Washington State University
College of Agriculture and Home Economics

Tree Fruit Research and Extension Center
Information Series

Implementing Codling Moth Mating Disruption in Washington Pome Fruit Orchards

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Over the past 35 years codling moth has primarily been controlled by organophosphate insecticides. These materials have provided good control of codling moth in most Washington orchards, but many factors acting together have heightened interest in alternative control tactics for this key pest. Organophosphate insecticides are highly toxic to natural enemies of most pests, and their use is a major factor limiting the potential of biological control in pome fruit. High levels of codling moth resistance to organophosphates have been detected in California, South Africa and elsewhere, and reduced efficacy of these broad-spectrum insecticides has been reported in most fruit growing regions in Washington. Regulations governing pesticides have become increasingly complex, and the public has voiced an interest in reducing the use of insecticides in agriculture.

A unique pest control tactic termed mating disruption has recently become a commercially viable option for codling moth control. Codling moth mating disruption is a very specific control tactic that does not affect natural enemies of other pests. In addition, because mating disruption products are very safe, their use is governed by a reduced set of regulations. The purpose of this bulletin is to introduce the concept of mating disruption, provide guidelines for effective use of codling moth mating disruption products in Washington orchards, and discuss the risks and benefits of implementing a pheromone-based pest management program.

Codling Moth Mating Behavior

Codling moth and many other insects rely on chemical signals to facilitate mate location. Females attract males by releasing minute amounts of volatile chemicals called pheromones. A male can detect the pheromone using sensors on its antennae. The male codling moth flies upwind toward the pheromone source following a zigzagging path within the pheromone plume (Fig. 1). By continuing to orient upwind and responding to increasing pheromone concentrations, the male moth eventually locates the source, the "calling" female, and mating occurs.

The pheromones of many pome fruit pests, including codling moth, have been identified. Each is comprised of a blend of chemical components. Differences in the kinds

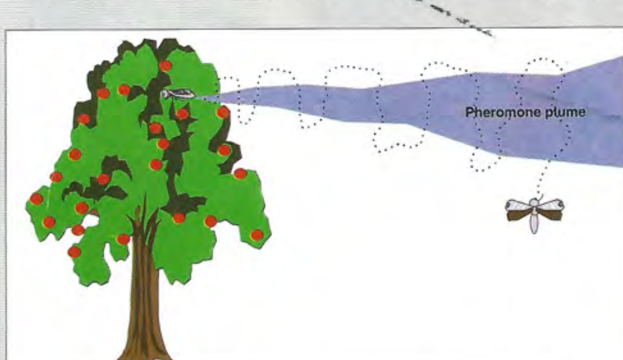

Fig. 1. Normal codling moth mate finding, where a female releases pheromone and the male flies toward the source.

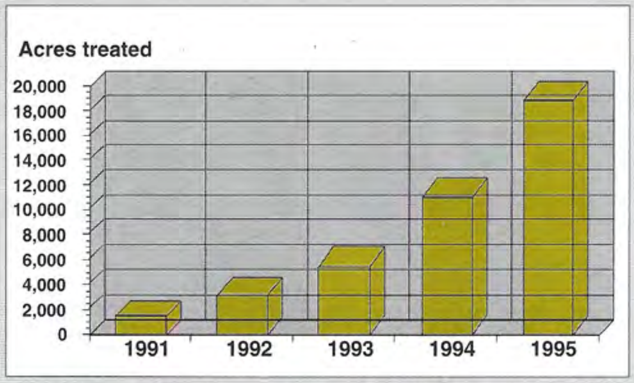

Fig. 2. Use of codling moth mating disruption products in Washington State.

of chemical components or their relative proportion make a pheromone specific for each insect species. The major component of the codling moth pheromone is an alcohol which has been given the common name codlemone. Two other alcohols, dodecanol and tetradecanol, have also been shown to be important components of codling moth pheromone.

Concept of Mating Disruption

Chemists are able to make copies of insect pheromones in the laboratory, and these have been used principally to monitor pest populations. When a small amount of a species' pheromone is put in a rubber or plastic release device and placed in a trap, males of that species are attracted to the trap as they would be to a calling female. Pheromone traps are a key component of a codling moth management program. The combination of pheromone traps and a degree-day model provides a highly reliable method of monitoring codling moth activity and timing insecticide sprays. Furthermore, thresholds based on cumulative male catch in traps can be used to determine the need to apply control treatments in many situations. The potential of using pheromone to control pests was recognized over 25 years ago. Scientists speculated that release of large amounts of pheromone could interfere with mate location and thus reproduction. A high level of interference would result in insect birth control, effectively preventing females from producing the next generation.

Fig. 3. Two mating disruption control systems, Isomate-C+ (left) and Checkmate-CM (right).

Mating disruption has grown into a commercially viable control for some key Lepidopteran pests, including codling moth. In 1991 pheromone was applied as the primary control for codling moth on over 1,500 acres of apples and pears in Washington. The use of mating disruption has steadily increased over the past four years, with about 18,000 acres treated throughout the state in 1995 (Fig. 2).

Codling moth mating disruption entails placement of pheromone dispensers in trees in sufficient numbers to block mate location. A dispenser consists of a physical package plus the pheromone (Fig. 3). The package functions to regulate the emission of the pheromone. Depending on the kind of dispenser, the pheromone is either contained in an internal reservoir, in a matrix or between layers of a laminate.

The two most widely used dispensers are Isomate C+® and Checkmate CM® (Fig. 3). The Isomate C+ dispenser is a polyethylene tube loaded with a 63:31:6 blend of codlemone, dodecanol and tetradecanol. The Checkmate CM dispenser is a plastic membrane dispenser loaded with codlemone alone. How these pheromone dispensers interfere with the normal process of mate location is uncertain, but the most probable mechanisms involve inhibition of the male's responsiveness to pheromone or competition between dispensers and calling females (Fig. 4).

An individual dispenser releases several thousand times more pheromone than a calling female. Exposure to high concentrations of synthetic pheromone may raise the male's response threshold so that it is no longer able to sense the small amount of pheromone released by the female. Or high pheromone concentrations may act to saturate the male's senses so that it can no longer even detect the pheromone, similar to the situation we experience when we can no longer smell a strong odor after prolonged exposure. The outcome in either case is the inability of males to detect calling females (Fig. 4, left).

The other likely mode of action, competition, is fundamentally different in that the male's sensory system continues to work normally within the background of synthetic pheromone. However, female moths and their pheromone plumes are camouflaged by the presence of many synthetic pheromone trails (Fig. 4, right). The chance of a male locating a mate is reduced because it spends considerable time and energy orienting to false sources of pheromone rather than to females.

Influence of Physical Factors

Codling moth mating disruption is influenced by several physical factors, including orchard topography, size and shape, wind and canopy structure. The best opportunity for control is achieved where physical conditions allow for uniform distribution of pheromone concentration within an orchard. Thus, sites that are relatively calm and flat are better candidates for codling moth mating disruption than sites that experience frequent high winds or have steep slopes. Orchards with large numbers of missing trees or uneven canopies are considered poor candidates for codling moth mating disruption.

Using codling moth mating disruption in a large, contiguous area is considered a better strategy than in small, individual orchards. However, good control of codling moth by mating disruption has been achieved in blocks as small as two acres. We know that the borders of mating disrupted orchards are especially vulnerable to codling moth. Thus, when implementing codling moth mating disruption, we recommend that you maximize the amount of orchard interior relative to orchard edge as illustrated in Fig. 5. If only a single orchard is to be treated, the best choice is the one with least amount of border exposed to open areas. Long, narrow orchards are very poor choices for mating disruption.

Dispenser Application

Successful use of codling moth mating disruption requires placing dispensers high in the orchard canopy prior to moth emergence in the spring. Positioning dispensers in the upper canopy provides the best chance of interfering with mate location. We know that codling moth activity and mating are concentrated in the upper third of the canopy. We also know that pheromone is heavier than air and tends to sink toward the orchard floor as it is released from dispensers. Our recommendation is that dispensers be placed within the top 2 feet of the tree but within the foliage canopy. They should be placed near foliage to protect them from UV radiation and high temperatures.

In orchards with canopy heights greater than 10 feet, proper placement of dispensers cannot be achieved from the ground. A very good method for applying dispensers is with the assistance of a pole and clip. Some dispensers, such as Checkmate CM, are engineered with a clip attached. Other dispensers, such as Isomate C+, require attachment to a large plastic clip (similar to a bread clip). Application entails pushing a clip holding a dispenser onto a selected branch and leaving it there when the pole is twisted and pulled away. It takes less than 2 hours to treat an acre of apples with this technique. Dispensers can also be applied from ladders, but this method takes longer than the pole application method and adds the extra risk of accidents.

Effectiveness of mating disruption is reduced if dispensers are applied late since this tactic provides no control once mating has taken place. To control the first generation of codling moth, pheromone dispensers should be applied prior to the emergence of the first moths. Spring emergence usually begins at full bloom on Delicious. Since codling moths can mate the first or second night after they emerge, a late pheromone application, such as at petal-fall, can allow an opportunity for 10% or more of the population to mate.

Amount of Pheromone Needed

In Washington the codling moth mating period is 140 to 160 days, covering both the spring and summer moth flights. Therefore, to control codling moth a mating disruption product must deliver a sufficient amount of pheromone throughout this period. The length of time a mating disruption product is effective depends on its design, that is, the physical characteristics that determine the rate of pheromone emission. All currently registered codling moth mating disruption products are sensitive to temperature, releasing more pheromone when it is hot and less pheromone during cool periods. Based on our experience, a release rate of 0.5 mg of pheromone per dispenser per day is a minimum for satisfactory control.

In Washington codling moth mating disruption products fall into either a one- or two-application system. Isomate C+ releases levels of 0.5 to 1.5 mg of pheromone per day over at least a 140-day period so that only one

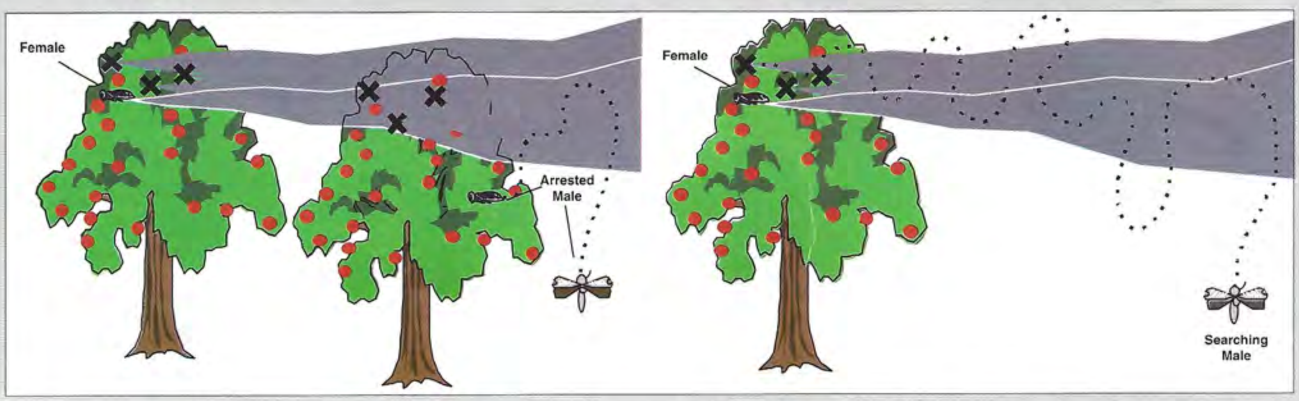

Fig. 4. In mating disruption, pheromone released from dispensers inhibits the male's ability to respond to pheromone signals (left), or dispensers act as false sources and camouflage or compete with the calling female (right).

application is necessary. Other mating disruption products, such as Checkmate CM, have been designed to release higher rates of pheromone for approximately 70 days. Full season codling moth control thus requires reapplying these kinds of dispensers prior to the second generation flight. Regardless of the mating disruption product used, the effectiveness is compromised whenever the pheromone release rate drops below 0.5 mg per day per dispenser at any time during the 140-day control period. Low pheromone emission rates are most likely to occur during the last few days of a dispensers expected release period.

Application Rate

Mating disruption, like any other control, will only work well if the application rate is high enough and coverage is adequate. Codling moth mating disruption products are hand applied; thus, the rate of application corresponds to the number of dispensers applied per acre. Dispenser densities that can provide satisfactory codling moth control in Washington range from 120 to 400 dispensers per acre. Good coverage entails a more or less uniform distribution of dispensers throughout the orchard. The number of dispensers placed in trees varies from four per tree to one every third or fourth tree. If two or more dispensers per tree are applied, it is best to spread them out within the upper canopy. Strategies for evenly distributing dispensers in orchards with various tree densities are provided in Table 1.

The main factor that will determine the number of dispensers required to achieve codling moth control is the pest's density within the orchard. Controlling codling moth by mating disruption becomes more difficult as codling moth densities increase. We think this occurs in part because as codling moth densities increase the number of males successfully finding calling females increases, resulting in mating. Our experience strongly suggests that as codling moth densities increase the number of dispensers that are needed per acre to prevent mating increases.

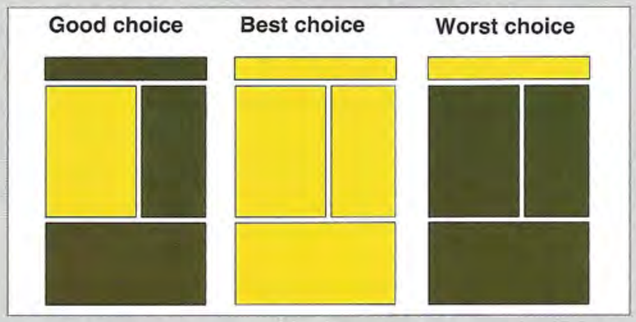

Fig. 5. Choosing appropriate orchards for codling moth control with pheromones.

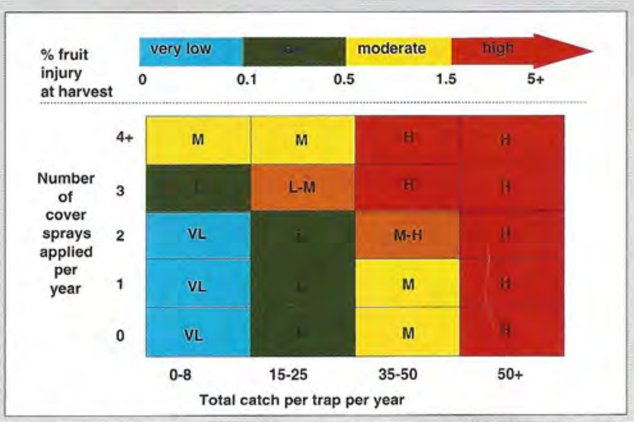

Fig. 6. Orchard risk rating as determined by fruit injury, number of cover sprays and seasonal moth catch in a pheromone trap.

Estimating Codling Moth Pressure

We often refer to the density of codling moth as the level of codling moth pressure the orchard is under. We can measure and characterize codling moth pressure in an orchard using three criteria, each related to codling moth activity or controls the previous year. Codling moth fruit injury data from packout records or field counts probably provide the best measure of codling moth pressure. A seasonal count of codling moths captured in pheromone traps also gives an indication of codling moth pressure. In addition, the number of insecticide applications used to control codling moth can provide an indication of codling moth pressure, especially if treatments were based on some measure of need, e.g., fruit injury or pheromone trap catch.

We have devised a method to characterize Washington apple orchards into four risk classes (very low, low, moderate and high) relative to their potential for implementing codling moth mating disruption (Fig. 6). It is our intent that these criteria be used to determine the relative risk associated with the adoption of codling moth mating disruption in orchards that have been managed using conventional methods of control and to help design a first year management strategy.

Very low and low risk orchards are the best candidates for codling moth mating disruption. Very low risk orchards are characterized as having codling moth fruit injury of less than 0.1%. A very low risk orchard would typically have a seasonal moth catch in pheromone traps between zero and eight moths and require none or one application of insecticide to control codling moth. Our experience indicates that reduced rates of mating disruption dispensers can provide acceptable codling moth control in very low risk orchards (Table 2). Low risk orchards are characterized as having codling moth fruit injury between 0.1 and 0.4%. Seasonal moth catch in pheromone traps would be between 15 and 25 and require one or two insecticide treatments to control codling moth. Mating disruption alone can provide satisfactory control of codling moth in low risk orchards (Table 2). Lower rates of pheromone dispensers can also be effective in low risk orchards but should be supplemented with at least one insecticide spray.

Moderate risk orchards are characterized as having codling moth fruit injury between 0.5 and 1.5%. Seasonal moth catch in pheromone traps would be between 35 and 50 and require two or more applications of insecticides to control codling moth. Mating disruption alone, even at a rate of 400 dispensers per acre, will most likely not provide adequate control of codling moth under these conditions (Table 2). Supplementing mating disruption with at least one insecticide against the first codling moth generation is suggested as a standard practice in moderate risk orchards.

High risk orchards are characterized as having codling moth fruit injury greater than 1.5%. Seasonal moth catch in pheromone traps would exceed 50 and require a full season control program for codling moth, four or more insecticide treatments. Insecticides should continue to be a major component of the codling moth management program under these circumstances (Table 2). It is still possible to move some high risk orchards into moderate and eventually low risk categories by using combinations of mating disruption and insecticides. While this would represent an intensive and expensive program for the grower, it can provide long-term benefits by establishing a more stable pest management system.

Monitoring

Trapping: Monitoring codling moth adults is difficult in orchards treated with mating disruption products. A pheromone trap baited with a red septum containing 10 milligrams (mg) of codlemone has been adopted as an important component of a pheromone-based codling moth control program. Codling moth activity in mating disruption orchards is more effectively monitored with this "high load lure" than with the standard red septum used to monitor conventional orchards, which contains only 1 mg of codlemone. While there are situations where the high load lure-baited pheromone traps fail to detect "hot spots" in mating disruption orchards, we continue to encourage their use as a management tool. However, we stress three factors that will greatly improve the reliability of high load lure-baited pheromone traps: use a trap for every 2 to 2.5 acres, replace lures frequently, and place traps high in the canopy.

Effective use of high load lure-baited pheromone traps will require changing lures every three weeks during the first codling moth generation and every two weeks during the second. Codling moth pheromone traps used in conventionally managed orchards have typically been placed at mid-canopy or lower because this position has resulted in good moth capture, and they are easier to maintain than traps placed higher in the canopy. However, when high load lure-baited pheromone traps are used in mating disrupted orchards, they are more sensitive when placed in the upper part of the canopy. High traps capture about three times more moths in the first codling moth generation and almost seven times more moths in the second generation than mid-canopy traps. High traps also track codling moth phenology better than the mid-canopy traps.

Vissual inspection: Monitoring with pheromone traps is not intended as a stand-alone method for assessing the effectiveness of codling moth mating disruption. Trapping should be used in conjunction with visual inspection of fruit for codling moth damage. We recommend that fruit on at least 50 trees per orchard be monitored twice each generation. During the first generation it is valuable to monitor fruit damage during hand thinning activities and again in late June. It is more important to examine a few fruits (15-20) on many trees compared to examining many fruits on a few trees. Concentrating visual examinations of fruit to the upper canopy, orchard borders and susceptible varieties, such as Golden Delicious, increases the chance of early detection of codling moth fruit damage. Other locations where codling moth fruit damage will show up is the top of slopes, near prop or bin piles and near fruit packing operations.

Supplemental Control

As discussed previously, mating disruption alone will not be sufficient for codling moth control in moderate and high risk orchards. Insecticides should be applied whenever codling moth fruit injury exceeds 1% or if moth catch in a pheromone trap exceeds suggested action thresholds. Using the monitoring protocols outlined in this article, and summarized in Fig. 7, the cumulative capture of moths in a high load lure-baited pheromone trap

Planting density *(trees/acre)*	**Application strategy** *(dispensers/tree)*	**Application rate** *(dispensers/acre)*
90-109	4	360-436
110-119	one-half at 4, one-half at 3	385-416
120-145	3	360-435
146-175	one-half at 3, one-half at 2	365-437
176-219	2	352-436
220-259	two-thirds at 2, one-third at 1	366-434
260-290	one-half at 2, one-half at 1	390-435
291-324	two-thirds at 1, one-third at 2	388-432
325-375	2 on border trees, 1 on others	360-436
376-436	1	360-436
600	two-thirds at 1, one third at 0	400
800	one-half at 1, one-half at 0	400
1200	two-thirds at 0, one-third at 1	400

Table 1. Guidelines for applying dispensers (ca. 400 d/a) in orchards of various planting densities.

Risk rating	**Suggested application rate(s)**	**Probable supplemental insecticides**
Very low	120-200	0
Low	160-400	0-1
Moderate	400	1-2
High	400	≥ 2

Table 2. Guidelines for codling moth control by mating disruption in orchards with the indicated risk rating.

can help the grower determine if a supplemental insecticide is warranted.

Based on our experience in Washington apple orchards, we have developed action thresholds using codling moth capture in high load lure-baited pheromone traps placed at the mid-canopy position (Fig. 8). If traps are placed higher in the canopy, use of these action thresholds can result in an over estimation of codling moth pressure and the application of supplemental insecticides where they may not be needed. However, many growers have opted to use this more conservative approach as a way of reducing their risk of codling moth fruit injury. A cumulative capture of fewer than four moths during the first generation indicates that mating disruption alone is sufficient for control. Supplemental insecticides are recommended if 4 to 10 moths are captured in a trap, but growers with experience using mating disruption may choose to continue trapping and monitor for codling moth fruit injury before making a decision to apply a supplemental insecticide. A cumulative capture of more than 10 moths signals high pressure and the need to use a supplemental insecticide when the appropriate timing occurs. The efficiency of the high load lure-baited trap declines as the season progresses. Therefore, suggested action thresholds are lower for the second codling moth generation (Fig. 8).

Orchard borders require extra attention when implementing codling moth mating disruption. Experience teaches us that orchard borders are often the Achilles' heel of this pest control technology. Two processes are thought to contribute to the frequent development of border infestations, immigration of mated females from nearby sources and an increase in successful mating of codling moth along orchard borders. Mating disrupted orchards are especially susceptible to invasion by codling moth from external sources. Since typically no insecticides are applied in mating disruption orchards, larvae hatching from eggs laid by immigrating females have a good chance of survival. Pheromone concentrations on orchard borders are thought to be lower than in the interior, possibly because of wind sweeping away pheromone. Lower pheromone concentrations on borders may allow males to locate females more frequently than in the orchard interior, leading to higher levels of successful mating and fruit injury in these areas.

Three tactics can be used to protect orchard borders. Additional pheromone can be applied to border trees or extended into adjacent orchards if possible. Our experience suggests that this approach is most effective when initial codling moth densities are low. In orchards that historically have a codling moth problem, it is best to treat borders with insecticides in addition to applying more pheromone to the borders or extending pheromone treatments into neighboring orchards. An effective border treatment (insecticides or extra pheromone) in most orchards would be an area equivalent to three or four rows around the orchard perimeter or along the problem border.

- pheromone trap (wing-type e.g. Pherocon 1CP or equivalent) baited with 10mg red septum
- one trap every 2 to 2.5 acres
- place traps within the middle or upper third of the canopy (illustrated below)
- check traps weekly and change trap bottom if dirty, or at least every 6 weeks
- change lures every 3 weeks in first flight and every other week in second flight

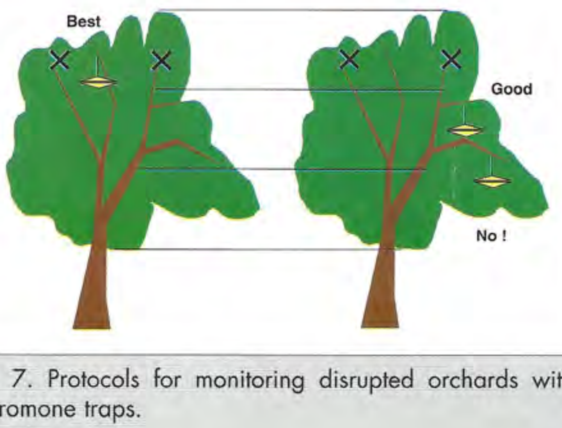

Fig. 7. Protocols for monitoring disrupted orchards with pheromone traps.

Mating Disruption Limitations

High cost: The relatively high cost of mating disruption is probably the major constraint to its widespread adoption. The direct cost of mating disruption for control of codling moth in most orchards in Washington ranges from $90-120 per acre plus $20-50 for application. A conventional insecticide program for codling moth control costs between $30-75 per acre (two to four sprays) plus about $20 per application. The cost differential between conventional and mating disruption approaches to codling moth control will likely decrease in coming years. Lowering application rates in orchards that have been under a pheromone-based pest management program for several years can substantially reduce the cost. For example, treating an orchard with Isomate C+ at 200 rather than 400 dispensers per acre would lower the direct cost by $55 per acre. New technology, changes in government regulations and a greater awareness of the less tangible benefits gained from the use of selective controls are among the factors that will contribute to making mating disruption a viable codling moth control option for more growers.

Secondary pests: Mating disruption is a highly specific pest control tactic. However, implementing this tactic for codling moth control will have a significant impact on non-target arthropods. Some pests that are kept at non-damaging levels by insecticides used to control codling moth will be released from all but natural controls in mating disruption orchards. Natural controls may provide sufficient suppression of some non-target pests. For others, however, the removal of insecticides will mean their populations will increase, sometimes reaching damaging levels. Intervention with insecticides may well be required in mating disruption orchards to control pests other than codling moth.

Leafrollers have consistently become the most important pest in codling moth mating disruption orchards in Washington. Two species of leafroller, *Pandemis pyrusana* (pandemis leafroller) and *Choristoneura rosaceana* (obliquebanded leafroller), have caused high levels of crop loss, in many cases exceeding that of codling moth, in apple and pear orchards using mating disruption for codling moth control. Any grower planning to use codling moth mating disruption should maintain an aggressive leafroller control program and institute a monitoring program to detect increasing leafroller densities before excessive crop loss can occur.

Benefits of a pheromone-based pest management program are reduced if summer insecticide treatments are needed to control leafrollers and other pests. Reliable monitoring methods and use of alternative controls to suppress leafrollers will be important components of future pheromone-based pest management programs. Four tactics that are useful or appear promising as alternatives for leafroller control are bacterial insecticides, insect growth regulators, biological control and mating disruption.

Bacterial insecticides which use strains of *Bacillus thuringiensis* (Bt) as the toxic agent can be used successfully to control leafroller larvae in the spring and summer. There are many Bt products available, and little differences in the level of leafroller control have been observed if proper rates are used and they are applied correctly. Bts are stomach poisons and must be consumed to be effective. It is therefore critical to have good spray coverage when using these products. It is also important in the spring to apply Bts when weather forecasts predict warm (maximums of 65°F or more), dry periods for three or more days. Applying Bts in cool wet weather will not provide good control because leafroller larvae are not feeding. Usually two Bt applications between pink and petal fall of Delicious give good leafroller control. Summer Bt applications should be targeted at young larvae in late June or early July.

Insect growth regulators and other new chemistries are promising as controls for leafrollers, and registrations are anticipated within the next one to three years. These materials have unique modes of action and are more selective than conventional insecticides. They generally are soft on predators and parasites, fitting well into a pheromone-based pest management program.

Biological control of leafrollers shows promise as there are many native parasites that attack leafroller larvae. The release of parasites in orchards is currently being investigated as a leafroller control tactic. Two parasitoids in particular, *Trichogramma platneri* and *Colpoclypeus florus*, hold promise as biological controls for leafrollers. Research is in progress on control of leafrollers by mating disruption, and this approach has shown some promise.

The use of organophosphate insecticides for codling moth control has probably been the primary factor preventing many other pests, such as tent caterpillar, lygus and stinkbugs, from becoming more frequent pests in commercial apple orchards. None of these pests has been reported as a serious problem in mating disruption orchards in Washington during the past five years. However, low numbers of tent caterpillars and other moth larvae frequently colonize mating disruption orchards. The regular occurrence of these pests suggests the need for careful monitoring of rare or sporadic pests in mating disruption orchards.

Information requirements: Using mating disruption as a control for codling moth alters the pest management program compared to the use of conventional insecticides. Careful monitoring of codling moth and other potential pests is time-consuming but mandatory. High levels of fruit injury can occur if orchards are not properly monitored or pheromone dispensers are improperly applied. Monitoring other pests and natural enemies provides the information necessary to evaluate the potential for biological control or determine the need for insecticide controls. Growers may perceive that implementing codling moth mating disruption holds greater risk than conventional pest control programs. However, this should not be the case if an adequate monitoring program is implemented. Implementation of codling moth mating disruption may require growers or their consultants to have a better understanding of pest and natural enemy biology, monitoring methods and action thresholds than they currently have. Education and information are both needed to successfully implement codling moth mating disruption.

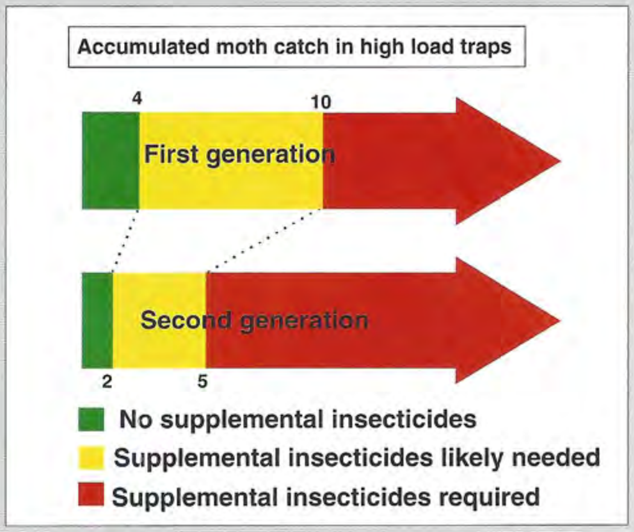

Fig. 8. Accumulated numbers of moths captured per high load lure-baited pheromone trap (action threshold) that indicate a need for supplemental insecticides in mating disrupted orchards.

Mating Disruption Benefits

Less regulation: Pheromones already have a distinct advantage over conventional insecticides when it comes to registration by the Environmental Protection Agency (EPA). Mating disruption products, like other pesticides, are regulated by the EPA, but the agency recognizes that pheromones have a unique, non-toxic mode of action, are highly specific, occur naturally, and are used in very low volumes. In general, mating disruption products are considered to be environmentally safe. The bottom line is that it takes much less time and money to register a mating disruption product than to register a conventional insecticide. Growers find that the elimination of some or all codling moth cover sprays helps reduce concerns with spray drift regulations.

Improved biological control: Many secondary pests in Washington apple orchards, such as aphids, leafhoppers and leafminers, have developed resistance to insecticides used to control codling moth. This forces growers to use other insecticides to control secondary pests. The use of mating disruption allows for increased activity of natural enemies. In many orchards, populations of aphids, leafhoppers, leafminers, grape mealybug and some other secondary pests will be regulated by their natural enemies, reducing the need for additional insecticide treatments.

The replacement of broad-spectrum insecticides with pheromones for codling moth control also provides an opportunity for supplemental release of predators and parasites to achieve biological control. Prior to the use of mating disruption there was little interest in introducing natural enemies to orchards because they would not survive organophosphate cover sprays. There is now an increased interest in finding and developing biological controls for secondary pests.

Slower development of resistance: Resistance of pests to insecticides continues to make their control more difficult. In some areas of California and South Africa, codling moth injury to fruit exceeds 2% even when a full season insecticide program is used. Mating disruption represents an alternative control tactic that can slow the development of resistance of codling moth to insecticides.

It is important to conserve the usefulness of insecticides we have available at this time.

Reduced residue and exposure: Codling moth pheromone is highly volatile and not applied directly to the fruit. Thus, implementing a pheromone-based pest management program in apple and pear will help reduce the already low levels of pesticide residues on fruit.

Farm workers are most often exposed to insecticide residues during fruit thinning and harvest activities. Adoption of codling moth mating disruption will reduce the use of summer insecticides and thus the exposure of farm workers. Since the active ingredient of mating disruption products, e.g. codlemone, is enclosed inside a dispenser, any possible exposure only occurs at the time of application.

Worker management: Changing pesticide regulations, including increased reentry intervals, have made farm worker management more difficult. There is no reentry restriction for pheromone treatments. Growers have found that eliminating codling moth cover sprays makes it easier to manage activities of farm workers without having to be concerned about reentry intervals.

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