Codling moth management by insecticides in Ohio apple orchards

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SUMMARY: A field trial was conducted to evaluate the effects on codling moth control of three insecticide programs including alternatives to organophosphates. 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. Each insecticide program was used with and without one mid-summer insecticide application of Imidan when the codling moth population was between broods. All programs were followed by Assail or Imidan for late-season codling moth control. Fruit were evaluated for insect injury in mid-summer and at harvest. All insecticide programs provided control of codling moth that was significantly better than the untreated check treatment. There was no difference between Rimon and Guthion for control of first brood codling moth. There was no benefit from applying an insecticide between broods of codling moth in mid-summer. All three insecticide programs (Rimon followed by Assail, Guthion followed by Asana, and Guthion followed by Guthion) provided equally excellent control of codling moth in harvested apples.

Background: Codling moth and other key insect pests have been controlled with organophosphate insecticides like Guthion or Imidan in most commercial orchards for the past 30 years. Due to recent restrictions on use of organophosphates and due to failing efficacy of organophosphates for codling moth control at some orchards, many growers are seeking information on which insecticides are best to replace the conventional organophosphate program. In 2003 to 2005, field trials were conducted in Ohio to evaluate several new insecticides for efficacy on codling moth; results showed that insect growth regulators, neonicotinoids, and pyrethroids can provide effective control, but questions remain about which insecticide combinations are most effective and whether or not insecticide could be omitted in mid-summer and late summer. Continuing problems from codling moth infestations in some orchards, especially in late-maturing cultivars, is likely due to either extremely prolonged emergence of the second generation, or the occurrence of a partial third generation of codling moth, which develop after insecticide sprays have stopped for the season. A third generation not only causes immediate damage in late summer and early fall, but it can contribute to prolonged emergence of the overwintering generation the following spring. Our recommended spray schedule is targeted at only two generations per year, but data is needed to develop an effective spray schedule to target the third generation and overlapping generations of codling moth.

Objective: Evaluate control of codling moth and other insect pests under three insecticide programs in comparison with untreated checks, both with and without an insecticide applied between broods in mid-summer.

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 seven treatments each with three replicates in a randomized complete block design, with three adjacent trees per plot. Treatments were combinations of two factors: two levels of mid-summer insecticide (with Imidan or without Imidan), and three levels of insecticide treatment, plus an untreated check. A third factor of presence or absence of late-season sprays was intended but did not get done due to a communications error with the farm crew. Each insecticide treatment included one product for control of first-generation codling moth and one or two products for control of second-generation codling moth; intended timing and actual timing are detailed in Table 1. 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. For mite control in all plots including the check, Envidor 2SC (spirodiclofen) was applied on 5/19/06 at 6 fl 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 miticide but were sprayed with Avaunt at first cover. Insecticides and miticide 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.

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; and Captan plus Topsin-M on 7/21/06 and 8/9/06.

Table 1. Insecticide treatment timing and product combinations in codling moth trial in Delicious apple orchard at OSU's Waterman Lab, Columbus, Ohio, 2006.

Target	Codling moth 1st brood				between broods	Codling moth 2nd brood		tail of 2nd brood, & partial 3rd brood	
Intended timing[a,b]	1C early (75 DD)	1C late (250 DD)	2C early	2C late	3C	5C	6C	7C	8C
Actual timing	5/10 (87DD)	5/26 (234 DD)	5/24	6/8	6/22	7/19	8/3	8/17	8/31
Treatment									
1	Rimon	–	Rimon	–	Imidan	Assail	Assail	Assail	Assail
2	–	Guthion	–	Guthion	Imidan	Asana	Asana	Assail	Assail
3	–	Guthion	–	Guthion	Imidan	Guthion	Guthion	Imidan	Imidan
4	Rimon	–	Rimon	–	–	Assail	Assail	Assail	Assail
5	–	Guthion	–	Guthion	–	Asana	Asana	Assail	Assail
6	–	Guthion	–	Guthion	–	Guthion	Guthion	Imidan	Imidan
7	none	none	none	none	none	none	none	none	none

[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.

Pheromone traps were used to monitor adult populations of codling moth and lesser appleworm. The date of sustained flight of codling moth was used as a biofix to start a degree-day count on which insecticide timing was based. Multipher-3 funnel traps were used with lures made by Trécé; for codling moth, long-life lures were changed every 8 weeks, while for lesser appleworm, standard lures were changed every 4 weeks. Oriental fruit moth was not monitored due to its absence at this site in the previous few years.

Insect injury to fruit was evaluated on 100 fruit in the center of each plot, non-destructively on 7/21/06 to evaluate injury by first-brood codling moth, and destructively at harvest from 9/25/06 to 9/29/06. 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 and discussion:

Codling moth adults reached peak density in pheromone traps on 6/21/06 for the overwintering generation, on 8/9/06 for the summer generation, and on 8/30/06 for a partial third generation (Table 2). Lesser appleworm adults peaked on 5/31/06 and 8/2/06 (Table 2). Based on an estimate of 1118 degree days per generation, the cumulative degree-days showed the potential for a third brood of larvae (Table 2).

Fruit evaluated in mid-summer showed that the most important insect injury was internal Lepidoptera, which affected 0.0 to 6.4% of fruit (Table 3). Injury from internal Lepidoptera was significantly less where either Rimon or Guthion was used than in the untreated check treatment. Tarnished plant bug injury and plum curculio oviposition injury were found in most plots but these did not differ significantly among treatments. There was a trace of late leafroller damage and early fruitworm damage. Analysis of main treatment factors showed no significant effect of insecticide used for first generation codling moth (Rimon versus Guthion) and no significant effect of insecticide used at third cover (Imidan versus no Imidan; Table 3).

At harvest in September, the most important insect injury was internal Lepidoptera, which affected 0.3 to 14.9% of fruit (Table 4). Injury from internal Lepidoptera was significantly less where insecticides were used than in the untreated check treatment. Injury from San José scale was also significantly lower in insecticide plots than in check plots. Tarnished plant bug injury and plum curculio oviposition injury were found in most plots but did not vary significantly among treatments. A few plots had late leafroller damage, late plum curculio adult feeding damage, or early fruitworm damage, but these did not vary significantly among treatments. There was damage from an unidentified pest that had not been previously found at this site, but this damage did not vary significantly among treatments. Analysis of main treatment factors showed no significant difference among insecticide programs for both generations of codling moth, or for insecticide used between generations (Table 4).

Conclusions: All insecticide programs provided control of codling moth that was significantly better than the untreated check treatment. There was no difference between Rimon and Guthion for control of first brood codling moth. There was no benefit from applying an insecticide between broods of codling moth. All three insecticide programs (Rimon followed by Assail, Guthion followed by Asana, and Guthion followed by Guthion) provided equally excellent control of codling moth in harvested apples.

Table 2. Seasonal activity of codling moth and lesser appleworm as monitored by pheromone traps, and degree days for codling moth after trap-based biofix on 5/4/06, in orchards at OSU's Waterman Lab, Columbus Ohio.

Date	Codling moths caught in previous 7 days				Lesser appleworm caught in previous 7 days	Cumulative degree days[c] after biofix
	Trap 1[a]	Trap 2 [a]	Trap 3 [b]	Mean of 3 traps		
4/26	0	0	0	0.0	0	-
5/3	1	1	0	0.7	5	-
5/10	4	7	12	7.7	19	87
5/17	7	0	5	4.0	1	131
5/25	11	10	5	8.7	6	192
5/31	13	7	4	8.0	50	358
6/7	9	6	13	9.3	22	470
6/14	3	1	4	2.7	9	562
6/21	28	9	12	16.3	11	709
6/28	7	4	5	5.3	7	861
7/5	6	0	0	2.0	5	1020
7/12	7	0	2	3.0	10	1165
7/19	14	6	2	7.3	29	1365
7/26	16	4	11	10.3	18	1538
8/2	14	7	9	10.0	34	1749
8/9	22	5	6	11.0	21	1936
8/16	12	3	7	7.3	6	2094
8/23	14	5	9	9.3	5	2251
8/30	21	10	12	14.3	7	2413
9/6	8	8	8	8.0	12	2508
9/13	14	6	5	8.3	22	2632
9/20	10	5	1	5.3	6	2719
9/27	6	2	2	3.3	3	2797
10/4	2	2	2	2.0	2	2878
10/11	3	0	0	1.2	2	2942

[a] Traps 1 and 2 located in check plots in apple orchard where trial was conducted.
[b] Trap 3 located in check plot in older apple orchard 50 meters from orchard where trial was conducted.
[c] Degree-days calculated as mean of daily maximum and minimum temperature, base 50F, with low cutout at 50F (50F substituted for minimum temperature if actual minimum below 50F) and high cutout at 88F (88F substituted for maximum temperature if actual maximum above 88F).

Table 3. Effect of insecticide program on insect injury by early-summer insects to Delicious apple fruit, by non-destructive evaluation, July 2006, mean of three blocked replicates at OSU's Waterman Lab, Columbus, Ohio.

Treatment		Percentage of fruit[a]					
Insecticide at 1C & 2C	Insecticide at 3C	Clean	Internal Lepidoptera[b]	Tarnished plant bug	Plum curculio oviposition	Leaf-roller	Fruit-worm
Rimon	Imidan	95.9 A	0.4 B	3.2	0.5	0	0
Rimon	none	96.2 A	0.0 B	3.7	0.2	0	0
Guthion	Imidan	95.9 A	0.1 B	3.6	0.4	0	0
Guthion	none	96.2 A	0.1 B	3.3	0.3	0	0
none	none	86.5 B	6.4 A	3.2	2.6	0.7	0.7
Probability value for treatment effect from ANOVA		*0.0193*	*<0.0001*	*1.00*	*0.07*	*0.46*	*0.46*
Rimon		96.0	0.2	3.4	0.3	0	0
Guthion		96.1	0.1	3.5	0.4	0	0
Probability value for insecticide effect from ANOVA		*0.99*	*0.77*	*0.91*	*0.97*	-	-
With Imidan at 3C		95.9	0.2	3.5	0.4	0	0
No Imidan at 3C		96.2	0.1	3.4	0.3	0	0
Probability value for Imidan effect from ANOVA		*0.65*	*0.39*	*0.90*	*0.33*	-	-

[a] Within each column and group, 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.
[b] Damage by an undetermined pest, possibly apple curculio larvae, caused internal damage in some plots. At harvest, this damage was clearly different than internal Lepidoptera damage, but at the mid-summer non-destructive evaluation, it was recorded as internal Lepidoptera damage.

Table 4. Effect of insecticide program on insect injury to Delicious apple fruit at harvest, September 2006, mean of three blocked replicates at OSU's Waterman Lab, Columbus, Ohio.

Treatment		Percentage of fruit[a]										
Insecticide for codling moth, first generation/ second generation	Imi–dan at 3C	Clean	Internal Lepidoptera[b]			Tarn–ished plant bug	Plum cur–culio ovipo sition	Plum cur–culio late feed–ing	San José scale	Leaf roll er	Fruit wom	Unid entif ied[c]
			entry	sting	total							
Rimon/Assail	yes	91.2A	1.2 B	0.3 B	1.5 B	6.3	1.0	0	0 B	0.2	0	0
Guthion/Asana	yes	91.0A	0.4 B	0.2 B	0.5 B	7.2	1.5	0	0 B	0	0	0
Guthion / Guthion	yes	91.7A	0.3 B	0.0 B	0.3 B	6.3	1.8	0	0 B	0	0	0
Rimon/Assail	no	89.8A	0.2 B	0.3 B	0.5 B	7.7	1.8	0	0 B	0.2	0	0.2
Guthion/Asana	no	91.5A	0.7 B	0.2 B	0.8 B	6.3	1.4	0	0 B	0	0	0.3
Guthion / Guthion	no	90.2A	0.8 B	0.3 B	1.2 B	7.2	1.7	0	0 B	0	0	0
none/none	no	66.9B	11.6A	3.3 A	14.9A	2.6	8.0	0.7	1.3 A	1.0	0.3	5.6
Probability value for treatment effect from ANOVA		*0.0006*	*0.005*	*0.0005*	*0.002*	*0.32*	*0.16*	*0.47*	*0.02*	*0.10*	*0.47*	*0.20*
Rimon/Assail		90.5	0.7	0.3	1.0	7.0	1.4	0	0	0.2	0	0.1
Guthion/Asana		91.2	0.5	0.2	0.7	6.7	1.4	0	0	0.0	0	0.2
Guthion /Guthion		90.9	0.6	0.2	0.7	6.7	1.7	0	0	0.0	0	0.0
Probability value for insecticide effect from ANOVA		*0.93*	*0.89*	*0.23*	*0.98*	*0.97*	*0.65*	–	–	*0.21*	–	*0.63*
With Imidan at 3C		91.3	0.6	0.2	0.8	6.6	1.4	0	0	0.1	0	0.2
No Imidan at 3C		90.5	0.6	0.3	0.8	7.1	1.6	0	0	0.1	0	0.2
Probability value for Imidan effect from ANOVA		*0.61*	*0.96*	*0.46*	*0.83*	*0.87*	*0.80*	–	–	*1.00*	–	*0.21*

[a] Within each column and group, 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.
[b] The target populations were codling moth and lesser appleworm; Oriental fruit moth was absent.
[c] Damage by an undetermined pest, possibly apple curculio larvae, caused internal damage in some plots. At harvest, this damage was clearly different than internal Lepidoptera damage, but at the mid–summer non–destructive evaluation, it was recorded as internal Lepidoptera damage.