Ohio Apple Pest Management Trial, 2002
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Objectives: To evaluate control of European red mite by the new miticide Acramite used at two different timings, to refine the pesticide tolerance guidelines for the predatory mite *Zetzellia mali* by comparing a standard organophosphate program with an organophosphate plus early Danitol program and with an organophosphate plus early Avaunt program, and to assess efficacy of Danitol and Avaunt for control of insect pests.

Methods: A field trial was conducted at a 18-year old block of Scarlet Spur Delicious apples at OSU's Waterman Laboratory in Columbus. The experimental design was randomized complete block with four replicates of six treatments as detailed in Table 1. Plot size was three adjacent trees; all data were taken from one central tree per plot. Treatment sprays were applied at a dilute volume of 150 gallons per acre by an airblast PTO-driven Agtec 4002 Crop Sprayer operated at pressure of 20 psi, with TeeJet 6510 and 6520 nozzle tips. All plots including the checks were treated with Esteem 35WP at half-inch green for control of San José scale, which had been a significant problem the previous year.

Thresholds for mite control were 2.5 mites per leaf in early summer (mid-May until mid-June), 5 mites per leaf in mid-summer (mid-June until mid-July), and 7.5 mites per leaf in late summer (mid-July until mid-August). Due to high density of European red mite, rescue treatment with Savey was needed in July in three treatments as detailed in Table 1. Acramite was scheduled for a single application in each of two treatments but due to inadequate control from the first application, a second application was made in early July. In the first Acramite application, no adjuvants were used, but in the second Acramite applications several adjuvants were used as detailed in Table 1. Water was tested for pH and hardness using test kits: a vial test (Aquarium Pharmaceuticals Inc., Chalfont PA) was used in May and a dip strip test (Mardel's Aqua Lab I, St. JON Laboratories, Harbor City, CA) was used in July.

Decisions about whether or not to include insecticide in summer cover sprays were based on codling moth trap and degree-day data. Three Multipher-I traps baited with Trécé standard codling moth lures were checked twice per week and lures were replaced every 4 weeks. Optimal timing to target hatching eggs was assumed to be 250 degree days (base 50F) after the initial surge in flight activity.

A standard fungicide program was used in all plots including the checks. Fungicides used were Captan at quarter-inch green (4/11/02); Captan plus Nova at pink (4/17/02) and at bloom (4/24/02); Captan at petalfall (4/30/02); Captan plus Topsin-M at first cover (5/15/02), second cover (5/31/02), and third cover (6/14/02); Captan at fourth cover (6/28/02) and fifth cover (7/12/02); Captan plus Topsin-M at sixth cover (7/24/02) and seventh cover (8/16/02); and Captan at eighth cover (9/9/02).

Mite populations on 25 randomly selected leaves per tree were evaluated every 1 to 3 weeks from late April through late August with more frequent evaluations when density was approaching the threshold. Samples of predatory mites were preserved for species verification. Plots were scouted for white apple leafhopper 3 and 6 weeks after petalfall. At harvest on 4 October, insect damage was evaluated on 100 fruit per plot. Data were subjected to analysis of variance and mean comparisons by least significant difference (LSD) tests in the ANOVA procedure of the SAS statistics program.

Table 1: Timing and rates of mite and insect treatments on Red Delicious apples in 2002 at OSU's Waterman Lab, Columbus, Ohio.

Timing >> *Treatment*	1/2" green (4/11)	Tight cluster (4/15)	Pink (4/18)	Petal-fall (5/1)	1C (5/16)	2C (5/31) 3C (6/14) 4C (6/28) 6C (7/24) 7C (8/16) 8C (9/9)	Extra sprays for mites
Check	Esteem 35WP, 4 oz/A	none	none	none	none	none	none
Standard	Esteem 35WP, 4 oz/A	none	Lorsban 50WP, 2 lb/A	Imidan 70WP, 3 lb/A	Imidan 70WP, 3 lb/A + **AgriMek** 0.15EC, 10.7 oz/A + SunSpray UF oil, 0.25%	Imidan 70WP 2.1 lb/A	7/16**: Savey**, 3 oz/A
Danitol	Esteem 35WP, 4 oz/A	**oil** 1%	Danitol 2.4EC, 10.7 oz/A	Danitol 2.4EC, 16 oz/A	Imidan 70WP, 3 lb/A	Imidan 70WP 2.1 lb/A	7/16**: Savey**, 3 oz/A
Avaunt	Esteem 35WP, 4 oz/A	**oil** 1%	Avaunt 30DG, 6 oz/A	Avaunt 30DG, 6 oz/A	Avaunt 30DG, 6 oz/A	Imidan 70WP 2.1 lb/A	7/16**: Savey**, 3 oz/A
Acramite early	Esteem 35WP, 4 oz/A	none	Lorsban 50WP, 2 lb/A	Imidan 70WP, 3 lb/A + **Acramite** 50W, 1 lb/A	Imidan 70WP, 3 lb/A	Imidan 70WP 2.1 lb/A	7/3**: Acramite** 50W, 1 lb/A + LI700 + Latron
Acramite late	Esteem 35WP, 4 oz/A	none	Lorsban 50WP, 2 lb/A	Imidan 70WP, 3 lb/A	Imidan 70WP, 3 lb/A	Imidan 70WP 2.1 lb/A	6/7**: Acramite** 50W, 1 lb/A at threshold 7/3**: Acramite** 50W, 1 lb/A + LI700 + Latron + Choice

Results and Discussion: Water used in spray applications had a pH of 7.2 to 7.4 and moderate hardness of about 120-197 ppm (Table 2). Addition of the adjuvant ammonium sulfate ('Choice', 1 qt/100 gal) or the adjuvants LI-700 (1 qt/100 gal) plus Latron B-1956 (2 oz/100 gal) reduced the pH but apparently did not reduce the hardness level. Addition of LI-700 and Latron B1956 resulted in lowering of the buffering capacity but no apparent reduction in hardness (Table 2). It is possible that there was some reduction in hardness that was not detectable with the test kit. The test kit gives a result as one of 6 discrete values such as 80 ppm, 120 ppm, 180 ppm, with no intermeduate values. For example, if water before adjuvants were added had hardness of 150 ppm and it was reduced to 100 ppm, both values might show up in the 120 ppm category. The water test kits were designed for testing plain water thus are fine for pre-treatment testing, but using them in water after colored adjuvants were added might cause unreliable results.

Population density of European red mite reached above threshold levels by early June in the untreated check and in the Acramite treatment that was to be treated at threshold (Table 3). European red mite density by mid-July was the highest seen in this orchard in several years. In the standard treatment, Agri-Mek applied at first cover on 16 May kept mites suppressed longer than any other treatment but kept mites under threshold only until mid-July, when a rescue treatment of Savey was applied. The mite density differed significantly among treatments ($P \leq 0.05$) on 4 June, 12 June, and 15 July (Table 3). Acramite applied without adjuvants at petal-fall (1 May) kept mites below threshold until late June. Acramite applied without adjuvants at threshold (7 June) kept mites suppressed below threshold for less than two weeks. The second round of Acramite applications that included adjuvants was more effective than the first round of applications despite the high density of mites at the time of treatment on 3 July (Table 3). There was no significant difference between the two Acramite treatments in European red mite density by 15 July, although there was a numerically greater reducion in the treatment that included Choice than in the treatment without Choice. Density of European red mite eggs (Table 4) followed trends similar to motiles (Table 3).

The abundance of predatory mites in the Acramite and Avaunt treatments showed that these two pesticides are IPM compatible. *Z. mali* was unaffected by Acramite or Avaunt. *Z. mali* was suppressed by Danitol used at pink and petalfall but recovered to moderate levels by late summer (Table 5). Unlike previous years, *Z. mali* was also suppressed in the standard treatment, probably due to use of Agri-Mek for the first time in several years. Some phytoseiids were also found in this orchard (Table 6) and surprisingly they rebounded to higher density in the Danitol treatment than in the standard treatment; inclusion of Agri-Mek in the standard program could have caused this suppression. Rescue treatment with Savey on 16 July had no negative effect on *Z. mali* (Table 5) but was associated with a sharp drop in phytoseiid density (Table 6), possibly due to prey depletion.

Apple rust mite was significantly lower in the standard treatment than other treatments from late May until early July (Table 7), which was assumed to be due to Agri-Mek. Neither Acramite nor Avaunt was associated with reduced rust mite density. Lack of effect on rust mite is generally considered good for mite IPM due to the role of rust mites as alternate prey for predatory mites when spider mites are not available for predators to feed on.

The white apple leafhopper population did not differ significantly among treatments 3 weeks after petalfall when nymph density was evaluated ($P > 0.05$) but cumulative damage ratings 6 weeks after petalfall showed significantly better control in the Danitol and Avaunt treatments than in the standard treatment, and leafhopper control in the standard was significantly better than in the untreated check (Table 8).

The codling moth population was higher than normal. Moths began emerging at the usual time; the biofix date for sustained flight was 6 May. Moth emergence was more prolonged than usual (Table 9) due to a long period of cool wet weather in May and early June. The optimal time for control of hatching eggs was on 30 May, which coincided with the second cover spray. Insecticide was omitted from only one cover spray, fifth cover on 12 July, due to low codling moth activity at that time. For the summer generation,

increased moth emergence began between 10 and 15 July, and optimal spray time was 24 July, which coincided with the sixth cover spray. Continual trap catches above 7 moths per week throughout August and the first half of September probably indicate a partial third generation, thus insecticide was included in cover sprays on 16 August and 9 September.

At harvest, fruit showed high levels of injury from internal lepidoptera (Table 10), primarily codling moth but with some lesser appleworm and European corn borer also observed. The percentage of fruit undamaged by insects in all insecticide treatments (70.5 to 72.8%) was significantly higher than in the untreated check (49.7%) but not different than each other (Table 10). Tarnished plant bug damaged 4.8% of fruit in untreated checks, was well controlled by Danitol and the standard treatment, but not well controlled by Avaunt. Some damage by late leafrollers, plum curculio, and San Jose scale occurred but did not differ significantly among treatments (Table 10). The reason for poor control of codling moth in all insecticide treatments is not known; resistance to organophosphates is possible but has not been tested. The codling moth adult population was larger than normal and its emergence period was more prolonged than usual, but this was addressed by using more cover sprays than usual so that during the period when eggs hatched, insecticide residue should have been adequate.

Conclusions: The orchard was under heavy pressure from European red mite and codling moth in this trial. Acramite showed potential for control of European red mite but issues of which adjuvants are needed must be worked out before recommendations to growers can be made with confidence. Acramite and Avaunt appear to be IPM-compatible because they do not harm the stigmaeid predatory mite *Zetzellia mali* or the phytoseiid predatory mite *Neoseiulus fallacis*. Both Agri-Mek, which was used in the standard treatment, and Danitol suppressed *Z. mali*. Avaunt used as pink, petalfall, and first cover provided good control of white apple leafhopper but not of tarnished plant bug. Danitol used just at pink and petalfall provided good control of leafhopper and tarnished plant bug and did suppress European red mite but was unable to keep European red mite below threshold by early July.

Table 2: Water quality test results for water used in spray tank in 2002 at OSU's Waterman Lab, Columbus, Ohio.

Date sampled	Date tested	Test kit type	Water sample	pH	Buffering capacity	General hardness (ppm)	Total hardness (ppm)
22 May	22 May	vials	Pre-mixing	7.4	-	143	-
3 July	5 July	vials	Pre-mixing	7.2	-	197	-
			After Choice (1 qt/100 gal) added	6.0	-	197[a]	-
			After Choice (1 qt/100 gal) and LI-700 (1 qt/100 gal) and Latron B-1956 (2 oz/100 gal) added	6.0	-	233[a]	-
			After LI-700 and Latron added (without Choice)	6.0	-	233[a]	-
3 July	11 July	strips	Pre-mixing	7.2[b]	80[c]	-	120[d]
			After Choice added	<6.4[b]	80[c]	-	120[d]
			After Choice and LI-700 and Latron added	<6.4[b]	0[c]	-	120[d]
			After LI-700 and Latron added (without Choice)	<6.4[b]	0[c]	-	120[d]

[a] value uncertain due to the color of adjuvants confounding the test.
[b] In strips test, pH values possible are 6.4, 6.8, 7.2, 7.6, 8.0, 8.4 .
[c] In strips test, buffering values possible are 0, 80, 120, 180, 240, 300.
[d] In strips test, hardness values possible are 0, 25, 50, 120, 250, and 425.

Table 3: Number of motile European red mite per leaf on 10 sampling dates; mean of 4 replicates.

Treatment	*4/26*	*5/14*	*5/29*	*6/4*	*6/12*	*6/19*	*7/1*	*7/15*	*7/31*	*8/26*
Check	0.70	0.94	1.74	4.6 AB	3.3 A	7.2	46	74 BC	6.8	0.18
Standard	0.10	0.57	0.20	0.3 B	0.1 B	1.1	4	40 CD	0.8	0.04
Danitol	0.26	0.10	0.04	0.1 B	0.7 B	1.0	13	126 A	1.0	0.08
Avaunt	0.14	0.74	0.54	1.9 B	4.0 A	9.5	48	96 AB	0.6	0.00
Acramite early	0.12	0.16	0.14	0.7 B	1.0 B	3.1	35	21 D	2.1	0.06
Acramite late	0.38	0.90	1.71	8.1 A	4.2 A	7.8	61	13 D	2.6	0.00
P (trt effect)	*0.34*	*0.11*	*0.13*	***0.05***	***0.002***	*0.34*	*0.48*	***0.0001***	*0.08*	*0.60*

Table 4: Number of European red mite eggs per leaf on 10 sampling dates; mean of 4 replicates.

Treatment	*4/26*	*5/14*	*5/29*	*6/4*	*6/12*	*6/19*	*7/1*	*7/15*	*7/31*	*8/26*
Check	0	2.4	12.0	6.7 AB	21 A	50 AB	118 AB	201 AB	14 B	1
Standard	0	0.3	0.7	0.4 B	2 B	3 C	16 C	124 BC	35 B	3
Danitol	0	0.0	0.5	0.8 B	2 B	10 C	39 BC	294 A	89 A	12
Avaunt	0	0.8	4.0	5.6 AB	22 A	51 A	132 A	230 AB	20 B	9
Acramite early	0	0.2	2.6	1.7 B	8 AB	21 BC	118 AB	57 C	12 B	2
Acramite late	0	1.8	22.9	15.0 A	16 AB	9 C	80 ABC	45 C	10 B	1
P (trt effect)	*-*	*0.06*	*0.08*	***0.04***	***0.03***	***0.01***	***0.04***	***0.002***	***0.0004***	*0.28*

Table 5: Number of predatory stigmaeid mite motiles per leaf; mean of 4 replicates.

Treatment	*4/26*	*5/14*	*5/29*	*6/4*	*6/12*	*6/19*	*7/1*	*7/15*	*7/31*	*8/26*
Check	0.04	0.06 A	0	0.02	0	0.06	0.04	0.62	2.70 A	0.70 AB
Standard	0.02	0.00 B	0	0	0.02	0	0	0.06	0.49 B	0.14 C
Danitol	0.02	0.00 B	0	0	0	0	0.02	0.02	0.25 B	0.16 C
Avaunt	0.08	0.06 A	0	0.08	0.10	0.20	0.14	1.77	1.43 B	0.16 C
Acramite early	0.10	0.00 B	0.06	0	0.06	0.12	0.52	1.56	2.80 A	1.00 A
Acramite late	0.04	0.02 AB	0.02	0.08	0.04	0.10	0.20	1.10	1.39 B	0.45 BC
P (trt effect)	*0.66*	***0.05***	*0.11*	*0.29*	*0.10*	*0.11*	*0.16*	*0.09*	***0.002***	***0.004***

Table 6: Number of predatory phytoseiid mite motiles per leaf; mean of 4 replicates.

Treatment	*4/26*	*5/14*	*5/29*	*6/4*	*6/12*	*6/19*	*7/1*	*7/15*	*7/31*	*8/26*
Check	0	0	0	0.02	0.06	0.14 A	0.16	0.84	0.30	0.16
Standard	0	0	0	0	0	0.00 B	0.02	0.44	0.12	0.04
Danitol	0	0	0	0	0.02	0.04 B	0.06	1.06	0.12	0.12
Avaunt	0	0	0	0	0	0.06 AB	0.20	1.03	0.20	0.12
Acramite early	0	0	0	0	0.02	0.00 B	0.04	0.18	0.30	0.06
Acramite late	0	0	0	0	0	0.00 B	0.04	0.44	0.38	0.16
P (trt effect)	*-*	*-*	*-*	*0.45*	*0.09*	***0.01***	*0.25*	*0.15*	*0.50*	*0.44*

Table 7: Apple rust mite density rating (0 = none; 1 = low [<5 per leaf]; 2 = moderate [5 to 50 per leaf]; 3 = high [>50 per leaf]); mean of 4 replicates.

Treatment	*4/26*	*5/14*	*5/29*	*6/4*	*6/12*	*6/19*	*7/1*	*7/15*	*7/31*	*8/26*
Check	0.5	1.2	2.2 A	2.2 A	3.0 A	2.8 A	3.0 A	3.0	2.5 A	0.50
Standard	0.5	1.0	0.5 B	0.2 C	1.2 D	0.5 B	1.5 C	2.5	1.2 C	0.50
Danitol	0.2	0.2	0.5 B	1.2 B	1.8 CD	1.8 A	2.2 B	2.8	2.2 AB	0.00
Avaunt	0.2	0.8	1.5 A	1.8 AB	2.2 BC	2.2 A	2.8 AB	3.0	1.5 C	0.25
Acramite early	0.8	1.0	1.8 A	2.2 A	2.5 AB	2.2 A	2.8 AB	2.8	1.8 BC	0.00
Acramite late	0.5	1.2	2.0 A	2.2 A	2.5 AB	1.8 A	2.5 AB	2.2	1.2 C	0.25
P (trt effect)	*0.79*	*0.26*	***0.003***	***0.0008***	***0.001***	***0.006***	***0.007***	*0.17*	***0.009***	*0.25*

Table 8: White apple leafhopper density and damage on Red Delicious apples in 2002 at OSU's Waterman Lab, Columbus, Ohio; mean of 4 replicates.

Treatment	*Mean number of nymphs per leaf on 5/21 (3 weeks after petalfall)*	*Mean damage rating on 6/13 (6 weeks after petalfall); 0 = none, 1 = light, 2 = moderate, 3 = heavy.*
Check	0.16	1.5 A
Standard	0.02	0.7 C
Danitol	0.00	0.3 D
Avaunt	0.00	0.1 D
Acramite early	0.09	1.3 AB
Acramite late	0.14	1.0 B
P (treatment effect)	*0.07*	*0.0001*

Table 9: Weekly catch of adult codling moth in pheromone traps in apple orchard at OSU's Waterman Lab, Columbus, Ohio (mean of 3 traps).

Date at week's end	*Mean number of moths per trap*	*Cumulative degree-days (base 50F) after biofix*
4/24/2002	0.0	-
5/1/2002	0.3	-
5/8/2002	8.0	38
5/15/2002	15.0	98
5/22/2002	11.3	114
5/29/2002	14.3	220
6/5/2002	16.7	383
6/12/2002	15.3	537
6/19/2002	11.7	671
6/26/2002	10.3	878
7/3/2002	2.7	1087
7/10/2002	2.7	1282
7/17/2002	12.3	1458
7/24/2002	21.0	1658
7/31/2002	17.0	1863
8/7/2002	14.7	2064
8/14/2002	19.0	2246
8/21/2002	9.3	2423
8/28/2002	12.0	2604
9/4/2002	10.3	2779
9/11/2002	7.3	2963
9/18/2002	2.0	3104
9/25/2002	1.0	3219

Table 10: Insect damage on Red Delicious fruit at harvest on 4 October 2002; mean of 4 replicates (means shown are actual percentages, but analysis was based on transformed values).

Treatment	*% undamaged*	*% codling moth or other internal lepidoptera*	*% tarnished plant bug*	*% leafroller (surface, late)*	*% plum curculio*	*% San José scale*
Check	49.7 B	44.0 A	4.8 A	2.5	1.3	4.3
Standard	70.7 A	31.4 AB	1.0 BC	0.5	1.0	0.0
Danitol	70.0 A	27.4 B	0.5 C	1.8	0.5	0.7
Avaunt	71.8 A	19.8 B	6.2 A	2.5	1.5	0.7
Acramite early	72.8 A	20.0 B	4.0 A	2.8	1.0	0.0
Acramite late	70.5 A	27.5 B	3.5 AB	1.3	1.7	0.0
P (treatment effect)	***0.002***	***0.009***	***0.005***	*0.87*	*0.92*	*0.09*