Insect and Mite Research

Project No.: **08-ENTO7-Zalom**

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Objectives:

1. Purchase pheromone traps, navel orangeworm bait traps, and lures for UC Cooperative Extension Farm Advisors for their ongoing monitoring and extension efforts. Assist in evaluating NOW pheromone blends and formulations and in ten lined June beetle monitoring as necessary in collaboration with other UC researchers.
2. Evaluate efficacy and May treatment timing for newly registered and candidate insecticides against peach twig borer; Dormant spray best management practices (BMPs) – establish efficacy and possible phytotoxicity (from oils) resulting from earlier dormant spray timing, and from use of other mitigation practices (completion from 2007-08)
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*.

Interpretive Summary:

This project continues to address the most significant chronic pest of almonds with a long-term production perspective. In the past several years, we have evaluated a number of viable options for off-season control of peach twig borer and other insects and mites that had been traditionally controlled by the dormant season application of an organophosphate insecticide with dormant oil. Options included alternative products and best management practices (BMPs) that mitigate the effects of the

organophosphates. In this annual report, we conclude that work and begin to evaluate new control options for navel orangeworm and peach twig borer during the season. This is possible, in part, because of products that are registered or soon to be registered for control of navel orangeworm and peach twig borer. The likely availability these products make it possible to consider earlier season control such as 'May sprays'. This annual report presents the final year of many dormant season control studies, and the initiation of research to identify less risky in season control options.

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. As in the previous year, I have continued to assist in Dr. Walter Leal's field work to evaluate NOW pheromone blends and formulations, and for monitoring ten lined June beetle populations. This required a number of visits to the field by me and members of my lab to monitor traps and make collections. The ten lined June beetle collections must take place in the evening when the adults emerge from the soil and are active.

Objective 2: Peach twig borer studies

An experiment to determine efficacy of registered and candidate insecticides for control of PTB was conducted on third leaf Nonpareil almonds in collaboration with Sutter County CE Farm Advisor, Franz Neiderholzer. All dormant treatments were applied on January 30, 2008. Materials and rates applied per acre were Diazinon (Helena) at 4 pts, Asana (Dupont) 2 EC at 9.6 oz and 12.8 oz, Altacor (Dupont) at 2 oz, 3 oz, and 4 oz, Avaunt (Dupont) at 6 oz, Delegate (Dow) 25 WDG at 1.6 oz, 2.4 oz, and 3.2 oz, Belt (Bayer) 480 SC at 2 oz and 4 oz, with and without oil, Mustang Max EW (FMC) at 4 oz, and Warrior (Syngenta) at 5.12 oz. All dormant sprays except as indicated previously were applied with 4 gal of IAPP 440 oil in 100 gal of water to runoff. An additional treatment consisted of Intrepid (Dow) at 10 oz with Latron B1956 at 0.125% v/v applied at budswell. PTB shoot strikes were evaluated on April 29. All treatments were replicated 6 times. Unfortunately, for the first time since we began working on PTB, we did not obtain useable results from this experiment because of a lack of PTB shoot strikes in the untreated trees.

We were successful in conducting an experiment to determine the use of new products for control of PTB as a May spray in 2009. The study site was in a third leaf almond orchard east of the Sutter Buttes and northwest of Yuba City. Once again, Franz Neiderholzer was our able collaborator. Materials and rates applied per acre and treatment dates are given on the data table presented under the results section of this report. All treatments and an untreated control were replicated 6 times with all treatments blocked into single tree rows. The peach twig borer biofix for the site was determined to be April 13, and the navel orangeworm biofix April 21. It was our intention to base the treatments on degree-days (DD), so most applications were planned to be applied at a timing of about 400 DD the treatment timing for PTB recommended in the *UC Pest Management Guidelines for Almonds*. Three products, Intrepid, Altacor and Delegate were applied at earlier and later treatment timings as well. All sprays were applied at the equivalent of 100 gal of water and were applied with an Echo Duster-Mister Air Assist Sprayer. PTB shoot strikes were evaluated June 2, 2009, at 781 DD following biofix.

Dormant spray best management practices (BMPs). Although this objective was not continued in winter 2008-09, the final year of this objective has not been reported in last year's annual report because all of the data had not yet been summarized, so I will report it now. Earlier dormant spray timing has been one of the most effective methods for reducing insecticide runoff from orchards in our BMP studies. However, there is concern about both the efficacy of the approach against target pests such as PTB, and also possible phytotoxicity from the oils included in the dormant sprays. In 2005-06, Franz Niederholzer and I initiated a study to test the hypothesis that earlier dormant season treatments could be applied effectively without affecting almond bloom. The study was repeated both in 2006-07 and 2007-08 concentrating only on one variety, Nonpariel bloom in 2006-07 and Aldrich bloom in 2007-08, and with treatments applied as early as October 18 in 2006 and November 3 in 2007.

Table 1. Treatments and treatment dates for the dormant treatment timing experiment, 2007-08.

Treatment	Rate (form. / ac.)	Application Date
Diazinon EC + oil	0.5 gal. + 4 gal.	11/2/07
Diazinon EC	0.5 gal.	11/2/07
Oil	4 gal.	11/26/07
Asana + oil	9.6 oz. + 4 gal.	11/26/07
Diazinon EC + oil	0.5 gal. + 4 gal.	11/26/07
Diazinon EC	0.5 gal.	11/26/07
Oil	4 gal.	12/31/08
Diazinon EC + oil	0.5 gal. + 4 gal.	12/31/08
Diazinon EC	0.5 gal.	12/31/08
Diazinon WP + oil	4 lbs. + 4 gal.	12/31/08
Diazinon WP	4 lbs.	12/31/08
Asana + oil	9.6 oz. + 4 gal.	12/31/08
Diazinon EC +oil	0.5 gal. + 4 gal.	1/31/08
Asana + oil	9.6 oz. + 4 gal.	1/31/08
Untreated	na	na

The site of this study was a commercial third leaf almond orchard located north of the Sutter Buttes and northwest of Yuba City, Sutter County. Treatments were applied at 4 different timings, November 2, November 26, December 31, 2007, or January 31, 2008. Treatments and treatment dates for each are shown on **Table 1**. Rates for products applied were esfenvalerate (Asana) at 9.6 oz per acre, Diazinon EC at 0.5 gal per acre, Diazinon 50WP at 4 lb. per acre and horticultural mineral oil (Gavicide Super 90) at 4 gal per acre. All applications were made at a volume of 100 gal per acre to individual Nonpareil trees using an air assist sprayer and replicated 8 times. Return bloom and bloom progression on each tree was determined by counting the number of opened flowers per tree from February 18 through March 8 when 94 to 100 percent bloom was recorded. PTB shoot strikes were evaluated on April 29.

Objective 3: Navel orangeworm.

The site of our May navel orangeworm control study is a mature 20 acre almond orchard on Graves Road in Manteca, San Joaquin Co. The block had not been treated by the grower and had a mummy load recorded on January 31 averaging 7 per tree. Mummies could still be found in trees when this study was initiated in late April, 2009 when navel orangeworm and peach twig borer traps were hung to establish a biofix. Ten black navel orangeworm eggs traps were hung for better resolution of a biofix. The first eggs were found on May 1, 2009, then eggs were also recorded on May 6 and May 8 at which time 5 of the 10 traps had eggs. We selected May 6 as the navel orangeworm biofix date. Peach twig borer biofix was established as April 20.

Table 2. Treatments and treatment timing for the navel orangeworm May treatment timing experiment, 2009.

Treatment	Chemical name	IRAC #	Rate (form./ac.)	Degree days
Control (water)	Na			
Belt	flubendiamide	28	4.0 oz	100
Belt*	flubendiamide	28	4.0 oz	100
Dimilin 2L	diflubenzuron	15	12 oz	100
Dimilin 2+ Lorsban	diflubenzuron+ chlorpyrifos	15; 1B	12 oz + 4 pt	100
Athena EW	bifenthrin + abamectin	3A; 6	805.7 ml	100
Danitol 2.4EC	fenpropathrin	3A	16 oz	100
Assail 30SG**	acetamiprid	4A	6.4 oz	100
Assail 70WP**	acetamiprid	4A	2.7 oz	100
KFD-72 10DF**	na	na	na	100
Intrepid 2F	methoxyfenozide	18	16 oz	0
Intrepid 2F	methoxyfenozide	18	16 oz	100
Intrepid 2F	methoxyfenozide	18	16 oz	208
Delegate	spinetoram	5	7 oz	0
Delegate	spinetoram	5	7 oz	100
Delegate	spinetoram	5	7 oz	208
Altacor 35WG***	chlornitraniliprone	28	4.5 oz	0
Altacor 35WG***	chlornitraniliprone	28	4.5 oz	100
Altacor 35WG***	chlornitraniliprone	28	4.5 oz	208
Altacor 35WG + Asana XL***	chlornitraniliprone+ esfenvalerate	28	4.5 oz + 10 oz	100
Proclaim	emamectin benzoate	6	4.0 oz	100

(*add a NIS surfactant @ 0.25% v/v)
(**add a silicone surfactant @ 1% v/v + MSO)
(***add Induce - NIS @ 1.0 v/v)

Uninfested Nonpareil mummy nuts collected in fall 2009, were hot glued to the outside of plastic mesh bags, 20 per bag. The bags were hung in the trees on May 6, which would have been their first possible exposure to navel orangeworm egg laying. The mummies were treated by dipping them into solutions of various products (**Table 2**). Most treatments were applied on May 14, when 100 degree-days had accumulated by removing the mummies from the trees, dipping them into a solution and rehanging. Altacor, Delegate and Intrepid were also treated and hung on May 6 (0 DD), and on May 20 (208 DD). The 3 treatment dates corresponded to 200, 325 and 458 degree-days, respectively, when using peach twig borer developmental thresholds. The mummies were removed from the trees on June 29, 2009 (when 783 DD had accumulated) and are being cracked out at this time. Navel orangeworm were present in the controls so we anticipate that useful data will be collected using this unique bioassay method.

The biological work on navel orangeworm were have initiated in 2008-09 is part of the USDA-ARS Areawide Navel Orangeworm Management Program, and our data will help provide northern California parameters for the risk assessment model developed by Dr. Joel Siegel with parameters for Kern and Fresno Counties. Data include overwintering mortality of navel orangeworm in tree vs. ground mummies, oviposition by females on ground mummies, and amount of natural mummy fall at different sites.

Objective 4: Predator mite and spider mite research

Two studies were conducted to further determine effects on predatory mites. The first study completed a suite of studies to determine total effects of new miticides on the predator *Galendromus occidentalis*. The second represents the start of a series of experiments to determine direct and sublethal effects of representative insecticides representing the newer classes of products being registered for control of navel orangeworm and peach twig borer on almonds. The predators used in our experiment are from a colony of *G. occidentalis* originally obtained from Sterling Insectary (McFarland, CA), and a colony *Neoseiulus fallacis* originally obtained from Biotactics, Inc., Riverside CA. Both colonies are maintained on twospotted spider mites in growth chambers at 24±1ºC, 75-85% RH and 16:8 photoperiod.

The final acaricide study was intended to determine the irritant effects of the acaricides fenpyroximate (Fujimite, Nichino America), etoxazole (Zeal, Valent), acequinocyl (Kanemite, Arysta Lifescience), bifenazate (Acramite, Chemtura) and spirodiclofen (Envidor, Bayer) on adult females of *G. occidentalis* and *N. fallacis*, the Twospotted spider mite (*Tetranychus urticae*), and the Pacific mite (*T. pacificus*). Six adult females obtained from colonies maintained in our laboratory were offered a choice between a pesticide-treated leaf disk and an untreated leaf disk by releasing them, one at a time, at the base of an acetate T-bridge that connected the leaf disks. The leaf disks and T-bridge were placed on the surface of wetted filter paper lining a Petri dish. The T-bridge was cleaned with 70% ethanol and then distilled water before and after each use. Mite distribution was recorded after 5 minutes. This choice test was repeated twenty times for each species- acaricide combination. A control using two untreated leaf disks connected by a T-bridge was used to confirm that mite movement to the leaf disks was random. Data were arcsine transformed and means were compared using a paired-sample t test for treatment to determine if the proportion of female mites present on the control versus the pesticide-exposed disk differed significantly from 0.5.

As indicated in Objective 2 and 3, a number of products have been or are becoming available for navel orangeworm and peach twig borer 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 have initiated a study to determine total effects of these products on *G. occidentalis*. It would be very time consuming to test all possible products, so we have begun the study by selecting products that share similar modes of action in anticipation that others with similar activity will also have similar effects on non-target species. Products and Insecticide Resistance Action Committee (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). Our only completed study to date evaluates the effects of leaf surface residue on survival, fecundity and fertility of female *G. occidentalis.* The predators used in our experiment are from a colony of *G. occidentalis* originally obtained from Sterling Insectary (McFarland, CA), and maintained on twospotted spider mites in growth chambers at 24±1ºC, 75-85% RH and 16:8 photoperiods. For the experiment, 2 cm leaf disks were cut from leaves using a cork borer, and then placed on wet filter paper in Petri dishes. Three leaf disks were placed into each Petri dish, and this served as an arena. Seven of these arenas were used for each experimental treatment, and the same number of arenas treated only with water served as controls for the experimental treatments. An excess of spider mites and eggs were provided so that the female remained satiated. The treatments were applied with a hand sprayer and allowed to dry in a fume hood before a gravid female was transferred to each leaf disk. Survival and number of eggs laid by each female was observed daily for three days, then the females were removed and the eggs transferred to untreated leaf disks. The eggs were observed thereafter for hatching.

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 2008 season, supplies purchased and distributed included 280 traps of various kinds, 300 pheromone lures for peach twig borer (PTB), SJS, oriental fruit moth, and obliquebanded leafroller, and 6 lbs of NOW bait. My lab also participates in the development and evaluation of new lures with other almond researchers who solicit our assistance. For example, during the past five years, my lab has helped assist Dr. Walter Leal in his field work to evaluate NOW pheromone blends and formulations, and for monitoring ten lined June beetle populations.

Objective 2: Peach twig borer studies

A number of new products are now registered or in the registration process, which provide an alternative to the organophosphates and pyrethroids for PTB control, and our research has helped identify their efficacy, optimal rates and winter season timing. In 2009, we took a similar approach 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 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. New reduced-risk insecticides being registered for Lepidoptera pest control are potentially less disruptive of natural enemies, and there is also 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 in that there will be less overlapping of generations earlier in the season making May spray timing (and therefore efficacy) more precise. The current PTB 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.

Two-way ANOVA results from our 2009 study (just completed) revealed significant differences between treatments and blocks:

Effects test results:

Source	df	Sum of Squares	*F* ratio	*P*
Treatment	20	1230.64	3.9396	<0.0001
Block	5	804.58	10.3028	<0.0001

It was clear that the row of trees representing Block 1 that closest to an older orchard had far greater numbers of shoot strikes across treatments than did the other rows, so this row was excluded and the number of blocks (replicates) was reduced to 5 so that there were no longer significant block effects. ANOV statistics on the remaining 5 blocks revealed significant treatment differences (ANOVA statistics, F=4.8132, df=20, 109, $p<0.0001$). Means were separated by Fisher's Protected. The analysis revealed that all treatments except for the low rate of an experimental product from Nichino (NAI-3202 EC) and the middle treatment timing of Intrepid significantly reduced the number of peach twig borer shoot strikes relative to the untreated check (**Table 3**).

The comparison of treatment timings of Altacor, Delegate and Intrepid indicated that in each case the early treatment timing was as good as or better than the treatment timing currently recommended in the *UC Pest Management Guidelines for Almonds* (**Table 4**). ANOV statistics for the treatment timing for each product were Altacor (F=6.9897, df=3, 24, p<0.0019), Delegate (F=5.202, df=3, 24, p<0.0076), and Intrepid (F=2.4452, df=3, 24, p<0.0923). In each case, the later treatment timing was not as effective. 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 5 (252 DD using peach twig borer degree-day developmental thresholds), which was between our first and second treatment timing. It is likely that any of these materials could have been applied for navel orangeworm in this experiment and also achieved excellent control of peach twig borer.

Table 3. Mean (± SD) peach twig borer shoot strikes per tree, 2009.

Treatment	Rate (form. /ac.)	Application Date	Degree -days	PTB strikes/tree Mean ± SD			
untreated	na	na	Na	10.30	±	7.18	A
Tourismo*	10.3 oz	May 12, 2009	367	1.20	±	1.64	F
Tourismo*	13.7 oz	May 12, 2009	367	1.00	±	1.00	F
NAI-3202 EC*	14 oz	May 12, 2009	367	7.20	±	3.03	ABC
NAI-3202 EC*	21 oz	May 12, 2009	367	2.20	±	1.92	EF
Dimilin 2L	12 oz	May 11, 2009	352	6.60	±	3.58	BCD
Dimilin 2L+Lorsban	12 oz +4 pt	May 11, 2009	352	1.80	±	2.49	EF
Athena EW	805.7 ml	May 12, 2009	367	0.80	±	1.10	F
Danitol 2.4EC	16 oz	May 12, 2009	367	1.60	±	2.07	F
Assail 30SG**	6.4 oz	May 12, 2009	367	2.40	±	2.88	DEF
KFD-72 10DF**	16 oz	May 12, 2009	367	0.80	±	0.84	F
Intrepid 2F	16 oz	April 28, 2009	193	2.40	±	2.88	DEF
Intrepid 2F	16 oz	May 11, 2009	352	8.40	±	4.67	AB
Intrepid 2F	16 oz	May 19, 2009	516	6.00	±	3.74	BCDE
Delegate	7 oz	April 28, 2009	193	1.20	±	2.68	F
Delegate	7 oz	May 11, 2009	352	1.40	±	1.95	F
Delegate	7 oz	May 19, 2009	516	4.20	±	3.56	BCDEF
Altacor 35WG***	4.5 oz	April 28, 2009	193	0.40	±	0.89	F
Altacor 35WG***	4.5 oz	May 11, 2009	352	0.20	±	0.45	F
Altacor 35WG***	4.5 oz	May 19, 2009	516	3.40	±	3.44	CDEF
Proclaim	4.0 oz	May 11, 2009	352	2.00	±	1.58	EF

Means followed by the same letter are not significantly different by Fisher's LSD at $P < 0.05$
*NIS surfactant added @ 0.25% v/v
**Silicone surfactant added @ 1% v/v + MSO
***Induce (Latron) added - NIS @ 1.0 v/v

Table 4. Effects of treatment timing for control of peach twig borer when using Altacor, Delegate and Intrepid.

Treatment	Rate (form./ac.)	Degree days	Application Date	PTB strikes/tree Mean ± SD		
untreated	na		na	10.30	±	7.18
Altacor 35WG*	4.5 oz	193	4/28/09	0.40	±	0.89
Altacor 35WG*	4.5 oz	352	5/11/09	0.20	±	0.45
Altacor 35WG*	4.5 oz	516	5/19/09	3.40	±	3.44
Delegate	7 oz	193	4/28/09	1.20	±	2.68
Delegate	7 oz	352	5/11/09	1.40	±	1.95
Delegate	7 oz	516	5/19/09	4.20	±	3.57
Intrepid 2F	16 oz	193	4/28/09	2.40	±	2.88
Intrepid 2F	16 oz	352	5/11/09	8.40	±	4.67
Intrepid 2F	16 oz	516	5/19/09	6.00	±	3.74

*Induce (Latron) added @ 1.0 v/v

Dormant spray best management practices (BMPs). PTB shoot strikes were very low in 2008, yet significant differences were found in all of the esfenvalerate (Asana) and diazinon treatments on all treatment dates when compared to untreated controls (F=3.3774, df=14,119, P<0.0002) (**Table 5**). As in all of our earlier efficacy studies, no significant PTB control was afforded by the application of oil alone. Results of the return bloom and bloom progression were similar to what we reported in 2006 and 2007. Bloom was accelerated by as much as 6 days in the December treatments containing oil (**Figure 1**) relative to the other treatment timings and untreated controls, with the primary effect occurring in the first half of the bloom period.

Table 5. Effects of treatment timing on efficacy of dormant sprays, 2008.

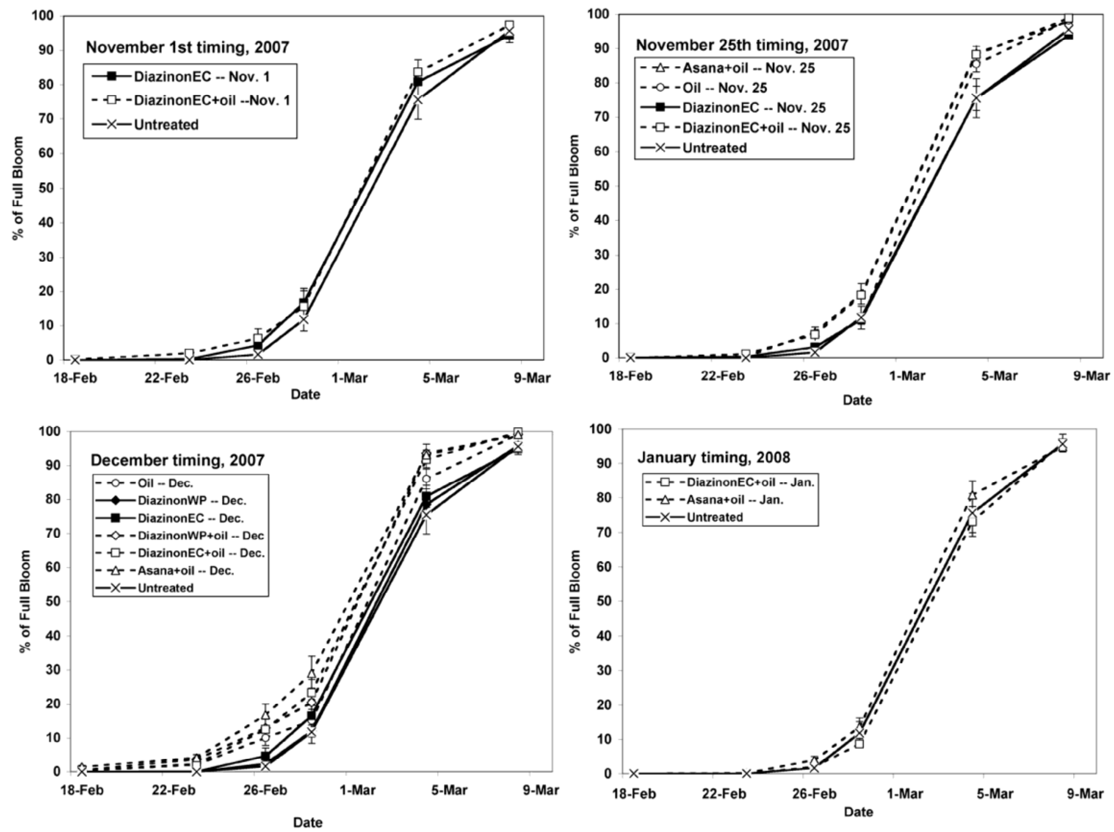
Treatment	Rate (form. / ac.)	Application Date	Mean (± SE) shoot strikes per tree[1]
Diazinon EC + oil	0.5 gal. + 4 gal.	11/2/07	0.00 ± 0.00 c
Diazinon EC	0.5 gal.	11/2/07	0.00 ± 0.00 c
Oil	4 gal.	11/26/07	0.88 ± 0.30 ab
Asana + oil	9.6 oz. + 4 gal.	11/26/07	0.00 ± 0.00 c
Diazinon EC + oil	0.5 gal. + 4 gal.	11/26/07	0.25 ± 0.25 c
Diazinon EC	0.5 gal.	11/26/07	0.00 ± 0.00 c
Oil	4 gal.	12/31/08	0.50 ± 0.27 bc
Diazinon EC + oil	0.5 gal. + 4 gal.	12/31/08	0.00 ± 0.00 c
Diazinon EC	0.5 gal.	12/31/08	0.00 ± 0.00 c
Diazinon WP + oil	4 lbs. + 4 gal.	12/31/08	0.00 ± 0.00 c
Diazinon WP	4 lbs.	12/31/08	0.00 ± 0.00 c
Asana + oil	9.6 oz. + 4 gal.	12/31/08	0.00 ± 0.00 c
Diazinon EC +oil	0.5 gal. + 4 gal.	1/31/08	0.00 ± 0.00 c
Asana + oil	9.6 oz. + 4 gal.	1/31/08	0.13 ± 0.13 c
Untreated	na	na	1.13 ± 0.58 a

[1] Means followed by the same letter do not differ significantly at (P=0.05) from one another by Fisher's Protected LSD, following SQRT (x + 0.5) transformation.

Objective 3: Navel orangeworm

UC researchers have not promoted the use of organophosphate or pyrethroid May sprays for control of NOW because of the potential for disrupting natural enemies in the orchards. The same reduced-risk insecticides used for PTB control are also likely to affect NOW. Most of the work with these products for NOW control has been done at the hullsplit timing. May sprays have an advantage over hullsplit sprays in that there will be less overlapping of generations earlier in the season, so timing should be more precise. *UC Pest Management Guidelines* for the spring NOW spray timing states that this spray should be applied just after the first eggs of the spring brood hatch, which is expected when 100 DD have accumulated from the biofix (when at least 50% of the egg traps in a given location show increases in the number of eggs on two consecutive monitoring dates).

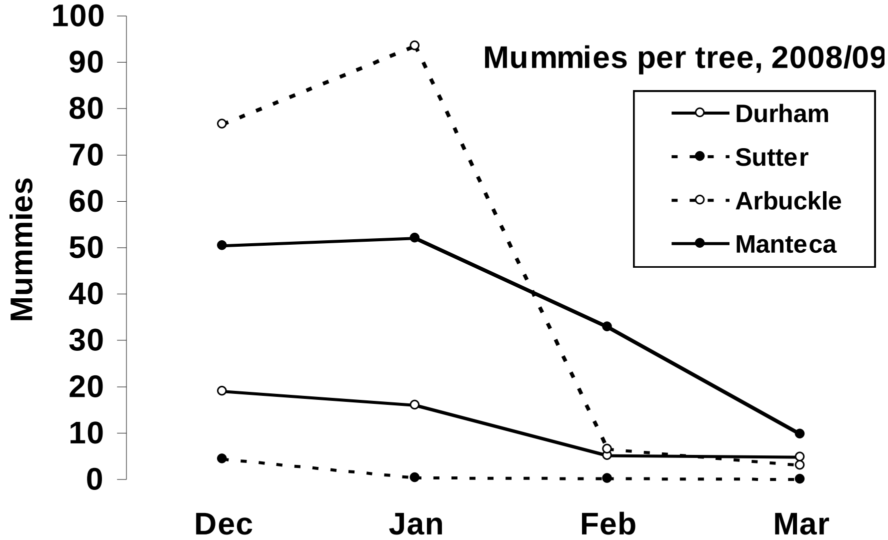
Figure 1. Aldrich bloom date as affected by treatment timing, 2007-08.



This timing is basically a cover spray – that is applied to cover the period when egg laying and egg hatch is occurring. This can be quite an extended period during spring depending on how consolidated the period of emergence of the overwintering generation is and therefore how long the first flight will last. The 2009 season represents the first year of this objective, and although we have described what we have done to this time in the methods section of this report, data collection is still in progress. It will be reported in the Proceedings for the 2009 Almond Board Research Conference.

During the winter of 2008-09, we began to collect data on overwintering mortality of navel orangeworm in tree vs. ground mummies, oviposition by females on ground mummies, and amount of natural mummy fall at four different sites in support of Dr. Joel Siegel's risk assessment model and as part of the USDA ARS Areawide Navel Orangeworm Management Program. Most of these data are still being summarized. **Figure 2** presents the natural seasonal progression of mummies present in ten uncleaned trees at the four sites we are working at. In this graph, mummies were counted from ten uncleaned trees at each site on a monthly basis. Remaining mummies were removed by poling in mid-March before spring navel orangeworm adults had emerged. Only mummies from the Manteca site following the last count in mid-March had any navel orangeworms present; three of the 97 mummies collected at the site were infested.

Figure 2. Monthly average mummies per tree (n=10) found in 4 almond orchards.



Objective 4: Predator mite and spider mite research

Results of the experiment to look at behavioral effects of the new acaricides on predator mites and spider mites are presented on **Table 6**. Twospotted spider mites were repelled by all acaricides applied except for Zeal (etoxazole). Pacific mites were repelled by Envidor (spirodiclofen) and Acramite (bifenazate), but not by the other products. These results are interesting in that they suggest that spider mites that are not killed by the products applied either because they were not contacted by the spray or because they were not exposed to residues for a sufficient period of time to kill them could escape to untreated leaf surfaces and survive an application. Redistribution of the mite population on a tree could also increase the number of potential colonies resulting in a resurgence of the mite population that would encompass a greater area of the tree than before the application. Conversely, irritation and more rapid mite movement could potentially lead to greater control if thorough leaf surface coverage by the spray is achieved. That both spider mite species are not repelled by Zeal (etoxazole) is significant in that they would be as likely as not to remain on treated leaf surfaces where they would remain exposed to its residue. *G. occidentalis* was repelled by Envidor (spirodiclofen), Acramite (bifenazate) and Fujimite (fenpyroximate), and *N. fallacis* by Acramite (bifenazate) and Fujimite (fenpyroximate). Presumably, the ability to sense and avoid treated surfaces would be beneficial to predators that might otherwise be exposed to a toxic pesticide and be killed. These results are useful when considered in light of the direct and sublethal effects of these products reported in our previous Almond Board of California Annual Reports which showed that the total effects on *G. occidentalis* of Acramite (bifenazate) and Kanemite (acequinocyl) were low and that these products were only slightly persistent (by International Organization for Biological Control [IOBC] standards), that Envidor (spirodiclofen) was slightly harmful and slightly persistent, and that Fujimite (fenpyroximate) and Zeal (etoxazole) were harmful and persistent. Interestingly, both predatory mites were highly repelled by

Fujimite (fenpyroximate), with over 90% of those released choosing the untreated leaf disk within 5 minutes, while the predators showed no indication of avoiding Zeal (etoxazole) treated leaf surfaces. The knowledge of direct, sublethal and indirect (including behavioral responses) of pesticides toward the target pest species and beneficial arthropods are important in making use decisions.

Table 6. Repellent effects of different acaricides on two species of spider mites and two species of predatory mites.

Acaricide	Concentration (ppm)	Species			
		G. occidentalis	*N. fallacis*	*T. urticae*	*T. pacificus*
Spirodiclofen	76.20	+	0	+	+
Acequinocyl	158.00	0	0	+	0
Bifenazate	112.75	++	+	+	+
Etoxazole	24.12	0	0	0	0
Fenpyroximate	0.21	++	++	++	0

+ = more than 60 percent of mites on untreated leaf disk
++ = more than 90percent of mites on untreated leaf disk
0 = no significant difference in mite distribution

Research on effects of new insecticides registered or soon to be registered on almonds on the predator mite *G. occientalis* has begun in 2009. Our first study is intended to determine direct and side-effects of gravid females placed on recently treated leaves with the insecticide residues - similar to what might be expected from females that had escaped direct contact of a spray but must crawl onto leaf surfaces with insecticide residue to search for prey. Results for survivorship are presented on **Table 7**. As expected, the pyrethriod, Brigade, killed all of the females by the end of the first day. Of these products, Altacor and Dimilin resulted in the least mortality to females over the 3 days of post treatment observations.

Table 7. Survivorship of predator mite *G. occidentalis* exposed to insecticide treated leaves

Treatment	Rate (form./ac.)	Mean ± SD Surviving Females		
		Day 1	Day 2	Day 3
Control	na	2.62 ± 0.58	2.52 ± 0.67	2.23 ± 0.88
Altacor	6.0 oz	2.85 ± 0.37	2.29 ± 0.48	2.00 ± 0.57
Avaunt	4.5 oz	1.28 ± 1.38	0.57 ± 0.53	0.28 ± 0.48
Brigade WSB	32 oz	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Delegate	7.0 oz	1.43 ± 0.53	0.85 ± 0.69	0.42 ± 0.53
Dimilin 2L	16 oz	2.57 ± 0.53	2.42 ± 0.53	2.28 ± 0.48
Intrepid	16 oz	1.57 ± 0.79	1.42 ± 0.79	1.14 ± 1.06

Table 8 presents the number of eggs laid per surviving females after exposure to the insecticide residues. Again, the Altacor and Dimilin treatments appeared to have the lowest impact on G. occidentalis, Intrepid an intermediate effect, Delegate and Avaunt a

more substantial effect. There were no eggs laid and no surviving female beyond the first day in the Brigade treatment.

Table 8. Eggs laid per surviving female and number of surviving females (n).

		Mean ± SD eggs laid per female and No. surviving											
Treatment	n	Day 1			n	Day 2			n	Day 3			n
Control	21	0.90	±	0.66	18.33	2.01	±	1.12	20.67	1.62	±	1.08	15.67
Altacor	21	1.23	±	0.94	20.00	0.85	±	0.67	16.00	0.81	±	0.91	14.00
Avaunt	21	0.48	±	0.75	9.00	0.22	±	0.44	4.00	0.25	±	0.50	2.00
Brigade	21	0.10	±	0.30	2.00	0.00	±	0.00	0.00	0.00	±	0.00	0.00
Delegate	21	0.29	±	0.56	10.00	0.40	±	0.52	6.00	0.17	±	0.41	5.00
Dimilin 2L	21	0.81	±	0.67	18.00	2.06	±	1.30	17.00	1.12	±	0.99	16.00
Intrepid	21	0.52	±	0.75	11.00	1.09	±	0.86	10.00	0.90	±	1.45	8.00

Table 9 presents the number of eggs laid on each day following exposure to each product and the total eggs that were laid by the original 21 females. *G. occidentalis* fecundity was reduced by all insecticide applications. Altacor had the least total impact on total eggs laid, while Dimilin and Intrepid had moderate effects. There was no effect of treatment on egg hatch.

Table 9. Total eggs laid by the 21 initial females and eggs hatched on each day.

Treatment	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Total laid	Total hatched
Control	0	0	12.67	9.33	11.33	8	87.67	41.33
Altacor	0	0	17	4	13	1	55	35
Avaunt	0	0	7	2	0	1	13	10
Brigade WSB	0	0	0	0	0	0	2	0
Delegate	0	0	5	3	0	0	11	8
Dimilin 2L	0	0	9	6	4	4	34	23
Intrepid	0	0	10	2	10	3	32	25