Annual Progress Report to:
Almond Board of California

Project Number: 96-C1

Project No.: 96C1 Insect and Mite Research

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Project Participants: UC Farm Advisors in 8 counties for Objective 1; Doug Walsh (Entomology, UC Davis), Carolyn Pickel (Sutter-Yuba Co.), Walt Bentley (UC Kearney Agricultural Center), Bill Krueger (Glenn Co.), and Dr. Michael Stimmann (Environmental Toxicology, UC Davis) for Objective 2; James Brazzle (Kern Co.), Rich Coviello (Fresno Co.) and Barry Wilson (Avian Sciences and Environmental Toxicology, UC Davis) for Objective 3; Walt Bentley and Mario Viveros (Kern Co.) for Objective 4.

Objectives:

1. Purchase pheromone traps and lures, and other monitoring supplies for UC Cooperative Extension Farm Advisors as part of their ongoing monitoring efforts.

2. Conduct field trials in the San Joaquin Valley and in the Sacramento Valley to test the effect of esfenvalerate, permethrin, and organophosphate dormant sprays and in-season sprays on peach twig borer and non-target species including mites.

3. Conduct a field trial to examine the efficacy of diazinon dormant sprays under certain conditions.

4. Support for the insect monitoring efforts within the BIOS project being conducted by Walt Bentley.

Results:

Objective 1. This objective has been a cooperative effort with many UC Cooperative Extension Farm Advisors over the years, and has led to the validation of degree-day phenology models for several key insect pests of almonds. The use of pheromone traps and degree-day phenology models by pest control advisors and some growers has become fairly common in the industry, but it is possible that these techniques can be misused or misinterpreted. Trapping supplies are purchased each year for use by participating UC Farm Advisors to help confirm the accuracy of the techniques, and to help them to monitor the activity of specific insects in their counties for use in newsletters, field trials, etc. The trapping records are assembled at UC Davis at the end of each season. This year over 600 traps and 1000 pheromone lures (plus almond press cake bait) were purchased and distributed to monitor navel orangeworm (14 lbs. presscake), peach twig borer (575 lures), oriental fruit moth (225 lures) and San Jose scale (250 lures). These data are sent to our lab at UC Davis where we keep them as part of a long term trapping record in all almond growing areas.

Objective 2. Many almond growers had reported mite outbreaks in 1993 and 1994. Although the extended draught or other factors might have been responsible for this observation, the possibility that these may have been secondary outbreaks resulting from increased use of pyrethroid insecticides could not be discounted, and therefore we initiated this research. Some growers are choosing to use pyrethroids - either permethrin (Pounce or Ambush) or esfenvalerate (Asana) - in the dormant season as an alternative to organophosphate insecticides for control of peach twig borer and scale insects even though it continues to be possible to use several organophosphates and *Bacillus thuringiensis* (for peach twig borer) which we have shown does not induce secondary pest problems in several years of research and demonstration. Other growers are choosing to apply the pyrethroids in-season for other insect pests instead of more costly treatments.

The scientific literature implicates in-season applications of both permethrin and fenvalerate (Pydrin) with such outbreaks in apple and grape systems, and attributes the mechanism to killing mite predators, dispersing the mites on the tree to create more mite colonies, or some other yet unknown factor. Permethrin applications in almond orchards were shown to induce spider mite outbreaks the following season in a published study by Bentley, Zalom and John Sanderson in 1987. Pyrethroids can be very stable compounds, so it is not surprising that such results might occur.

Both permethrin (Pounce or Ambush) and esfenvalerate (Asana) are being used as dormant sprays, but it is not known if they can be used without inducing secondary pest problems at that time or how long their residues will persist on twigs. Similarly, it is not known if esfenvalerate can be used during the growing season without inducing secondary outbreaks.

The one year old residual effect of dormant season applications of esfenvalerate (Asana XL) and permethrin (Ambush 3.2 EC), was determined in an almond orchard in Glenn County in cooperation with Carolyn Pickel and Bill Krueger. Other treatments consisted of current dormant season applications of esfenvalerate, permethrin, and diazinon (Diazinon 4E), and previous year dormant and in-season esfenvalerate treatments and previous year dormant and in-season applications of permethrin. Untreated control trees were also maintained in the completely randomized block. There were 10 treatments total of 8 single tree replicates applied by handgun with buffer trees between each treatment replicate. The trees were sampled for spider mites and predators every 2 weeks beginning in May. Treatments in the plots were applied 3 February, 1995, and 6 February, 1996, and hull split sprays on 21 July, 1995. Treatments consisted of:

1. Asana (Dormant 95)
2. Ambush (Dormant 95)
3. Organophosphate (Dormant 95 & 96)
4. Untreated
5. Asana (Dormant 95) + Asana (Hull split 95)
6. Ambush (Dormant 95) + Ambush (Hull split 95)
7. Asana (Dormant 96)
8. Ambush (Dormant 96)

Sampling was conducted monthly for spider mites and mite predators. Cardboard bands were placed around all trees in each treatment before larval emergence, and removed before adult emergence to determine peach twig borer abundance. No subsequent treatments were made in these plots. Twigs were cut from trees in the esfenvalerate, permethrin and control treatments at various times during the year in 1995 including during the dormant season and again in the dormant season of 1996 after the dormant sprays were applied. A laboratory experiment was conducted late in the summer of 1995 to determine effect of residues remaining on the twigs on the western orchard predator mite, and these results were reported in the 1995 Annual Report. We have just concluded this laboratory experiment again for 1997.

Small branches and twigs were cut from all 8 trees in each treatment on February 9, 1996, following the dormant spray, and were sent to Mike Stimmann's laboratory for residue analysis. The wood was stored at 0°F. Extraction and analysis for pyrethroids on twig samples was conducted using field collected twigs which were stored at -21C in clean mason jars. The twigs were thawed, and cut into sections about 2 cm long chosen from the internodal portion of the twigs to enable more accurate determination of surface area than is possible with buds and nodes. Each was then immersed in hexane, then placed in a sonic dismembrator and sonicated for 2 minutes to extract the pyrethroids from the plant cuticle. The extracted material was cleaned using solid phase extraction (SPE) chromatography, yielding samples that are almost free of unwanted chemicals such as other pesticides, oils, and waxes. An HP Gas Chromatograph equipped with a robotic autosampler was used for analysis. The entire cleanup and analysis process involved about 20 separate steps, and one technician could analyze 30-40 samples per week. Permethrin and esfenvalerate residues could be detected at levels as low as 0.1 ng/mm sq of bark surface.

Bioassays were conducted 3 times, on February 13, February 27 and March 5, 1997. Predator mites were placed on a subsample of these twigs and evaluated for mortality and egg laying after 48 hours. Results indicated that residues of both esfenvalerate (0.047 ng/mm^2) and permethrin (cis- = 1.153 ng/mm^2; trans- = 0.120 ng/mm^2) had persisted the entire year since the previous dormant season application (Table 1), and that there remained biological activity during this time.

Residues remaining from the one year old dormant spray and a hullsplit spray applied to the same trees was not significantly different from that remaining from the one year old dormant spray alone. By comparison, residue analysis of small branches collected less than 1 day following application yielded higher residues of esfenvalerate (0.265 ng/mm^2) and permethrin (cis- = 1.693 ng/mm^2; trans- = 1.603 ng/mm^2). In the bioassay of the small twigs collected from these treatments, all esfenvalerate and permethrin treatments resulted in significantly higher predator mite mortality than was observed on the untreated control twigs (Table 2). The diazinon applications resulted in some mortality of predator mites (~15%), but this was not as great as that observed for the various esfenvalerate and permethrin treatments which varied from 24% to 38% for esfenvalerate and from 19% to 42% for permethrin. Similarly, the number of eggs per treatment replicate were also significantly affected relative to the untreated control, and somewhat more by the esfenvalerate treatments than by the permethrin treatments.

In associated laboratory trials, we were able to develop a relationship of field rate of both esfenvalerate and permethrin to bark residues, and to relate this to predator mite mortality and oviposition. This model will allow us to accurately predict what the biological effect of a given level of bark residue might be (Figures 1 and 2) without having to conduct further bioassays which are quite expensive and time consuming. In an associated study, we were also able to determine the effect of permethrin leaf residues on predator mite mortality and oviposition. In this study we found significantly increased mortality (54%) and decreased oviposition (86%) at 0.125 of the label rate (Table 3). During 1997 we hope to develop a model similar to that developed for bark residues, and to validate this with field samples of leaf residues.

Field data collected from these trees indicated that there was a significant effect of the 1996 dormant treatment of both esfenvalerate and permethrin on spider mites and eggs in early April, but that these differences became less pronounced as the season progressed and mite populations declined (Figures 3 and 4). The residual effect from the prior season was less apparent for the esfenvalerate treatments than for the permethrin treatments. The abundance of European red mites (which were also counted in the orchard) was very low (Figures 5 and 6), and therefore differences between treatments could not be statistically separated.

These results indicate that the pyrethroid insecticides esfenvalerate (Asana) and permethrin (Ambush or Pounce) can have long term negative residual effects on predaceous mites on bark where they overwinter and disperse within trees, and short term negative effects resulting from residues on leaves. Apparently this effect can persist into the next season resulting in some increase in spider mite abundance.

Objective 3. Efficacy of diazinon (Diazinon 4E) at rates of 0.5, 1.0 and 2.0 lbs. a.i./acre, 1 day before and 1 day following wetting of trees was determined by James Brazzle in Kern County almond trees of variety Monterey and Nonpariel. Other treatments consisted of esfenvalerate (Asana XL) at 0.26 lb. a.i./acre, permethrin (Pounce 3.2 EC) at 0.4 lb. a.i./acre, phosmet (Imidan 70-WSB) at 3.2 lbs. a.i./acre, methidathion (Supracide 25 WP) at 2.0 lbs. a.i./acre, and *Bacillus thuringiensis* (Dipel ES) at 2 qts/acre applied 1, 2 and 3 times during bloom. All dormant treatments also contained 3.0 gallons/acre of Volck supreme oil. Water was applied as a control treatment. Each treatment was replicated 3 times. All applications were made with an airblast sprayer at 125 gallons per acre. The plot size was 4 rows by 15 trees (0.7 acre), with 6 center trees in each treatment replicate being sampled for twig strikes on April 25 to determine efficacy of treatments. Spider mites and mite predators were sampled every 2 weeks beginning in late May.

Statistically significant differences in twig strikes per tree were observed between treatments and varieties in the trial, with the number of twig strikes in the variety Nonpariel less than that of Monterey (Tables 4 and 5). Curiously, the number of twig strikes at the 3 treatment rates of diazinon did not reflect the amount applied, and the 2.0 lbs./acre rate was better when water was applied before the treatments were made. Methidathion and phosmet gave similar control to that observed for the best diazinon treatments. The number of twig strikes in the *B. thuringiensis* (Dipel) treatments were comparable to those found in the organophosphate dormant spray treatments, with better control observed in those treatments where more applications were made. The best control was achieved where following the 2 pyrethroid (esfenvalerate and permethrin) applications. The number of spider mites per leaf was significantly higher in both pyrethroid treatments than in all others (Figures 7 and 8), with peak populations reaching almost 58 mites per leaf in the esfenvalerate treatment and almost 22 mites per leaf in the permethrin treatment as opposed to only 6 mites per leaf in the control treatment and 5 mites per leaf in the Dipel treatment. This illustrates the problem that might be expected following even dormant season applications of either pyrethroid, and provided better evidence of this effect in the field than we were able to determine previously at our sites where spider mite population pressures were relatively low.

Efficacy of diazinon (Diazinon 4E) on variety Butte trees at rates of 0.5, 1.0 and 2.0 lbs. a.i./acre was also determined by Rich Coviello in a Fresno County almond orchard. Other treatments included esfenvalerate (Asana XL) at 0.25 lbs. a.i./acre, and *Bacillus thuringiensis* (Dipel ES) at 1 qt./acre applied at bloom and petalfall. Each treatment was replicated 8 times in completely randomized blocks. All applications were made with a handgun sprayer at 121 gallons per acre. All trees were sampled for twig strikes on April 26 to determine efficacy of treatments.

There was no significant difference in number of twig strikes between any of the 3 rates of diazinon (~84% control) and the esfenvalerate treatment, although the number of twig strikes was lower in the esfenvalerate treatment (92% control) (Table 6). We had observed this relationship in previous years, but were cautious to jump to conclusions about the effects of reduced rates because in the previous work the number of twig strikes in the orchards were relatively low. The number of twig strikes in the Dipel treatment (57% control) was significantly lower than in the untreated control, but was significantly greater than in any of the conventional pesticide treatments. Peach twig borer emergence was extended in 1996, so the short residual activity of this product was undoubtedly the cause of its reduced efficacy in this year.

Dr. Barry Wilson and his colleagues ran residue tests on bark samples from the diazinon rate treatments and untreated controls from both the Kern County and Fresno County trials. We had hoped that these data can be used to determine a dose response of diazinon and peach twig borer (Table 7), but it was interesting to note that the residue resulting from applications with a handgun sprayer were much higher than were found with that of the orchard sprayer. This might indicate that reducing rates of diazinon could only be successfully accomplished with excellent coverage. It appeared that the applications with the orchard sprayer were done properly, so perhaps a higher volume application such as would be seen with a handgun application is needed to successfully implement such a strategy.

Objective 4. Walt Bentley and Mario Viveros have been involved in monitoring insects within the Paramount Farms BIOS project in Kern County, and Bentley and Lonnie Hendricks within the BIOS orchards in Merced and Stanislaus counties. Funding from this project in the amount of approximately $6,000 was transferred to Bentley and Viveros in support of their work. They have indicated that their progress will be reported under Bentley's Almond Board project.

Table 1. Mean±SE residues (ng/mm^2) from field applications to almond in February, 1996.

Treatment	cis-permethrin[a]	trans-permethrin[b]	esfenvalerate[c]
Untreated	0.000±0.000 a	0.000±0.000 a	0.000±0.000 a
Diazinon (W95+96)	0.000±0.000 a	0.000±0.000 a	0.000±0.000 a
Asana (W95)	0.000±0.000 a	0.000±0.000 a	0.089±0.036 a
Asana (W95+S95)	0.000±0.000 a	0.000±0.000 a	0.119±0.036 a
Asana (W96)	0.001±0.001 a	0.000±0.000 a	0.610±0.112 b
Ambush (W95)	0.095±0.032 a	0.134±0.047 a	0.000±0.000 a
Ambush (W95+S95)	0.110±0.043 a	0.116±0.022 a	0.000±0.000 a
Ambush (W96)	1.867±0.275 b	1.603±0.184 b	0.000±0.000 a

[a] F=7.938; P<0.0001.
[b] F=32.984; P<0.0001.
[c] F=14.928; P<0.0001.
[d] column means followed by the same letter are not significantly different (P>0.05) by Fishers Protected LSD.

Table 2. Mean±SE number of predator mite adult females and eggs remaining on almond twigs after 48 hours.

Treatment	Adult females [a, c]	Eggs [b]
Untreated	7.96±0.227 a	8.16±0.967 a
Diazinon (W95+W96)	6.52±0.232 b	4.68±0.415 bc
Asana (W95)	6.04±0.313 bc	2.84±0.373 d
Asana (W95+S95)	5.32±0.395 cd	3.28±0.467 cd
Asana (W96)	5.40±0.332 cd	3.40±0.551 bcd
Ambush (W95)	5.04±0.426 d	4.44±0.592 bcd
Ambush (W95 + S95)	6.20±0.306 bc	4.96±0.495 b
Ambush (W96)	5.48±0.448 cd	3.96±0.677 bcd

[a] F=7.590; P<0.0001; n=25.
[b] F=8.212; P<0.0001; n=25.
[c] No sign. difference (P>0.05) in treatment x assay date interaction by 2 way ANOV. Column means followed by the same letter are not sign. different (P>0.05) by Fishers Protected LSD.

Table 3. Mean±SE number of predator mite adult females and eggs remaining on almond leaf punches treated with permethrin after 96 hours.

Treatment (label rate)	Live females [a, d]	Dead females [b]	Eggs/ female [d]
Untreated	6.50±1.50 a	1.50±0.50 a	3.50±0.50 a
Ambush (1.00)	0.00±0.00 c	9.00±0.00 c	0.00±0.00 b
Ambush (0.250)	3.50±0.50 ab	5.00±0.00 b	0.00±0.00 b
Ambush (0.125)	3.00±0.00 bc	5.50±0.50 b	0.50±0.50 b

[a] F=11.333; P<0.0001; n=10.
[b] F=75.333; P<0.0001; n=10.
[c] F=22.667; P<0.0001; n=10.
[d] Column means followed by the same letter are not sign. different (P>0.05) by Fishers Protected LSD.

Table 4. Efficacy of several dormant and bloom sprays on peach twig borer on variety Nonpariel almonds. Trial conducted by James Brazzle, Kern Co., 1996.

Treatment (lb. a.i./acre)	mean±SE twig strikes/tree	
Asana XL (0.26)	0.50±0.00	a
Pounce 3.2EC (0.4)	1.71±0.81	ab
Diazinon (2.0)+1 rain	2.47±0.39	ab
Dipel (0.15) 3x	2.60±0.35	ab
Diazinon (0.5)	3.57±0.30	abc
Imidan (3.2)	4.13±0.47	bcd
Diazinon (2.0)+2 rains	4.43±0.70	bcd
Diazinon (1.0)	6.73±1.27	cde
Dipel (0.15) 2x	6.83±1.24	cde
Supracide (2.0)	7.03±0.93	de
Dipel (0.15) 1x	7.97±0.88	e
Diazinon (2.0)	11.2±0.35	f
Control	17.6±2.35	g

Table 5. Efficacy of several dormant and bloom sprays on peach twig borer on variety Monterey almonds. Trial conducted by James Brazzle, Kern Co., 1996.

Treatment (lb. a.i./acre)	mean±SE twig strikes/tree	
Pounce 3.2EC (0.4)	1.23±0.15	a
Asana XL (0.26)	1.57±0.19	a
Diazinon (2.0)+2 rains	3.67±0.73	ab
Dipel (0.15) 3x	4.97±0.51	b
Imidan (3.2)	5.50±1.10	b
Diazinon (2.0)+1 rain	5.67±1.48	b
Dipel (0.15) 2x	5.83±1.01	b
Supracide (2.0)	9.53±0.73	c
Diazinon (1.0)	10.13±1.79	c
Diazinon (0.5)	11.27±1.87	c
Dipel (0.15) 1x	11.87±0.43	c
Diazinon (2.0)	27.93±2.20	d
Control	31.03±2.53	e

Table 6. Efficacy of reduced rates of diazinon + oil on peach twig borer. Trial conducted by Rich Coviello, Fresno Co., 1996.

Treatment (rate)	twig strikes/tree[a] mean±SE
Untreated	28.88±2.64 a
Dipel (1 qt/acre, 2x)	12.50±1.59 b
Diazinon (2.0 lb ai/ac)	4.62±1.13 c
Diazinon (1.0 lb ai/ac)	4.62±0.82 c
Diazinon (0.5 lb ai/ac)	4.50±1.27 c
Asana (0.25 lb ai/ac	2.38±0.92 c

[a] F=48.12; P>0.0001; n=8. means followed by the same letter so not differ significantly (P>0.05) by Fishers Protected LSD.

Table 7. Mean±SE diazinon residues (ng/mm^2) from dormant applications to almond in 1996.

Treatment	Handgun sprayer Fresno Co. [a, c]	Orchard sprayer Kern Co. [b]
Untreated	0.175±0.023 a	0.238±0.033 a
Diazinon 0.5 lb ai/ac	13.335±0.914 b	1.296±0.130 b
Diazinon 1.0 lb ai/ac	24.916±1.620 c	3.579±0.326 c
Diazinon 2.0 lb ai/ac	28.521±4.350 c	7.366±0.472 d

[a] F=29.282; P<0.0001; n=8.
[b] F=114.744; P<0.0001; n=8.
[c] column means followed by the same letter are not significantly different (P>0.05) by Fishers Protected LSD.

Figure 1

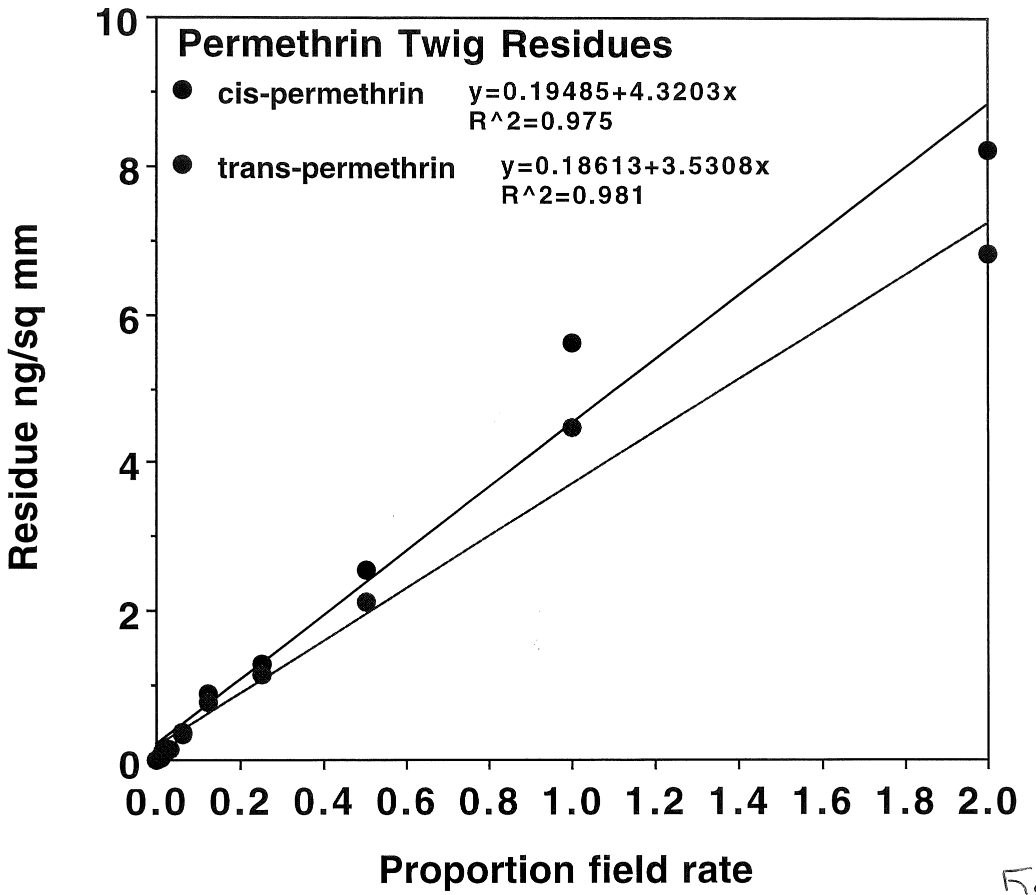


Figure 2

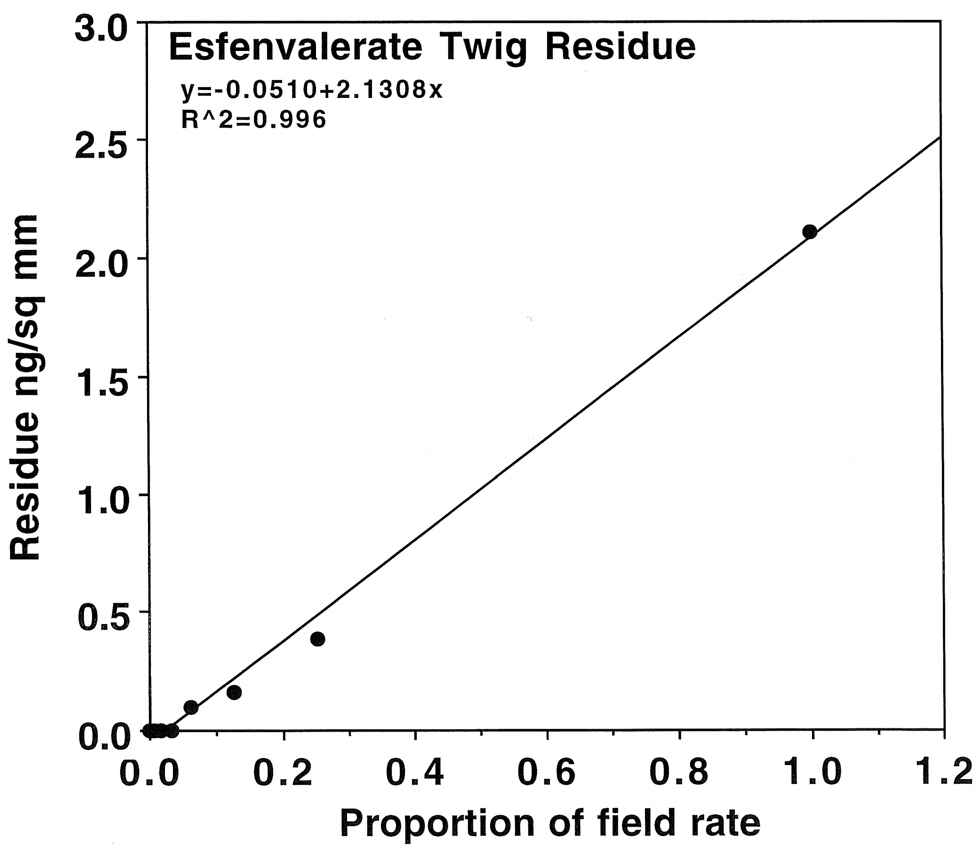


Figure 3

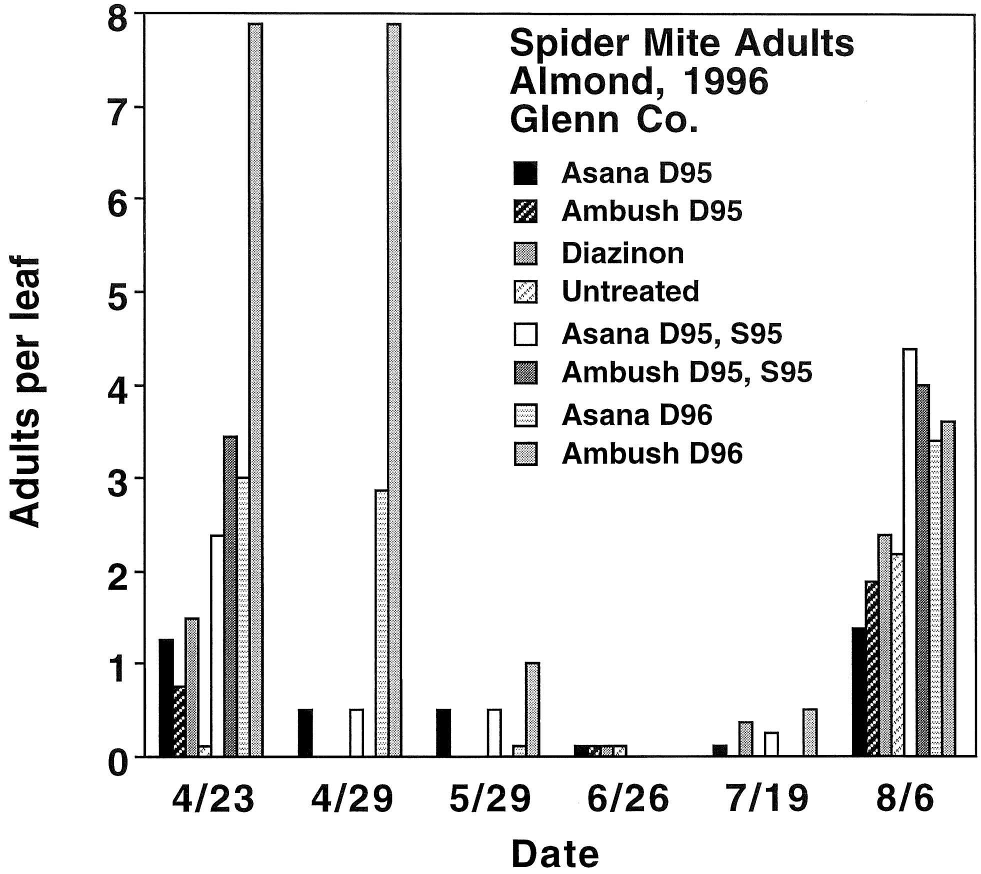


Figure 4

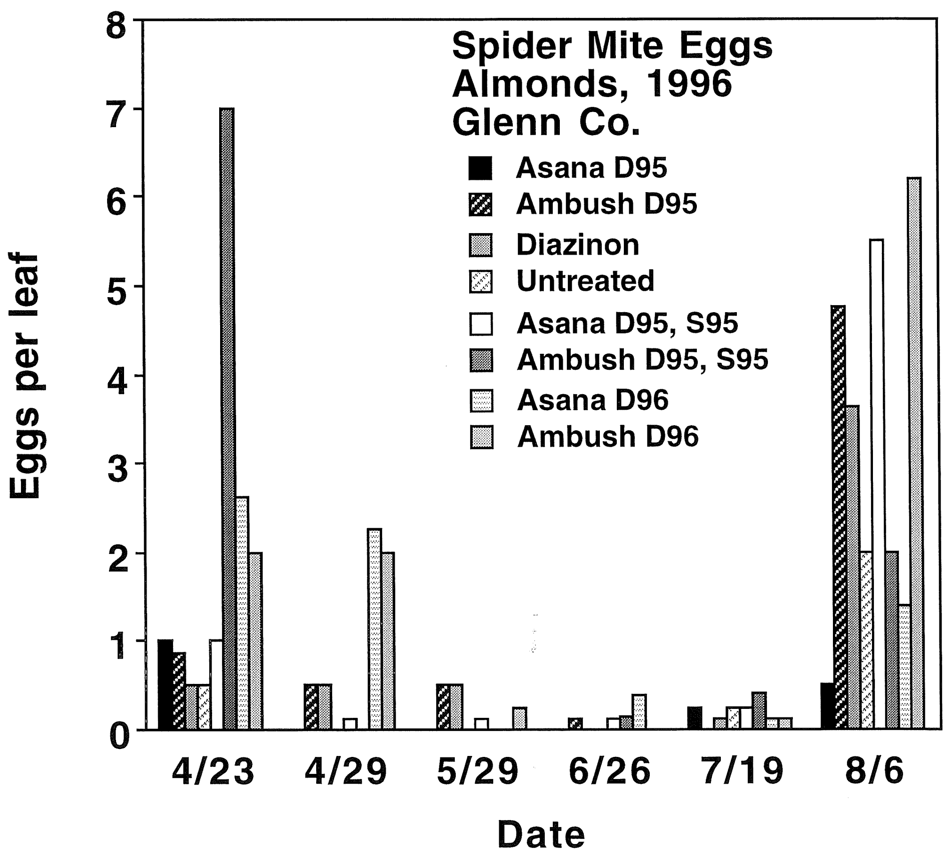
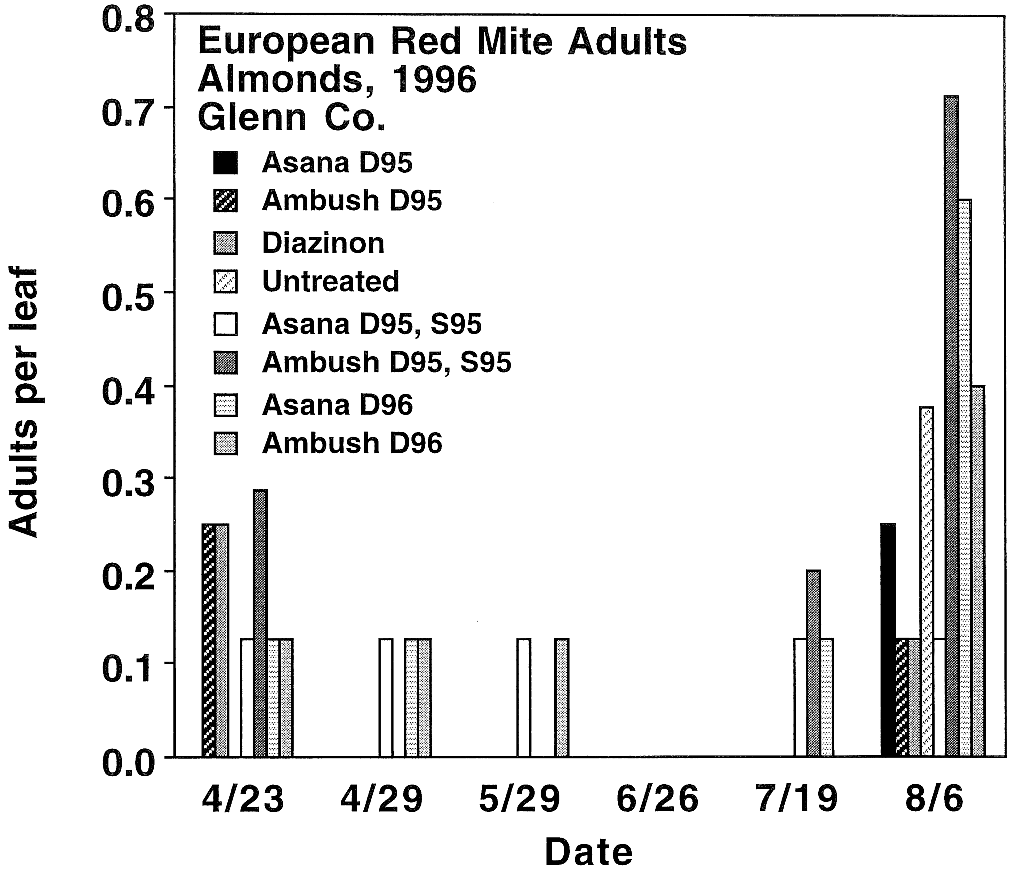


Figure 5



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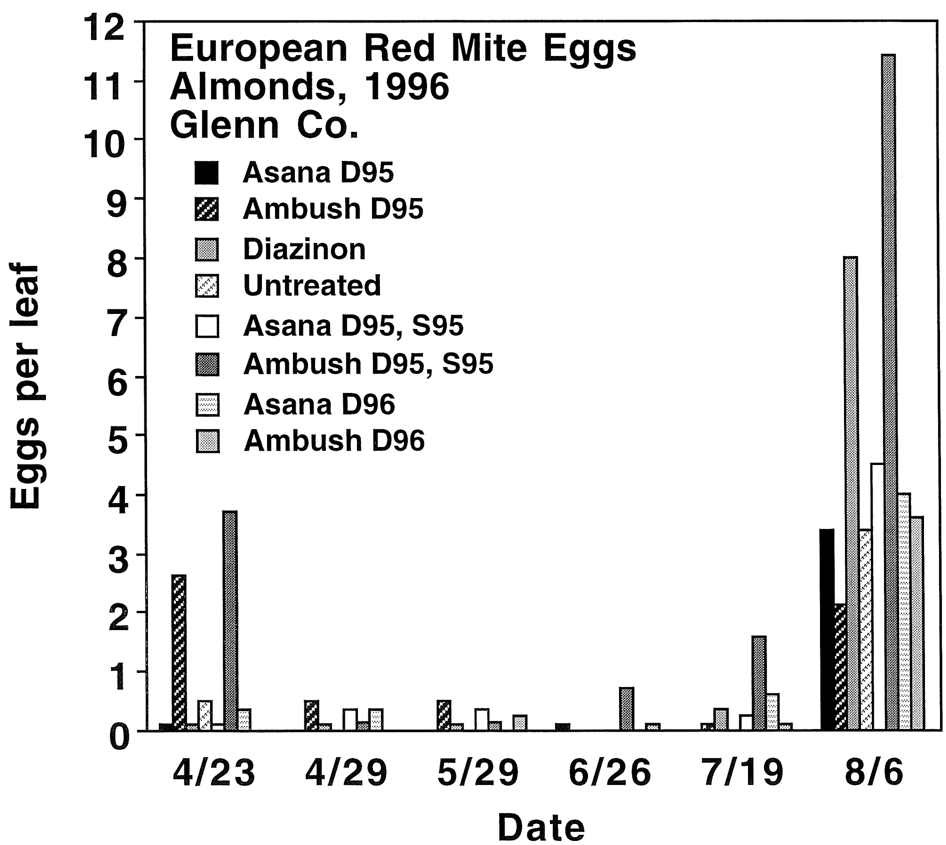

Figure 7

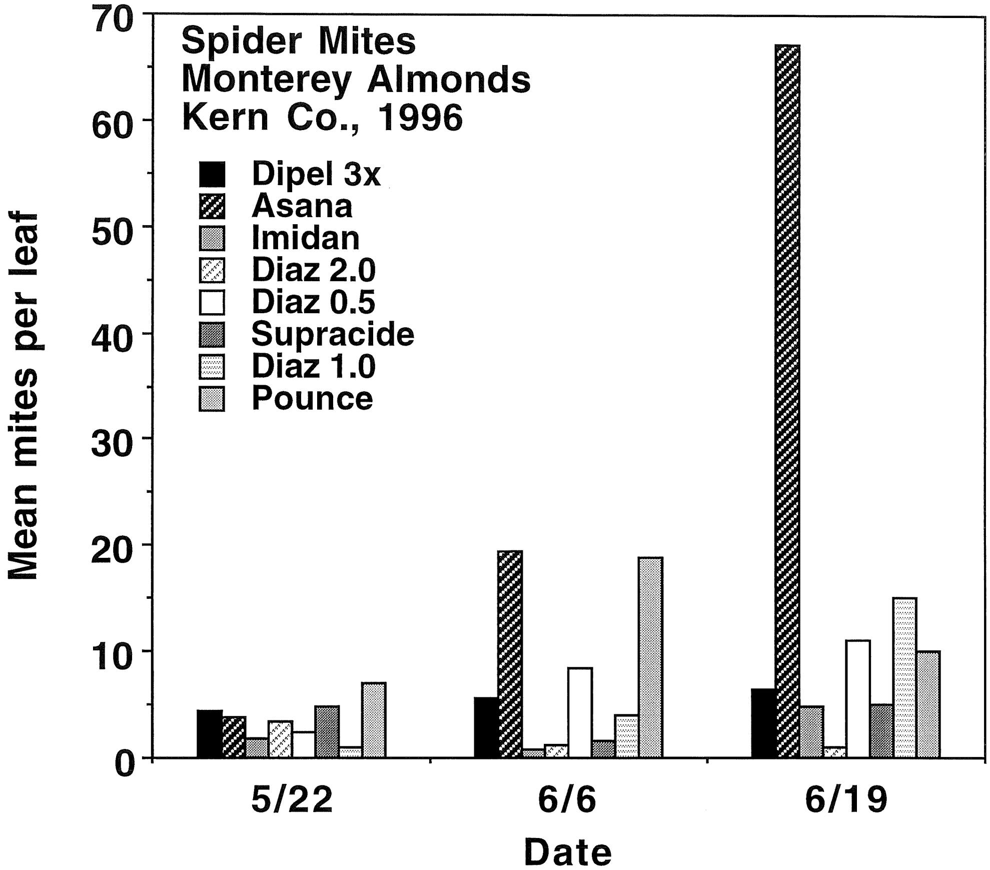

Figure 8