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Optimizing codling moth control using RIMpro

Codling moth is a key pest in orchards. Commercial integrated- or organic apple production is not possible without effective control of codling moth populations. The available insecticides have different modes of action and not all of them are equally effective. Accurate timing of insecticide treatments in relation to their mode of action and the local biology is crucial to achieve effective control with minimal residues and costs.

Worldwide. codling moth (*Cydia pomonella*) is a key pest almost everywhere where apples are grown. *EFM*

Worldwide. codling moth *(Cydia pomonella)* is a key pest almost everywhere where apples are grown. Even in the most northern production areas were the codling moth develops only a single generation per year, 10 to 50% of the crop can be destroyed. Codling moth is highly specialized to attack apple and pear. While natural enemies have some effect on the population, under natural conditions codling moth populations and damage tend to increase from year to year. At low population levels, management is not very problematic, but once 2-5% fruit damage is reached control becomes increasingly difficult.

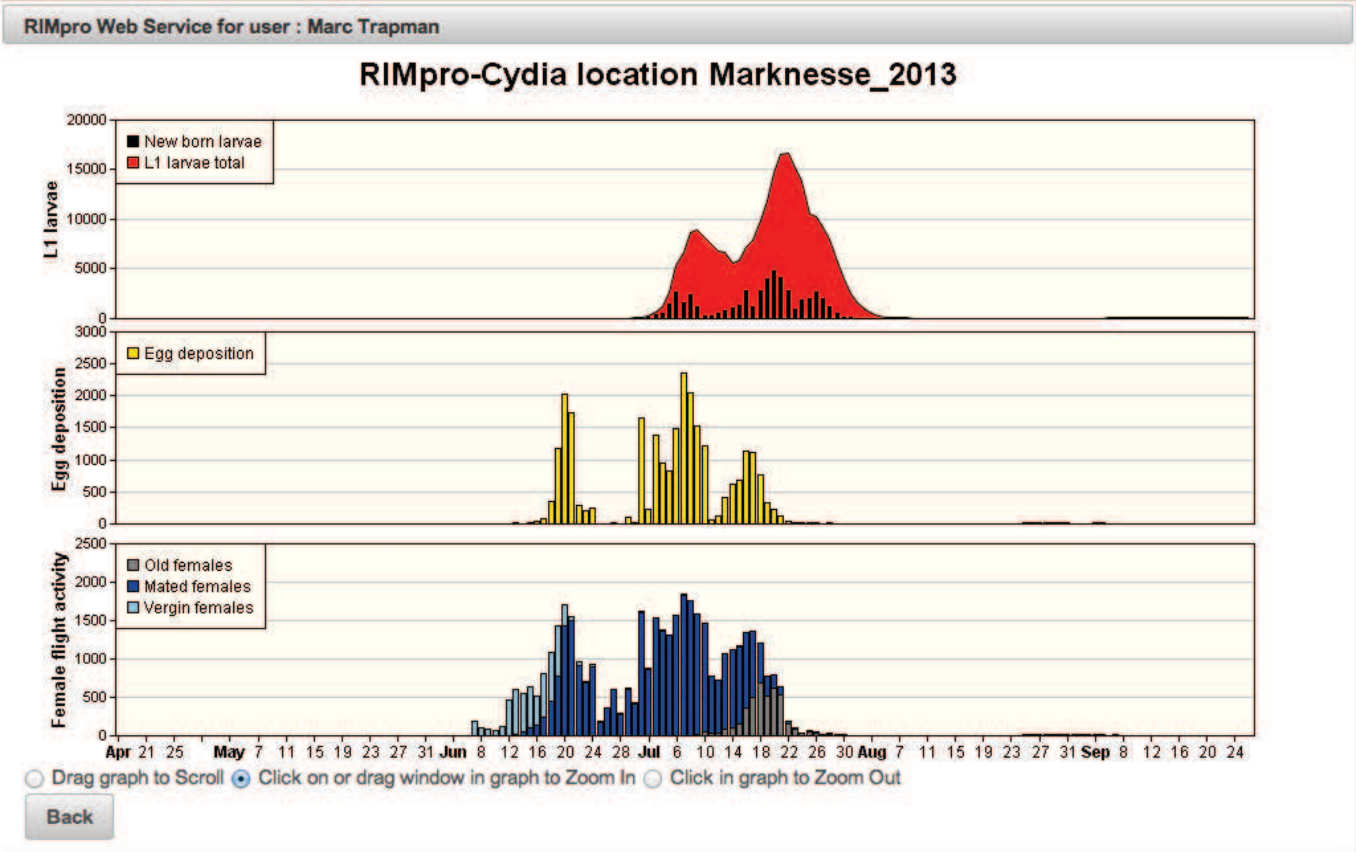
Biology

In spring, increasing day length awakens the codling moth from winter dormancy (diapause) and pupation begins. In August, decreasing day length forces the larvae to enter winter diapause. Development during the months to follow will be dependent on temperature. In the northern part of Europe the climate allows only one generation to develop, whereas in the very south it is warm enough to develop three generations.

Simple models

Models help us to find the best moments for treatments to control codling moth. Simple models use temperature sums (=degree days) higher than 10°C. These provide a crude indication of the time when the first eggs are laid and expected to hatch. This approach has several limitations however that make it of limited use for practi-

Figure 1. The weather in the northern part of the Netherlands in 2013 allowed only a single codling moth generation to develop.



cal decision-making. It is not the average temperature during the day but instead the weather conditions around sunset which determine if the moths fly and how many eggs are laid. Moreover, we are not so much interested in the very first egg or larvae, but rather need to know how long egg-hatching continues and where the peaks in egg-hatching occur, which will help us guide and refine our treatments.

Modelling the population

The RIMpro-Cydia model simulates the evolution of an overwintering codling moth population during spring and summer. From this we can easily determine the key times for our treatments. The model uses all current knowledge on the responses of the insect to environmental conditions. These reactions are universal. The local microclimate determines the local codling moth biology. When the model is run using weather data from the north of The Netherlands, we see that the codling moth could only develop a single generation in 2013 (Figure 1). When we feed the same model data from South-East Austria we see that two complete codling moth generations could develop before the population entered diapause again (Figure 2).
On the sun-exposed side of the tree eggs, larvae and pupae develop at different rates compared to the shady side. To account for this, the model calculates for sub-populations in different parts of the tree. The user won't notice this as all results are merged in a single graph.

Practical interpretation of the graphs

The bottom graph shows the flight of the female moths. Juvenile unmated females are shown in light blue, mated females in dark blue, and females that have laid all their eggs in grey. The more females present and the more favourable

Handling resistance
Local codling moth populations have developed resistance against many insecticides, including strains of the codling moth granulose virus. In parts of southern France even the most modern insecticides are insufficiently effective. Several insecticides have limited efficacy and must be timed carefully to achieve the best possible effect. When designing a strategy, plan to use different groups of insecticides and apply mating disruption to suppress egg deposition. With fewer larvae to kill, all other treatments get a better chance to provide acceptable control.

Sustainable system approach
Several of the insecticides used against codling moth have side effects on beneficial insects such as European earwigs *(Forficula auricularia)*. Repeated use of these products can cause outbreaks of woolly apple aphid (*Eriosoma lanigerum*) or pear psylla (*Cacopsylla pyricola*). A sustainable codling moth strategy should therefore be based on the application of mating disruption and carefully timed treatments of granulose virus. Chemical insecticides should be regarded as a last-resort resource for extreme situations.

the evening flight conditions, the higher the flight activity.

The middle graph shows the number of eggs deposited per day (yellow). Ovicidals like Insegar (fenoxycarb) and Dimilin (diflubenzuron) kill fresh eggs that are laid on top of the insecticide residue. These products have to be applied just before a period of intense egg deposition. The upper graph shows the hatching eggs. The small black bars represent the number of eggs hatching that day. In red are all the larvae still in the first larval stage that can still be reached by larvicides. Biological insecticide containing granulose virus (Madex, Carpovirusine) have only a few days of efficacy and should be timed accurately following egg hatching. More potent chemical larvicides can be scheduled during the peaks in egg hatch.

Codling moth management

The codling moth population in an orchard develops over the course of years. This long-term development has to be recognized to plan the right strategy.

Management based on pheromone traps is quite problematic. The traps only show male moths looking for females, while it is the females that lay the eggs in the weeks after mating that we want. Research has shown that there is no correlation between the time and number of male moths trapped, and the time or number of eggs laid by female moths. RIMpro has proven to be far more reliable.

Growers and consultants repeatedly find that there is no relationship between the number of moths trapped and the risk for damage. It is better to use the observations on damage in the previous year to estimate the population pressure for this year.

In production areas where codling moth control is difficult, mating disruption has become a standard treatment. Additional insecticides can then be limited to a few treatments just before the peaks in the egg hatching (red graph).

If no mating disruption is applied several options are open. We were very effective where we applied Insegar just before egg deposition, followed by treatments with granulose virus during the period of egg hatching.

In the absence of ovicidal treatments, the larvicidal treatments should be started earlier; not with the first egg hatching, but as soon as the number of hatching eggs increases. These treatments are to be repeated while monitoring the next predicted peaks in egg-hatching and considering the properties of the insecticide used.

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Figure 2. In south-eastern Austria, the flight of the codling moth started much earlier than in The Netherlands. At the beginning of the flight the evening conditions were not favourable for egg deposition, but two complete generations were still able to develop in 2013.