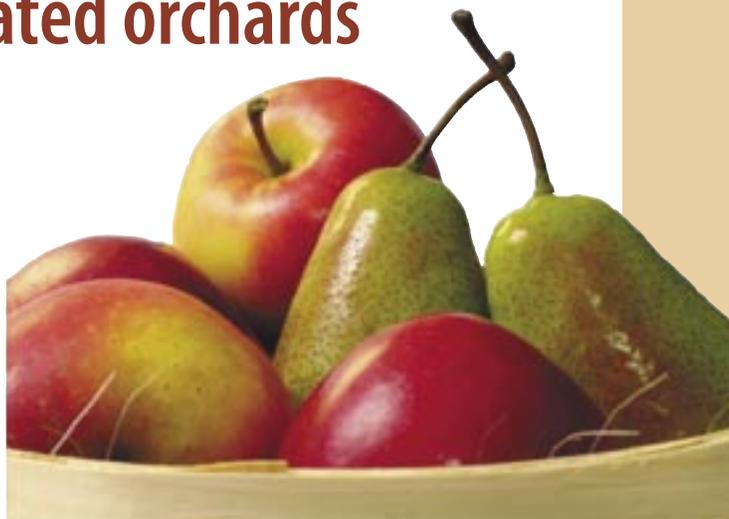


Using pear ester to monitor codling moth in sex pheromone treated orchards

A. Knight, R. Hilton, P. VanBuskirk, and D. Light

Advantages in using pear ester include:

- Tracking female flight patterns
- Improving prediction of first egg hatch
- Using action thresholds to optimize a spray program



Pear ester is a characteristic pear flavor attractive to codling moth (i.e., a kairomone). Traps baited with a pear ester lure can be used to monitor male and female adult codling moth activity.

Pear ester is a natural volatile produced by ripening pears. Male and female codling moths have specialized receptors on their antennae that can detect pear ester. Male moths respond to pear ester while searching for a host where female moths will be available for mating. Female codling moths also use the pear ester to locate the host, and mated females use the pear ester to locate specific sites to lay eggs near or on fruit. Other host-produced chemicals can affect the behavior of codling moth, but no other compound tested so far has proven to be as attractive and chemically stable as pear ester.

Growers' use of sex pheromones to disrupt codling moth mating strongly impacts male moth behavior but does not affect moths' responses to pear ester. Thus, pear ester can be an effective lure to use in orchards treated with sex pheromone. Many studies have been conducted to understand how to best use pear ester. This publication summarizes the current state of our knowledge regarding the use of pear ester; as additional information is gathered, recommendations for use will be updated.



How to monitor

Careful monitoring of codling moth in orchards treated with sex pheromone mating disruption is critical due to the influence of moth density on effective disruption and the potential for undetected moth immigration into treated orchards. Thresholds have been established both to minimize the unnecessary use of insecticides and to avoid failing to detect a within-orchard population. Growers' monitoring programs need to be standardized, and recommendations in this report are based on the best available data. Any changes in this program will likely influence the interpretation of trap counts and may affect the efficacy of your management program.

The pear ester lure often will catch fewer moths than a sex pheromone lure; this is particularly true in orchards that are not treated with sex pheromone and where densities of codling moth are high. However, in sex pheromone treated orchards with low populations of codling moth, the pear ester lure generally will catch similar numbers of moths as a standard (i.e., high load) sex

Alan Knight, research entomologist, U.S. Department of Agriculture, Agricultural Research Service, Wapato, WA; Richard Hilton, senior research assistant, and Philip VanBuskirk, Extension horticulturist, both of Southern Oregon Research and Extension Center, Oregon State University; and Douglas M. Light, research entomologist, U.S. Department of Agriculture, Agricultural Research Service, Albany, CA.



Figure 1.—A gray septa, loaded with pear ester, and moth catch. Photo: USDA-ARS.



Figure 2.—The large orange delta trap, baited with pear ester, will attract codling moth but is not as attractive to bees as a white trap.



Figure 3.—It's best to place the trap in the upper third of the tree canopy, near a fruit cluster and positioned so that foliage does not obstruct the trap's openings.

pheromone lure. The value of the pear ester lure is that it catches both sexes and better reflects local pest population densities (Figure 1).

Place traps in the orchard just before the date you expect the first moth to emerge or at the same time you place sex pheromone baited traps. Pear ester lures are effective for 8 weeks and should be replaced as needed. Early in the season, check traps twice per week to detect the start of sustained moth flight; later in the season, check traps once per week.

Use large orange delta traps to monitor codling moth with pear ester (Figure 2). These traps catch fewer bees, which often are found in high numbers in the standard white traps, especially during bloom time. Higher counts of male codling moth have been reported with the use of orange versus white traps.

Using orange traps for the pear ester lure also allows you to easily tell the difference in lure types and thus helps avoid cross-contamination of traps.

Take special care to avoid contaminating pear ester traps with sex pheromone.

Catch of female moths improves if neither of the trap's opening is obstructed by foliage and if the trap is placed near a fruit cluster.

Place traps in the upper third of the tree canopy. For example, if the orchard's canopy averages 14 feet, place traps at least 10 feet up (Figure 3).

Traps can be attached to a pole to ensure proper placement high in the tree; see Figure 4 for a simple pole design. To avoid breakage, we recommend constructing poles with half-inch schedule 40 PVC pipe.

The pear ester appears to attract moths from a much shorter distance than seen with male moths attracted to a sex pheromone baited trap. Therefore, we recommend using pear ester baited traps at a relatively high density. For best results, use one

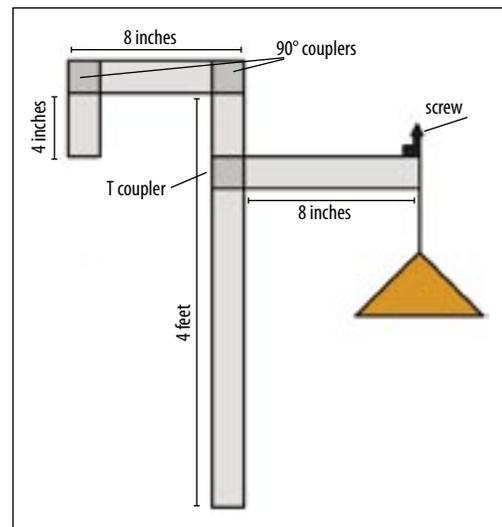


Figure 4.—A simple trap pole design, using half-inch schedule 40 PVC pipe.

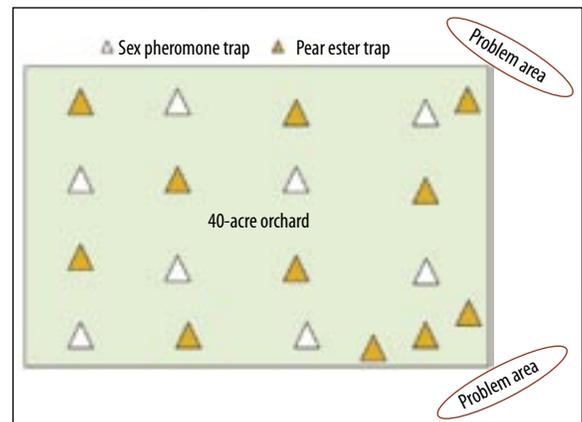


Figure 5.—One recommended placement of sex pheromone traps and pear ester traps in an orchard.



Figure 6a.—Male (at left) and female codling moths.



Figure 6b.—The male codling moth's abdomen (left) is more pointed at the tip than the female's. Photo: Helmut Riedl.

trap for every 2 to 3 acres, in a grid pattern starting 25 to 30 feet from the edge of the orchard. Or, alternate pear ester and sex pheromone traps within the grid (Figure 5).

Pear ester traps are especially useful in known problem areas of the orchard, such as where sex pheromone baited traps have failed to detect injury or near borders adjacent orchards or bin piles where pest pressure is high.

Pear ester attracts both male and female moths, and so it is important to learn how to sex moths.

Standard monitoring protocol

- Use an orange delta trap with the pear ester lure.
- Place trap in top third of tree canopy, near a fruit cluster and positioned so that foliage does not obstruct trap openings.
- Set one trap for every 2 to 3 acres, using a grid and starting 20 to 30 feet from border.
- Especially monitor codling moth problem areas with pear ester.
- Avoid contaminating pear ester traps with sex pheromone.

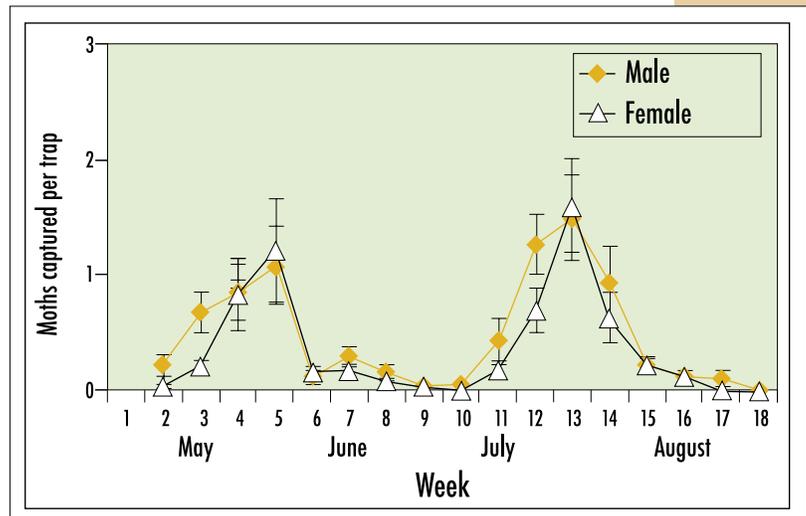


Figure 7.— Pear ester lures generally trap similar numbers of male and female moths during the season.

Moths that are dried or covered with adhesive may be difficult to sex.

Sex determination is easier if you roll the moth on its back and use a hand lens to examine the end of the abdomen (Figure 6a). Generally, male abdomens are pointy and consist of two claspers that are held together at rest. The individual claspers may be difficult to see because the abdomen is covered with minute scales. Squeezing the abdomen of a live male moth will cause the claspers to extend. The tip of a female's abdomen is broader than that of a male and has an opening with a lobed pad covered with hairs, which is used to lay eggs (Figure 6b). With some practice, determining the sex of a codling moth can be done easily.

The pear ester lure generally catches similar numbers of male and female moths during the season though the catch of males may be higher at the start of each moth flight (Figure 7).

If the pear ester baited trap catches many more males than females, this may indicate that the trap or lure has become contaminated with sex pheromone. Replace these traps.

Combination pear ester and sex pheromone lure

A similar gray septa lure loaded with both pear ester and sex pheromone is also available to growers. This "combo" lure is very effective in monitoring codling moth in sex pheromone treated orchards. Traps baited with this lure catch primarily male moths. However, the thresholds and

timing models presented here were developed only for the pear ester lure; therefore, **moth catches from traps baited with the “combo” lure should not be used with this publication.**

Predicting egg hatch

Models predicting codling moth egg hatch currently are based on the start of adult flight, which is based on the capture of male moths in sex pheromone baited traps. These models have been widely adopted and are generally effective. However, it can be difficult to trap males in a sex pheromone treated orchard.

Growers are more interested in activities of the egg-laying female moths, and the timing of initial flight activity can differ substantially between the sexes. Research has found that using a model based on female moth activity can more precisely predict the start of codling moth egg hatch.

Effective use of predictive timing models depends on correctly establishing a **Biofix** for codling moth. Biofix is defined as the start of sustained moth flight. Both the frequency of trap checking and the population density of codling moth within an orchard can strongly influence the Biofix date selected. In many commercial orchards with low population densities of codling moth, establishing an accurate Biofix can be difficult. Monitor a few traps placed in areas of the orchard that most likely have the highest population densities of codling moth. To use our models effectively, follow a strict protocol, described below, to establish Biofix.

Establishing a Biofix

1. Check traps at 3- to 4-day intervals (e.g., check on Mondays and Thursdays or on Tuesdays and Fridays) and summarize moth catch data.
2. Average moth catch has to be at least two moths and/or one female moth in the designated pear ester traps for two consecutive trap-check dates.
3. If moth catch meets the threshold on a given trap-check date but not on the following trap-check date, Biofix is established on the next trap-check date that moth catch at least equals the threshold. For example, see the data for DA-F catch (column 10) in Table 1; Biofix was established on 9 May because no moths were caught on 5 May.

4. This same rule is used with male catch in sex pheromone baited traps, using four moths per trap as the threshold.

Adjusting Biofix

The accuracy of predicting the start of egg hatch can be improved by adjusting the timing of Biofix (i.e., establishing an **adjusted-Biofix**) based on the occurrence of suitable maximum temperatures for moth sexual activity. Daily maximum temperatures can be used to precisely pick an adjusted-Biofix date within the 3- to 4-day trap-check period that was selected as the Biofix.

The adjusted-Biofix is the first day between trap-check dates when average maximum temperatures have been 70°F or above for at least 2 consecutive days. If the mean maximum temperatures during any 2 consecutive days in this time period were not 70°F or above, then the adjusted-Biofix date is the first day after the trap-check date when the temperature threshold was exceeded for 2 consecutive days. In the example in Table 1, the DA-F Biofix established on 9 May was corrected to 12 May due to the lack of adequate maximum temperatures.

How to use Table 1

Table 1 shows how data are entered into an Excel spreadsheet. These data were collected at the Oregon State University Southern Oregon Research and Extension Center in Central Point, OR, in 2005.

A blank Excel file is available on the Web at <http://ars.usda.gov/pwa/yarl>. After you download this file, open it, rename it, and create individual spreadsheets for each orchard you are monitoring. Before the season starts, fill in columns 2 and 3 with either historical temperature data (for example, 30-year averages, starting on March 1) or temperature data from the previous year. The program automatically will calculate daily degree-days (DD) for codling moth based on lower and upper development thresholds of 50° and 88°F. You may want to use different font colors (e.g., black, orange, green) to differentiate daily maximum and minimum temperatures from historical, current-season, and short-term temperature forecasts in the spreadsheets.

Current daily maximum and minimum temperatures should be recorded for each orchard. Alternative temperature data also are available from numerous sites around the Pacific Northwest (see “Sources of temperature data”). Select data from sites that best fit conditions in your orchard.

Sources of temperature data

California

www.ipm.ucdavis.edu

Oregon

pnwpest.org/wea/

Washington

frost.prosser.wsu.edu

Table 1.—The role of maximum daily temperatures in establishing Biofix and predicting the start of egg hatch using moth catch in traps baited with sex pheromone and pear ester.

-1- Date	-2- Max	-3- Min	-4- DD	-5- Adjusted Biofix	-6- Ptrap catch	-7- Ptrap Biofix	-8- DA catch	-9- DA Biofix	-10- DA-F catch	-11- DA-F Biofix
20-Apr	67	34	5.5	-						
21-Apr	72	39	8.3	+		265.0				
22-Apr	76	39	10.1	-	10.0	254.9	0		0	
23-Apr	60	48	4.4	-		250.5				
24-Apr	63	45	5.2	-		245.4				
25-Apr	68	44	7.3	-	4.0	238.1	0		0	
26-Apr	74	43	9.9	+		228.1				
27-Apr	74	44	10.2	-		217.9				
28-Apr	64	49	6.6	-	8.0	211.3	0		0	
29-Apr	67	44	6.8	-		204.5				
30-Apr	69	45	8.0	-		196.5				
1-May	67	49	8.1	-		188.4				
2-May	70	51	10.5	+	6.0	177.9	1.0		1.0	
3-May	73	46	10.2	-		167.7				
4-May	69	51	10.0	-		157.7				
5-May	63	52	7.5	-	11.0	150.2	0.0		0.0	
6-May	58	51	4.5	-		145.7				
7-May	65	50	7.5	-		138.2				
8-May	63	49	6.1	-		132.1				
9-May	53	46	0.9	-	6.0	131.3	1.0		1.0	
10-May	53	44	0.8	-		130.5				
11-May	67	46	7.3	-		123.2				
12-May	74	43	9.9	+		113.3		205.0		190.0
13-May	77	51	14.0	+	25.0	99.3	2.0	191.0	1.0	176.0
14-May	75	52	13.5	-		85.8		177.5		162.5
15-May	65	54	9.5	-		76.3		168.0		153.0
16-May	61	45	4.2	-		72.1		163.8		148.8
17-May	59	44	3.2	-		68.9		160.6		145.6
18-May	65	46	6.3	-	21.0	62.6	5.0	154.3	2.0	139.3
19-May	65	43	5.7	-		56.8		148.6		133.6
20-May	63	47	5.6	-		51.3		143.0		128.0
21-May	71	38	7.7	-		43.6		135.3		120.3
22-May	67	47	7.5	-		36.1		127.8		112.8
23-May	71	38	7.7	+		28.4		120.1		105.1
24-May	78	37	10.7	+		17.7		109.4		94.4
25-May	89	43	17.1	+	18.0	0.6	8.0	92.3	4.0	77.3
26-May	93	50	20.8	+		HATCH		71.5		56.5
27-May	91	56	23.1	-				48.4		33.4
28-May	68	55	11.5	-				36.9		21.9
29-May	64	51	7.5	-				29.4		14.4
30-May	73	54	13.5	+				15.9		0.9
31-May	74	54	14.0	+				1.9		HATCH
1-Jun	79	49	13.7	+				HATCH		

Table 1 legend

Moth catch numbers shown in red in columns 6, 8, and 10 initially trigger the establishment of Biofix.

Maximum temperatures shown in red in column 2 exceeded the activity threshold for codling moth.

Plus signs shown in red in column 5 are the dates that the adjusted-Biofix is triggered.

Degree days shown in blue are pasted into rows where the adjusted-Biofix is set.

Daily degree days (column 4) are subtracted from the initial Biofix values in columns 7, 9, and 11 until egg hatch is predicted.

Three separate cumulative degree-day (DD) totals following the adjusted-Biofix are used to predict egg hatch based on these moth catches:

- 265 DD for male moths in a sex pheromone trap
- 205 DD for total moths in a pear ester trap
- 190 DD for female moths in a pear ester trap

Daily DD accumulations are subtracted from these totals until the remainder is <0. On that date the start of egg hatch is predicted. In the Table 1 example, three different predicted egg hatch dates were generated: 26 May, 1 June, and 31 May. Within this orchard, hatch predictions from the adjusted-Biofix based on pear ester moth catches were more accurate than predictions from the use of a sex pheromone trap, as the first hatched egg was sampled on 1 June.

Action thresholds

The cumulative count of moths caught in pear ester baited traps can be used to evaluate codling moth population pressure in your orchard. These action thresholds are conservative and were developed to avoid unnecessary spraying and to minimize the failure of traps to detect low levels of codling moth infestation. Thresholds for different crops and cultivars may need to be adjusted. For example, moth catches with the pear ester baited trap are much higher in Granny Smith than in Delicious, Golden Delicious, Gala, or Fuji cultivars. Further studies in Granny Smith will address whether thresholds should be increased. At

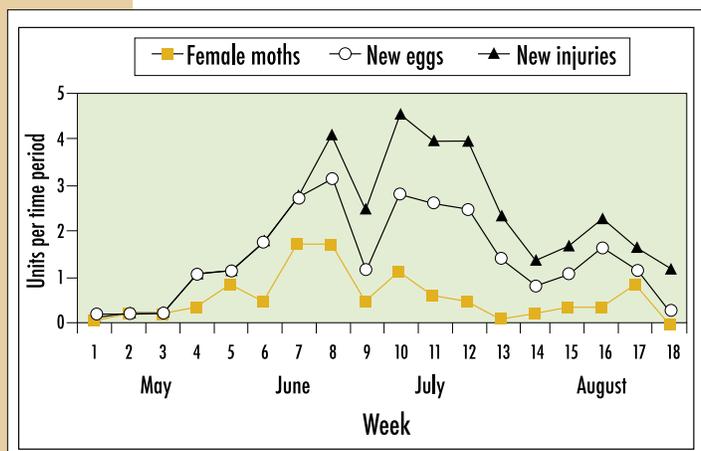


Figure 8.—In orchards with high pest pressure, female moth emergence, egg laying, and fruit injury can occur every week after codling moth activity begins.

Table 2.—Action thresholds for cumulative codling moth catches in traps baited with either pear ester or sex pheromone.

Time period	Pear ester - all moths	Pear ester - female moths	Sex pheromone - male moths
To initiate first spray after Biofix	2 or more	1 or more	4 or more
Following initial spray and before July 1	1 or more	1 or more	4 or more
To initiate first spray after July 1	2 or more	1 or more	2 or more

present, thresholds established for pear are the same as for apple. Differences in the attractiveness of the pear ester lure among pear cultivars and between apple and pear may allow us to adjust these thresholds in the future.

Thresholds were developed both for the total number of moths and for only female moths caught in pear ester baited traps. It is noteworthy that using the slightly higher threshold for total moths has resulted in fewer failures to treat low-level infestations than the use of the female moth threshold.

Thresholds also were developed for the use of a sex pheromone lure. Unfortunately, the attractiveness of the various commercial sex pheromone lures can vary, and thresholds may need to be adjusted based on this factor.

Table 2 provides thresholds for cumulative moth counts just prior to the typical recommended timing of an insecticide to control codling moth larvae (organophosphate, neonicotinyl, other classes of insecticides, and the codling moth granulosis virus). Similar thresholds have not been developed for the earlier timing for insecticides targeting eggs (various insect growth regulators and horticultural mineral oil). However, if moth counts exceed the larval timing threshold at this earlier timing, then also this would trigger the use of sprays targeting the egg.

Codling moth flights overlap egg laying for each generation. In orchards under high pest pressure, female emergence, egg laying, and fruit injury can occur every week after codling moth activity begins (Figure 8). Thus, effective management must be maintained throughout the entire season.

Capturing one or more moths in the pear ester baited trap after using an insecticide at the first spray timing triggers the use of a supplemental control program for the entire first flight. Please consult your local Extension agent for a description of an effective codling moth control program.

Pear ester baited traps can be used to assess whether insecticide sprays are needed for the second generation. Beginning July 1, use the same thresholds as for the first moth flight. If one or more female moths or two or more total moths are caught in traps after July 1, then apply supplemental controls. Continuing to catch moths after this application would trigger continued use of insecticides to treat the entire second generation of codling moth. Thresholds based on sex pheromone traps are lower during the second moth flight, as these traps become less effective late in the season. As noted above, please follow the recommendations of your local Extension agent on an effective control program.

Monitoring low population densities of codling moth in orchards with any trap and lure combination is difficult and subject to misinterpretation. **It is always important to remember that failing to catch moths does *not* guarantee that the pest is not present. But, capturing codling moths in pear ester baited traps is a very good indicator that a population *is* in your orchard.**

Growers can further reduce the risk of failing to detect codling moth infestations with these traps by increasing trap density, intensifying the monitoring in known problem areas of orchards, and implementing an effective season-long pest management program. Conversely, accepting low levels of fruit injury (i.e., 0.3 percent or less) at harvest may be a reasonable target in many orchards since postharvest sorting practices can further sanitize fruit shipments before export.

Implementing the use of the pear ester

Tracking the seasonal activity and population density of codling moths with pear ester baited traps can be an important tool in orchards treated with sex pheromone; it can help to optimize management programs targeting both eggs and larvae. However, growers should continue to use sex pheromone baited traps because of their experience with this tool.

Growers and pest management consultants should become familiar with the pear ester attractant, gaining experience with this new monitoring tool while comparing its performance with the standard sex pheromone attractant. Using these two monitoring tools together will improve estimates of codling moth population activity in orchards (Figure 5, page 2).



Figures 9a–c (above and left).—Various types of hand-applied dispensers used for sex pheromone treatments in orchards.

To implement a highly effective monitoring program for codling moth, we strongly advise that—in conjunction with a standardized trap-checking program—a sample of fruit be inspected for injury at midseason. Check fruit on several trees within 150 feet of each trap location and along orchard borders every week.

Using multiple methods to monitor codling moth (pear ester traps, sex pheromone traps, and visual sampling of fruits throughout the orchard) should yield a robust system for detecting resident or invading codling moths early and for either preventing fruit injury or limiting it to very low levels. Using the recommended standardized protocol with pear ester baited traps to monitor codling moth will be a valuable tool to maintain effective control of codling moth.

Using pear ester with mating disruption

Technologies that use codling moth sex pheromone to manage populations in orchards include several types of hand-applied dispensers (Figures 9a–c), aerosol puffers (Figure 10a, following page) and a microencapsulated sprayable formulation (Figure 11b, following page).



Figures 10a–c.— Placement of aerosol puffers such as the type at left according to a perimeter system (below left) or an internal grid system (below right).

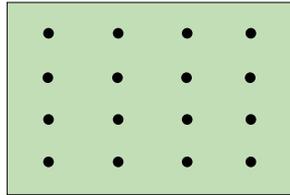
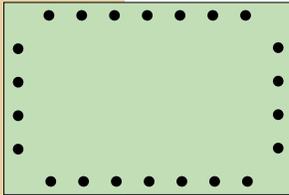


Figure 11a (above).—An all-terrain vehicle is used to apply a microencapsulated formulation of sex pheromone.

Figure 11b (at right).—An ultra-low-volume spray of microencapsulated pheromone.

Hand-applied dispensers, widely adopted by growers in western North America, are used at densities of 100 to 400 per acre. Thresholds presented here were developed in orchards treated with Isomate-C Plus dispensers.

Aerosol puffers can be used to treat either the orchard perimeter, at a density of one per acre, or as an internal grid at a density of one per 2.5 acres (Figure 10). In the latter case, the puffers are supplemented with hand-applied dispensers around the perimeter of the orchard.

The microencapsulated product can be applied from the ground as an ultra-low-volume spray (1.25 to 2.5 gallons of water per acre) using a GF120 sprayer mounted on an all-terrain vehicle (Figure 11a). The ULV application can deposit 6 to 10 times more microcapsules in the canopy than the standard air blast spray.

The effectiveness of these sex pheromone based tools is that they both disrupt and delay female moth mating. All three approaches have proven effective when matched with a rigorous monitoring program and use of supplemental insecticides as needed.

The development of new pheromone based technologies will continue. Currently, both sticky fibers and flakes that require specialized applicators are being evaluated. In addition, pear ester in combination with sex pheromone is being tested in both hand-applied dispensers and as a microencapsulated formulation. We encourage growers to conduct trials with these various technologies before adopting new approaches to manage codling moth.

Research publications on the development of the pear ester lure and mating disruption can be downloaded from the Web at <http://ars.usda.gov/pwa/yarl>.



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