Codling moth management by insecticides in Ohio apple orchards, 2010

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Introduction: New insecticides were evaluated for control of codling moth, which is challenging in some Ohio orchards due to resistance to organophosphate insecticides. Efficacy of Altacor (chlorantraniliprole) on a standard timing schedule and an experimental early timing schedule, and the standard organophosphate Imidan (phosmet) were evaluated alone, and Danitol (fenpropathrin) and Beleaf (flonicamid) were evaluated in combination with Delegate (spinetoram). This trial also had a mite component for evaluation of European red mite control and survival of its natural predators under a Danitol versus a standard program, in comparison with untreated plots.

Materials & Methods

The trial was conducted in a block of 8-year old apple trees at Ohio State University's Waterman Laboratory in Columbus, Franklin County, Ohio. There were six treatments, each with four replicates in a randomized complete block design. There were five adjacent Red Delicious trees per plot. There were three guard rows between adjacent treatment rows; guard rows were sprayed with oil at tight cluster and with Avaunt at petal-fall, but no other insecticides. The codling moth adult population was monitored with three pheromone traps: one with a standard long-life lure (Trécé) in a Multipher-1 trap, one with a standard long-life lure in a standard unitrap, and one with the DA lure (Trécé) in a Multipher-1 trap. Two additional traps, one standard and one DA, were located in another apple block that was 50 m from the trial block. Traps were checked daily from bloom through biofix, then 3 days per week for the rest of the season. Lesser appleworm and oriental fruit moth (OFM) were also monitored by pheromone traps, but those for OFM were discontinued after no moths were caught in April or May.

The target timing of insecticide for control of first generation codling moth for the standard schedule was 200 to 250 degree-days after biofix, followed by two more sprays at 14-day intervals. This was used for Altacor and Imidan. Danitol was applied on the same schedule but in only two sprays followed by Imidan for the third spray. The target timing for the experimental early schedule of Altacor was 100 degree-days after biofix, followed by a second application at 350 degree-days after biofix, and a third application 14 days later. The first spray of Beleaf was the same as the early Altacor but it was followed by three more sprays at 14-day intervals.

The trap-based codling moth biofix was 30 April. The timing and sequence of insecticide sprays is summarized in Table 1. Insecticides were applied on 13 May, which was 173 degree-days after biofix, for the standard timing of Altacor and Imidan, each followed by a second application on 27 May and a third application on 10 June. Application for the experimental early timing of Altacor was on 6 May, which was 105 degree-days after biofix, followed by a second application at 344 degree-days, on 25 May, and a third application on 8 June. Beleaf was also applied early, on 6 May, followed by three applications on 20 May, 3 June, and 22 June.

Second-generation codling moth was controlled after a second-generation biofix on 2 July, which was 1207 degree-days after first-generation biofix. Altacor, Delegate, and Imidan on the standard timing schedule were applied on 8 July, which was 171 degree-days after the new biofix, and again on 22 July and 5 August. The experimental early application of Altacor was on 6 July, which was 115 degree-days after the new biofix, and again on 15 July (348 degree-days) and 29 July. After a surge in trap catch in mid-August indicated the start of a partial third generation, an eighth cover spray of Imidan was made over all 5 treatments on 19 August.

Insecticides as well as fungicides, nutrients, and thinners were applied by an AgTech 4002 airblast sprayer operated at pressure of 20 psi, with TeeJet 6510 and 6520 nozzle tips, in a volume of 75 gallons of water per acre for insecticides and in 150 gallons of water per acre for oil, fungicides, and plant growth regulators. Products used for control of codling moth were chlorantraniliprole (Altacor 35WG, 3 oz/A), fenpropathrin (Danitol 2.4EC, 21.3 fl oz/A for the first spray and 16 oz/A for the second spray), flonicamid (Beleaf 50SG, 2.8 oz/A), phosmet (Imidan 70WP, 3 lb/A), and spinetoram (Delegate 25WG, 5.2 oz/A). To assess the effects of Beleaf on retention of fruit, a 5-gallon pail was placed under the canopy of the center tree in each plot of Beleaf and untreated check on 5 May. Dropped apples in these pails were collected at weekly intervals for 5 weeks, and were counted, measured, and evaluated for type of insect injury. Injury by all insects was evaluated on 100 randomly selected fruit from the center of each plot, non-destructively on 28 June, and destructively at harvest on 10 September.

For control of San Jose scale and mites, oil (PureSpray, 1%) was applied in all plots except the untreated checks at tight cluster on 6 April. For control of rosy apple aphid at the pink bud stage on 8 April, esfenvalerate (Asana XL, 4.8 fl oz/A) was used in plots in which Altacor was to be used for codling moth control, and chlorpyrifos (Lorsban 50W, 3 lb/A) was used in plots in which Danitol/Delegate, Beleaf/Delegate, and Imidan were to be used for codling moth control. For control of plum curculio and other pests at petal-fall on 27 April, indoxacarb (Avaunt 30WDG, 6 oz/A) was applied to all plots except the untreated checks. Fungicides, nutrients, and thinners were applied to all trees, including check plots and guard rows. For fireblight control, Kocide 3000 (1 lb/100 gal) was used at the delayed dormant stage on 30 March, and AgriMycin (8 oz/100 gal) was used at early bloom on 13 April. For scab control, after Kocide on 30 March, Captan 80WSG (2 lbs/100 gal) was applied at early bloom on 13 April, at bloom on 20 April, and at petal-fall on 27 April; Ziram 76DF (2 lbs/100 gal) was applied on 6 May; Captan again on 1 June, 17 June, and 1 July; Ziram again on 13 July; and Captan again on 27 July and 10 August. Foliar nutrients applied at petal-fall on 27 April were boron (Solubor, 1 lb/100gal), and Nutrileaf 20-20-20 N-P-K (2 lbs/100 gal). For fruit thinning, NAA (7.5 ppm, Fruitone N) plus Regulaid (1 pt/100 gal) was applied on 29 April, and Sevin XLR Plus (1 qt/A) was applied on 13 May.

For mite control, pre-bloom oil was used as a standard treatment, which was to be followed by hexythiazox (Onager) at threshold in plots that were not treated with Danitol. The threshold was never reached, so Onager was never applied. Mite populations were sampled six times at 14- to 29-day intervals from late April until early August. This sampling was less frequent than usual due to low mite density. A sample of 25 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 stigmaeid and phytoseiid 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 by plot using the number of days in the interval between counts.

Data were subjected to analysis of variance (ANOVA) and mean comparisons by least significant difference (LSD) tests in the SAS 9.1 microcomputer statistics program. Percentage data were transformed by arcsine square root before analysis.

Results & Discussion

Both codling moth and lesser appleworm were present (Fig. 1); oriental fruit moth was absent. In late June, the percentage of fruit damaged by the first generation of internal Lepidoptera was significantly lower in all five insecticide treatments than in the untreated check (P = 0.0001; Table 2). Control by Altacor in two timing treatments did not differ statistically from each other or from Danitol or Imidan. Control by Beleaf was significantly better than untreated plots but significantly less effective than Altacor, Danitol, or Imidan (Table 2). Injury by plum curculio and tarnished plant bug was found in late June but did not differ significantly by treatment (Table 2). Dropped fruit were most abundant on 19 May when a trend of more dropped fruit and larger dropped fruit were found in Beleaf plots than in untreated checks but there was no difference in the insect injury index on dropped fruit (Table 3).

At harvest in September, the percentage of fruit damaged by internal Lepidoptera again was significantly lower in all five insecticide treatments than in the untreated check (P = 0.001; Table 4). Control by Altacor in two timing treatments did not differ statistically from each other. Among the five insecticide programs, control by either timing of Altacor was statistically better than control by Imidan, Danitol/Delegate, or Beleaf/Delegate (Table 4). Other insects that caused damage to fruit were tarnished plant bug, plum curculio, leafrollers, and rosy apple aphid, and a trace of San Jose scale and woolly apple aphid (Table 4). No apple maggot was detected. All five insecticide programs resulted in significantly more clean fruit than the untreated check (Table 4). The percentage of clean fruit was significantly higher in all five insecticide treatments than in the untreated check. No phytotoxicity was observed.

The population of European red mite (ERM) was unusually low for the entire season, both for motile stages (Table 5) and eggs (Table 6). Frequent heavy rains from April through June are the likely cause of the low population, along with presence of predators. Stigmaeid predatory mites were found in most plots throughout the season (Table 7), while phytoseiid predatory mites were detected somewhat later and at lower density (Table 8). Apple rust mite was found at low density in all treatments throughout the season (Table 9). Significant treatment effects on ERM were found only on 25 May, when there were significantly more ERM motiles in the check plots than in treated plots, and in cumulative mite-days, when there were significantly more mite-days in the check plots and standard Altacor plots than in the Danitol/Delegate plots, Altacor early timing, and Imidan plots, while mite-days were intermediate in Beleaf/Delegate plots (Table 5). The stigmaeid mites showed significant treatment effects in July and August and in cumulative mite-days; predators were most abundant in the untreated plots and least abundant in the Danitol/Delegate plots (Table 7). No significant treatment effects were found in the Phytoseiid or apple rust mite populations (Tables 8 and 9).

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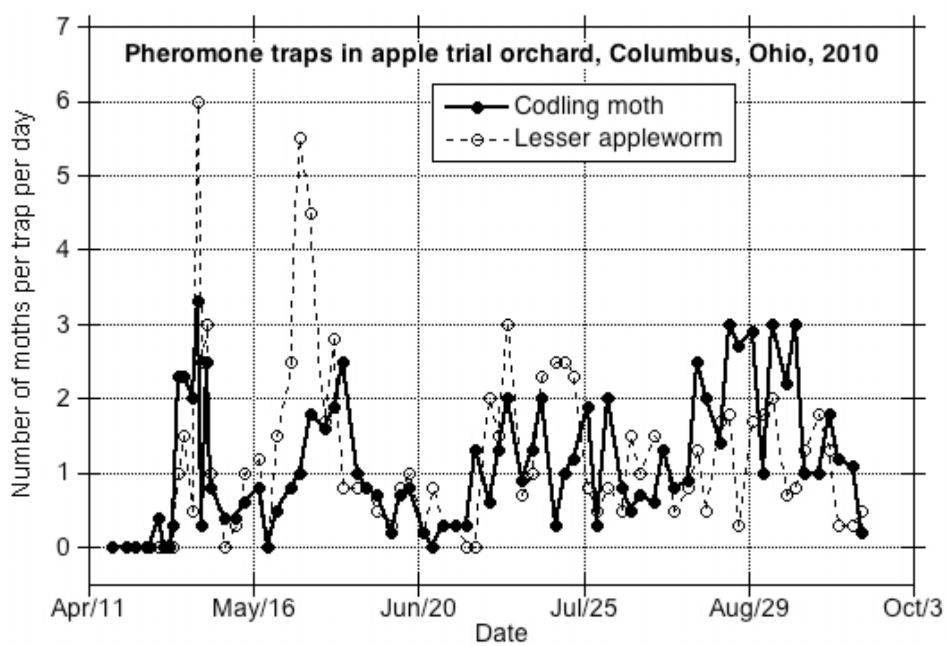

Figure 1. Seasonal trends in codling moth and lesser appleworm adult populations as detected by pheromone traps in apple orchards at Waterman Lab, Columbus, Ohio, 2010; mean of 3 traps with standard lure for codling moth and mean of 2 traps with standard lure for lesser appleworm.

Table 1. Sequence of insecticide sprays in experimental plots of apples, Columbus, Ohio, 2010.

	Stage												
	Pre-pink	Pink	Petal-fall	First cover (1C)		2C		3C		4C	5C, 6C, 7C		8C
				Early	Late	Early	Late	Early	Late	Early	Early	Late	Late
Intended timing				100 DD	200 DD	350 DD or 14 d	14 d	14 d	14 d	14 d	Same as first generation		
Actual timing	4/6	4/8	4/27	5/6 (105 DD)	5/13 (173 DD)	5/20 (344 DD) or 5/25	5/27	6/3 or 6/8	6/10	6/22	7/6, 7/15, 7/29	7/8, 7/22, 8/5	8/19
Treatment													
1	oil	Asana	Avaunt	Altacor	-	Altacor (5/25)	-	Altacor (6/8)	-	-	Altacor	-	-
2	oil	Asana	Avaunt	-	Altacor	-	Altacor	-	Altacor	-	-	Altacor	Imidan
3	oil	Lorsban	Avaunt	-	Danitol 21.3 oz/A	-	Danitol 16 oz/A	-	Imidan	-	-	Delegate	Imidan
4	oil	Lorsban	Avaunt	Beleaf	-	Beleaf (5/20)	-	Beleaf (6/3)	-	Beleaf	-	Delegate	Imidan
5	oil	Lorsban	Avaunt	-	Imidan	-	Imidan	-	Imidan	-	-	Imidan	Imidan
6	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 2. Insect injury to apple fruit after treatment by six insecticide programs, evaluated non-destructively on 28 June 2010; mean of four blocked replicates at OSU's Waterman Lab, Columbus, Ohio.

Treatment (product and timing)	% Internal Lepidoptera			% Plum curculio, oviposition	% Tarnished plant bug	% Clean[a]
	Entry[a]	Sting	Total[a]			
Altacor early	0.0 C	0.25 BC	0.25 C	0	0.75	99.0 A
Altacor normal	0.5 BC	0.00 C	0.50 C	0	1.75	97.8 AB
Danitol normal	0.0 C	0.25 BC	0.25 C	0	2.50	97.3 ABC
Imidan normal	0.5 BC	0.25 BC	0.75 C	0	3.25	96.0 BC
Beleaf early	3.0 B	1.25 AB	4.25 B	0.25	3.00	92.5 C
untreated	9.5 A	3.00 A	12.50 A	1.00	3.25	83.5 D
probability	*P=0.0003*	*P=0.0031*	*P<0.0001*	*P=0.57*	*P=0.30*	*P=0.0002*

[a] Within each column, means followed by same letter are not significantly different (*P*>0.05); mean separations by LSD. Values shown are actual percentages but ANOVA based on transformed values.

Table 3. Number, size, and insect injury on dropped apple fruit as intercepted by one 5-gallon pail under the center tree of each plot for one-week periods, after a petal-fall spray of Avaunt on 27 April, Beleaf sprays on 6 and 20 May and 3 June, and fruit thinner sprays on 29 April (NAA) and 13 May (Sevin); mean of 4 replicate blocks.

Date collected	Treatment	Number of fruit	Fruit diameter (mm)	Injury index[a]
12 May	Untreated	4.8	6.0	0.08
	Beleaf	3.5	7.0	0.03
		P = 0.68	P = 0.30	P = 0.63
19 May	Untreated	22.5	7.2	0.03
	Beleaf	27.3	7.8	0.03
		P = 0.61	P =0.07	P = 0.96
26 May	Untreated	4.8	7.5	0.05 A (N = 4)
	Beleaf	2.0	7.1	0.00 B (N = 2)
		P = 0.09	P = 0.77	P < 0.0001
2 June	Untreated	0.5	14.2 (N = 2)	0.00 (N = 2)
	Beleaf	0.8	19.9 (N = 2)	0.25 (N = 2)
		P = 0.72	-	-
9 June	Untreated	0.3	23.5 (N = 1)	0.00
	Beleaf	1.0	16.2 (N = 3)	0.00
		P = 0.0577	-	-

[a] Injury index: sum of presence/absence scores for 3 types of injury: codling moth, plum curculio, and tarnished plant bug. Total insect injuries on all samples:

7 codmoth (1 on 5/12; 4 on 5/19; 1 on 5/26; 1 on 6/2)
3 plum curculio (1 on 5/12; 2 on 5/19)
1 tarnished plant bug (on 5/19)

Table 4. Insect injury to apple fruit after treatment by six insecticide programs, evaluated on 10 September 2010; mean of four blocked replicates at OSU's Waterman Lab, Columbus, Ohio.

Treatment		% Internal Lepidoptera			% Tarn-ished plant bug	% Plum curculio		Leaf-roller (late)	Rosy apple aphid	San Jose scale	Woolly apple aphid	% Clean[a]
1st gener-ation cod-moth	2nd gener-ation cod-moth	Entry[a]	Sting	Total[a]		early ovi-position	Late feed-ing					
Altacor	Altacor	1.0 C	2.0 D	3.0 C	2.0	0.8	0.8	1.2	0.8	0.2	1.0	91.2 A
Altacor early	Altacor early	1.5 C	2.2 CD	3.8 C	1.0	1.0	0	0.2	1.5	1.0	0.5	91.8 A
Imidan	Imidan	6.2 B	4.2 BC	10.5 B	2.8	0.5	0	2.2	1.2	0	0	83.5 A
Danitol	Dele-gate	6.0 B	5.2 B	11.2 B	1.2	0.2	0	1.2	0.2	0	0	85.8 A
Beleaf	Dele-gate	8.0 B	3.2 BCD	11.2 B	2.0	0.2	0	2.8	1.2	0	0	83.5 A
Untreated	Untreated	38.8 A	8.8 A	47.5 A	3.2	1.5	0	3.0	1.0	0	0	47.5 B
Probability		*<0.0001*	*0.0014*	*0.0001*	*0.43*	*0.17*	*0.054*	*0.35*	*0.50*	*0.57*	*0.59*	*<0.0001*

[a] Within each column, means followed by same letter are not significantly different (P>0.05); mean separations by LSD. Values shown are actual percentages but ANOVA based on transformed values.

Table 5. European red mite (ERM) density of motiles on Delicious apple leaves in 2010, Columbus, Ohio.

Treatment			*Mean density on six sampling dates*						*Cumulative mite-days*
Pre-bloom	*1st generation codling moth*	*2nd generation codling moth*	*26 April*	*25 May*	*18 June*	*2 July*	*19 July*	*9 August*	
Oil, Asana	Altacor	Altacor	0.00	0.02 B	0.08	0.00	0.00	0.00	2.0 AB
Oil, Asana	Altacor early	Altacor early	0.00	0.00 B	0.00	0.00	0.00	0.00	0.0 C
Oil, Lorsban	Imidan	Imidan	0.00	0.00 B	0.00	0.00	0.00	0.00	0.0 C
Oil, Lorsban	Danitol	Delegate	0.00	0.00 B	0.00	0.00	0.00	0.00	0.0 C
Oil, Lorsban	Beleaf	Delegate	0.00	0.00 B	0.00	0.02	0.00	0.00	0.3 BC
Untreated	Untreated	Untreated	0.02	0.08 A	0.06	0.00	0.00	0.00	3.6 A
ANOVA			*P = 0.45*	*P = 0.008*	*P = 0.06*	*P = 0.45*	-	-	*P = 0.0046*

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

Table 6. European red mite (ERM) egg density on Delicious apple leaves in 2010, Columbus, Ohio.

Treatment			*Mean density on six sampling dates*					
Pre-bloom	*1st generation codling moth*	*2nd generation codling moth*	*26 April*	*25 May*	*18 June*	*2 July*	*19 July*	*9 August*
Oil, Asana	Altacor	Altacor	0.00	0.00	0.04	0.06	0.00	0.00
Oil, Asana	Altacor early	Altacor early	0.00	0.00	0.04	0.02	0.00	0.00
Oil, Lorsban	Imidan	Imidan	0.00	0.08	0.00	0.06	0.00	0.00
Oil, Lorsban	Danitol	Delegate	0.00	0.00	0.00	0.02	0.00	0.00
Oil, Lorsban	Beleaf	Delegate	0.00	0.00	0.06	0.08	0.02	0.00
Untreated	Untreated	Untreated	0.00	0.16	0.22	0.06	0.02	0.00
ANOVA			-	*P = 0.14*	*P = 0.30*	*P = 0.92*	*P = 0.45*	-

Table 7. Stigmaeid predatory mite density on Delicious apple leaves in 2010, Columbus, Ohio.

Treatment			*Mean density on six sampling dates*						*Cumulative mite-days*
Pre-bloom	*1st generation codling moth*	*2nd generation codling moth*	*26 April*	*25 May*	*18 June*	*2 July*	*19 July*	*9 August*	
Oil, Asana	Altacor	Altacor	0.10	0.00	0.08	0.10 B	0.28 BC	0.59 BC	17 BC
Oil, Asana	Altacor early	Altacor early	0.02	0.00	0.06	0.04 B	0.18 BC	0.92 AB	16 BC
Oil, Lorsban	Imidan	Imidan	0.08	0.02	0.04	0.04 B	0.24 BC	0.48 BC	13 BC
Oil, Lorsban	Danitol	Delegate	0.06	0.00	0.00	0.02 B	0.00 C	0.14 C	3 C
Oil, Lorsban	Beleaf	Delegate	0.06	0.02	0.24	0.22 B	0.36 B	1.00 AB	28 B
Untreated	Untreated	Untreated	0.02	0.00	0.30	0.55 A	0.97 A	1.28 A	49 A
ANOVA			*P = 0.70*	*P = 0.60*	*P = 0.06*	*P = 0.0115*	*P < 0.0001*	*P = 0.0256*	*P = 0.0018*

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

Table 8. Phytoseiid predatory mite density on Delicious apple leaves in 2010, Columbus, Ohio.

Treatment			*Mean density on six sampling dates*						*Cumulative mite-days*
Pre-bloom	*1st generation codling moth*	*2nd generation codling moth*	*26 April*	*25 May*	*18 June*	*2 July*	*19 July*	*9 August*	
Oil, Asana	Altacor	Altacor	0.00	0.02	0.18	0.22	0.18	0.04	11
Oil, Asana	Altacor early	Altacor early	0.00	0.02	0.18	0.32	0.40	0.08	18
Oil, Lorsban	Imidan	Imidan	0.00	0.02	0.10	0.36	0.08	0.10	11
Oil, Lorsban	Danitol	Delegate	0.00	0.00	0.02	0.14	0.36	0.10	11
Oil, Lorsban	Beleaf	Delegate	0.00	0.00	0.22	0.34	0.18	0.16	15
Untreated	Untreated	Untreated	0.00	0.02	0.14	0.28	0.10	0.10	11
ANOVA			-	*P = 0.86*	*P = 0.21*	*P = 0.43*	*P = 0.07*	*P = 0.64*	*P = 0.14*

Table 9. Apple rust mite density rating on Delicious apple leaves in 2010, Columbus, Ohio.

Treatment			*Mean density rating on six sampling dates*					
Pre-bloom	*1st generation codling moth*	*2nd generation codling moth*	*26 April*	*25 May*	*18 June*	*2 July*	*19 July*	*9 August*
Oil, Asana	Altacor	Altacor	1.0	1.0	1.5	1.0	1.0	0.5
Oil, Asana	Altacor early	Altacor early	0.8	1.0	1.2	1.2	1.0	0.5
Oil, Lorsban	Imidan	Imidan	1.0	1.0	1.0	1.0	0.8	0.8
Oil, Lorsban	Danitol	Delegate	1.0	1.0	1.0	1.0	1.0	0.2
Oil, Lorsban	Beleaf	Delegate	1.0	1.0	1.5	1.0	1.0	0.5
Untreated	Untreated	Untreated	1.0	1.2	1.5	1.2	1.0	0.2
ANOVA			*P = 0.92*	*P = 0.45*	*P = 0.45*	*P = 0.60*	*P = 0.45*	*P = 0.69*

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