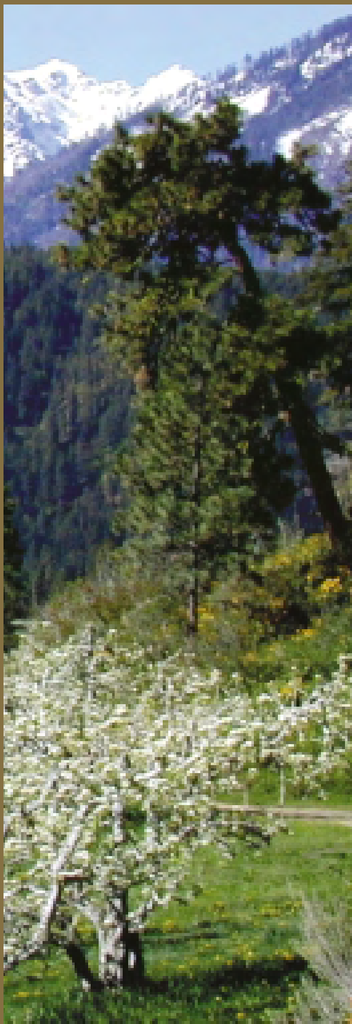
SPECIAL REPORT



Conquering Codling MOTH

Codling moth (CM) is the "key" pest of pome fruit in the western United States. Recently, crop injury by CM has increased in most growing areas. In some cases the level of damage from CM has threatened the apple and pear growers' ability to produce a marketable crop. Growers are asking many questions as they try and understand what has happened with CM control:

- Has the biology of CM changed?
- Are we timing insecticides poorly?
- Do the older insecticides work the same as in the past (resistance)?
- Are the new insecticides really effective?
- Does CM mating disruption work?

This special report on codling moth control covers three essential topics:

1. The current status of codling moth control and what is necessary in the future.
2. Codling moth control through insecticide management.
3. Controlling codling moth through the use of pheromone dispensers.

Codling Moth: What Went Wrong So Far, And Where We Go From Here

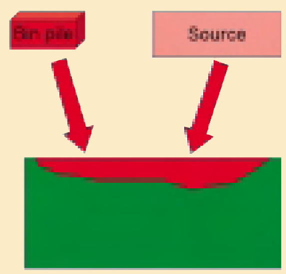
Resistance and rising populations have forced researchers to come up with new strategies for controlling this dreaded pest.

By Mike Doerr, Jay Brunner, John Dunley and Tim Smith, Washington State University Tree Fruit Research and Extension Center, Wenatchee, WA

THE increase in codling moth (CM) problems on a regional scale may be linked to the tough economics of growing fruit over the past five years. Abandoned or poorly managed orchards allow CM populations to dramatically increase and impact nearby orchards. We know that under western orchard conditions 0.5% CM damage at harvest in one year can reach 5% to 10% during the 1st generation and 30% to 50% damage at harvest in the following year with no controls. Moths will move from these high population sources as fruit become over exploited. CM infestations can reach more than one larvae/fruit in a very short time.

Immigration

Most CM adults move less than 100 meters if host fruit are present, but when oviposition sites are scarce individuals will certainly move much further.



Codling moth adult can migrate into an orchard from bin piles or other outside sources such as neglected or abandoned orchards or backyard trees.

Some sources of CM infestations are:

- Neglected or abandoned orchards
- Backyard trees
- Bin piles
- Tree props

Very little can be done to interrupt immigration except control at the source. A good monitoring program should detect CM immigration and a grower must be ready to respond.

Perceived Reduction In Efficacy

It's a numbers game: No CM management program can guarantee 100% control, but rather operate at levels closer to 90-95% control. 90% control of a small CM population will likely result acceptable levels of crop loss. However, 90%, or even 95%, control of a high CM population will result in detectable fruit injury that in some cases is unacceptable. In these cases growers must respond with more insecticide or pheromone inputs to reduce CM populations and crop losses. The perception may be that the insecticide is not working as well as in the past.

Coverage

There are few factors affecting insecticide efficacy that are more important than coverage. Often the results of poor spray coverage are attributed to insecticide resistance. The efficacy of an insecticide is based on two factors:

- Acute toxicity at a known rate
- Length of residual control

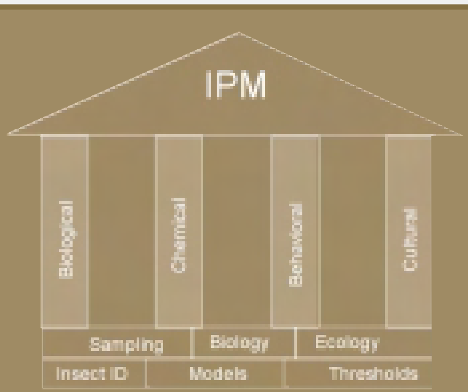
Applications that deliver insecticide at a lower than expected rate (poor calibration) or with a poor distribution on the target can reduce the efficacy of an insecticide. Errors that affect spray coverage include:

- Poor thinning and pruning resulting in clustered fruit and dense foliage
- Inefficient sprayer technology.

Airblast sprayers not calibrated or nozzled correctly can deliver a lower than expected rate of an insecticide that is not properly distributed within the canopy. We often see insecticide applications at ground speeds that are too fast, 3 to 4 mph, to deliver the spray uniformly. Before blaming the insecticide for control failures check sprayer calibration and apply a tank of Surround to visually check coverage in all parts of the tree.

The first sign of CM resistance to Guthion (azinphos-methyl, Bayer CropScience) was the lack of moth suppression following an application. This was usually followed by diminished residual control of larvae. Growers have countered this by using higher rates and shorter re-treatment intervals. Insecticide resistance has been more widespread and at higher levels in CA than WA or OR. However, WA has some areas with elevated resistance. Although resistance to OP insecticides such as Guthion and Imidan (phosmet, Gowan Co.) is of greatest concern, resistant CM may be tolerant of many other insecticides including pyrethroids and some growth regulators due to cross-resistance.

New sprayer technologies allow growers to efficiently apply very low volumes throughout the canopy. Conventional sprayers can also deliver high volumes of water efficiently if calibrated correctly and driven slowly enough.



IPM programs are built upon a strong foundation of information and knowledge. The pillars represent all possible control options available to growers. If the foundation is weak or pillars are missing the program becomes unstable.

Where do we go from here?

Areawide Insect Management: This model has been successfully repeated over and over again in systems as diverse as pears in the Sacramento delta and apples along the Canadian border in Oroville, WA. If there is one thing we are certain of is that areawide management works. This concept is not based on forcing everyone to conform to one management strategy, but rather encouraging growers to work together to solve problems. Growers that can work within a community to share information, exchange ideas, and isolate and respond to sources of infestation will be the most successful in the end.

Pay a little now, or a lot later: A complete IPM program starts with a strong foundation of biological understanding, monitoring, models and thresholds (see drawing). Management tactics represented by pillars include:

- Cultural controls — pruning and crop load management
- Pesticides — insecticide choice and timing

• Behavioral control — exploiting a pests own pheromone communication system
• Biological control — conserve natural enemies of secondary pests (e.g. mites, aphids and leafrollers) by selecting the least disruptive insecticides for CM.

Two basic concepts of IPM can never be ignored. Growers must invest the time to understand the biology of CM. They then must invest the money in a reliable monitoring program. A monitoring program has several facets:

• Enough traps must be used to reflect CM density and distribution in the orchard.
• Visual inspection of borders is necessary to detect hot spots
• Degree-day models should be used to predict oviposition and hatch.

Commercially available high-load lures include (clockwise from left) SuperLure, BioLure, MegaLure, and red septa. Manufacturers are listed in the chart to the right.

Monitoring Program

CM traps: Sticky traps (e.g Delta style) baited with a pheromone lure or a kairomone (DA Lure, Trécé, Inc.) are the best tools to measure relative density in an orchard. Traps are essential for the initiation of the CM model and tracking seasonal phenology. Trap captures may not necessarily match model predictions. These atypical flight patterns may constitute the majority of captures and must be viewed as "real" and responded to appropriately. If placed properly, traps can also provide the first warning of immigration.

A delta-style trap offers growers ease of use, durability, and a large sticky surface.

Trap density and treatment thresholds: We recommend one trap be used for every 2-3 acres. We also understand that implementation of trapping programs is often at a density of one trap every 5 or even 10 acres. As trap densities are reduced the resolution of CM density and distribution is also reduced.

It is difficult to recommend treatment thresholds based on moth capture in traps as the level of capture can be affected by:

• Mating disruption product and rate
• Trap density
• Lure choice
• Trap placement
• Trap maintenance

Therefore, a grower's experience with an orchard and trapping system is as or even more important than a researcher's idea of a treatment threshold.

Lure Manufacturers

Lure	Manufacturer
High-load pheromone (10X)	
Red septa	All manufacturers
MegaLure	Trécé, Inc.
SuperLure	Phero Tech, Inc.
BioLure	Suterra, Inc.
Pear kairomone	
DA Lure	Trécé, Inc.
Standard-load pheromone(1X)	
Red septa	All manufacturers
L2	Trécé, Inc.
NoMate Fiber	Scentry Biologicals, Inc.
BioLure	Suterra, Inc.

Lure choice: There are many acceptable lures for monitoring CM. High-load lures (10X) are best suited for all hand-applied pheromone treatments and standard load lures (1X) are best for sprayable pheromone and non-pheromone treated orchards. Lures must be maintained to manufacturer's specifications as each lure has its own pheromone release characteristic. One important note, the DA Lure attracts both male and female moths and can be helpful in understanding female behavior. However, this lure has reduced attractiveness in pear orchards. ●

Codling Moth: Insecticide Management of Codling Moth In High Pressure Situations

There are several possible codling moth control programs you can develop, depending on local populations and your method of attack.

By Mike Doerr, Jay Brunner, John Dunley and Keith Granger, Washington State University Tree Fruit Research and Extension Center, Wenatchee, WA

IN LIGHT of recent population increases and an observed efficacy reduction with some previously reliable insecticides, codling moth (CM) management has become more complex and reliant on a variety of different insecticides. When a grower is designing an insecticide program it is wise to consider:

- Targeting as many life stages as possible
- Using products with different modes-of-action
- Rotate insecticide chemistries to slow resistance development
- Supplement mating disruption (MD) with insecticides

The registration of new, highly selective insecticides provides several management options. However, the knowledge level required to manage CM increases as growers move away from a reliance on organophosphate (OP) insecticides. A careful and thoughtful approach to incorporating new insecticides into the management program will ensure the best possible control of CM, while improving control of secondary pests (e.g. leafrollers, aphids and mites) and conserving natural enemies.

An insecticide program that potentially interrupts the CM life cycle in as places as possible would include:

- Reducing oviposition with MD or adulticides
- Ovicides to kill eggs
- Larvicides that kill larvae and prevent fruit infestation
- Viruses or growth regulators that work against the next generation
- Biological control agents that attack larvae or pupae outside the fruit

Codling moth phenology: A thorough understanding of the CM life cycle is necessary to accurately time insecticide applications against desired life stage. A degree-day (DD) model allows growers a method of timing insecticides that is a significant improvement on calendar timings. Different regions have validated DD models and these should be implemented based on recommendations of the pest management advisors in the region.

Reducing oviposition: OP insecticides have lost much of their adulticide activity in most areas in the west. Pyrethroids may retain adults activity but disrupt biological control of spider mites, which may result in additional miticides treatments. MD is a viable alternative for suppressing adult activity in all orchards, even those experiencing high CM pressure. MD plus supplemental insecticides is a very stable CM management program.

Ovicides: Several insecticides will provide control of CM eggs. Careful monitoring of CM activity is necessary with these sprays because of very specific timing requirements.

- Insect growth regulators are generally applied prior to egg deposition (prior to 100DD), however Intrepid is also effective when applied on topically
- Chloronicotinyls have greater ovicidal activity if applied topically (200 DD)
- Horticultural oils work only if applied topically and have no residual activity (200, 400 and 600 DD)

Products And Uses

Insecticide class	Insecticide	Registrant	Target	Considerations
Organophosphate	Guthion	Bayer CropScience	Larvae	Fast acting, residual control depends on resistance levels
	Imidan	Gowan Co.		
Pyrethroids	Asana	E.I. duPont de Nemours and Co.	Adults, Larvae	Fast acting, possible mite problems, depends on cross resistance with OPs
	Danitol	Valent BioSciences		
	Warrior	Syngenta Crop Protection		
Chloronicotinyls	Assail	Cerexagri, Inc.	Larvae, Eggs	Fast acting, 17-21 day residual control, larval timing also kills eggs
	Calypso	Bayer CropScience		
	Clutch	Arvesta Corp.		
Growth regulators	Diamond	Crompton/ Uniroyal Chemical	Eggs	Apply prior to oviposition
	Esteem	Valent BioSciences		
	Intrepid	Dow AgroSciences	Eggs, Larvae	Apply either prior to or after oviposition
Spinosad	Entrust (organic)	Dow AgroSciences	Larvae	10-14 day residual control, combine with oil for best results
	Success	Dow AgroSciences		
Granulosis virus	Carpovirusine	Calliope SAS	Larvae	10-14 day residual control, limited fruit protection but reduces surviving population
	Cyd-X	Certis USA, LLC		
	Virosoft CM	BioTepp, Inc.		

Larvicides: Larvicides are the most common CM control measure. They protect fruit from infestations by newly hatched larvae. These insecticides should be applied as close to but prior to the start of egg hatch (250 DD).

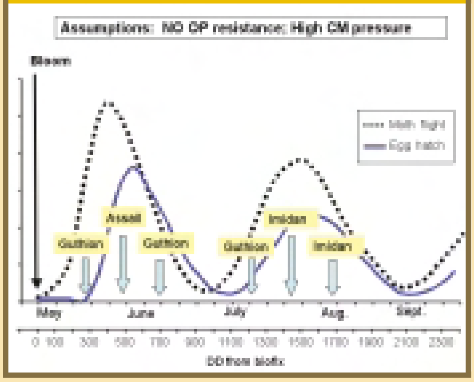
- OPs and pyrethroids are fast acting nerve poisons that work through direct contact or contact with residues
- Chloronicotinyls and spinosad are nerve poisons that must be ingested, thus the potential exists for shallow, unsuccessful entries ('stings").
- Intrepid (methoxyfenozide, Dow AgroSciences) is a growth regulator that must be consumed and is relatively slow acting, dead larvae may be detected below the fruit surface
- Granulosis virus is a biological product providing limited protection from fruit injury, but significantly reduces the subsequent generation.

Creative combinations employing different modes of action: IPM practitioners can use combination of insecticides with different modes of action to optimize insecticide applications. We recommend that spinosad (Success or Entrust, Dow AgroSciences) be used with oil (0.25-1.0%) to kill both eggs and hatching larvae. Another approach is to use products with ovicidal and larvicidal activity (e.g. Intrepid+Assail) applied as a tank mix at 250 DD to control CM during the first generation. Eggs controlled by Intrepid after application will extend the residual control of this one application much longer than Assail by itself.

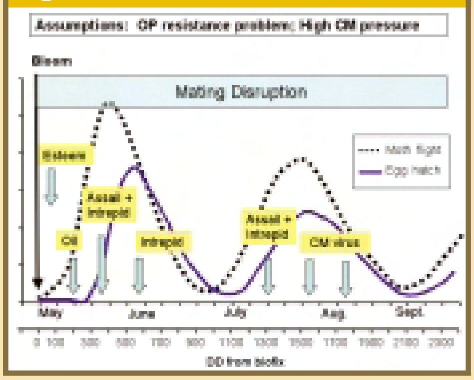
Developing an insecticide program

In order to plan an insecticide program a grower must have an accurate understanding of the carryover CM population as well as its susceptibility to insecticides (resistance levels). There are several different scenarios you may encounter, four of which are described below and illustrated in graphs on this page and the following page.

Scenario #1: No OP Resistance, High CM Pressure



Scenario #2: OP Resistance, High CM Pressure



Scenario 1- High CM pressure with no insecticide resistance: An example of this would be a poorly managed or abandoned orchard that has a history of insufficient insecticide inputs.

- Economic benefit of MD limited if Guthion is highly toxic to CM
- Begin applying Guthion at 250 DD
- Guthion should last 17-21 days if population is susceptible
- Replace Guthion with a chloronicotinyl when worker reentry is important
- Second generation sprays begin at 1250 DD
- Use Imidan near harvest and after using season's allotment of Guthion

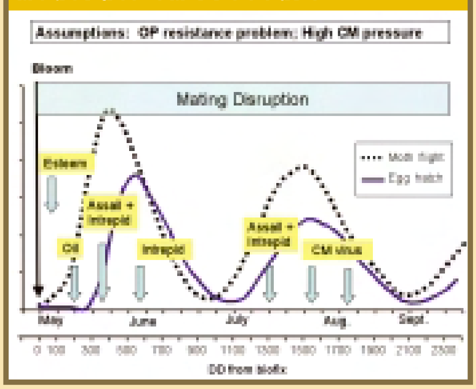
Scenario 2- High CM pressure with an OP resistance problem: If populations are resistant to OP insecticides and higher rates or more applications are necessary to achieve control the relatively low cost of an OP program is lost. A very aggressive first generation treatment strategy that attacks all life stages will reduce the CM population substantially so that fewer insecticides are need against the second generation.

- Foundation of this program is a mid-high rate of hand-applied pheromone
- Apply ovicidal growth regulator at 50-100 DD.
- Oil can be applied just prior to hatch (200 DD) in order to restrict the CM hatch period.
- A combined ovicide+larvicide treatment is applied at 300DD.
- Plan to apply another insecticide after 14-21 days
- Second generation sprays begin at 1250 DD
- Introduce virus treatments during the second generation to reduce the overwintering population

Scenario 3- Moderate CM pressure with an OP resistance problem:

- There may be some flexibility in the rate of hand-applied pheromone treatments
- Continue an aggressive first generation treatment program with some reductions due to pest pressure
- Second generation pressure should be reduced
- Consider an oil and spinosad program with virus supplements if monitoring shows that the second generation pressure is reduced

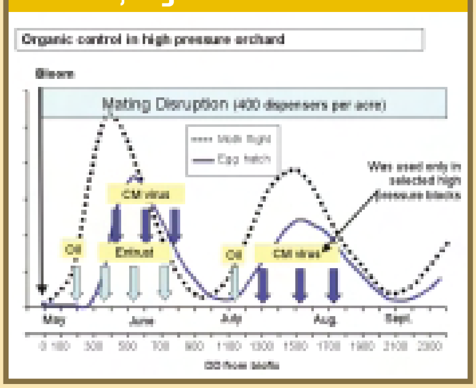
Scenario #3: OP Resistance, Moderate CM Pressure



Scenario 4- Organic orchard with extreme CM pressure, a case study from 2003: A 270-acre demonstration orchard was established in the Royal Slope area of WA. In 2002, an average of 67 moths/trap were captured during a 3-week period. The grower hand removed 158 bins of damaged apples (1000 man-hours). Still 5% damage was noted at harvest and the grower packed only 16 of 25 boxes/bin. Total insecticide cost was $407/acre. In 2003 a high carryover population resulted in an average capture of 46 moths/trap during the first generation. After using a program employing two newly registered organic products, Entrust and Cyd-x virus, CM captures were reduced to an average of 3.6 moths/trap during the second generation. Less than 1% damage was noted at harvest and no hand removal of CM injured fruit was needed. The grower packed 21 of 25 boxes/bin. The total insecticide cost was $80/acre more in 2003 but this was more than offset by the reduction in lost fruit and higher packout.

- Apply full rate of hand-applied pheromone
- Oil applied at 200 DD as an ovicide
- Entrust and oil applications began at 350DD and repeated every 10 days (3 total applications).
- Virus treatments applied every 10 days, alternating with the Entrust for the duration of the first generation
- Only spot treatments of virus or Entrust were required during the second generation

Scenario #4: Organic Control, High CM Pressure



Summary

If what you are doing isn't working then try the alternatives we have suggested. Growers have a variety of tools utilizing different modes of action to attack all CM life stages. Use mating disruption as the foundation to your CM control program. Learn all you can about the new insecticides and use them appropriately. The new CM programs may initially be more expensive than traditional OP programs. However, consider that chloronicotinyls also control Campylomma, aphids, leafminers and leafhoppers and the growth regulators and spinosad control leafrollers, leafminers, cutworms and fruitworms, the overall cost of pest control may be reduced. ●

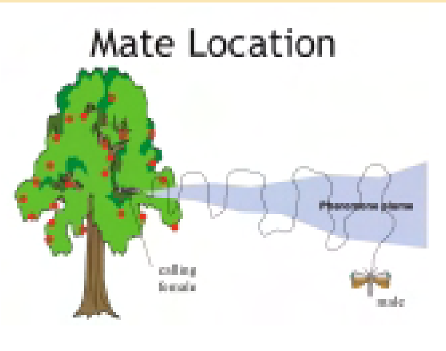
Codling Moth: Use of Pheromones to Disrupt Normal Mating

Mating disruption through pheromones requires careful monitoring, and timing is crucial.

By Mike Doerr, Jay Brunner and Betsy Stutzman, Washington State University Tree Fruit Research and Extension Center, Wenatchee, WA

Scenario #4

A male codling relies on the signals sent out by females to find a mate. Pheromones send out multiple signals at once, which makes finding a mate virtually impossible.



MATING disruption (MD) as a commercially available option for codling moth (CM) control was first available in Washington in 1991. Suppression of CM populations by MD entails dispensing sex pheromone into orchards in quantities sufficient to interfere with the normal process of mate location. MD for CM is currently being used in approximately 120,000 acres of pome fruit and walnut throughout the western United States. We have identified six steps in establishing a MD program:

- Orchard selection
- Product selection
- Pheromone application
- CM monitoring
- CM management
- Non-target monitoring and management.

Choosing appropriate orchards: CM MD is influenced by several physical factors, including: orchard topography, size and shape, wind conditions and canopy structure. The best control is achieved where physical conditions allow for uniform distribution of pheromone within the orchard. The ideal MD site is relatively calm and flat with a contiguous and even canopy structure.

We know that the borders of mating disrupted orchards are especially vulnerable to CM. Thus, when implementing a MD control program we recommend that you maximize the amount of orchard interior relative to orchard edge.

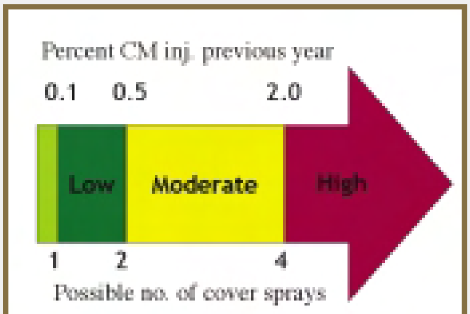
Choosing an appropriate orchard for mating disruption can be an important factor in successful implementation. A larger, more contiguous orchard that minimizes the border effect is best.

A key factor determining the efficacy of MD is the initial density of CM within or adjacent to an orchard being considered a candidate for CM MD. Controlling CM by MD becomes more difficult as CM pressure increases. Three criteria can be used to characterize CM pressure:

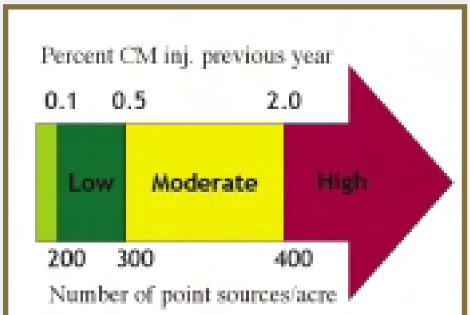
- Codling moth fruit injury
- Season-long capture of moths in traps
- The number of insecticide applications required to achieve good control

Selecting a pheromone product: Each pheromone dispensing technology has its pluses and minuses. As of now, hand applied dispensers remain the industry standard. Manufacturers should be able to provide you with three critical pieces of information:

- Amount of pheromone emitted under different conditions (i.e. cool, warm and hot)
- Longevity of their product under local growing conditions
- Level of CM control expected in low and moderate risk orchards



The above figure indicates the number of cover sprays you should consider making based on codling moth injury the previous year.



The above figure indicates the number of point sources for pheromone dispensers in the orchard, based on codling moth injury the previous year.

Pheromone application: MD does not provide control once mating has taken place. To control the first generation, pheromone should be applied prior to moth emergence in the spring. Since CM can mate the first or second night they emerge, late pheromone applications provide an opportunity for a portion of the population to mate. Apply pheromone at a rate that is reflective of CM pressure. The figure below provides a guide on the number of dispensers needed per acre in a low, moderate and high-pressure orchard.

Monitoring codling moth: Monitoring is difficult in orchards treated with MD. Concerns have been raised with regards to traps being able to detect "hot spots". We recommend the use of traps with high load lures as a tool in MD orchards but stress three factors that will greatly reduce inconsistencies:

- Use one trap every 2 or 3 acres
- Replace lures to manufacturers specifications
- Place traps high within the canopy

Monitoring with traps is not intended as a stand-alone method for accessing the effectiveness of CM MD. Visual examination of high-risk areas is essential to detect hot spots. Concentrating sampling on orchard borders, tops of slopes and near bin or prop piles will provide early warning of developing problems.

Managing codling moth. MD alone will not be sufficient for control of CM under certain circumstances. Growers should anticipate the need for supplemental insecticide applications. The number of applications should be a reflection of CM pressure and risk of additional damage.

The borders of an orchard (50 ft into or outside of a block) require extra attention. Two processes are thought to contribute to border infestations; immigration of mated females and aggregation of internal moths on borders where more successful mating can occur. Two tactics can be used to protect orchard borders:

- Treat borders with additional pheromone
- Treat borders with insecticides

Monitoring and managing non-targets: MD is a highly specific pest control tactic. Implementing this tactic for CM control will have a significant impact on non-target arthropods, both pests and their natural enemies. If the orchard is managed carefully biological control of many secondary pests is possible as their natural enemies increase due to a reduction of broad-spectrum insecticide use. Growers will have to increase their basic knowledge of orchard ecology and insect identification if they are going to realize these benefits of CM MD. ●

A bamboo pole can help place traps high.

Commercially Available Mating Disruption Products

Product	Manufacturer	Positives	Negatives
Hand-applied		Very reliable, consistent results, uniform coverage, high release with full season longevity	Higher initial investment, more costly application
NoMate CM	Scentry Biologicals, Inc.		
Isomate C+	Pacific Biocontrol, Inc.		
Isomate CTT	Pacific Biocontrol, Inc.		
CheckMate XL	Suttera, Inc.		
Fibers		Higher number of point sources, moderate but consistent release, moderate longevity (30-60 days), flexible in response to problems	Limited data (new product), application must be subcontracted, requires repeat applications
NoMate CM Fiber	Scentry Biologicals, Inc.		
Sprayable		Maximum point sources, very flexible in response to problems, easy to apply	Lowest release per point source, longevity is limited, frequent reapplication needed
CheckMate CM-F	Suterra Inc.		
3M MEC	Certis USA, LLC.		
Aerosol puffers		Maximum release rate from minimum sources, least expensive for season long	Fewest point sources, more "gaps" in coverage, potential for mechanical failure
CM Puffer	Suttera, Inc.		
Attract and kill		Very flexible in response to problems, combines insecticide with pheromone	Troublesome to apply, requires high rates and repeat applications
Last Call CM	IPM Technologies, Inc.		