This article is the first in a series intended to help the apple industry transition insect pest management programs to the use of new pest control technologies. It discusses options for leafroller and codling moth control in the early part of the season—delayed dormant through petal fall. Subsequent articles will focus on the period from petal fall through the first codling moth generation and then on summer leafroller generation and second-generation codling moth control.

The first insecticide application in Washington apple orchards typically comes at the delayed dormant (or half-inch green) stage of bud development. The products used at this time have been horticultural mineral oil and Lorsban (chlorpyrifos) applied as a tank mix. The target pests are San Jose scale, European red mite eggs, and leafroller larvae, with suppression of aphids also likely achieved.

Both pandemis and obliquebanded leafrollers overwinter as small larvae in hibernacula in bark crevices or other protected areas on the tree. While most pandemis larvae have emerged from their hibernacula by the delayed dormant stage, obliquebanded leafroller larvae do not complete emergence until about three weeks later. The practical result of this difference is that Lorsban residues applied at delayed dormant decline prior to the full emergence of the obliquebanded population, thereby limiting the value of this treatment. Further, Lorsban triggers the cholinesterase testing requirement for many pesticide applicators, and farmworker advocacy and environmental groups have targeted Lorsban for additional regulatory action. Limited efficacy against targeted pests coupled with worker safety issues make choosing an alternative to Lorsban for leafroller control an appealing option.

Leafrollers

Petal fall is the best time to determine the density of leafroller larvae in the orchard and apply controls if required. The timing for application of organophosphate (OP) alternatives should be based on predictive models rather than on when petal fall occurs. New predictive models for leafrollers are available via the WSU Decision Aid System at http://entomology.tfrec.wsu.edu/das powered by the WSU AgWeatherNet, which provides the temperature data to run the models. The leafroller models can be used to determine the best time to sample for larvae and can aid in choosing the best time to apply insecticides to achieve optimal control.

Organophosphate alternatives that control leafrollers include Esteem (pyriproxifen), Intrepid (methoxyfenozide), Rimon (novaluron), Success (spinosad), Proclaim (emamectin benzoate), and Bt (Bacillus thuringiensis). All of these insecticides should be timed to target the larval stage. Most are best timed against the fourth larval instar. Esteem is the exception and should be timed to target the last larval instar, but before pupae are formed. Using the new leafroller models on the Decision-Aid System will be very important to precisely time controls for specific larval stages in the absence of a Lorsban treatment.

Proclaim and Success act on the insect’s nervous system and are fast-acting and highly toxic to leafroller larvae that feed on their residues. The insect growth regulators, Esteem, Rimon, and Intrepid, disrupt the normal development of the insect. Esteem, a juvenile hormone mimic, prevents the transition from the last larval stage to the pupa and should be timed to coincide with the presence of larger larvae (fifth and sixth instars). Rimon interferes with the normal formation of the insect cuticle after a molt, causing immobility and excess water loss resulting in death.

How ovicides work

- **Egg**
- **Leaf**
- **Residue**

Some ovicides work if applied over the top of the egg (oil, Assail, Calypso).

Some ovicides work when applied before organophosphates after the egg is laid (insect growth regulators).

**Consider the options before applying an early season OP.**

by Dr. Jay F. Brunner, Keith Granger, Mike Doerr, and Dr. Elizabeth Beers, WSU TFREC, Wenatchee
Intrepid causes the insect to initiate a molt that is lethal because it is not successfully completed.

Rimon and Esteem have an extended time-to-kill, but both are effective at reducing the subsequent leafroller generation. The full impact of a Rimon application may not be realized until 14 to 17 days after the application, whereas with Esteem the impact is often difficult to see during the overwintering generation. Esteem-intoxicated larvae often do not die until they reach the pupal stage. Because pupae can be difficult to find, mortality is not always obvious.

Bt products consist of a protein, the product of a bacterium, which is lethal to larvae after it is consumed. Repeat applications of Bt are usually necessary to achieve good control. Bt should only be used when periods of warm weather, 65°F, are predicted for at least three days.

Codling moth
A key to successful codling moth control with organophosphate alternatives is the ability to disrupt its life cycle in multiple places (see “Target multiple life stages” above). Codling moths overwinter as mature larvae protected in hibernacula under loose bark scales on the tree or under leaf litter at the base of the tree.

The first opportunity to begin a control program for this pest is to target the adult moth. Very few insecticides currently registered have activity against adult moths; however, mating disruption products applied before moths begin to emerge can reduce the number of eggs deposited in the orchard by interfering with mating. Reduced egg

**OP alternatives for secondary pests**

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<th>INSECTICIDE</th>
<th>Leafhopper</th>
<th>Campyломма</th>
<th>Green aphids</th>
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Products in the same color category are from the same pesticide class.

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laying results in a smaller codling moth population to control with insecticides. In our experience, all insecticide programs perform better when used in combination with mating disruption. Traditional codling moth control programs have focused on control of the larvae at egg hatch. Some organophosphate alternatives allow growers to target the egg stage, reducing or eliminating eggs that otherwise would have hatched. This approach allows the insecticides that kill codling moth eggs to also kill leafroller larvae, making it possible to target multiple pests with a single application.

Ovicides are insecticides that kill eggs. Some ovicides—horticultural mineral oil and the neonicotinyls Assail (acetamiprid) and Calypso (thiacloprid)—work if applied over the top of the egg. The insect growth regulators—Esteem, Intrepid, and Rimon—control eggs that are deposited on top of spray residues as well as eggs that are covered by the spray (see “How ovicides work”). This characteristic of insect growth regulators allows more flexibility in application timing. Optimal timing for these products to control codling moth is between 75 and 200 degree-days past first moth flight (biofix).

As discussed, the insect growth regulators also kill overwintering leafroller larvae that are active during this time. The flexibility in application timing with these products allows growers the opportunity to optimize leafroller timing without compromising codling moth control.

If oil is used as an ovicide against codling moth, the optimal application timing is just before egg hatch begins at 200 degree-days. Repeated oil applications at 150 to 200 degree-day intervals are necessary to control eggs deposited after the initial application.

The ovicidal activity of Assail and Calypso adds value to their control activity when applied at the more typical egg-hatch timing (250 degree-days). While these products do kill codling moth eggs, they do not provide coincidental control of leafroller larvae.

Other products that might be applied for leafroller control in the immediate postbloom period (Success, Bt products, and Proclaim) do not control codling moth because they do not kill eggs. If these products are used for leafroller larval control then codling moth control should start at the beginning of egg hatch to target larvae before they enter the fruit.

Secondary pests
Changes in pest management programs will inevitably bring new challenges. In some cases, these may come from secondary pests. For most secondary pests, there are organophosphate alternatives that provide control (see “Organophosphate alternatives for secondary pests”). In some cases (e.g., woolly apple aphid and stink bugs), control will require using other traditional broad-spectrum insecticides such as Thiodan (endosulfan), Carzol (formetanate hydrochloride), or pyrethroids (Danitol, Warrior, Asana). In other cases, removing organophosphate insecticides from a pest management program may result in a temporary increase in secondary pests that will be resolved by an increase in beneficial insects previously suppressed by organophosphate use.

The next in this series will be published prior to the traditional first codling moth generation control treatments.

For additional information, go to the WSU-TFREC Web site at: http://entomology.tfrec.wsu.edu/op-alternative.