Demonstration of Codling Moth Control with Diamond (Novaluron) in Apple
2003
Diane Alston and Thor Lindstrom
Utah State University

Objective: To demonstrate the efficacy of the insect growth regulator, Diamond (novaluron), for codling moth control in apple. Four novaluron sprays were rotated with two Guthion (azinphosmethyl) sprays to provide coverage of two generations. Adjacent orchard rows were untreated to provide substantial codling moth pressure for the demonstration plot.

Background on New Insecticide: Diamond (novaluron) is an insect growth regulator (IGR) that inhibits normal synthesis of chitin in the insect cuticle (exterior skeleton). Novaluron causes death of 1st instar codling moth larvae over several days by disrupting the cuticle formation process. Novaluron acts mainly by ingestion, but has some contact activity. The timing of application for an IGR, such as Novaluron is typically earlier than a conventional neurotoxic insecticide because the material needs to be applied to foliage and fruit by the time eggs are deposited to provide a high level of mortality. The risk of injury caused by "stings" to the fruit surface is greater with an IGR than with a neurotoxin. We did not observe more stings with a full-season, 6-spray program of novaluron in a research trial in 2002. Novaluron has a targeted date for full federal EPA registration by late 2003 or early 2004.

Methods:
The trial was conducted in a 2.1-acre apple orchard of mixed cultivars ('Gala', 'Mutzu', 'Prime Gold', 'Idared', 'Jonathan', and three strains of 'Red Delicious') at the Utah State University research farm in Kaysville, UT. The orchard was 13 rows wide by 30 trees long (12 ft x 20 ft spacing). A single, 1-acre plot was placed in the center of the orchard. This plot (rows 5-10 by 30 trees long) was treated with the Diamond program while the adjacent, outside rows (rows 1-4 and 11-13) were not treated with insecticide for codling moth control (see plot map on pg. 2).

A delayed dormant treatment (applied at one-quarter to half-inch-green) of Superior oil (3%) + Lorsban 4E (4 pt/acre) was applied to the entire orchard on April 8 for early season control of apple aphids. Fungicides (Procure, Flint or sulfur) for control of apple powdery mildew were applied on April 16, May 1 and 21, and June 13. Streptomycin to protect open flowers from fire blight infection was applied on May 15.

Insecticides were applied with an orchard air-blast sprayer at a rate of 70 gpa of dilute spray. Diamond 7.5WG was applied at a rate of 3.2 lb product/acre + 0.25% horticultural mineral oil. Guthion 50WP was applied at 2 lb product/acre.

Adult male codling moth flight was monitored with one pheromone-baited trap to determine biofix (first consistent moth catch) and follow seasonal flight patterns and moth densities. Timing of spray applications was based on biofix and a degree-day (DD) model. The timing and type of insecticides applied was as follows:

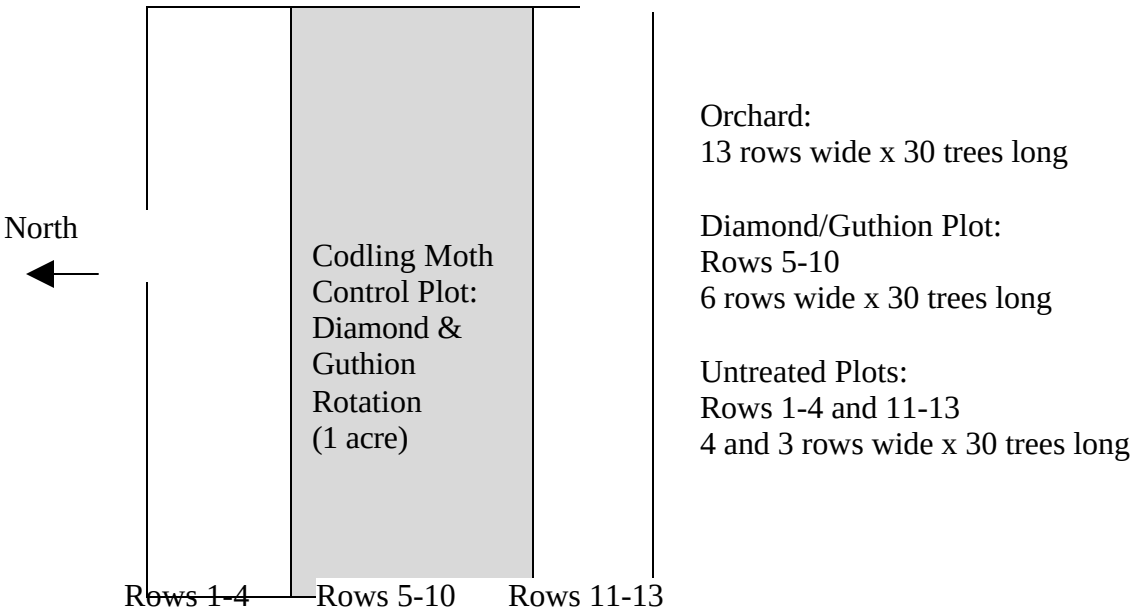
1st generation of codling moth:
1st spray: **Diamond** at 89 DD after biofix (May 15) (Target: 50-75 DD)
2nd spray: **Diamond** 14 days later (May 29)

3rd spray: Guthion 15 days later (June 13)

2nd generation of codling moth:
4th spray: **Diamond** at 911 DD after biofix (July 1) (Target: 950-1000 DD)
5th spray: **Diamond** 14 days later (July 15)
6th spray: Guthion 16 days later (July 31)

Apple fruits were sampled to determine codling moth injury levels (% fruit with stings and larval entries) following the first generation on July 8 and following the second generation on August 20. Injury from thrips and campylomma feeding was also recorded. Analysis of variance (Proc Glm; SAS Institute, Inc.) was used to compare injury levels between Diamond treated and untreated plots. Data were arcsine-square root transformed before analysis to meet normality assumptions.

Plot map:



Orchard:
13 rows wide x 30 trees long

Diamond/Guthion Plot:
Rows 5-10
6 rows wide x 30 trees long

Untreated Plots:
Rows 1-4 and 11-13
4 and 3 rows wide x 30 trees long

Results:

Codling moth population densities were moderate in the trial orchard with peak flights of 15 and 10 moths/night for the first and second summer generations, respectively (Fig. 1). First consistent moth catch (i.e., biofix) occurred on April 25 and degree-day (DD) accumulations were initiated from this date.

Total fruit injury following the first codling moth generation averaged 5.3% in the Diamond/Guthion plot and was significantly less than in the untreated plot for stings, larval entries and total injury (Table 1). The majority of injury in the Diamond plot was stings (2.0-8.0%) while larval entries didn't exceed 3.0%. Untreated fruit averaged 33.8% injury and larval entries predominated. There was no statistical difference among cultivars within the Diamond or untreated plots (Table 1).

Table 1. Mean percentage fruit injury following the first generation of codling moth on July 8, 2003. The number of fruit sampled was 100 per cultivar per treatment and 800 total per treatment.

Insecticide	Cultivar	Stings	Entries	Total CM	Insecticide	Cultivar	Stings	Entries	Total CM
Diamond	Gala	3.0	1.0	4.0	Untreated	Gala	13.0	34.0	47.0
	Idared	8.0	3.0	11.0		Idared	8.0	27.0	35.0
	Jonathan	3.0	0	3.0		Jonathan	10.0	18.0	28.0
	Mutzu	2.0	3.0	5.0		Mutzu	16.0	39.0	55.0
	Prime Gold	6.0	0	6.0		Prime Gold	16.0	22.0	38.0
	Red Del. Dixiered	6.0	0.0	6.0		Red Del. Dixiered	5.0	21.0	26.0
	Red Del. Supreme	4.0	3.0	7.0		Red Del. Supreme	12.0	22.0	34.0
	Red Del. Ultrastripe	5.0	1.0	6.0		Red Del. Ultrastripe	13.0	20.0	33.0
	Mean of 8 Cultivars	**3.9**	**1.4**	**5.3**		**Mean of 8 Cultivars**	**11.0**	**22.8**	**33.8**
Comparison Among Cultivars Within Diamond	*P*>F*	0.24	0.38	0.34	Comparison Among Cultivars Within Untreated	*P*>F	0.58	0.23	0.21
Comparison Between Insecticides	*P*>F	0.0003	<0.0001	<0.0001					

Comparisons were made with analysis of variance and means separated with Waller-Duncan *k*-ratio *t*-test.

'Dixiered' ('Red Delicious' strain) had too few fruit to include in the second-generation assessment, so only seven cultivars were evaluated on August 20. Fruit injury in the Diamond/Guthion program increased only slightly between the second and first generation assessments (5.3% to 8.3%) while it almost doubled for untreated trees (33.8% to 62.6%) (Table 2). The Diamond and Guthion rotation program kept total codling moth fruit injury below 9% under a high pest pressure environment (due to adjacent untreated

trees). Only 1.3% of the injury was from larval entries. Again, fruit injury was significantly reduced in the Diamond/Guthion plot as compared to the untreated for stings, larval entries and total injury (Table 2).

On August 20 there were some differences in injury among cultivars within each treatment. In untreated trees, 'Mutzu' had more total injury than 'Idared' and 'Prime Gold'. 'Gala', 'Jonathan' and the 'Red Delicious' strains were intermediate in injury levels (Table 2). In the Diamond/Guthion treatment, 'Mutzu' had more stings than 'Jonathan', 'Prime Gold' and 'Supreme'. 'Mutzu' was the only cultivar that was consistently more susceptible to codling moth injury in both treatments.

Injury from thrips and campylomma was very low in all plots; less than 1% and no different among treatments or cultivars.

Table 2. Mean percentage fruit injury following the second generation of codling moth on August 20, 2003. The number of fruit sampled was 250 per cultivar per treatment and 1,750 per treatment.

Insecticide	Cultivar	Stings	Entries	Total CM	Insecticide	Cultivar	Stings	Entries	Total CM
Diamond	Gala	6.8	2.0 ab	8.8	Untreated	Gala	14.0	48.4	62.4 abc
	Idared	4.8	1.2 ab	6.0		Idared	11.6	46.4	58.0 bc
	Jonathan	4.4	0 b	4.4		Jonathan	14.8	55.6	70.4 ab
	Mutzu	4.9	3.1 a	8.0		Mutzu	13.6	63.6	77.2 a
	Prime Gold	8.0	0 b	8.0		Prime Gold	8.8	38.8	47.6 c
	Red Del. Supreme	3.2	0.4 b	3.6		Red Del. Supreme	14.8	48.4	63.2 abc
	Red Del. Ultrastripe	3.1	2.7 ab	5.8		Red Del. Ultrastripe	8.8	51.2	60.0 abc
	Mean of 7 Cultivars	**5.0**	**1.3**	**8.3**		**Mean of 7 Cultivars**	**12.3**	**50.3**	**62.6**
Comparison Among Cultivars Within Diamond	*P*>F*	0.94	0.03	0.87	Comparison Among Cultivars Within Untreated	*P*>F	0.74	0.22	0.01
Comparison Between Insecticides	*P*>F	<0.0001	<0.0001	<0.0001					

Comparisons were made with analysis of variance and means separated with Waller-Duncan *k*-ratio *t*-test. Means followed by the same letters are not different ($p \leq 0.05$)

Conclusions:

The Diamond/Guthion spray program consisted of two Diamond sprays at the beginning of each generation followed by a single Guthion spray. The first Diamond application in each generation was timed to be in place before egg laying began. The interval between sprays within a generation was 14-16 days. This program had a total of 4 Diamond applications (12.8 lb product) and two Guthion applications (4 lb product). The codling moth pressure in the demonstration orchard was high as 62.6% of the untreated fruit was injured by harvest (50.3% larval entries). The Diamond/Guthion program protected the

fruit well. Harvest injury was 8.3% with the majority from stings and only 1.3% larval entries. The insect growth regulator, Diamond, appears to be a good material for codling moth control and suitable to rotation with other insecticides in a resistance management program.

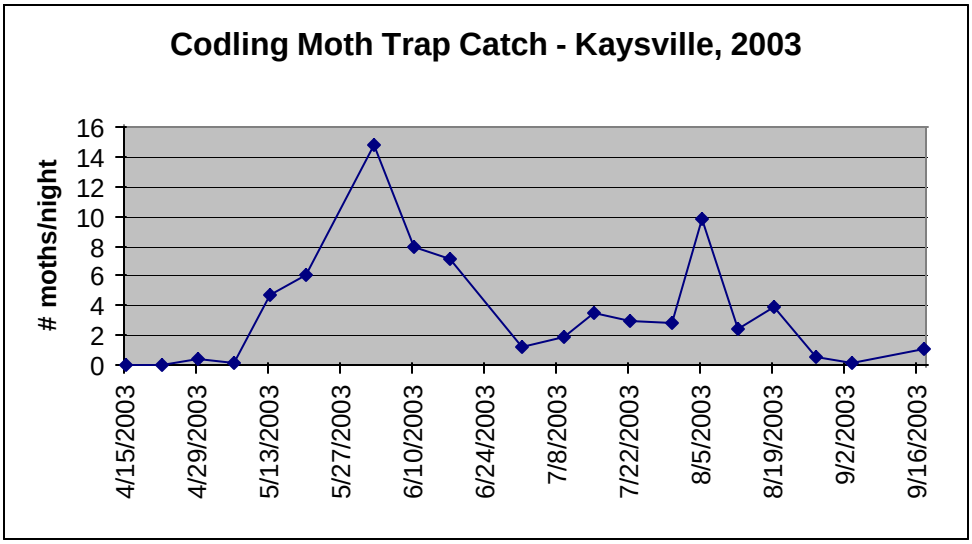


Figure 1.