A4172

FIGURE 1. **Adult codling moth.**

Codling Moth

Management options for commercial and backyard growers

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Codling moth, *Cydia pomonella* L. (Lepidoptera: Tortricidae; figure 1), is a well-established insect pest of apple, pear, and walnut crops in Wisconsin and across the United States. According to Slingerland (1898), codling moth was a well-known pest of pome fruit in New England (USA) as early as 1750. This insect was probably introduced from Europe in packages containing infested apples and pears.

The primary damage caused by codling moth is due to larval feeding inside apples, which makes the fruit unmarketable. If left uncontrolled, this insect has the potential to cause severe economic loss. In addition, this pest has developed resistance to a number of commonly used insecticides. Thus, pome fruit growers should monitor for codling moth and watch for signs of developing pesticide resistance.

Key terms

biofix—A biological event, an indicator of a developmental event, or a calendar date that is used to initiate the calculation of degree days.

degree day—A way of incorporating both temperature and time into one measurement to quantify the rate of plant or insect development. In general, plants and insects develop in response to temperature. The warmer the weather, the more quickly they develop, and the cooler the temperature, the slower they develop.

Damage symptoms

Codling moths primarily affect apples and pears, although occasionally they have been found feeding on other crops such as quince and walnuts. Damage symptoms vary depending on whether the larva was able to develop inside the fruit. In some cases, larvae attack a fruit unsuccessfully. In these cases, damage is characterized as small "sting" marks on the fruit, with no surrounding damage, softness, or necrosis. While stings do not cause a breakdown of fruit tissue, these fruits have decreased value due to external blemishing (figure 2).

Larvae that successfully enter the fruit to feed and develop inside are associated with fruit breakdown. As opposed to other apple-tunneling worms, codling moth larvae feed in the core of the fruit on both flesh and seeds. The entrance of the tunnel, which can be anywhere on the fruit but is most often on the calyx end of an apple, will have sawdust-like debris or excrement known as frass extruding from it. Fruit with codling moth tunnels have extensive internal damage and are unmarketable (figure 3).

FIGURE 2. **Codling moth stings.**

FIGURE 3. **Codling moth damage to apple, showing both stings and tunnels.**

Identification and life cycle

Codling moths overwinter as last-instar larvae in a sheltered location, such as leaf litter or loose tree bark. Larvae pupate in their overwintering location in early May as the buds are beginning to open (referred to as first pink). The first-generation adult moth flight begins in mid-May when the fruit trees are in full bloom. Adults are light- to dark-grey, and approximately ½ inch long. Wings tend to be darker near the base and have coppery tips. Moths fly for about eight weeks, during which time each female lays up to 100 individual eggs on or near developing fruit.

After about a week, eggs hatch into tiny cream-colored caterpillars, which feed on the surface for a short time. As they bore into the fruit, the larvae turn pale pink with brown heads, and move to the middle of the fruit feeding on the flesh and seeds for three to four weeks (figure 4).

FIGURE 4. Codling moth larva.

Mature caterpillars can reach up to ⅝ inch in length. At this stage they exit the fruit, drop to the ground, and spin cocoons.

Codling moths have two or three generations per year. Regardless of environmental conditions, in any given year there is a group of moths that have only one generation, a group that goes on to a second, and a group that has a third generation. The second adult flight lasts from approximately mid-July to late August, and the third flight begins in mid-August. The offspring of third generation adults do not survive the winter, but may cause some late-season fruit damage.

Degree days

Codling moth development is greatly influenced by temperature; these insects will develop more quickly in a warm year and more slowly when temperatures are cooler. For this reason, calendar dates provide only a rough estimate of their life cycle. A more accurate estimate of the timing of codling moth development can be made using **degree days** (DDs), which tally a running total of heat units, calculated based on the daily high and low temperature. These calculations also account for differences in the temperatures each insect experiences during its development. For more information on DD models, see the UW-Extension publication, *Degree Day Calculation*, available online at **https://pddc.wisc.edu/wp-content/blogs.dir/39/files/Fact_Sheets/FC_PDF/Degree_Day_Calculation.pdf**. Degree days can be calculated using regional weather station data, or pre-calculated degree day accumulations can be found using the NEWA website (available at **http://newa.cornell.edu/index.php?page=apple-insects**).

Once calculated, the accumulated annual DDs can be compared to important developmental thresholds for each species. For codling moth, the **biofix** (the day to begin accumulating DDs) is set when more than one moth is caught in a trap on two consecutive nights (referred to as **sustained trap catches**). Therefore, the first flight, by definition, begins at 0 DDs. Thresholds for codling moth development are listed in table 1 and shown in figure 5.

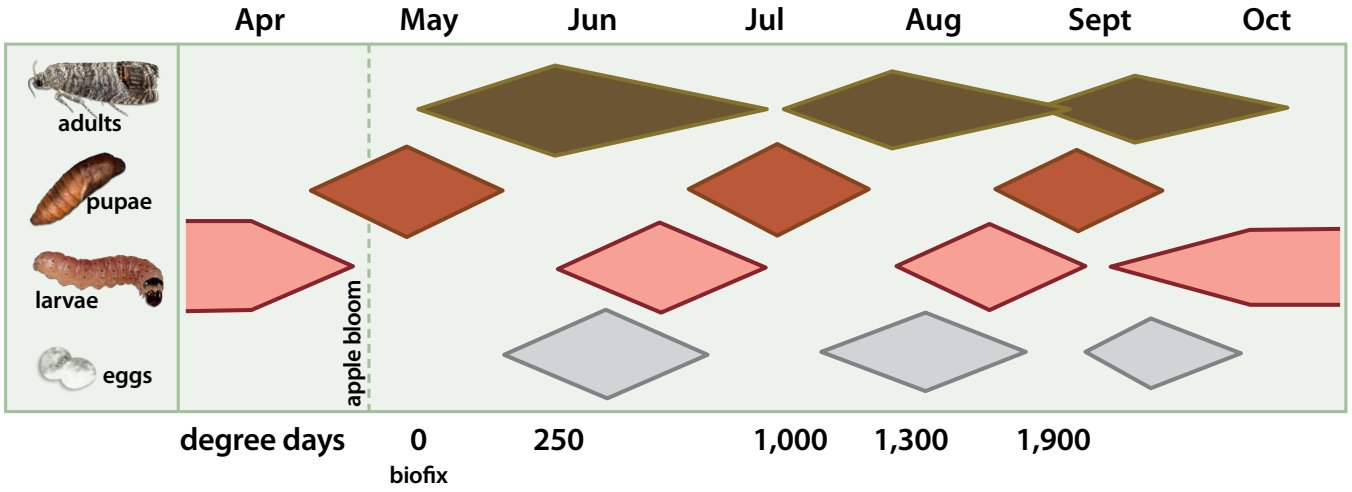

FIGURE 5. Graphical depiction of the codling moth life cycle with degree day accumulation based on calculation information in table 1.

Monitoring

Monitoring in non-mating disruption orchards provides an estimate of the date when adult moths first emerge in the spring, allows for the calculation of degree days, and informs the timing for insecticide applications. Monitoring for codling moth adults should begin in mid-May, using a sticky trap with a female sex-pheromone lure (figure 6). Set out monitoring traps within the tree canopy (6 to 9 feet high in full-size trees, or around head height in high density plantings). Place one trap for approximately every five acres baited with a 1-mg strength, commercially available pheromone lure.

These traps should be checked daily from bloom until first trap catch, and every 1 to 2 weeks from first trap catch until harvest. When checking traps, it is important to carefully inspect the moths found in the trap, as the trap may attract other closely related and similar-looking species, such as the maple twig borer (figure 7).

FIGURE 6. Commercially available Delta trap with pheromone lure (lure not visible).

FIGURE 7. Maple twig borer adult moth (a codling moth look-alike commonly found in monitoring traps).

TABLE 1. Equation for calculating codling moth degree days and relevant developmental thresholds.

$$\text{Daily DD accumulation} = \frac{\text{daily high} + \text{daily low}}{2} - 50$$

Exceptions

- If the high is warmer than 88°F, use 88.
- If the low is cooler than 50°F, use 50.

first generation	**flight begins**	**0 DD**
	larvae begin hatching	**250 DD**
second generation	**flight begins**	**1,100 DD**
	larvae begin hatching	**1,300 DD**
	90% moths emerged	**1,700 DD**
third generation	**flight begins**	**1,900 DD**

Management options

Mating disruption

Mating disruption is a very common practice for controlling codling moth, because it is a highly efficient, cost effective, and reduced-risk management option. The concept behind mating disruption is to permeate the orchard with the codling moth female sex pheromone, preventing male moths from locating female moths.

Mating disruption is an appealing option because it:

1. can be used by organic growers as it is certified organic,
2. leaves no residue on the fruit,
3. is safe for non-target organisms,
4. is effective all season long, rain or shine, and
5. effectively prevents or delays mating, resulting in decreased populations.

Even if the male moth is able to find a female and mate, if mating is delayed by just three days, the female will lay half as many viable eggs, drastically reducing infestations in the future. For more information on mating disruption, see *Utilizing Insects' Sense of Smell for Pest Management* (Deutsch and Guedot 2017, A4135, **https://learningstore.uwex.edu/Assets/pdfs/A4135.pdf**).

However, mating disruption is not as effective as other options in certain situations. This technique is best used in orchards that are larger than 10 acres, in a regularly shaped square block, and in areas with relatively low codling moth densities. Once codling moth numbers get too high in an orchard, it is likely that the males will "accidentally" run into the females, so mating disruption becomes less effective. However, by using both mating disruption and chemical sprays for a year or two, populations can usually be brought down to low enough numbers so that mating disruption can work without augmentation from insecticides.

The most commonly used dispensers for mating disruption are hand-applied twist-tie dispensers (figure 8a). Depending on the product, dispensers should be applied at a rate of 150 to 400 per acre. Some hand-applied dispensers need to be twisted on to the tree, while others easily clip onto the branches or are shot into the canopy. Dispensers should be placed in the top third of a tree, and distributed evenly throughout the orchard block, or placed slightly more densely at the edges of the orchard. These dispensers are effective throughout the duration of the growing season and should be in place before the expected beginning of moth flight (see **Identification and life cycle**).

Puffers are another type of pheromone dispenser (figure 8b). Applied at a rate of just 1 to 2 puffers per acre, puffers release the codling moth pheromone every 10 to 15 minutes. Puffers should be evenly spaced throughout the orchard, with more near the edges. Special attention needs to be paid to prevailing winds when setting up puffers, so that the pheromone gets distributed inside the block rather than to the surrounding areas. The canister on the puffer contains enough product for a single growing season and should be set out before the expected beginning of moth flight. Although puffers require more up-front costs, they can be refilled and require low labor costs because so few are set out per acre.

When using mating disruption, sex pheromone-baited monitoring traps are used to check whether the males are unable to find the lure, which would indicate that they are unable to find the actual females. For orchards using mating disruption, it is recommended to use one to two traps per acre (1 to 2 traps/acre). Lures should be loaded with at least 5 to 10 mg of the pheromone or the Codling moth Combo (CM DAC) lure, and place the sticky traps higher in the canopy than you would for normal monitoring. If over 10 codling moth adults are caught in the traps during the first adult flight, mating disruption is not adequately effective, and additional management techniques are necessary.

Cultural control

Orchard sanitation is an important management component to minimize codling moth populations. Removing and properly disposing of fallen apples from the orchard can help control codling moth, as well as other apple pests such as apple maggot and plum curculio. Tree trunks can also be banded with corrugated cardboard, which provides a protected place for the larvae to pupate inside the cardboard (figure 9). Following pupation, during the winter, the cardboard can be removed and burned with the pupae inside. Banding is most effective on young trees with smooth bark. In general, cultural controls complement, instead of replace, the use of mating disruption or an insecticide, especially in orchards with significant codling moth pressure.

Biological control

The codling moth granulosis virus can be an effective method of control (figure 10). If ingested by a codling moth caterpillar, the virus replicates itself inside the caterpillar's cells, leading to discoloration, swelling and eventual death. The virus is available commercially with several brand names including Carpovirusine, Cyd-X, Cyd-X HP, and Madex HP. Some advantages over other management techniques are that it is very host-specific, minimally impacts the environment, can be applied using conventional spray equipment, and is approved for use in organic production. The virus takes some time after digestion before killing the caterpillar, so sting damage is often seen in orchards treated only with the virus. Generally, it is necessary to spray every 10 to 14 days to maintain adequate control. Read the label for specifics regarding application rates, the number of applications allowed per year, and reentry and preharvest intervals.

Chemical control

Codling moth insecticides are available to target the eggs (ovicides), larvae (larvicides), or adults (adulticides). Larvicides are the most frequently used insecticides against codling moth, because this developmental stage is the most susceptible to chemical management. However, spray application timing needs to be precise, since there is only a short period of susceptibility after egg hatch before the larvae buries itself inside the fruit (generally around mid-May, and again

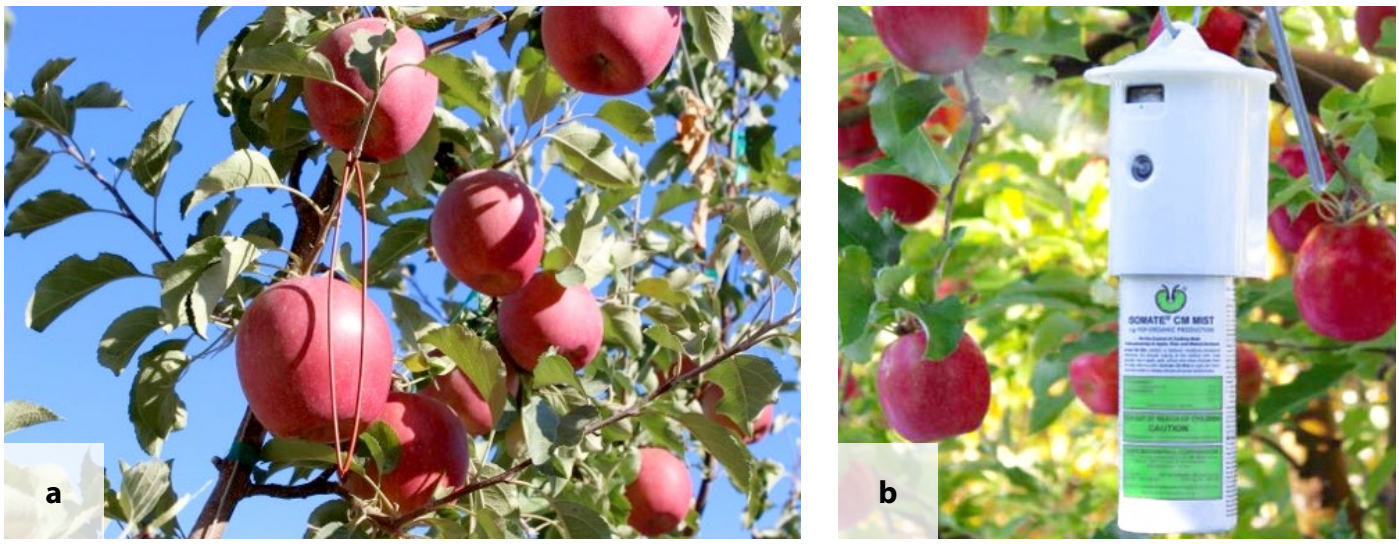

FIGURE 8. Commercially available dispensers for mating disruption pheromones include hand-applied twist-ties (a) and puffers (b).

FIGURE 9. A band of corrugated cardboard placed around the trunk of a tree can attract pupating codling moth larvae, where they can be removed and destroyed.

in late July for the second generation). It is also important to note that the larvae may continue to cause superficial damage to the fruit for several days before death. Ovicides provide the most immediate control, by preventing the caterpillars from being able to hatch in the first place. However, eggs are often protected in bark crevices. Adulticides are rarely used on codling moth, because the adult stage is very mobile and it is likely that other moths will fly in and continue to lay eggs in an orchard following an adulticide application.

The effectiveness of an insecticide can be greatly increased by monitoring and using a DD model to improve spray timing. (See the **Monitoring** section for a description of how to monitor and set the biofix. A description of how to calculate degree days is provided in the **Identification and life cycle** section.) First sustained trap catch, which is used as the biofix, represents the point at which moth flight begins, and therefore when egg laying begins. Approximately 250 to 300 degree days after this biofix, the majority of the larvae will have hatched, but will not yet be inside the fruit. This is the optimal time to spray a larvicide. At approximately 1,250 DD, the second generation larvae will hatch, which is the optimal timing to spray a larvicide targeting the second generation. Depending on the product used, two or three total sprays may be required during each generation's egg hatch period. If using an ovicide (e.g., methoxyfenozide), spray at about 150 DDs

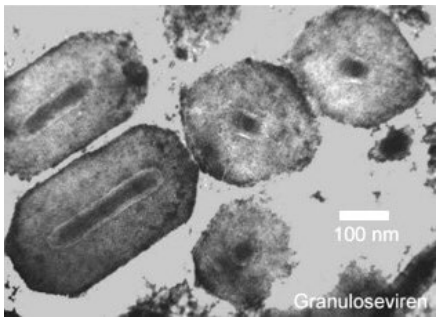

FIGURE 10. Codling moth granulosis virus.

to correspond with when the majority of first generation codling moths are in the egg stage.

Effective insecticide classes for codling moth control include: diamides, spinosyns, insect growth regulators, neonicotinoids, pyrethroids, and organophosphates for conventional production, and Spinosad and Kaolin clay for organic production. Care should be used when applying insecticides, and in particular broad spectrum insecticides, such as pyrethroids, as they have negative impacts on many beneficial predators of apple pests, and may cause secondary pest outbreaks. See the most recent *Midwest Fruit Pest Management Guide* (**https://ag.purdue.edu/hla/Hort/Pages/sfg_sprayguide.aspx**) for current chemical control recommendations, which vary by year, by state, and by crop. As always, be sure to read the label before using any pesticide.

The choice of which insecticide to use should consider the preharvest interval and reentry restrictions, other pests present, and the potential effects on beneficial insects and the environment. Make sure to rotate chemical classes (including codling moth granulosis virus) to delay resistance development. Avoid spraying insecticides during bloom or when bees are active. If you need to apply an insecticide at petal fall when bees are still present, it is recommended to spray products with the lowest toxicity to bees (refer to environmental hazards and bee advisory information on insecticide labels) and in the evening when bees are not actively foraging.

Information for backyard gardeners

Apples grown in the home gardens are often seriously affected by codling moth. Control can be difficult because mating disruption is not effective on such a small scale, and many home growers prefer to avoid insecticides. These fruit trees often harbor large codling moth populations and can negatively impact commercial orchards up to three miles away. Homeowners should consider implementing cultural controls, such as bagging fruit (figure 11) and sanitation, to avoid creating codling moth refuges.

One option for controlling codling moth in small blocks or single trees is using tree bands to trap larvae looking for pupation sites (see **Cultural control**). Sanitation and other cultural control methods may be effective on a small orchard or backyard scale, when trees are far from other sources of codling moths. Immediately removing any fallen fruit will help prevent most caterpillars from pupating, as many of the damaged fruits will prematurely abort and fall before the moth can complete development. Fruit that does not fall will have frass-filled entry holes, and any fruit with these symptoms should be removed and destroyed.

If there is a source of codling moths nearby, adults will appear each spring to re-infest your crop. In this case, bagging fruit can also be effective to prevent adults from ovipositing on the flowers or caterpillars from accessing the developing fruit. Secure the bag tightly around the branch, and leave in place until shortly before harvest. Cutting a small slit into plastic and paper bags will help prevent moisture from building up inside the bag and subsequently rotting the fruit. Do not bag when flowers are open, so bees can reach the flowers. However, bag soon after petal fall, using a plastic, paper, or small-mesh net bag.

An insect control method that is approved for use in organic production and is effective against codling moth is kaolin clay, which is sold under the trade name Surround. This clay substance covers the apple with a white paste, and deters caterpillars from finding or entering the apple to feed. Kaolin clay is also effective in reducing damage from other apple insects, such as plum curculio and apple maggot. However, to be effective, kaolin clay must cover the entire fruit, and will need to be reapplied immediately after a rain event and as the fruit grows.

FIGURE 11. Bagging apple fruit during development is a time-intensive technique that prevents pests from infesting the fruit.

Many, but not all, commercially available codling moth insecticides are also registered for use in home orchards. When using insecticides, always read the label prior to use and never spray insecticides during bloom or when bees are flying. For more information about insecticide choice and application, consult the **Chemical control** section.

References

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