from developing.

The Future of Apple Disease Control

Growers can prevent resistance by using fungicide mixtures or alternating chemicals. All possible control tactics, including cultural controls, must be used against diseases like apple scab.

USING PHEROMONES FOR MATING DISRUPTION

A pheromone is a chemical messenger produced naturally by an organism and released into the environment. When detected by a second individual of the same species, the pheromone changes the behavior of that second individual. A sex pheromone is used to help one sex (typically the male in insects) orient toward and find the other sex for mating. Sex pheromones can be detected over hundreds of yards on wind currents, and by flying upwind in the pheromone plume, the male can almost always find the female.

Chemists have extracted and analyzed natural pheromones and have created processes to produce these complex chemicals in large quantities. This has given entomologists several new tools to use in pest management. To date, the most successful and widespread use of pheromones has been in monitoring traps. Monitoring traps consist of cardboard or plastic devices that contain a pheromone emitter and a sticky surface. A male moth, fooled into thinking that the emitter is a female releasing a pheromone, flies into the trap and is caught on the sticky surface.

Monitoring traps are placed in the orchard before the beginning of moth emergence. They are checked daily to record the first capture, or biofix, and then at weekly intervals. Each week the trapped insects and debris are removed. Traps and pheromones are replaced as necessary. The biofix can be used to begin accumulating degree days to predict future insect stage distribution. By recording the number of males found each week, a grower may monitor the development of a pest population over time.

Each season the information on moth capture in pheromone traps for codling moth, Oriental fruit moth, leafrollers, and various other insect species in Biglerville is available at the Penn State Fruit Research and Extension Center (FREC) Web site: http://frec.cas.psu.edu/ and published by Penn State Cooperative Extension in the monthly newsletter, Fruit Times (http://fruittimes.cas.psu.edu/Default.html). Degree days based insect development models (eggs hatch models) are also used to track insect development and provide the information to growers so they will know the optimum timing to control the various pests. This information can be combined with scouting information from individual orchards and used in making pest management decisions.

Recently mating disruption, another pheromone-based tool, has emerged as a useful method in insect management. Mating disruption by pheromones takes place when enough artificial sources of pheromone are placed in an area that the probability of a female being found by a male, mating, and laying viable eggs is reduced below the point where economically significant damage occurs. Mating disruption pheromone systems are available for the codling moth, Oriental fruit moth, peachtree borer and lesser peachtree borer as well as for some leafroller species. These are used extensively in the western states and a number of growers are using them in the eastern seaboard.

Large-scale mating disruption implementation trials have yielded significant reductions in pesticide use while keeping crop damage levels acceptably low. Because of difficulties in managing high populations of pests, mating disruption programs should not be viewed as stand-alone strategies, but rather as one tactic within the toolbox of pest management options.

The advantages of pheromone-based pest management systems include the following:

- Negligible health risks to applicator and consumer.
- Virtually no detectable residues for some types of dispensing systems.
- No accumulation in groundwater or wildlife.
- Reduced worker reentry in orchards after application and shorter preharvest intervals.
- Strong tool for managing insecticide resistance to other pesticides and no documented cases of resistance to the pheromone itself.
- Highly selective to the pest species being targeted for disruption without causing secondary pest outbreaks due to the elimination of biological control agents. This selectivity creates opportunities for the biological control of other pest species. Nontarget effects are generally not seen within or outside of the treated orchard.
- Improved control of the targeted pest if overlaid onto the standard insecticide program.

The disadvantages of pheromone-based pest management include the following:

- The high degree of selectivity can also be a disadvantage when other pests are able to move into orchards because insecticide targeted for the primary pest is eliminated and often unrealized collateral control of these other pests is released. For example, in apple, disruption of codling moth often releases leafrollers from pesticide control and in peaches; disruption of the Oriental fruit moth has led to an increase of stinkbug injury for the same reasons.
- High development and production costs that often make these products significantly more expensive than the synthetic pesticides they may be replacing.
- Requirements for specialized application techniques or equipment with some types of pheromone products and possible increases in labor costs.
- The need to supplement expensive pheromone programs in high pest pressure situations with other pesticides for the same target pest.
- Effectiveness is often directly related to the size of the orchards being disrupted, and may be ineffective in orchards fewer than 5 to 10 acres in size. Effectiveness may be reduced along borders with other orchards/crops that are not being disrupted as well.
- Monitoring the target pest in a disrupted orchard can be a problem because the pheromones used to disrupt mating will prevent moths from locating pheromone traps. The use of high dose lures that still attract some moths even under mating disruption is useful for tracking the flights of pests like codling moth and to assess effectiveness. Other moths like Oriental

fruit moth do not exhibit this response to high dose lures and other means for assessing effectiveness are needed.

- Treatment thresholds have been developed using these high dose lures, but in most cases are dependent on levels of injury from previous seasons or on the trap catches of pest generations previous to disruption.

Special considerations are necessary for type of mating disruption product, rate, and application method being used. Borders of disrupted blocks are often at higher risk because of pest mating occurring outside the disrupted area and therefore efficacy increased with the size of the block treated. Peach and apple orchards adjacent to each other benefit from disruption in both crops for pests like the Oriental fruit moth. The residual activities of many of these products vary greatly. Below are some of the type of pheromones and special considerations in use.

Sprayable Pheromones—Microencapsulated pheromones are enclosed in a polymer capsule that controls the pheromone release rate. These capsules are small enough and durable enough to be applied in water through normal airblast sprays in the same manner as conventional pesticides. This makes them very attractive to use by many fruit growers. Residual activity is generally up to 4 to 6, weeks which gives them some flexibility in pest management programs but also means they may need to be reapplied several times in a season for a target pest. Residual activity may be reduced by rainfall soon after application and a sticker type spray adjuvant is often recommended. Currently, the only effective material is for the control of Oriental fruit moth (Check-Mate OFM-F) and peachtree and lesser peachtree borers. Several formulations for codling moth and several species of leafrollers have been tested and even sold commercially, but have not given reliable control.

Hand Applied Dispensers—include systems with an impermeable reservoir fitted with an impermeable membrane for regulating pheromone release. Pheromone impregnated polymer spirals, ropes, dispensers, or tubes (Isomate products) are most commonly used products currently. Wires, clips, or circular twin tubes allow these dispensers to be twist-tied, clipped, or draped directly onto the plant. The larger reservoirs of these products allows for longer residual activity ranging from 60 to 140 days. This may allow early season applications to suppress mating for most or all of the growing season depending on the type of dispenser and pest species. Application rates vary from one to several dispensers per tree (5 to 400 dispensers per acre) and can be labor intensive. Costs for these products tend to be significantly higher than the chemical control programs they are replacing, especially in high pest pressure situations where supplemental insecticides would be needed for acceptable control.

Other Methods—Many other methods of mating disruption are being developed or tested in the eastern fruit regions, but most of them have not been proven commercially yet. These include: pheromone impregnated flakes (Hercon Disrupt OFM) applied aerially or with specialized ground equipment; "attract and kill" methods of applying droplets of pheromone to foliage by hand (Last Call OFM, Last Call CM) that also contain pyrethroids to kill attracted males; and high emission dispensers such aerosol "puffers" or polymer bags loaded with large doses of pheromone. Some of these products may become commercially viable within the next couple of years.

MANAGEMENT OF CODLING MOTH WITH A CM GRANULOVIRUS

Many apple growers in Pennsylvania continue to do battle with the internal fruit feeding pest complex, the codling moth (CM) *Cydia pomonella*, and the Oriental fruit moth (OFM) *Grapholita molesta*. Last year (2006) was the first time since 1998 that CM, rather than OFM, was responsible for the majority of rejected loads of fruit destined for Pennsylvania processors from eastern U.S. growers. Most growers continue to rely on insecticides as their principal control tool for this pest complex, but more and more growers are also adding sex pheromone mating disruption to their management toolbox. Despite the loss of some valuable insecticides due to the Food Quality Protection Act (FQPA) and the development of insecticide resistance to a number of other remaining products, the toolbox for the control of the internal fruit-feeding complex continues to expand each year. Among the many new tools available to control CM is a naturally occurring virus that was identified back in 1964 in Mexico on infected CM larvae. Because of its high selectivity toward this pest, it is called the codling moth granulovirus (CpGV). It does show some activity to a couple of closely related species (e.g., OFM), but it is noninfectious toward beneficial insects, fish, wildlife, livestock, and humans.

Mode of Action—Each CpGV particle is naturally microencapsulated within a protein occlusion body (OB) that protects it to some degree from degradation. These viral OBs are extremely small, 400 by 200 nanonmeters (i.e., 4,000 OBs placed end to end are approximately 1/16 inch). Depending on the product, a single ounce of the aqueous suspension concentrate can contain more than one to three trillion OBs. In order for the virus to be effective, the tiny particles must be ingested by the larva—there is no contact activity with CpGV. It only takes a couple of these OBs to cause death in a young larva. Once the larva ingests the virus, the OBs are dissolved in the alkaline gut of the larva, rapidly releasing the viral particles. The virus rapidly penetrates the gut lining, causing the virus to replicate numerous copies of itself, which then rapidly spread to other organs within the larva. This multiplication causes the larva to stop feeding within a few days, becoming sluggish and discolored as the virus moves throughout the body of the insect. Upon death, the larvae "melts," spreading billions of the viral OBs that can be ingested by other CM larvae. Each OB is capable of causing a new infection within other newly hatched larvae.

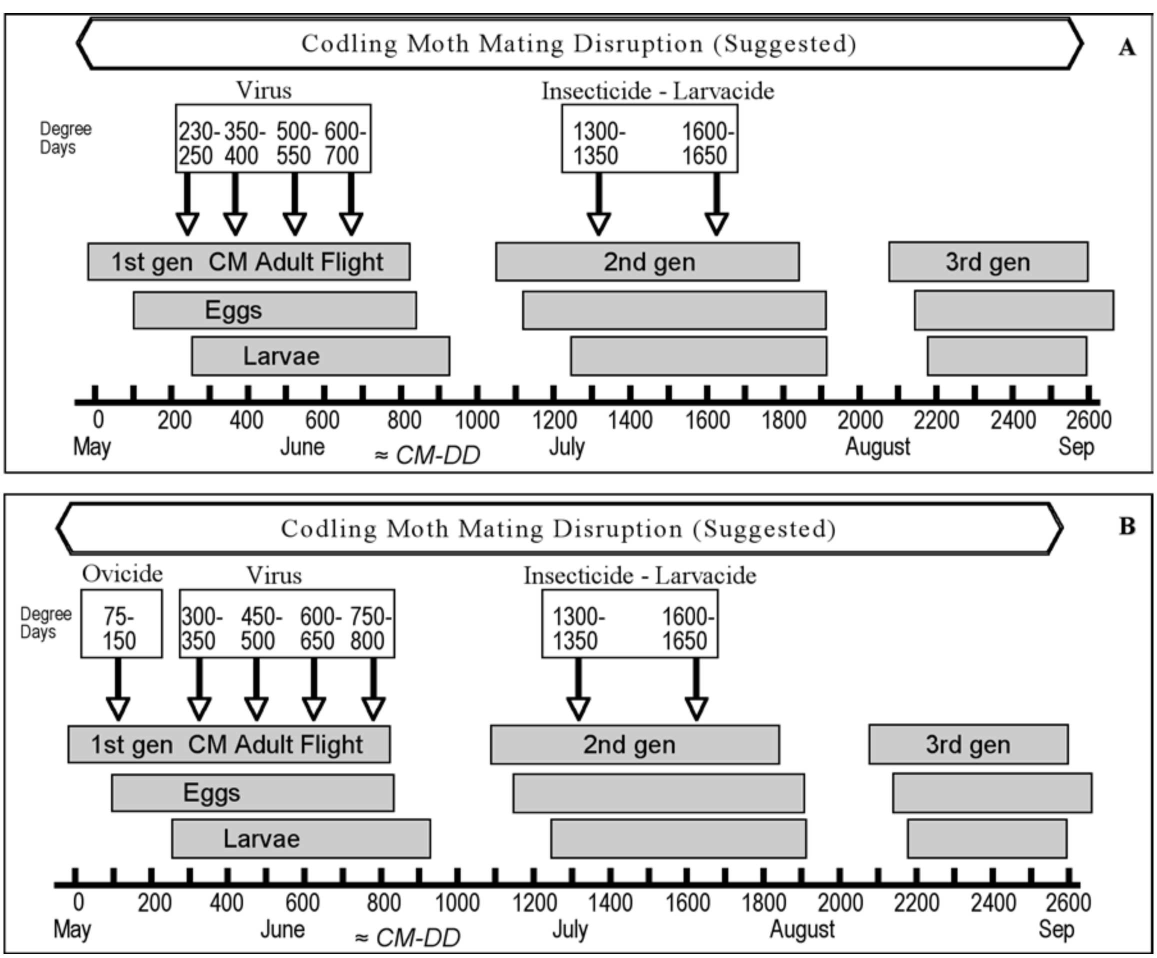
Products—In Pennsylvania, there are two products that are currently available for use by fruit growers, Cyd-X® (Advan LLC, formerly Certis USA) and Carpovirusine® (Arysta LifeSciences, Inc.). The label use rate for Cyd-X is 1 to 6 fluid ounces per acre, and the label rate for Carpovirusine is 6.8 to 13.5 fluid ounces per acre. Both products can be used right up to the day of harvest and they both have a 4-hour reentry window. The products should be refrigerated until use because warm temperatures cause the degradation of the OBs. Also, these products are certified for use in organic orchards.

We have been researching both products at the Fruit Research and Extension Center during the last few years and have achieved much success in substantially reducing CM populations, especially where CpGV was integrated with some form of sex pheromone mating disruption for CM. There are a number of opportunities for using CpGV in a CM management program. Before using a CpGV product there are a number of important points to understand: (1) the virus must be ingested by the larva, thus timing and coverage are extremely critical; (2) the virus breaks down rapidly in an orchard environment due to both UV rays from the sun and rainfall, thus spray intervals should not be stretched for more than 7 to 9 days; and (3) the feeding larva causes some injury to the fruit, commonly referred to as a “sting”—injury less than 1 to 2 mm in depth—before the virus eventually kills the larva.

Timing—Since CpGV is most active against young larvae and these larvae usually penetrate the fruit within 24 hourrs of hatching from the egg, it is very important to have the virus present when egg hatch begins (approximately 230 to 250 degree days [DD] following biofix—first sustained adult capture in a sex pheromone trap). If CpGV is intended as the primary control tactic for CM, then the first application should be timed to coincide with the beginning of egg hatch (Figure 3-2A). Depending on the length of the egg hatch period, normally a total of three to five applications each spaced about 7 to 9 days apart will be necessary to cover this time frame. Recently, in some apple orchards in Pennsylvania, we have observed the egg hatch period for CM to extend over a longer period of time than what is normally predicted by the CM developmental model. Under these conditions, it may be prudent to apply an insecticide with ovicidal activity (e.g., against the eggs, Esteem®, Intrepid®, or Rimon®) at approximately 75 to 150 DD, then start the CpGV applications at about 300 to 350 DD, and repeat the applications every 7 to 9 days or approximately every 125 to 150 DD following this initial application (Figure 3-2B). Since the virus rapidly breaks down in the orchard environment, it is our experience that frequent applications of a lower rate are better than high rates applied at longer spray intervals.

As stated above, the CpGV must replicate itself within the larva in order to be effective, thus allowing the larva to continue to feed for a few days and causing some shallow feeding damage (“stings”) to a fruit. If growers are trying to decide when to use a CpGV product, they may want to restrict their use of a CpGV product to the first generation. If stings or even some deep entries do occur in the small fruits during June from the first-generation larvae, these fruit often fall from the tree or can be thinned off.

Figure 3-2. Various scenarios for applying a CpGV product for codling moth control. (A) timing when using a CpGV product and CM mating disruption. (B) timing of CpGV applications when using an ovicidal insecticide to begin control of first-brood CM, followed by a CpGV product.



In addition, at this time of the season, the fruit on the tree are still small and canopy volume is still not complete, thus allowing more thorough coverage of the fruit.

CpGV products are compatible with most fungicides and insecticides sprayed on apples. However, since CpGV is sensitive to high alkaline conditions, it should not be mixed with copper fungicides or lime sulfur. In addition, it is recommended to use a buffer to neutralize the spray mix if the pH is above 9 or below 5. Also, Dr. Larry Gut, entomologist at Michigan State University, has cautioned Michigan growers to avoid tank mixing CpGV with the neo-nicotinoid insecticides, Assail® and Calypso®, since these compounds have some anti-feeding activity which may interfere with the larva ingesting the virus.

Since UV light can rapidly break down the virus particles, it is also recommended that growers avoid applying the virus during periods of intense sunlight conditions. Also, if rain is forecast in the immediate future, try to wait until after the rain period to make the application.

Many growers in Pennsylvania commonly make their pesticide applications using the alternate row middle (ARM) method of spraying. We have used CpGV successfully with ARM sprays, but the studies have always been conducted with sex pheromone mating disruption for CM as a basic component of the program. Thus, here are recommendations for applying CpGV using the ARM approach:

- Since the virus must be consumed, thorough coverage is critical. Thus, ARM sprays must provide some coverage on the unsprayed side of the trees.
- Depending on the size of the tree, water volumes of at least 50 (trees 6 to 10 feet in height) to 100 GPA (trees larger than 10 feet in height) should be used.
- Dependent on pest pressure and weather conditions, ARM intervals should not stretch beyond 5 to 7 days between sprays.
- This method of applying CpGV should only be used in conjunction with some form of CM mating disruption.

Recommended Use Options for CpGV Products within Pennsylvania Apple Orchards

- Make the first application at the beginning of egg hatch (i.e., approximately 230 to 250 DD after biofix) (Figure 3-2A).

~OR~

- Use an ovicidal insecticide at approximately 75 to 150 DD, then begin virus applications at roughly 300 to 350 DD (Figure 3-2B).

~AND~

- Repeat applications every 7 or 9 days or roughly every 125 to 150 DD.
- Use a higher rate of CpGV for the first application.
- Repeat applications at lower rates for subsequent applications.
- Apply three to five applications for the first brood depending on the length of the adult flight and egg hatch period.
- Use primarily for first-brood CM control.
- For more effective control, combine with CM mating disruption, especially where CM populations are high and/or fruit injury from CM was present last season.

NEMATODE MANAGEMENT STRATEGIES

Nematode problems in orchards are difficult to control and therefore good nematode management should focus on preventive measures. In general, nematode control is accomplished with either nematicides or cultural practices. The benefits of each strategy are outlined below.

Benefits of Nematicides and Soil Fumigants

Treating orchard soil before planting trees will reduce replant problems, control parasitic nematodes, and reduce the incidence of soilborne virus diseases, such as stem pitting in stone fruit and union necrosis in apple. Broad-spectrum fumigants may be used for all three purposes and are effective against most replant disorders. Fumigant and contact-type nematicides effectively control nematodes, including species which transmit soilborne viruses. See Table 4-4 for specific recommendations.

Decisions regarding chemical control options should be based on the history of the site and the results of a nematode diagnostic test. Options include treating the entire site (broadcast treatment), treating strips along the proposed tree rows, or treating only individual trees. Broadcast treatments effectively limit contamination and reinvasion by nematodes from untreated areas. If parasitic-nematodes are the only problem, a strip fumigation may be sufficient. Postplant treatment with nonfumigant-type materials may be desirable in areas that have received a preplant treatment with a fumigant-type material.

Soil fumigants should be applied during the late summer or fall and trees planted the following spring. Spring application is an option but raises the risk of phytotoxicity. Poor decomposition of root debris and previous cover crops will reduce the effectiveness of the fumigant. Adequate soil aeration is essential. Nonfumigant nematicides work well if applied in the spring when soil moisture and rainfall are plentiful. Fall application is an option if conditions are good.

Management of soilborne virus diseases in tree fruits requires control of the nematode vectors and the weeds which serve as virus reservoirs. Careful attention should be given to eliminating such weeds from tree rows as well as the groundcover in row middles. Consult Table 4-2 for recommended herbicides

Dagger Nematode Control with Green Manure

In recent years some fumigants have been identified as a threat to public health, and causes of groundwater contamination or ozone depletion. Many fumigants have been banned for environmental protection or withdrawn from the market due to the cost of meeting new regulations. Products that remain on the market have become increasingly expensive; thus, there is a need to develop safe and environmentally sound alternatives.

Over the past few years, we have evaluated a variety of novel rotation and green manure crops for the treatment of replant sites. This work showed that some plants can naturally reduce populations of plant-parasitic nematodes and improve soil structure. Based on these results we recommend the use of selected rapeseed