Integrated control of European red mite in Ohio apple orchards

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SUMMARY: A field trial was conducted in Red Delicious apple trees to evaluate the effects on pest mites and predatory mites of several insecticide programs used for control of the key fruit pest, codling moth. Each insecticide program was used with and without oil, and with and without miticide (Envidor), with three replicates of each treatment combination. The insecticide programs used one product for control of first generation codling moth and one product for control of second generation codling moth. The programs were: 1) Rimon followed by Assail, 2) Guthion followed by Asana, 3) Guthion followed by Guthion, 4) no insecticide. Mite density was evaluated at 2-week intervals. The density of European red mite showed that there were strong interactions between mite treatments and insecticide treatments. Where insecticides were used without pre-bloom oil or post-bloom miticide, heavy infestations of European red mite resulted, but where a miticide was used, European red mite population was kept at tolerable levels. The miticide Envidor resulted in excellent control of European red mite, but its use was associated with significantly fewer predatory mites. When oil was used pre-bloom and no miticide was used post-bloom, mites were suppressed only until mid-May. Despite this short period of control, use of pre-bloom oil is advocated for its benefit in resistance management. Among the three insecticide programs evaluated, the cumulative effect of European red mite was more severe where Guthion/Asana and Rimon/Assail were used than where Guthion/Guthion or no insecticides were used. On a mite-susceptible cultivar like Red Delicious, both oil and miticide are recommended with any insecticide program.

Background: Insecticides used by apple growers to control key pests such as codling moth have long been known to cause flare-ups of European red mite, due to the toxicity of insecticides to predatory mites that are the natural enemies of European red mite. Although standard organophosphate insecticides (Imidan and Guthion) have a good reputation for low toxicity to predatory mites, their use is declining due to new restrictions and due to failing efficacy of organophosphates for codling moth control at some orchards. Many growers are thus looking for alternatives to organophosphates. There is a need to document the effects of new insecticides on the mite complex so that growers can be prepared to manage the full complex of orchard pests. Trials in 2003 to 2005 in Ohio showed that pyrethroids were not as harsh on predators as expected if used at low rates, particularly in orchards where stigmaeid predatory mites were present. Research reported here was done to continue collecting data on whether or not predatory mites are conserved when new insecticides are used. The results will be used to develop pesticide recommendations that will allow control of European red mite as an integrated program of both biological and chemical control.

Objective: Evaluate how European red mite, apple rust mite, and predatory mites are affected by insecticide treatments used for codling moth control, in conjunction with oil and miticide treatments.

Methods:

The trial was conducted in small plots in a block of 4-year old Scarlet Spur Delicious apple trees at Ohio State University's Waterman Laboratory in Columbus, Franklin County, central Ohio. There were 16 treatments each with three replicates in a randomized complete block design, with three adjacent trees per plot. Treatments were all possible combinations of three factors: two levels of oil applied pre-bloom (treat with oil versus no oil), two levels of miticide (with Envidor versus without Envidor), and four levels of insecticide treatment (three insecticide combinations, and an untreated check). Envidor was applied when summer egg laying reached a peak and the first summer eggs were beginning to hatch. Each insecticide treatment included one product for control of first-generation codling moth and one product for control of second-generation codling moth; intended timing and actual timing are detailed in Table 1.

Formulations and rates used for mite control treatments were Damoil (superior oil) at 1%, and Envidor 2SC (spirodiclofen) at 16 fl oz per acre. Insecticide treatments were Asana XL 0.66EC (esfenvalerate) at 4.8 fl oz per acre, Assail 30SG (acetamiprid) at 5 oz per acre applied with oil at 0.5%, Guthion 50WP (azinphosmethyl) at 2 lb per acre, Imidan 70WP (phosmet) at 3 lb per acre, and Rimon 0.83EC (novaluron) at 20 fl oz per acre. All plots except the insecticide checks were treated at petal-fall with Avaunt 30WDG (indoxacarb) at 6 oz per acre. There was a guard row of Gala, Fuji, and Golden Delicious between adjacent treatment rows. The guard rows were not sprayed with oil or miticide but were sprayed with Avaunt at first cover. Insecticides and miticides were applied in a dilute volume of 150 gallons of water per acre by a handgun sprayer operated at pressure of 100 psi, with a D6 ConeTip nozzle tip.

Table 1. Timing of insecticide and miticide applications in Delicious apple trees at OSU's Waterman Lab, Columbus, Ohio, 2006.

Target pest	European red mite	Plum curculio	European red mite	First generation codling moth				Between generations	Second generation codling moth	2nd & 3rd generation codling moth
Target timing[a,b]	Tight cluster	Petal-fall	After eggs laid	1C early (75DD)	1C late (250DD)	2C early (+14 days)	2C late (+14 days)	3C (+14 days); skip 4C	5C & 6C	7C & 8C
Actual timing	4/13	5/1	5/19	5/10 (87 DD)	5/26 (234 DD)	5/24	6/8	6/22	7/19, 8/3	8/17, 8/31
Trtmt										
1	oil	Avaunt	Envidor	Rimon	–	Rimon	–	Imidan	Assail+oil	Assail+oil
2	oil	Avaunt	Envidor	–	Guthion	–	Guthion	Imidan	Asana	Assail+oil
3	oil	Avaunt	Envidor	–	Guthion	–	Guthion	Imidan	Guthion	Imidan
4	oil	–	Envidor	–	–	–	–	–		–
5	–	Avaunt	Envidor	Rimon	–	Rimon	–	Imidan	Assail+oil	Assail+oil
6	–	Avaunt	Envidor	–	Guthion	–	Guthion	Imidan	Asana	Assail+oil
7	–	Avaunt	Envidor	–	Guthion	–	Guthion	Imidan	Guthion	Imidan
8	–	–	Envidor	–	–	–	–	–	–	–
9	oil	Avaunt	–	Rimon	–	Rimon	–	Imidan	Assail+oil	Assail+oil
10	oil	Avaunt	–	–	Guthion	–	Guthion	Imidan	Asana	Assail+oil
11	oil	Avaunt	–	–	Guthion	–	Guthion	Imidan	Guthion	Imidan
12	oil	–	–	–	–	–	–	–		–
13	–	Avaunt	–	Rimon	–	Rimon	–	Imidan	Assail+oil	Assail+oil
14	–	Avaunt	–	–	Guthion	–	Guthion	Imidan	Asana	Assail+oil
15	–	Avaunt	–	–	Guthion	–	Guthion	Imidan	Guthion	Imidan
16	–	–	–	–	–	–	–	–	–	–

[a] Cover sprays designated as 1C for first cover, 2C for second cover, etc.
[b] DD refers to degree-days after a trap-based biofix date.

A standard fungicide program was used in all plots. Fungicides were applied by an AgTech 4002 airblast sprayer operated at pressure of 20 psi, with TeeJet 6510 and 6520 nozzle tips. On all trees including checks, Kocide was sprayed on 4/6/06. Fungicides applied were Mancozeb at 3/4-inch green on 4/12/06, at pink on 4/19/06, and at bloom on 4/26/06; Captan at petal-fall on 5/2/06, and in a cover spray on 5/15/06; Mancozeb on 6/5/06 and 6/22/06; Captan on 7/6/06; Captan plus Topsin-M on 7/21/06 and 8/9/06.

Mite populations were sampled at 12- to 21-day intervals from early May until mid-August. A sample of 20 randomly selected leaves was taken from one tree at the center of each plot. Leaves were brushed with a mite-brushing machine, and mites were counted in sub-samples to determine the average number of European red mite and predatory mites per leaf. The density of apple rust mite was rated as low (<5 mites per leaf), moderate (5 to 50 mites per leaf), or high (>50 mites per leaf) for each sample. Cumulative mite-days were calculated using the plot means and the number of days in the interval between counts. Samples of predatory mites were preserved for species verification. Plots were scouted for nymphs of white apple leafhopper on 5/9/06, and for cumulative leafhopper damage on 6/12/06, using a sample of one mid-cluster leaf, and 25 samples per plot. Data were subjected to analysis of variance (ANOVA) and mean comparisons by least significant difference (LSD) tests in the general linear models (GLM) procedure of the SAS 6.12 microcomputer statistics program.

Results and discussion:

European red mite (ERM) reached a peak density of 96 motiles per leaf (Table 2A) and 158 eggs per leaf (Table 3A) in untreated check plots on 6/26/06. Stigmaeid predatory mites were present throughout the season but reached maximum density of 1.7 per leaf in late July (Table 4A). Phytoseiid predatory mites were present at trace levels from early May until mid-June but more common from late June to mid-August, and they reached maximum density of 1.5 per leaf in late July (Table 5A). Apple rust mite was present in all treatments and peaked in late June and early July (Table 6A). No phytotoxicity was observed from applications of miticides or insecticides.

When density of ERM motiles was analyzed for effects of the main treatment factors (Table 2B), prebloom application of oil had a significant effect in early and mid-May, with significantly fewer ERM in plots sprayed with oil than in plots not sprayed with oil. ERM remained below threshold through mid-June in plots sprayed with oil prebloom. The trend of fewer ERM in oil plots than in no-oil plots continued until late July, but differences were not statistically significant after mid-May. Application of miticide had a highly significant effect from late May until late July, with significantly fewer ERM motiles in plots sprayed with Envidor than in plots not sprayed with Envidor.

There was no significant effect of insecticide on any of the eight sampling dates; ERM density was the same in plots treated with the three insecticide combinations and in the untreated check.

The cumulative effect of treatments on European red mite is shown by mite-day totals (Table 2A, final column), which differed among the 16 treatments. Cumulative mite-days ranged from a low of 8 in treatment 1 to a high of 2564 in treatment 14. For each of the three insecticide treatments, there was a consistent trend of highest mite-days where no oil and no miticide were used, and lowest mite-days where both oil and miticide were used. Use of miticide had a much greater impact on mite-days than use of oil. As shown in the analysis of main factors, there was no significant effect of oil, although lower mite-days resulted where oil was used. There was a highly significant effect of miticide, which resulted in lower mite-days where Envidor was used. There was no significant effect of insecticide, although the trend was higher mite-days in the Guthion/Asana and Rimon/Assail treatments then in the Guthion/Guthion and untreated check treatments. Although the benefits of oil were shorter lived than Envidor, oil has great benefit in resistance management, and its use in combination with miticide is strongly recommended.

Eggs of ERM were affected by oil and Envidor treatment the same as ERM motiles were affected; plots treated with oil had significantly fewer ERM eggs until late May, and plots treated with Envidor had significantly fewer eggs until late July (Table 3A). There was no significant effect of insecticide on density of ERM eggs on any of the eight sampling dates.

Density of stigmaeid predatory mites (*Zetzellia mali*) showed no significant effect of oil (Table 4B). There was a significant effect of miticide from mid-June until mid-August, with Envidor plots having significantly fewer stigmaeids than plots with no Envidor. This difference could be due to toxicity of Envidor, or due to shortage of prey because of the extremely low density of ERM that resulted from Envidor application. There was a significant effect of insecticide on stigmaeids on only one date in mid-June, when there were significantly more stigmaeids in the Rimon plots than in the Guthion or check plots.

Density of phytoseiid predatory mites (*Neoseiulus fallacis*) showed a significant effect of miticide from late June until mid-August, with Envidor plots having significantly fewer phytoseiids than plots with no Envidor (Table 5B). As with the effect on stigmaeids, this difference could be due to toxicity of Envidor, or due to shortage of prey because of the extremely low density of ERM that resulted from Envidor application. There was a significant effect of insecticide on phytoseiids on only the final sampling date in mid-August, when there were significantly more phytoseiids in the Guthion/Asana plots than in the other treatments.

Apple rust mite, which is important as alternate prey for predatory mites, showed a significant effect of Envidor, with fewer rust mites in Envidor than in no-Envidor plots from mid-June to mid-July (Table 6B). Apple rust mite was significantly affected by insecticide on only one sampling in mid-July, when there were significantly fewer rust mites in the Rimon/Assail treatment than in the other treatments. Apple rust mite was significantly affected by oil on only one sampling in mid-June, when there were significantly fewer rust mites in the oil treatments than in the no-oil treatments.

White apple leafhopper was found at very low density in 2006. Evaluation on 6/12/06, at the end of the nymph development period, showed nymphs present only in plots not treated with insecticide, but damage ratings showed leafhopper damage in some other treatments (Table 7A). When analyzed for effects of the main treatment factors (Table 7B), leafhopper damage ratings showed a significant effect of oil, miticide, and insecticide; there was less leafhopper damage in plots with oil than with no oil, in plots with Envidor than with no Envidor, and in plots with Rimon or Guthion than in plots with no insecticide.

<u>Conclusions</u>: The density of European red mite showed that there were strong interactions between mite treatments and insecticide treatments. Where insecticides were used without pre-bloom oil or post-bloom miticide, heavy infestations of European red mite resulted, but where a miticide was used, the European red mite population was kept at tolerable levels. The miticide Envidor resulted in excellent control of European red mite, but its use was associated with significantly fewer predatory mites. When oil was used pre-bloom and no miticide was used post-bloom, mites were suppressed only until mid-May. Despite this short period of control, use of pre-bloom oil is advocated for its benefit in resistance management. Among the three insecticide programs evaluated, the cumulative effect of European red mite was more severe where Guthion/Asana and Rimon/Assail were used than where Guthion/Guthion or no insecticide were used. On a mite-susceptible cultivar like Red Delicious, both oil and miticide are recommended with any insecticide program.

Table 2A. Number of European red mite MOTILES per leaf (mean of three blocked replicates) on Delicious apple leaves in 16 treatments on eight sampling dates in 2006 at OSU's Waterman Lab, Columbus, Ohio.

Treatment				Date								Cumu- lative Mite days
No.	Oil	Miti- cide	Insecticide (1st generation/ 2nd generation)	5/3	5/ 16	5/30	6/14	6/26	7/10	7/31	8/14	
				Number of mites per leaf								
1	yes	yes	Rimon/Assail	0.07	0.00	0.10	0.03	0.20	0.13	0.00	0.07	8
2	yes	yes	Guthion/Asana	0.63	0.40	0.40	0.03	0.03	0.03	0.20	0.47	24
3	yes	yes	Guthion/Guthion	0.27	0.07	0.40	0.10	0.20	0.10	0.77	1.27	37
4	yes	yes	none/none	0.40	0.23	0.80	0.07	0.10	0.03	0.20	0.20	25
5	no	yes	Rimon/Assail	0.33	0.47	0.47	0.07	0.10	0.00	0.17	0.00	21
6	no	yes	Guthion/Asana	0.50	0.51	0.47	0.07	7.17	0.13	0.27	0.37	121
7	no	yes	Guthion/Guthion	1.97	0.80	2.50	0.13	0.10	0.13	1.30	2.30	105
8	no	yes	none/none	1.33	1.03	3.53	0.03	0.10	0.07	0.10	0.53	84
9	yes	no	Rimon/Assail	0.58	0.98	7.92	7.41	18.1	17.5	20.5	3.70	1164
10	yes	no	Guthion/Asana	0.20	0.30	5.63	4.47	21.8	23.0	5.7	1.65	950
11	yes	no	Guthion/Guthion	0.23	0.07	2.30	2.37	13.1	7.9	0.5	3.10	410
12	yes	no	none/none	0.33	0.20	2.67	2.20	8.57	12.4	1.4	0.30	431
13	no	no	Rimon/Assail	1.10	0.90	11.4	12.5	34.1	42.6	13.9	1.57	1808
14	no	no	Guthion/Asana	1.89	1.07	29.1	25.3	96.0	14.1	14.3	0.47	2564
15	no	no	Guthion/Guthion	0.57	0.13	3.2	6.1	24.7	13.6	6.67	4.79	847
16	no	no	none/none	0.33	0.33	3.3	3.8	9.0	6.2	0.13	0.07	338

Table 2B. Main treatment effects on number of European red mite MOTILES per leaf (mean of three blocked replicates) on Delicious apple leaves in 16 treatments on eight sampling dates in 2006 at OSU's Waterman Lab, Columbus, Ohio.

Treatment	Number of mites per leaf [a] on each date								Cumu- lative Mite days
	5/3	5/ 16	5/30	6/14	6/26	7/10	7/31	8/14	
With oil	0.34 B	0.28 B	2.53	2.08	7.8	7.63	3.66	1.34	381
No Oil	1.00 A	0.66 A	6.74	6.00	21.4	9.60	4.61	1.26	736
P, oil effect	*0.02*	*0.03*	*0.10*	*0.09*	*0.21*	*0.62*	*0.69*	*0.92*	*0.14*
With Envidor	0.69	0.44	1.08	0.07 B	1.0 B	0.08 B	0.38 B	0.65	53 B
No Envidor	0.65	0.50	8.18	8.02 A	28.2 A	17.2 A	7.89 A	1.96	1064 A
P, Envidor effect	*0.90*	*0.72*	*0.008*	*0.0013*	*0.02*	*0.0002*	*0.0032*	*0.11*	*0.0002*
Rimon/Assail	0.52	0.59	4.96	5.00	13.1	15.04	8.64	1.33	750
Guthion/Asana	0.80	0.57	8.89	7.46	31.3	9.30	5.12	0.74	915
Guthion/Guthion	0.76	0.27	2.09	2.17	9.5	5.45	2.30	2.86	350
none/none	0.60	0.45	2.58	1.53	4.4	4.67	0.47	0.28	220
P, Insecticide effect	*0.88*	*0.50*	*0.22*	*0.24*	*0.32*	*0.26*	*0.10*	*0.13*	*0.14*

[a] Within each column and group, means followed by same letter are not significantly different (P>0.05); mean separations by LSD.

Table 3A. Number of European red mite EGGS per leaf (mean of three blocked replicates) on Delicious apple leaves in 16 treatments on eight sampling dates in 2006 at OSU's Waterman Lab, Columbus, Ohio.

Treatment				Number of mites per leaf on each date							
No.	Oil	Miti-cide	Insecticide (1st generation/ 2nd generation)	5/3	5/ 16	5/30	6/14	6/26	7/10	7/31	8/14
1	yes	yes	Rimon/Assail	0.00	0.7	0.2	0.3	0.8	0.9	0.03	0.2
2	yes	yes	Guthion/Asana	0.13	3.6	0.5	0.1	0.2	0.2	0.33	2.4
3	yes	yes	Guthion/Guthion	0.07	1.1	0.5	0.1	0.2	1.1	3.23	5.1
4	yes	yes	none/none	0.00	4.3	0.3	0.3	0.5	0.3	0.97	0.6
5	no	yes	Rimon/Assail	0.13	5.4	1.8	0.3	0.3	0.2	0.5	0.2
6	no	yes	Guthion/Asana	0.03	5.1	0.5	0.5	12.6	0.4	1.3	2.3
7	no	yes	Guthion/Guthion	0.87	16.3	7.8	1.5	1.0	0.5	3.1	10.3
8	no	yes	none/none	0.34	28.0	3.1	0.5	0.6	0.1	0.3	0.6
9	yes	no	Rimon/Assail	0.07	11.1	6.9	30.5	44.5	87.3	41.3	6.2
10	yes	no	Guthion/Asana	0.03	3.8	4.8	22.4	58.8	57.0	29.3	5.4
11	yes	no	Guthion/Guthion	0.00	2.7	1.6	14.7	49.9	21.0	1.5	8.7
12	yes	no	none/none	0.03	2.5	2.0	6.7	30.1	32.4	6.8	0.8
13	no	no	Rimon/Assail	0.30	16.9	7.9	48.8	84.7	113.7	38.5	4.2
14	no	no	Guthion/Asana	0.23	21.8	22.6	78.8	158.4	53.3	48.8	1.8
15	no	no	Guthion/Guthion	0.30	3.0	2.9	31.6	62.5	43.9	22.7	18.5
16	no	no	none/none	0.13	4.1	2.5	18.3	25.0	20.7	0.4	0.1

Table 3B. Main treatment effects on number of European red mite EGGS per leaf (mean of three blocked replicates) on Delicious apple leaves on eight sampling dates in 2006 at OSU's Waterman Lab, Columbus, Ohio.

Treatment	Number of mites per leaf[a] on each date							
	5/3	5/ 16	5/30	6/14	6/26	7/10	7/31	8/14
With oil	0.04 B	3.8 B	2.1	9.4	23.1	25.0	10.4	3.7
No Oil	0.29 A	12.6 A	6.2	22.5	43.1	29.1	14.4	4.8
P, oil effect	*0.0005*	*0.0114*	*0.08*	*0.07*	*0.23*	*0.72*	*0.55*	*0.69*
With Envidor	0.20	8.1	1.9 B	0.4 B	2.0 B	0.5 B	1.2 B	2.7
No Envidor	0.14	8.3	6.4 A	31.5 A	64.2 A	53.7 A	23.7 A	5.7
P, Envidor effect	*0.36*	*0.96*	*0.05*	*0.0001*	*0.0007*	*<0.0001*	*0.002*	*0.27*
Rimon/Assail	0.12	8.5	4.2	20.0	32.5	50.5	20.1	2.7
Guthion/Asana	0.11	8.6	7.1	25.4	57.5	27.8	19.9	3.0
Guthion/Guthion	0.31	5.8	3.2	12.0	28.4	16.6	7.6	10.6
none/none	0.13	9.7	2.0	6.4	14.1	13.4	2.1	0.6
P, Insecticide effect	*0.11*	*0.85*	*0.43*	*0.26*	*0.32*	*0.10*	*0.16*	*0.06*

[a] Within each column and group, means followed by same letter are not significantly different ($P>0.05$); mean separations by LSD.

Table 4A. Number of stigmaeid predatory mite motiles per leaf (mean of three blocked replicates) on Delicious apple leaves in 16 treatments on eight sampling dates in 2006 at OSU's Waterman Lab, Columbus, Ohio.

Treatment				Number of mites per leaf on each date							
No.	Oil	Miti-cide	Insecticide (1st generation/ 2nd generation)	5/3	5/ 16	5/30	6/14	6/26	7/10	7/31	8/14
1	yes	yes	Rimon/Assail	0	0	0	0	0	0	0	0
2	yes	yes	Guthion/Asana	0	0	0	0	0	0.03	0	0.03
3	yes	yes	Guthion/Guthion	0	0	0	0	0	0	0	0.13
4	yes	yes	none/none	0	0	0	0	0	0	0.03	0.04
5	no	yes	Rimon/Assail	0	0.03	0	0	0	0	0.07	0
6	no	yes	Guthion/Asana	0	0	0	0	0	0	0.07	0
7	no	yes	Guthion/Guthion	0	0.07	0.03	0	0	0	0.03	0.10
8	no	yes	none/none	0	0.07	0	0	0	0	0	0.10
9	yes	no	Rimon/Assail	0	0.07	0	0.17	0.83	0.77	1.67	1.57
10	yes	no	Guthion/Asana	0	0	0	0	0.25	0.93	0.30	0.13
11	yes	no	Guthion/Guthion	0	0.03	0.10	0.03	0.23	1.27	0.60	0.61
12	yes	no	none/none	0	0.03	0.03	0	0.14	0	1.33	0.43
13	no	no	Rimon/Assail	0	0	0	0.23	0	0.60	1.23	0.57
14	no	no	Guthion/Asana	0	0.03	0	0.03	0.10	0.23	1.00	0.10
15	no	no	Guthion/Guthion	0	0	0.03	0.03	0.03	0.23	0.53	0.90
16	no	no	none/none	0	0	0	0	0.07	0	0.37	0.53

Table 4B. Main treatment effects on number of stigmaeid predatory mites per leaf (mean of three blocked replicates) on Delicious apple leaves on eight sampling dates in 2006 at OSU's Waterman Lab, Columbus, Ohio.

Treatment	Number of mites per leaf [a] on each date							
	5/3	5/ 16	5/30	6/14	6/26	7/10	7/31	8/14
With oil	0	0.017	0.017	0.025	0.18	0.38	0.49	0.37
No Oil	0	0.025	0.008	0.038	0.02	0.13	0.41	0.29
P, oil effect	–	*0.63*	*0.57*	*0.61*	*0.13*	*0.12*	*0.61*	*0.64*
With Envidor	0	0.021	0.004	0.000 B	0.00 B	0.01 B	0.02 B	0.05 B
No Envidor	0	0.020	0.021	0.062 A	0.21 A	0.50 A	0.88 A	0.61 A
P, Envidor effect	–	*0.98*	*0.26*	*0.0163*	*0.047*	*0.0027*	*<0.0001*	*0.0033*
Rimon/Assail	0	0.025	0	0.100 A	0.21	0.34	0.74	0.53
Guthion/Asana	0	0.008	0	0.008 B	0.08	0.30	0.34	0.07
Guthion/Guthion	0	0.025	0.042	0.017 B	0.07	0.38	0.29	0.44
none/none	0	0.025	0.008	0.000 B	0.05	0.00	0.43	0.28
P, Insecticide effect	–	*0.84*	*0.16*	*0.026*	*0.68*	*0.30*	*0.19*	*0.27*

[a] Within each column and group, means followed by same letter are not significantly different ($P > 0.05$); mean separations by LSD.

Table 5A. Number of phytoseiid predatory mite motiles per leaf (mean of three blocked replicates) on Delicious apple leaves in 16 treatments on eight sampling dates in 2006 at OSU's Waterman Lab, Columbus, Ohio.

Treatment				Number of mites per leaf on each date							
No.	Oil	Miti-cide	Insecticide (1st generation/ 2nd generation)	5/3	5/ 16	5/30	6/14	6/26	7/10	7/31	8/14
1	yes	yes	Rimon/Assail	0	0	0	0	0	0	0	0
2	yes	yes	Guthion/Asana	0	0	0	0	0	0	0	0
3	yes	yes	Guthion/Guthion	0	0	0	0	0	0	0	0.03
4	yes	yes	none/none	0	0	0	0	0	0	0	0
5	no	yes	Rimon/Assail	0	0	0	0	0	0	0	0
6	no	yes	Guthion/Asana	0	0	0	0	0	0	0	0.07
7	no	yes	Guthion/Guthion	0	0	0	0	0	0	0.03	0.03
8	no	yes	none/none	0	0	0	0	0	0	0	0
9	yes	no	Rimon/Assail	0	0	0	0	0.03	0.03	0.53	0.03
10	yes	no	Guthion/Asana	0	0	0	0	0.10	0	1.47	0
11	yes	no	Guthion/Guthion	0	0	0	0	0	0.03	0.23	0
12	yes	no	none/none	0	0.03	0	0	0.14	0.07	0.37	0.03
13	no	no	Rimon/Assail	0	0	0	0	0	0.03	0.95	0
14	no	no	Guthion/Asana	0	0	0	0	0	0	1.17	0.23
15	no	no	Guthion/Guthion	0.03	0	0	0	0.03	0.11	0.77	0
16	no	no	none/none	0	0	0	0.03	0.10	0.10	0.27	0.03

Table 5B. Main treatment effects on number of phytoseiid predatory mites per leaf (mean of three blocked replicates) on Delicious apple leaves on eight sampling dates in 2006 at OSU's Waterman Lab, Columbus, Ohio.

Treatment	Number of mites per leaf [a] on each date							
	5/3	5/ 16	5/30	6/14	6/26	7/10	7/31	8/14
With oil	0.000	0.004	0	0	0.03	0.02	0.32	0.01 B
No Oil	0.004	0	0	0.004	0.02	0.03	0.40	0.05 A
P, oil effect	*0.33*	*0.33*	–	*0.33*	*0.44*	*0.45*	*0.66*	*0.0114*
With Envidor	0.000	0	0	0	0.00 B	0.00 B	0.01 B	0.02
No Envidor	0.004	0.004	0	0.004	0.05 A	0.05 A	0.72 A	0.04
P, Envidor effect	*0.33*	*0.33*	–	*0.33*	*0.0282*	*0.0115*	*0.002*	*0.052*
Rimon/Assail	0	0	0	0	0.01	0.02	0.37	0.01 B
Guthion/Asana	0	0	0	0	0.02	0	0.66	0.08 A
Guthion/Guthion	0.008	0	0	0	0.01	0.04	0.26	0.02 B
none/none	0	0.008	0	0.008	0.06	0.04	0.16	0.02 B
P, Insecticide effect	*0.41*	*0.41*	–	*0.41*	*0.33*	*0.33*	*0.20*	*0.002*

[a] Within each column and group, means followed by same letter are not significantly different (P>0.05); mean separations by LSD.

Table 6A. Apple rust mite density rating on Delicious apple leaves in 16 treatments on eight sampling dates in 2006, mean of three blocked replicates at OSU's Waterman Lab, Columbus, Ohio.

Treatment				Mite density rating[a] on each date							
No.	Oil	Miti-cide	Insecticide (1st generation/ 2nd generation)	5/3	5/ 16	5/30	6/14	6/26	7/10	7/31	8/14
1	yes	yes	Rimon/Assail	0.3	0.7	1.0	0.3	0.3	0	0.3	0
2	yes	yes	Guthion/Asana	0	0.7	1.0	0.3	0.7	0.3	0.7	0
3	yes	yes	Guthion/Guthion	0.7	1.0	1.0	0	0.7	0.7	0.3	0.3
4	yes	yes	none/none	0	1.0	1.0	0.3	0.7	0.3	1.0	0.7
5	no	yes	Rimon/Assail	0	0.7	0.7	0.7	0.7	0.3	0.3	0
6	no	yes	Guthion/Asana	0.3	1.0	1.0	1.0	1.3	0	0.7	0.7
7	no	yes	Guthion/Guthion	0	1.0	1.0	0.7	1.0	0.3	0	0.3
8	no	yes	none/none	0	1.0	1.0	0.3	1.0	0.3	0.3	0.7
9	yes	no	Rimon/Assail	0	1.0	1.0	1.0	1.0	0.3	1.0	0.3
10	yes	no	Guthion/Asana	0	1.0	1.0	1.0	1.7	2.3	1.3	0.7
11	yes	no	Guthion/Guthion	0	1.0	0.7	1.0	2.0	1.0	0.3	1.0
12	yes	no	none/none	0	1.0	1.0	0.7	1.3	1.7	1.0	0.7
13	no	no	Rimon/Assail	0	1.0	1.0	1.0	1.3	0.7	0.7	0.7
14	no	no	Guthion/Asana	0	1.3	1.3	1.0	1.3	1.7	0.7	0.7
15	no	no	Guthion/Guthion	0	1.0	1.0	1.0	2.0	2.0	0.3	0.7
16	no	no	none/none	0	1.0	1.0	1.3	2.0	2.7	0.3	0.7

[a] Density rating scale: 0 = none; 1 = low (<5 per leaf); 2 = moderate (5 to 50 per leaf); 3 = high (>50 per leaf).

Table 6B. Main treatment effects on apple rust mite rating on Delicious apple leaves on eight sampling dates in 2006, mean of three blocked replicates at OSU's Waterman Lab, Columbus, Ohio.

Treatment	Mite density rating[a,b] on each date							
	5/3	5/ 16	5/30	6/14	6/26	7/10	7/31	8/14
With oil	0.12	0.9	1.0	0.6 B	1.0	0.8	0.8	0.5
No Oil	0.04	1.0	1.0	0.9 A	1.3	1.0	0.4	0.5
P, oil effect	*0.27*	*0.29*	*0.56*	*0.03*	*0.06*	*0.46*	*0.14*	*0.50*
With Envidor	0.17 A	0.9 B	1.0	0.5 B	0.8 B	0.3 B	0.5	0.3 B
No Envidor	0.00 B	1.0 A	1.0	1.0 A	1.6 A	1.5 A	0.7	0.7 A
P, Envidor effect	*0.0313*	*0.0381*	*0.56*	*0.0002*	*<0.0001*	*<0.0001*	*0.27*	*0.0105*
Rimon/Assail	0.08	0.8	0.9	0.7	0.8	0.3 B	0.6	0.2
Guthion/Asana	0.08	1.0	1.1	0.8	1.2	1.1 A	0.8	0.5
Guthion/Guthion	0.17	1.0	0.9	0.7	1.4	1.0 A	0.2	0.6
none/none	0.00	1.0	1.0	0.7	1.2	1.2 A	0.7	0.7
P, Insecticide effect	*0.48*	*0.34*	*0.31*	*0.77*	*0.06*	*0.04*	*0.31*	*0.11*

[a] Density rating scale: 0 = none; 1 = low (<5 per leaf); 2 = moderate (5 to 50 per leaf); 3 = high (>50 per leaf).
[b] Within each column and group, means followed by same letter are not significantly different (P>0.05); mean separations by LSD.

Table 7A. White apple leafhopper density and damage rating on Delicious apple leaves in 16 treatments on 12 June 2006 (19 days after second spray with Rimon; 4 days after second spray with Guthion), mean of three blocked replicates at OSU's Waterman Lab, Columbus, Ohio.

Treatment					Number of leafhopper nymphs per leaf	Damage rating[a]
Code	Oil (applied on 4/13)	Insecticide at Petal-fall (5/1)	Miticide (applied on 5/19)	Insecticide used for first-generation codling moth control		
1	oil	Avaunt	Envidor	Rimon on 5/10 & 5/24	0	0
2	oil	Avaunt	Envidor	Guthion on 5/26 & 6/8	0	0.03
3	oil	Avaunt	Envidor	Guthion on 5/26 & 6/8	0	0.01
4	oil	none	Envidor	none	0	0.04
5	none	Avaunt	Envidor	Rimon on 5/10 & 5/24	0	0
6	none	Avaunt	Envidor	Guthion on 5/26 & 6/8	0	0
7	none	Avaunt	Envidor	Guthion on 5/26 & 6/8	0	0
8	none	none	Envidor	none	0.01	0.01
9	oil	Avaunt	none	Rimon on 5/10 & 5/24	0	0
10	oil	Avaunt	none	Guthion on 5/26 & 6/8	0	0.03
11	oil	Avaunt	none	Guthion on 5/26 & 6/8	0	0
12	oil	none	none	none	0.05	0.03
13	none	Avaunt	none	Rimon on 5/10 & 5/24	0	0
14	none	Avaunt	none	Guthion on 5/26 & 6/8	0	0
15	none	Avaunt	none	Guthion on 5/26 & 6/8	0	0.01
16	none	none	none	none	0.04	0.71

[a] Damage rating scale: 0 = none; 1 = light; 2 = moderate; 3 = heavy.

Table 7B. Main treatment effects on leafhopper rating on Delicious apple leaves on 6/12/06, mean of three blocked replicates at OSU's Waterman Lab, Columbus, Ohio.

Treatment	Nymphs per leaf[a]	Damage rating[a,b]
With oil	0.009	0.020 B
No Oil	0.009	0.120 A
P, oil effect	*1.00*	*0.0194*
With Envidor	0.002	0.013 B
No Envidor	0.016	0.127 A
P, Envidor effect	*0.17*	*0.0092*
Rimon	0.000 B	0.000 B
Guthion	0.000 B	0.013 B
none	0.027 A	0.197 A
P, Insecticide effect	*0.0453*	*0.0007*

[a] Within each column and group, means followed by same letter are not significantly different (P>0.05); mean separations by LSD.
[b] Damage rating scale: 0 = none; 1 = light; 2 = moderate; 3 = heavy.