Section 3

Using OP Replacements

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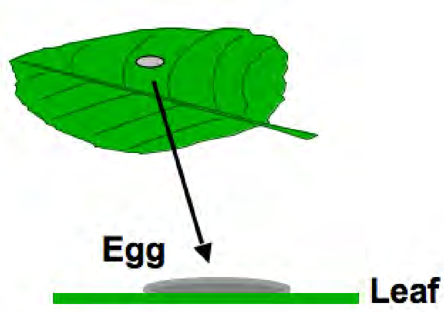
Ovicides ~ Egg Killers

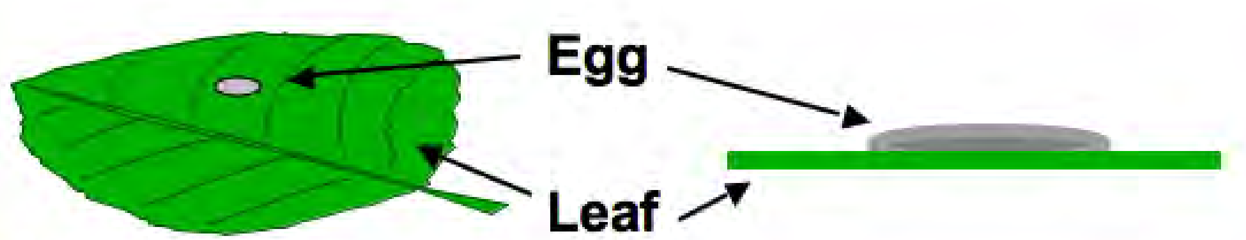
Ovicides ~ How do they work?



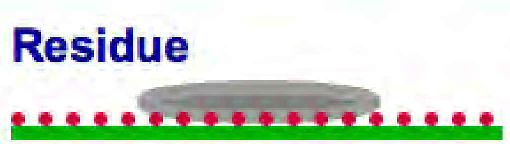
Codling moth eggs are laid on the upper surfaces of leaves near fruiting clusters and on fruit.

There are two ways to affect eggs prior to hatch:

1. Apply the product **before eggs are laid** (*residually*) OR
2. Apply the product **over the top of the egg** (*topically*)



Oil works as an ovicide when applied over the top of the egg.*



Esteem, *Intrepid*, *Rimon*, and *Altacor* work as ovicides when the egg is laid on top of a residue.

*Assail and Calypso are used as larvicides, but also act as topical ovicides. The ovicidal activity improves the overall level of control that is achieved.

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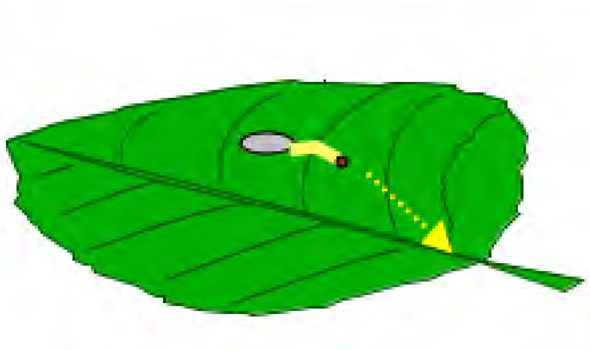
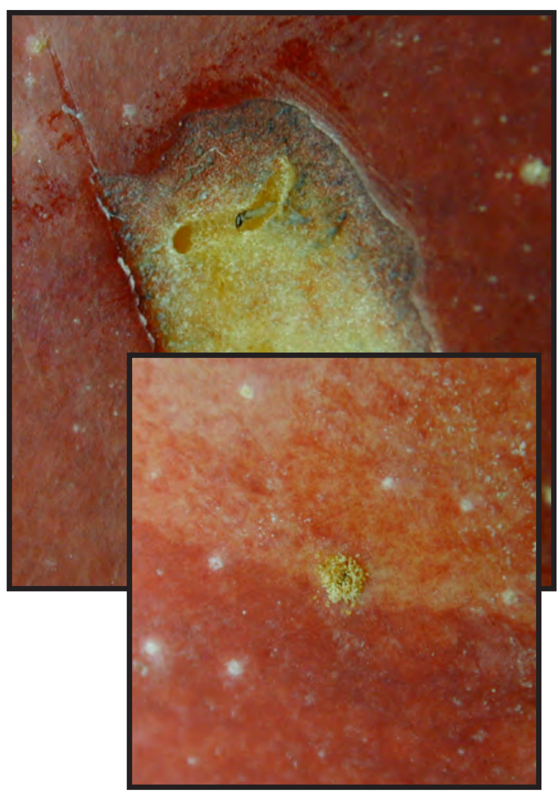
Larvicides ~ Larval Killers

Larvicides ~ How do they work?



Newly hatched larva enters fruit within 2-3 hours.

Traditional larvicides kill larvae as they crawl across residues or when they eat residues as they bore into the apple. (*Guthion, Imidan*)



Most new insecticides that act against larvae must be consumed to be effective. (*Assail, Calypso, Intrepid, Virus, Altacor, Delegate*)

Coverage is very important with new insecticides

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Targets and Treatments – Degree Day Models

Changes to Codling Moth Degree Day Model

What is biofix and how does DAS implement it?

Biofix is an easy to observe event (example: first moth capture) that was previously used to synchronize the model and field populations. None of the current models on DAS require a biofix within the state of Washington. We make no guarantees outside Washington State for any of the models.

The codling moth model is the model most people think of when they think of biofix. We had 32 orchard years worth of data taken at the WSU research centers in Wenatchee and Columbia View and compared this to 81 orchard-years worth of data from consultants from throughout the state. We found that if we compensated for the roughly weekly trap checking intervals used by consultants, that biofix occurred on average at 175 DD (°F) from 1 January for both data sets. We then compared model predictions to observed adult flight and egg hatch and found that there were no benefits in terms of accuracy using a biofix. Our codling moth model therefore automatically sets a biofix at 175 DD from 1 January. In the past, we would reset the model DD to 0, then accumulate the heat units from that point. However, this is counter-intuitive and confusing; for example 160 DD will occur twice during the same season and likely within 40 days of each other. Instead of using the old convention of resetting the biofix, we are now simply accumulating degree-days since 1 January. However, for people used to the old system, we will also report in parenthesis, the older number. For example, the start of egg hatch is at 425 DD from 1 January (250 DD old model).

The codling moth model used in Washington is probably fine in areas more northerly than Washington State, but definitely should not be used in more southern areas. We are collecting biofix timing information throughout North America and preliminary results show that the timing of first moth is related to temperature and solar radiation, but above 46°N latitude it levels off at roughly 175 DD. After further work, we will build the corrections into DAS to account for first moth in areas outside the state.

What are degree-days and why are they used in the models?

Degree-days (DD) are used in models because they allow a simple way of predicting development of cold-blooded organisms (insects, mites, bacteria, fungi, plants). The idea is that the development of cold-blooded organisms depends on the temperatures that they experience in the environment, because they cannot regulate their temperature to any significant degree. It has been shown that the biochemical processes involved in development through a particular stage (such as the egg or larval stages) require a given amount of time and that the amount

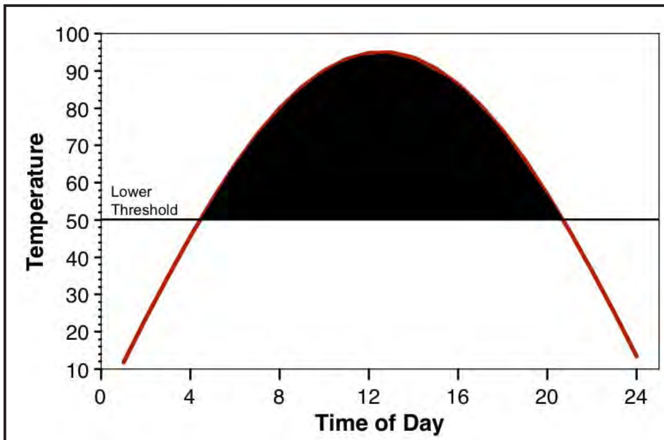

Fig. 1. The amount of heat accumulated (black area) using a lower threshold of 50˚F and no upper threshold using a single sine approximation from daily maximum and minimum temperatures.

of time varies depending on the temperature the organism experiences. Work in the early 1920's showed that there was a temperature below which development did not occur (= lower threshold for development) and above a certain temperature development rapidly slowed (= upper threshold for development). In between the lower and the upper thresholds, the developmental rate was a straight-line function of the temperature. This meant that development could be predicted by knowing how long the organism was held at any temperature between the thresholds. Another way of saying this is that the amount of heat units required to complete development was constant – a finding that is the basis for the models used on DAS.

Formally, the heat units are termed degree-days (DD) and by definition a DD is the amount of heat that accumulates when the temperature is 1° above the lower threshold for development for a period of 24 hours. Each organism has a different lower threshold for development, which makes comparisons sometimes more difficult. For the insects on the DAS system, each of them have a slightly different upper and lower thresholds for development.

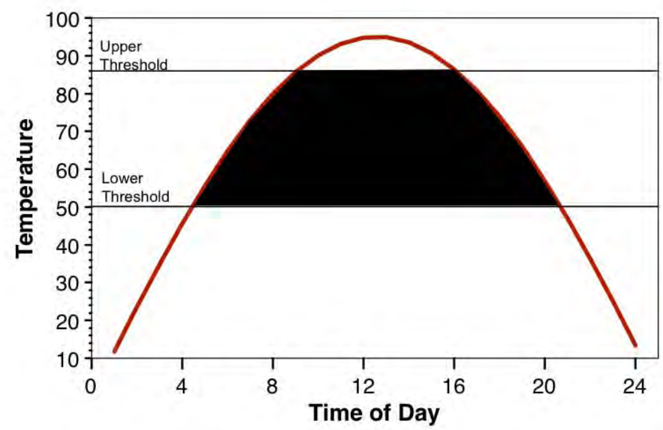

Fig. 2. The amount of heat accumulated (black area) using a lower threshold of 50°F and an 88°F upper threshold with a horizontal cutoff using a single sine approximation from daily maximum and minimum temperatures.

For most of the models on DAS, we use a single sine wave fit to the daily maximum and minimum temperatures to determine the DD accumulations. There are three ways commonly used to modify the sine wave. The simplest form uses no upper threshold for development and this is used for western cherry fruit fly and apple maggot. In this case the heat units are calculated by the computer as simply the entire area under the temperature curve (Fig. 1). For a codling moth, peach twig borer, and Lacanobia fruit worm, we use a horizontal cutoff, which eliminates the heat accumulations that occur above the threshold (Fig. 2). In effect, this approximation suggests that the development rate is constant above the upper threshold. While this doesn't seem logical given the discussion above, it works in practice pretty well. The other type of cutoff is a vertical cutoff, where no heat units are accumulated once the temperature goes above the threshold (Fig. 3). This type of cutoff is used for Pandemis leafroller, Obliquebanded leafroller, Campylomma bug, and San Jose Scale.

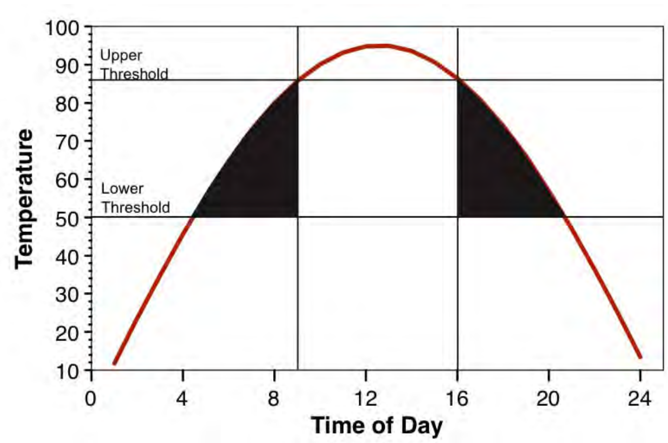

Fig. 3. The amount of heat accumulated (black area) using a lower threshold of 50°F and an 88°F upper threshold with a vertical cutoff using a single sine approximation from daily maximum and minimum temperatures.

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Targets and Treatments

Delayed Dormant

- **San Jose Scale** (SJS) and **Mite eggs** are controlled by horticultural mineral oil applied at delayed dormant.

- In the past, Lorsban has been used to control **Leafroller** (LR) at delayed dormant, but there are now many good options to use for leafroller control at petal fall.

- **Woolly apple aphid** (WAA) is a pest of increasing importance in OP transition scenarios. Lorsban, applied pre-bloom, can suppress WAA colonies. Diazinon has also been used to manage WAA when populations exceed tolerances. New insecticides for control of WAA are lacking, but there may be options in the future.

SJS, LR mite (egg)	LR (larva) LR&CM (egg)	CM (egg)	CM (larva)	CM (larva)	CM (larva)	CM (larva)
Delayed dormant	Petal fall 225-275DD (50-100DD)	375DD (200DD)	1st cover 425DD (250DD)	Delayed 1st cover 525DD (350DD)	2nd Cover 625-675DD (450-500DD)	3rd Cover 875-925DD (700-750DD)
Oil Lorsban						

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Targets and Treatments

Petal Fall Control - Leafroller Larvae and Codling Moth Eggs

- Proclaim and Success (Delegate) provide fast acting control of leafroller, and are good control options if leafroller populations are high enough to justify concern about damage from feeding larvae, but they do not provide control of codling moth eggs.
- Belt and Bt are slower acting but effective against leafroller. Neither provide control of codling moth eggs.
- Altacor, Intrepid, Rimon, and Esteem are slow acting but effective against leafroller and add value because they provide control of codling moth eggs that are laid on top of residues.

SJS, LR mite (egg)	LR (larva) LR&CM (egg)	CM (egg)	CM (larva)	CM (larva)	CM (larva)	CM (larva)
Delayed dormant	**Petal fall 225-275DD** (50-100DD)	**375DD** (200DD)	**1st cover 425DD** (250DD)	**Delayed 1st cover 525DD** (350DD)	**2nd Cover 625-675DD** (450-500DD)	**3rd Cover 875-925DD** (700-750DD)
Oil Lorsban	Proclaim Success Delegate Belt Bt Altacor Intrepid Rimon Esteem					

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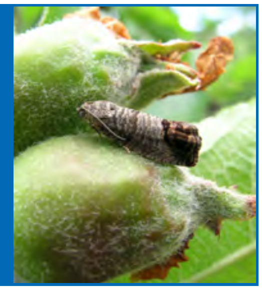
Targets and Treatments



First Generation Codling Moth Larvae

- If Proclaim, Success (Delegate), Belt, or Bt are used for leafroller control at petal fall and no other ovicides are used, control of codling moth larvae will need to be initiated at 425DD (250 DD).
- Additional larvicide applications will need to be applied based on the length of expected residual control of the product used.
- Under high pressure, codling moth larvicide programs that begin at 425DD (250 DD) may require three applications to control the first generation.

SJS, LR mite (egg)	LR (larva) LR&CM (egg)	CM (egg)	CM (larva)	CM (larva)	CM (larva)	CM (larva)
Delayed dormant	Petal fall 225-275DD (50-100DD)	375DD (200DD)	1st cover 425DD (250DD)	Delayed 1st cover 525DD (350DD)	2nd Cover 625-675DD (450-500DD)	3rd Cover 875-925DD (700-750DD)
Oil Lorsban	Proclaim Success Delegate Belt Bt	→	Delegate (Entrust) Altacor Assail Calypso Intrepid virus	→	Delegate (Entrust) Altacor Assail Calypso Intrepid virus	Delegate (Entrust) Altacor Assail Calypso Intrepid virus
	Altacor Intrepid Rimon Esteem					

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Targets and Treatments

Using Oil as an Ovicide to Delay First Larvicide Applications

- If Proclaim, Success (Delegate), Belt, or Bt are used for leafroller control at petal fall, it is still possible to control codling moth eggs before egg-hatch begins by applying horticultural mineral oil at 375DD (200 DD) at a rate of at least 1% v:v.
- Oil is a topical ovicide (kills eggs that are covered by the application) and its use at 375DD (200 DD) allows a delay of the first larvicide application until 525DD (350DD).
- Additional larvicide applications will need to be applied based on the length of expected residual control of the product used.

SJS, LR mite (egg)	LR (larva) LR&CM (egg)	CM (egg)	CM (larva)	CM (larva)	CM (larva)	CM (larva)
Delayed dormant	Petal fall 225-275DD (50-100DD)	375DD (200DD)	1st cover 425DD (250DD)	Delayed 1st cover 525DD (350DD)	2nd Cover 625-675DD (450-500DD)	3rd Cover 875-925DD (700-750DD)
Oil Lorsban	Proclaim Success Delegate Belt Bt →	Oil	→	Delegate (Entrust) Altacor Assail Calypso Intrepid virus	→	Delegate (Entrust) Altacor Assail Calypso Intrepid virus
	Altacor Intrepid Rimon Esteem					

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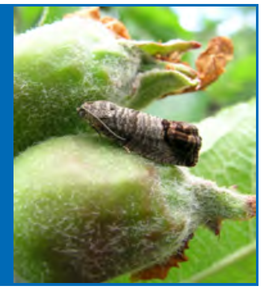
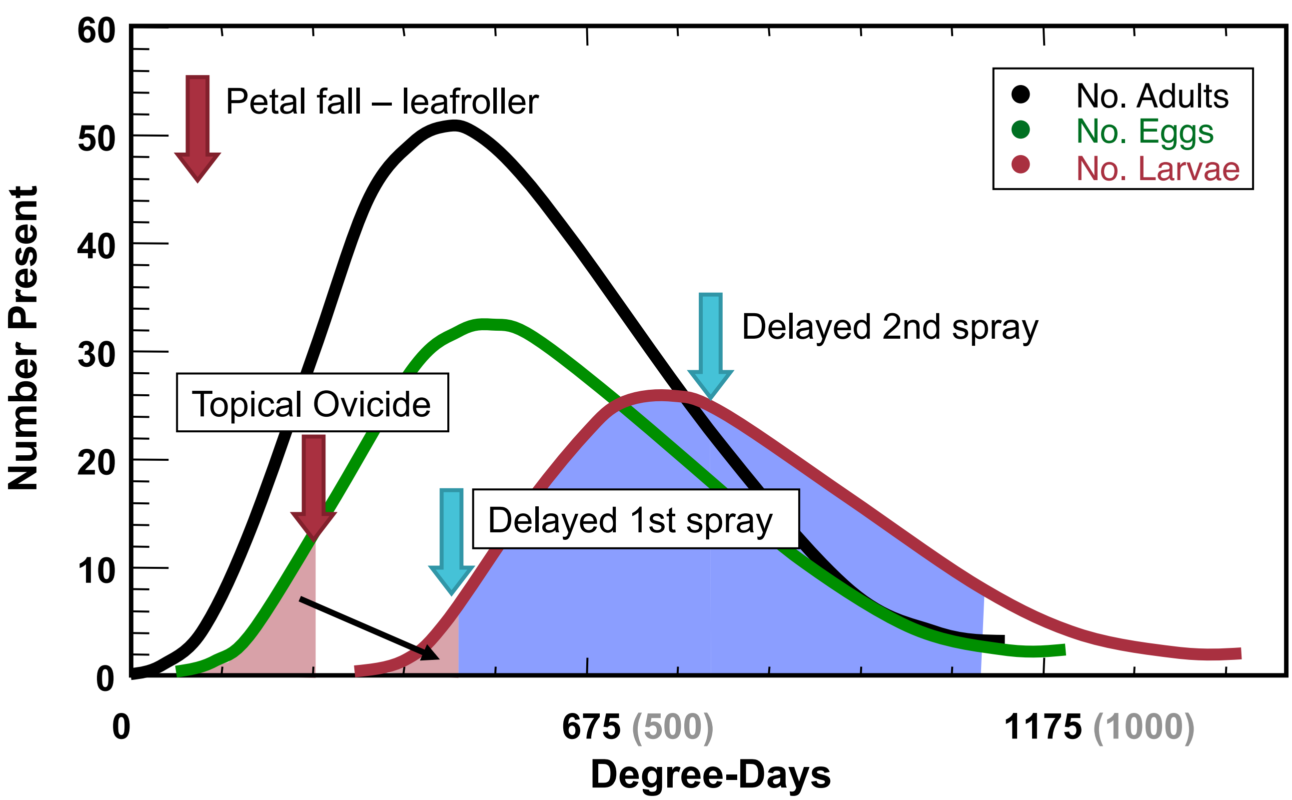
Targets and Treatments



Using Oil as an Ovicide to Delay First Larvicide Applications

- Oil, applied at 375DD (200 DD), kills eggs that have already been laid in the orchard.
- Larvae that would have emerged beginning at 425DD (250 DD) do not, because they were killed in the egg stage.
- Delaying the first larvicide application places the most active insecticide residues in the period of peak egg-hatch activity.
- Additional larvicide applications will need to be applied based on the length of expected residual control of the product used.



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Targets and Treatments

Using a Codling Moth Ovicide at Petal Fall

- If Altacor, Intrepid, Rimon, or Esteem are used at petal fall, codling moth eggs will also be controlled.
- These products act as residual ovicides, that is - they kill eggs that are laid on top of the residues from an application.
- If Altacor, Intrepid, Rimon, or Esteem are used at petal fall, the first larvicide application can be delayed until 525DD (350DD).
- Additional larvicide applications will need to be applied based on the length of expected residual control of the product used.

SJS, LR mite (egg)	LR (larva) LR&CM (egg)	CM (egg)	CM (larva)	CM (larva)	CM (larva)	CM (larva)
Delayed dormant	**Petal fall 225-275DD** (50-100DD)	**375DD** (200DD)	**1st cover 425DD** (250DD)	**Delayed 1st cover 525DD** (350DD)	**2nd Cover 625-675DD** (450-500DD)	**3rd Cover 875-925DD** (700-750DD)
Oil Lorsban	Proclaim Success Delegate Belt Bt Altacor Intrepid Rimon Esteem			Delegate (Entrust) Altacor Assail Calypso Intrepid virus		Delegate (Entrust) Altacor Assail Calypso Intrepid virus

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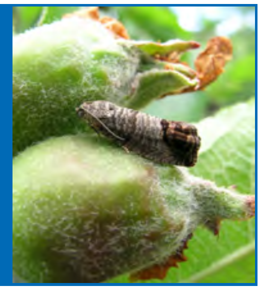
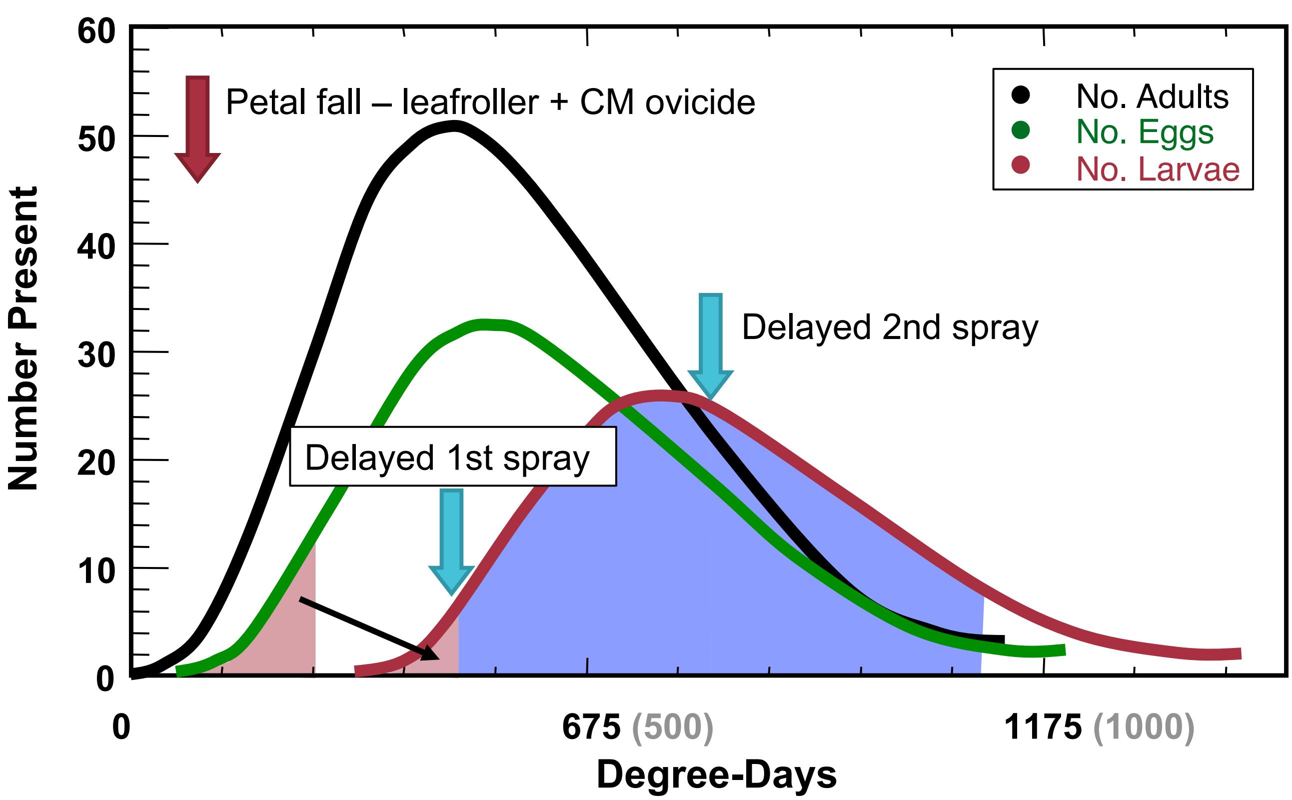
Targets and Treatments



Using a Codling Moth Ovicide at Petal Fall

- Altacor, Intrepid, Rimon, or Esteem kill codling moth eggs that are laid on top of their residues.
- The larvae that would have emerged beginning at 425DD (250 DD) do not, because they were killed in the egg stage.
- Delaying the first larvicide application places the most active insecticide residues in the period of peak egg-hatch activity.
- Additional larvicide applications will need to be applied based on the length of expected residual control of the product used.



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Targets and Treatments

Tank-Mix Ovicide + Larvicide at 525 DD (350 DD)

- A tank-mix combining an ovicide + larvicide can provide very robust codling moth control.
- The ovicide (Intrepid, Rimon, or Esteem) kills a portion of the eggs already in the orchard as well as eggs that are laid after the application.
- The larvicide (Delegate, Altacor, Assail, Calypso, or virus) kills larvae as they hatch and begin feeding.
- Eggs that would have hatched at the end of the generation do not because they were killed by the ovicide in the tank-mix.

SJS, LR mite (egg)	LR (larva) LR&CM (egg)	CM (egg)	CM (larva)	CM (larva)	CM (larva)	CM (larva)
Delayed dormant	Petal fall 225-275DD (50-100DD)	375DD (200DD)	1st cover 425DD (250DD)	Delayed 1st cover 525DD (350DD)	2nd Cover 625-675DD (450-500DD)	3rd Cover 875-925DD (700-750DD)
Oil Lorsban	Proclaim Success Delegate Belt Bt Altacor Intrepid Rimon Esteem		larvicide + ovicide	Delegate (Entrust) Altacor Assail Calypso Intrepid virus + Altacor Intrepid Rimon Esteem		May not need 2nd Cover

Tank mix strategy

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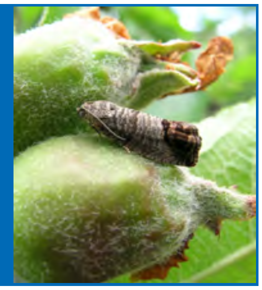
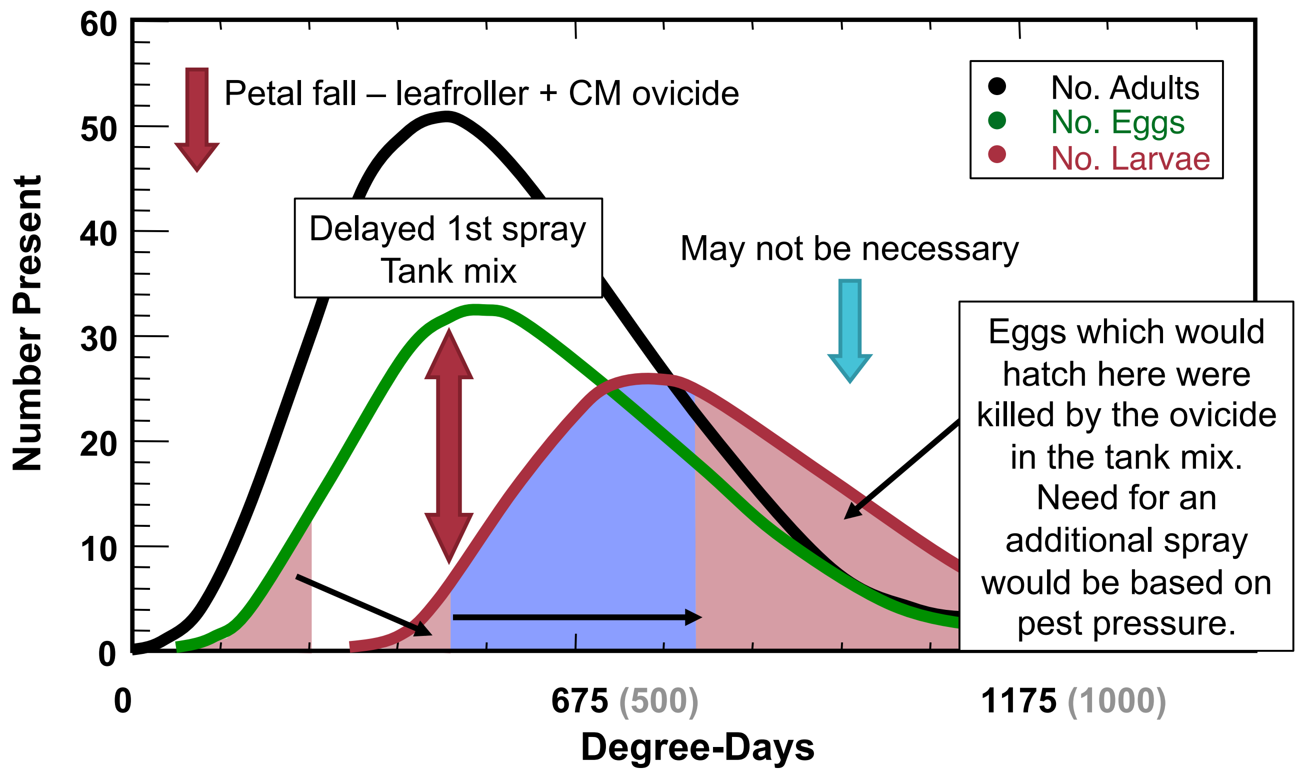
Targets and Treatments



Tank-Mix Ovicide + Larvicide at 525 DD (350 DD)

- This approach begins with a residual ovicide at petal fall (Intrepid, Esteem, Rimon, or Altacor) ***OR*** a topical ovicide at 375DD (200 DD) (Oil), which allows delaying the tank-mix to 525DD (350DD).
- The ovicide (Intrepid, Rimon, or Esteem) kills a portion of the eggs already in the orchard as well as eggs that are laid after the application.
- The larvicide (Delegate, Altacor, Assail, Calypso, or virus) kills larvae as they hatch and begin feeding.
- Eggs that would have hatched at the end of the generation do not because they were killed by the ovicide in the tank-mix.
- Monitor to determine the need for additional applications.



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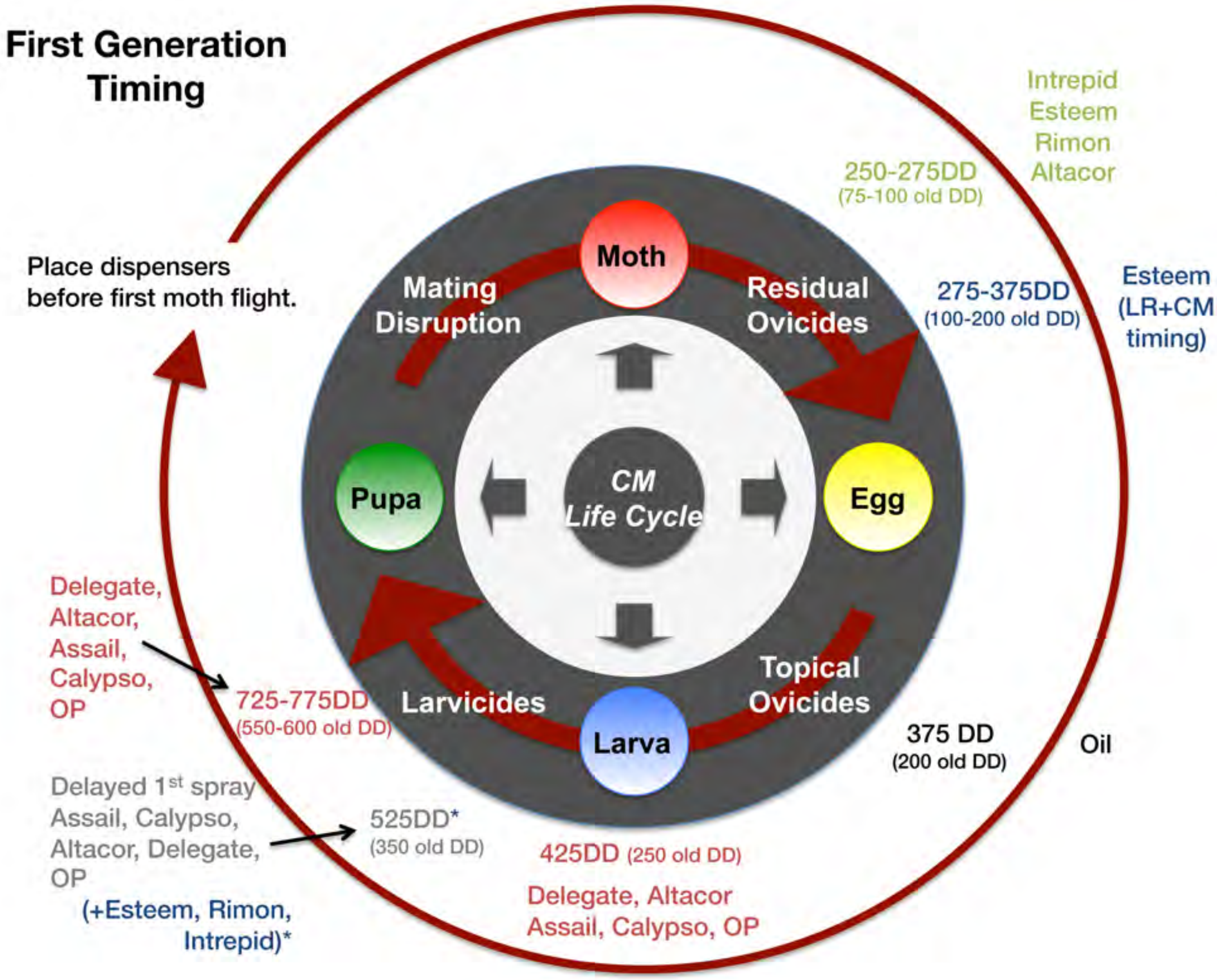
Targets and Treatments

First Generation Codling Moth Timing



* Ovicides to be used in tank mixes with larvicides only. Do not substitute these products directly for a larvicide as fruit protection will be sacrificed.

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Organophosphate Replacements for Key Pests ~ Codling Moth and Leafroller

Codling Moth and Leafroller

Insecticide	Chemical Name	Group*	Codling Moth		Leafroller
			ovicidal	larvicidal	larvicidal
Intrepid	methoxyfenozide	18A	X (residual)	X	X
Esteem	pyriproxyfen	7C	X (residual)		X
Rimon	novaluron	15	X (residual)		X
Altacor	rynaxypyr	28	X (residual)	X	X
Belt	flubendiamide	28			X
Assail	acetamiprid	4	X (topical)	X	
Calypso	thiacloprid	4	X (topical)	X	
Success	spinosad	5			X
Delegate	spinetoram	5		X	X
Proclaim	emamectin benzoate	6			X
HMO	oil	---	X (topical)		
CM virus	virus	---		X	
Bt	Bacillus thuringiensis	11A			X

*IRAC Resistance Management Group Number

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Leafroller Management with New Insecticides

Leafroller

Product	Group*	Efficacy	Speed of Action
Proclaim	6	Excellent	Fast
Success	5	Excellent**	Fast
Delegate	5	Excellent	Fast
Intrepid	18A	Good**	Moderate
Altacor	28	Excellent	Moderate
Belt	28	Good	Moderate
Rimon	15	Good	Slow
Esteem	7C	Good	Slow & Delayed
Bt products	11A	Good	Slow

*IRAC Resistance Management Group Number

**Some populations of leafroller are resistant to this product

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Codling moth Management with New Insecticides

Codling Moth

Product	Group*	Efficacy	Residual Activity	Ovicide	Larvicide
Assail	4	Good	14-17 days		X
Calypso	4	Good	14-17 days		X
Delegate	5	Good	14 days		X
Intrepid	18A	Fair	14 days	X	X
Altacor	28	Good	14-17 days	X	X
Rimon	15	Good	14 days	X	
Esteem	7C	Fair	10-14 days	X	
Virus	---	Fair	7-10 days		X
Oil	---	Fair	Topical Only	X	

*IRAC Resistance Management Group Number

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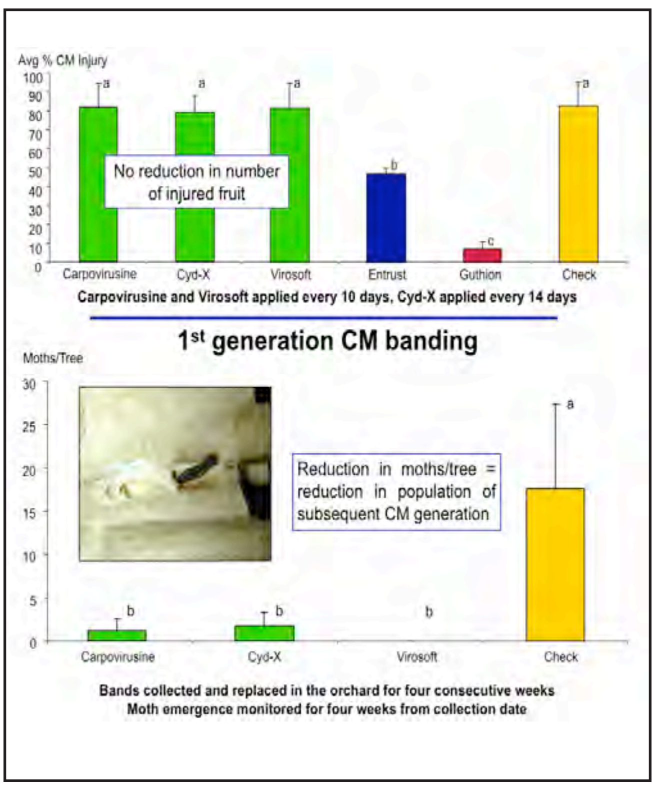
Codling Moth Granulosis Virus (CM-Gv)

Toxicity of codling moth granulosis virus:

Codling moth granulosis virus (CM-Gv) was originally discovered in dead CM larvae collected in Mexico. Since then, CM-Gv has been found around the world. After CM-Gv is ingested by the larva, the granules dissolve. CM-Gv infects the gut and replicates before moving to the fat body. Infected larvae cease activity, change color, and eventually dissolve. CM-Gv is highly toxic even in very small amounts; however, unique insecticidal properties have made it challenging for commercial apple growers to develop the best use patterns for CM-Gv.

Delayed mortality – Measuring impact on subsequent generations:

Under normal field conditions, CM generally consume only a small amount of CM-Gv. At this dose, it can take 14-21 days before CM-Gv replicates to a lethal level. The result is that there is often little or no reduction in fruit injury during the first generation of CM-Gv use. To determine the impact on the current larval generation, growers may need to dissect larvae from infested apples.



In research trials at the WSU-TFREC, cardboard bands were placed at the base of trees to recapture larvae that had exited apples. Bands were collected every two weeks and held for two more weeks to assess larval survival and the emergence of 2nd generation adults. The number of larvae that were recaptured was reduced in the 1st generation, but not in the 2nd. Pheromone traps are essential to monitoring adult emergence during the 2nd generation to measure the impact of 1st generation CM-Gv treatments.

Virus in Organic Orchards – ***attack CM at as many points in the life cycle as possible:***

- Mating disruption to reduce eggs.
- Repeated oil applications to kill eggs.
- Repeated virus applications to kill larvae.
- Target "hotspots" with Entrust.

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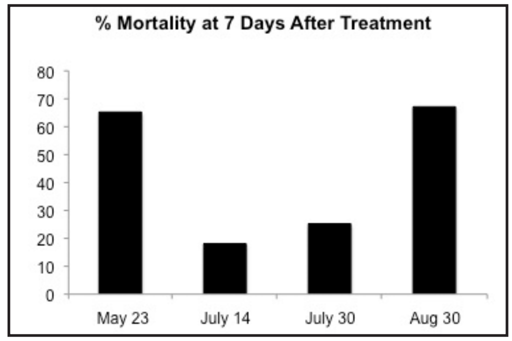
Codling Moth Granulosis Virus (CM-Gv)

Residual control of virus:



The most important factor limiting the widespread adoption of CM-Gv by conventional growers may be short residual control. This chart shows mortality of larvae exposed to apples 7 days after treatment. Note the decline during July. Europe relies heavily on CM-Gv, but climactic conditions are very different than central Washington. First generation sprays appear to be reliable, but the intensity of UV degradation during summer can lead to variable results.

Using virus in organic orchards:

The majority of organic orchards in Washington rely on CM-Gv to control CM larvae. However, CM-Gv alone is not sufficient to maintain low pest populations. Mating disruption, combined with repeated oil applications, is required to reduce egg hatch. Entrust is a highly effective CM larvicide, but judicious use is important. Entrust is used for control of thrips, leafroller, and CM. Overuse of Entrust will lead to insecticide resistance. Entrust should be used to suppress the CM population, then limited to spot treatments in high pressure areas. Growers will likely need to reapply CM-Gv every 7-10 days in moderate pressure orchards through the entire season to achieve acceptable crop protection.

Potential uses in conventional orchards:

Finding the best use for CM-Gv in conventional orchards has been a challenge. One strategy is to use CM-Gv as a "gap" spray. The time period between a 275DD (100 DD) ovicide and a 525DD (350 DD) larvicide application may be uncomfortably long for some growers. CM-Gv can be effective when applied between those sprays [425DD (250 DD)]. Likewise, applying CM-Gv between larvicide applications [775DD (550 DD)] may allow growers to extend retreatment intervals. Continuous flights in high pressure areas often obscures the traditional break between 1st and 2nd generations. CM-Gv may be a good fit in that extended time period where the potential for damage is low but larvae may still be hatching and feeding.

Virus in Conventional Orchards:

- Short residual control decreases efficacy during summer generations.
- Treat the "gap" between insecticide applications.
- Treat the "gap" between CM generations.