (*F* = 16.9; df = 4, 20; *p*<0.0001) (**Table 8**). Tukey post-hoc comparison revealed egg hatch was significantly reduced in the Altacor 4.0 oz/acre plus horticultural mineral oil, Altacor 4.0 oz only and Sunspray 1% v/v only treatments.

Table 8. Mean (+ SE) proportion of navel orangeworm eggs laid on almonds and then treated that hatched (n=5).

Treatment	Mean + SE proportion hatched		
Sunspray Horticultural Oil @ 1% v/v	0.573	+	0.090
Altacor @ 4.0 oz/acre	0.785	+	0.059
Altacor @ 4.0 oz/acre + Sunspray @ 1%	0.506	+	0.039
Intrepid @ 16.0 oz/acre	0.871	+	0.038
Control	0.985	+	0.015

Insecticide applied to uninfested almonds before oviposition. No significant treatment differences were observed in the mean number of eggs laid per treatment (*F*= 0.67; df = 4, 45; *p*=0.61) (**Table 9**). An average of 13.8+1.13 eggs were laid per almond. The proportion of eggs hatched when eggs were laid on unhulled almonds differed significantly by treatment (*F* = 6.50; df = 4, 45; *p*=0.0003). Tukey post-hoc analysis revealed that the source of significance was due to reduced egg hatch in the Sunspray at 1% v/v and Intrepid treatments.

Table 9. Mean (+ SE) number of navel orangeworm eggs that were laid on treated and air-dried almonds in oviposition chambers and proportion of those eggs that hatched (n=10).

Treatment	Mean + SE eggs laid	Mean + SE proportion hatched
Sunspray Horticultural Oil @ 1% v/v	16.8 + 3.09	0.82 + 0.047
Altacor @ 4.0 oz/acre	10.9 + 1.97	0.96 + 0.019
Altacor @ 4.0 oz/acre + Sunspray @ 1%	15.3 + 2.99	0.96 + 0.022
Intrepid @ 16.0 oz/acre	12.8 + 2.36	0.80 + 0.06
Control	13.2 + 2.15	0.98 + 0.02

There were no significant treatment effects when the eggs were first laid on filter paper prior to treatment as opposed to when the eggs were laid on paper towels was an interesting finding. We believe that this difference could be accounted for by egg age. Due to logistical constraints related to obtaining a sufficient number of viable eggs to conduct the experiment, the eggs laid on filter paper and then treated were 3 to 5 days old prior to treatment whereas eggs were freshly laid directly onto the treated paper surface in the experiment where we observed the treatment effect. Eggs that were laid on almonds and then treated were up to 48 hours days old when treated, and the only significant effects observed were in treatments that contained horticultural mineral oil. In contrast to the observed effects when eggs were laid on paper towels, eggs that were laid directly onto treated almonds did not exhibit the same amount of reduction in hatch, although there was a slight but significant reduction in eclosion in the Intrepid treatment.

Adult NOW survival. An interesting observation was that the mean number of days that adult NOW survived was reduced in the Altacor treatments (**Table 10**). This may help explain the reduction in number of eggs laid as well when the paper towels were pretreated. No reduction in adult survival time was observed for either the Avaunt or Intrepid treatments.

Table 10. Mean (+ SE) days that paired virgin navel orangeworm adult males and females survived in treated and air dried 475 ml covered plastic cups (n=20). Data were no longer collected after day 6.

Treatment	Mean + SE days female survived	Mean + SE days male survived
Altacor @ 2.0 oz/acre	1.25 ± 0.12	1.30 ± 0.13
Altacor @ 4.0 oz/acre	1.05 ± 0.05	1.05 ± 0.05
Avaunt @ 6.0 oz/acre	4.05 ± 0.55	3.10 ± 0.55
Intrepid @ 16.0 oz/acre	3.45 ± 0.54	4.20 ± 0.51
Control	5.50 ± 0.34	4.90 ± 0.44

Objective 4. Predator mite and spider mite research. Significant differences were found in female survival between residue insecticide treatments ($F = 7.50$; df = 7, 42; $p<0.0001$) but not among contact insecticide treatments ($F = 1.86$; df = 7, 42; $p = 0.1108$) (**Table 11**). However, when compared individually against the control, individual insecticide treatments were different in the contact experiment. Chlorantraniliprole resulted in no significant effect on female survivorship by either contact or residual exposure ($p>0.05$). Spinetoram and Indoxacarb both reduced survivorship when female *G. occidentalis* were exposed to the leaf surface residue for three days. However, neither chemical impacted survivorship when exposure was limited to contact only. Diflubenzuron had the reciprocal effect, reducing survivorship in those females exposed via direct contact, while having little effect in the residual treatments. Methoxyfenozide was the only insecticide that had a statistically significant impact on survival following both residual and contact treatments. Bifenthrin killed all females by the end of the first day when they were exposed to residue on leaf discs, however when females were exposed only through direct contact with bifenthrin, *G. occidentalis* survival was not significantly reduced.

None of the six insecticides evaluated had a significant impact on fecundity when the gravid female *G. occidentalis* were exposed through direct contact with the insecticide ($F = 2.07$; df = 6, 35; $p = 0.0816$) although a decline in egg production was noted for both indoxacarb and methoxyfenozide with no eggs being laid on the third day despite relatively high female survivorship (**Table 12**). The rather great amount of egg-laying variability between untreated control females may have masked statistical differences. Statistical differences were found when females were exposed to leaf surface residues ($F = 3.64$; df = 6, 25; $p = 0.0130$). Spinetoram and bifenthrin residues were the only ones that significantly reduced *G. occidentalis* fecundity.

Table 11. Mean mortality and fecundity for residue and contact exposure.

		Survival		Fecundity	
Treatment	Exposure	Adj. mean[1]	p[2]	Adj. mean[1]	p[3]
Control	Contact	0.86 ± 0.1	-	1.81 ± 0.5	-
	Residue	0.75 ± 0.1	-	3.04 ± 0.8	-
Bifenthrin	Contact	0.57 ± 0.1	0.25	0.76 ± 0.3	0.46
	Residue	- ± -	-	- ± -	-
Chlorantraniliprole	Contact	0.67 ± 0.1	0.54	0.69 ± 0.4	0.44
	Residue	0.67 ± 0.1	0.97	3.83 ± 0.6	0.17
Diflubenzuron	Contact	0.38 ± 0.1	0.04	1.30 ± 0.5	0.98
	Residue	0.76 ± 0.1	1.00	4.67 ± 0.7	0.64
Indoxacarb	Contact	0.62 ± 0.1	0.37	0.33 ± 0.2	0.18
	Residue	0.10 ± 0.1	0.00	3.00 ± 1.0	0.28
Methoxyfenozide	Contact	0.38 ± 0.1	0.04	0.20 ± 0.2	0.22
	Residue	0.38 ± 0.1	0.04	3.50 ± 0.7	0.14
Spinetoram	Contact	0.48 ± 0.1	0.10	1.83 ± 0.6	1.00
	Residue	0.14 ± 0.1	0.00	1.00 ± 0.5	0.01

[1] Comparisons between treatment groups and control were adjusted using Dunnett's method.
[2] Analyzed using generalized linear model with a Poisson response function adjusted for over-dispersion.
[3] Analyzed using a generalized linear model with a binomial response function adjusted for over-dispersion.

Table 12. Mean eggs laid per female *G. occidentalis* when exposed by direct contact.

	Mean ± SD eggs laid per female		
Treatment	Day 1	Day 2	Day 3
Control	0.38 ± 0.59	0.50 ± 0.61	0.78 ± 0.55
Bifenthrin	0.10 ± 0.30	0.19 ± 0.40	0.07 ± 0.27
Chlorantraniliprole	0.19 ± 0.40	0.24 ± 0.56	0.19 ± 0.4.0
Diflubenzuron	0.10 ± 0.30	0.22 ± 0.43	0.38 ± 0.44
Indoxacarb	0.10 ± 0.30	0.06 ± 0.24	0.00 ± 0.00
Methoxyfenozide	0.05 ± 0.22	0.00 ± 0.00	0.00 ± 0.00
Spinetoram	0.24 ± 0.44	0.53 ± 0.77	0.01 ± 0.34

Table 13 presents a comparison of *G. occidentalis* fecundity following residue and contact exposure to the six products. Egg hatch was lower for the residual exposure controls than for the contact exposure experiment for reasons we cannot explain given that the females were from the same source. A total of 87 eggs were laid by residual exposure control females, yet only 41 hatched (47.13%). By contrast, over 87 percent of the 32 eggs laid by contact exposure control females hatched. Egg hatch following either residual or contact exposure by chlorantraniliprole, indoxacarb, spinetoram and diflubenzuron were similar to that observed for the untreated control. The *G.*

occidentalis eggs remaining in the bifenthrin treatment of the residual bioassay and the methoxyfenozide treatment of the contact bioassay did not hatch, but the initial numbers of eggs were also extremely low in both instances.

Table 13. Eggs laid and percentage hatched for each pesticide treatment.

	Residue			Contact		
Treatment	Total laid	Total hatched	% hatched	Total laid	Total hatched	% hatched
Control	87	41	47.13	32	28	87.5
Bifenthrin	2	0	0	6	4	66.67
Chlorantraniliprole	55	35	63.64	11	7	63.64
Diflubenzuron	34	23	67.65	11	5	45.45
Indoxacarb	13	10	76.92	3	3	100
Methoxyfenozide	32	25	78.13	1	0	0
Spinetoram	11	8	72.73	17	14	82.35