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.
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 85-95% control. 95% control of a small CM population will likely result in 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.

**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.

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 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.

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

**Lure Manufacturers**

<table>
<thead>
<tr>
<th>Lure</th>
<th>Manufacturer</th>
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<tr>
<td>BioLab pheromone (10X)</td>
<td>All manufacturers</td>
</tr>
<tr>
<td>Red septa</td>
<td>Trécé, Inc.</td>
</tr>
<tr>
<td>Megalure</td>
<td>Trécé, Inc.</td>
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<tr>
<td>Genetix</td>
<td>Phyto-Tech, Inc.</td>
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<tr>
<td>BiciLure</td>
<td>Soterra, Inc.</td>
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<tr>
<td>Fear kairomone</td>
<td>Trécé, Inc.</td>
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<tr>
<td>DA Lure</td>
<td>Trécé, Inc.</td>
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<tr>
<td>Standard-load pheromone (1X)</td>
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<td>Trécé, Inc.</td>
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<tr>
<td>NoMat Fiber</td>
<td>Scarry Biologicals, Inc.</td>
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<tr>
<td>BioLure</td>
<td>Soterra, Inc.</td>
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**Behavioral control** — exploiting a pests 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.

**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.
Developing an insecticide program

To develop 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**

- **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 Gliotin is highly toxic to CM**
- **Begin applying Gliotin at 250 DD**
- **Gliotin targeted to last 17-21 days if population is susceptible**
- **Replace Gliotin 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 Gliotin**

**Scenario 2: OP Resistance, High CM Pressure**

- **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 needed 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 a need during the second generation.**
- **Second generation generation pressure is reduced**

**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 585 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 infected fruit was needed. The grower packed 21 of 25 boxes/bin. The total insecticide cost was $68/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.**

**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. Plan 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 codling moths, 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

MD. Controlling CM by MD becomes more difficult as CM pressure increases. Three criteria can be used to characterize CM pressure:

• Level of CM control expected in and around the block
• Level of CM control expected in high-risk parts of the orchard
• Level of CM control expected in low-risk parts of the orchard

Choosing an appropriate orchard: 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 CM MD orchard is flat with a contiguous and even canopy structure. The best control is achieved where physical conditions allow for uniform distribution of pheromone within the orchard. The ideal CM MD orchard is flat with a contiguous and even canopy structure.

Implementing a MD control program we recommend that you maximize the amount of orchard interior relative to orchard edge.

A key factor determining the efficiency 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.

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 CM 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 (MD) can be an important factor in successful implementation. A larger, more contiguous orchard that minimizes the border effect is best.

Scenario #4

Mating Disruption

A male-coding 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.

Mate Location

A bamboo pole can help place traps high.

Commercially Available Mating Disruption Products

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<thead>
<tr>
<th>Product</th>
<th>Manufacturer</th>
<th>Positives</th>
<th>Negatives</th>
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<tr>
<td>Hand-applied</td>
<td>Scentry Biologicals, Inc.</td>
<td>Very reliable, consistent results, uniform coverage, high release with full season longevity</td>
<td>Higher initial investment, more costly application</td>
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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.

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.

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