Technical information

Target pest
For the control of codling moth (Cydia pomonella):
CpGV-M (Mexican isolate) sensitive and resistant codling moth populations.

Crops
Apple, pear, walnut, quince, apricot, peach, almond, kaki, medlar, orange and others.

Formulation
Suspension concentrate containing $> 3 \times 10^{13}$ OB (occlusion bodies) of Cydia pomonella granulovirus (CpGV) per liter.

Standard dosage
100 ml/ha

Timing
At hatching of first larvae. Acts by ingestion.

Water volume
200–1600 l/ha. This should be adjusted according to leaf area index and spraying equipment.

Standard interval between sprays
Repeat after 8 days of full sunshine. This can be adjusted depending on the specific pest control strategy.

Pre-harvest and re-entry interval (PHI, REI)
Leaves no residues on fruits and plants. PHI and REI are defined according to national registration regulations.

Toxicity profile
No maximum residue levels (MRLs) are defined. Contains no chemical ingredients and leaves no residues on the crop. Complies with organic farming. No side effects on non-target organisms.

Compatibility
Compatible with most insecticides, fungicides and fertilizers. A pH level between 5 and 8.5 in the tank mix has to be respected.

Storage
Excellent storage stability: > 2 years at –18 °C, 2 years at 5 °C, 3 months at 20 °C. Avoid temperatures above 40 °C.

Rainfastness
Good rain resistance 3 to 4 hours after spraying.
High selectivity and safety

The active substance of Madex® Top is a Cydia pomonella granulovirus that was selected on CpGV-M resistant codling moth populations. These viruses belong to the family of insect pathogenic baculoviruses that occur naturally in lepidopteran species.

- No phytotoxic symptoms on plants after application.
- The formulation only contains food grade additives; therefore the use of Madex® Top does not leave any chemical residues, making it suitable for low residue or organic food production.
- No maximum residue levels (MRLs) are defined for Madex® Top.
- The product is free of genetically modified organisms.
- No production of metabolites or toxins
- Baculoviruses are safe and cause no hazards to human health (OECD Consensus paper, 2002)

No side effects

Madex® Top preserves natural antagonists due to its specific host range. Whilst being an effective codling moth control tool, aquatic organisms, birds and mammals are not affected. It is also safe for bees, bumble bees, predatory mites and parasitoids.

Compatibility

Madex® Top is compatible with most agricultural chemicals. A pH level between 5 and 8.5 in the tank mix with other products has to be respected. Otherwise, the protective protein capsule will be destroyed and the active substance inactivated.

Avoid tank mixes with copper products. Spraying of copper a few days before or after a Madex® Top application has no adverse effect.

Rainfastness

Virus particles naturally have lipophilic properties, favouring a strong adherence to the plant surface. Madex® Top is rain resistant within 3 to 4 hours of application. No additives are necessary to improve rainfastness.

Use of adjuvants

Madex® Top is ready to use. It is thus not necessary to add feeding stimulants, surfactant/wetting agents or other adjuvants.

Storage and handling

The product remains liquid at –18 °C and can be used immediately for spraying without unfreezing. Once opened, the bottle can be stored at low temperatures without loss of quality. Avoid temperatures above 40 °C during storage or transport. Temporarily sub-optimal storage conditions during transport or at the end-user may be accepted for a few days.
Granuloviruses are encapsulated within a protein occlusion body, which protects the virus to some extent from destructive environmental influences (e.g. UV radiation). The size of a single virus particle is not bigger than 400 nm.

Young larvae that are actively moving and feeding on twigs, leaves or fruits, will ingest the virus that was sprayed onto the plant surface. Following ingestion, the virus particles enter the larval midgut, where the protein capsules dissolve due to the high pH level (pH higher than 10). Within 2–4 days, the virus infests most organs of the host and the larva stops feeding. Upon death, the larval body liquefies and releases millions of new viruses into the environment, infecting other larvae.

Under laboratory conditions, only 1 ingested virus particle is sufficient to kill a first instar larva. Older larvae (older than L3) are not instantly killed and may therefore cause further damage before getting killed in later larval instars (which is often reflected by superficial or deeper, but stopped damage in the fruit). The virus infection can also be passed on to the next generation, where it can develop due to biotic or abiotic stress and kill the larva (also during hibernation), and providing excellent population control.
Resistance against CpGV-M isolates

In 2004, fruit growers were confronted with the first reports of granulovirus resistant codling moth populations. As a consequence, new virus isolates have been developed to overcome the resistance. These novel virus isolates were mainly selected from resistant codling moth populations.

What is important to know about granulovirus resistance?

- Resistance is only associated with the Mexican isolate (CpGV-M), which includes all commercial products in the European market.
- Resistant populations have been found in 40 – 50 orchards in Germany, Italy, France, Holland, Austria and Switzerland.
- Resistant populations are only of concern in organic orchards exclusively treated with CpCV-M. Orchards with an integrated pest management (IPM) were not affected.
- No cross-resistance to other insecticides was found.
- Within a population, resistance may spread quickly due to dominant inheritance and location on the sex chromosome. However, due to the restricted mobility of adult moths, spread to neighboring populations is limited.

Selection of MADEX® TOP

The virus isolate of Madex Top was selected on highly CpGV-M resistant codling moth populations. Andermatt Biocontrol has selected different isolates which can break resistance. Madex Top is the latest isolate on the market.

A sustainable future for the codling moth virus with virulence management

The new isolates are able to break resistance but it is important to keep in mind, that more resistances may occur in the future. Evidently, intense use of the virus, often the case in organic orchards, may be favourable for the development of new resistant strains. For this reason, Andermatt Biocontrol has decided to continuously develop new virus isolates for successful pest management of difficult codling moth populations. The idea is to create consistent virus management programmes, e.g. by switching isolates every 4 to 7 years. Another possibility is the rotation of isolates from different genotype groups between codling moth generations. For that purpose, isolate development, field trials and new registrations are necessary.
Comparison of efficacy of several CpGV isolates

Several CpGV isolates were tested in laboratory bioassays against different codling moth populations. LD$_{50}$ of Madex Top was as low as the LD$_{50}$ of the virus sensitive strain on all tested populations. Tests were conducted on field collected populations from orchards in Germany and Italy, as well as on laboratory selected codling moth strains.

<table>
<thead>
<tr>
<th>Codling moth population</th>
<th>MADEX®</th>
<th>MADEX® PLUS</th>
<th>MADEX® MAX</th>
<th>MADEX® TOP/PRO</th>
</tr>
</thead>
<tbody>
<tr>
<td>CpGV sensitive strain (lab-strain)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>resistant strain Fischingen, South Germany</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>resistant strain Emilia Romagna 1, Italy</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>resistant strain Emilia Romagna 2, Italy</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>resistant strain Wesel-Bislich, West Germany</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>field resistant lab strain 1</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>highly resistant lab strain 2</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

LD$_{50}$ [OB/g diet]  
- ● < 20 000  
- ● 20 000 – 100 000  
- ● > 100 000

Laboratory bioassay. LD$_{50}$ = Lethal dose (virus particles/g artificial diet) needed to kill 50% of the codling moth population. Assessment after 8 to 14 days.

Effectiveness of MADEX® TOP in laboratory

In laboratory, Madex Top was tested on a highly resistant codling moth population from Germany. The diet-incorporated virus was tested in a bioassay on L2 larvae. Assessment was done after 8 days. N = 50 per treatment.
Information on codling moth

Codling moth (CM)
The codling moth, *Cydia pomonella*, is regarded the most harmful insect pest in most pome fruit producing countries.

Geographical distribution of codling moth

The most common host plants where *Cydia pomonella* is a major pests:

- Apple
- Pear
- Walnut
- Almond
- Apricot
- Quince
- Rarely found on:
  - Peach
  - Kaki
  - Medlar
**Pest life cycle**

### General information
- Min. developmental threshold: 10 °C
- Max. developmental threshold: 31 °C

Degree-days (DD) that are needed to complete each stage of development of codling moth in pome fruit.

\[
DD \text{ (Degree-day)} = \frac{\text{min. + max. day temperature}}{2} - \text{min. developmental threshold of pest}
\]

#### Hibernation
Last larval instars undergo diapause in a cocoon. Mainly at the base of tree stem, but also in ground near the stem and in bark of old branches.

#### Emergence of adults
Starting in spring, when temperatures are rising.

#### Eggs per female
Up to 300 eggs.

#### Oviposition site
- During 1\(^{st}\) generation: Mainly on leaves
- During following generations: Directly on fruits

#### Larval development
After the larvae reach the 5\(^{th}\) instar, they leave the fruit and pupate in cocoons at the base of the trunk. Not all individuals of a population will go for a second or third generation. It is known that a part of the population will hibernate after just one generation, at least in regions of moderate climate.

#### Feeding behaviour
The larvae chew their way into the fruit, usually entering at the blossom end, at the stalk end, or at contact points between the fruits. Their spiral tunnel finally leads towards the where they feed on the kernels.

### Damage pattern

**Codling moth**
- **Penetration anywhere on the fruit.**
- **Tunnel contains reddish brown frass and leads to the kernels.** Entry point is usually not exit hole.
General instructions

The larvae have to ingest the viruses to get infected. Young larval instars are killed faster than older instars. For best crop protection, the first Madex® Top spray is therefore applied right before first egg-hatch, and before the larvae enter the fruit. Use local forecast system (based on phenology models) if available.

On sites with very high pest densities, it is recommended to combine fast acting larvicides at the peak of larval hatching, in order to keep superficial and stopped damage low. Madex® Top reduces the overall population on a long term. As viruses are sensitive to UV radiation, sprays must be repeated at intervals of 8 days of full sunshine to assure a constant coverage during the larval hatching period. 2 partly sunny days are equal to one sunny day. Application in the late afternoon or early evening hours is recommended.

Application strategies

Use in Integrated Pest Management
Madex® Top can be successfully used as a part of an Integrated Pest Management (IPM) programme, which may include chemical ovicides/larvicides and mating disruption.

Use in organic production
Madex® Top is a biological insecticide fully complying with the EU Regulation 834/2007 for organic farming.

Resistance management
Extensive use of broad spectrum pesticides has resulted in insecticide (cross-) resistance against various active substances and outbreaks of secondary pests due to disruption of natural antagonists. First cases of resistance against CpGV-products occurred in 2004. In all cases, resistance was detected in organic orchards. Unlike resistances against some chemically based active ingredients, cross-resistance was not observed. To effectively control codling moth and to delay development of resistant populations to new active substances, a spray programme including the most efficacious insecticides and alternating modes of action against consecutive pest generations is recommended.

Strategy for the control of Cydia pomonella

Application timing
• Right before egg-hatching of codling moth.
• If other insecticides are used, Madex® Top should be used preferably during the 1st codling moth generation or focused at the beginning of every generation.

Application rate
• 100 ml/ha every 8 days of full sunshine (standard)
• 50 ml/ha every 6 days of full sunshine
MADEX® TOP efficacy assessment

Monitoring of fruit damage
Due to the unique mode of action of the virus, infected larvae can still cause superficial damage on the fruit before getting killed by the virus. Therefore, it is important to distinguish between superficial damage, stopped damage and full damage to the core. Stopped damage indicates the activity of the granulovirus.

Monitoring of population
The monitoring of hibernating codling moth is important, because Madex® Top has a strong long-term effect on the pest population. The virus is underestimated by only assessing the total damage on the fruit. A larva infected with a low virus concentration will eventually die during its development cycle. Larvae that survive a chemical treatment will have no barrier, complete their development and reproduce without further population control.

The population can be assessed by using traps of corrugated cardboard wrapped around the tree stem. Double strips of corrugated card boards are fixed at the base of the trunks at a height of 10 to 20 cm. The hibernating larvae will spin inside of the strips. As a part of the larvae of the first summer generation may already go directly for hibernation, the traps should be installed before this time point. The traps are collected in autumn and the diapausing larvae found in the traps are counted.
Field trials with MADEX® TOP

Field trial on a virus sensitive codling moth population, Italy 2010

<table>
<thead>
<tr>
<th>Interval (days)</th>
<th>Nr. of appl.</th>
<th>Timing</th>
<th>Variety</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MADEX® TOP (0.1 l/ha)</td>
<td>8</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical treatment</td>
<td>8–14</td>
<td>2, 1, 1</td>
<td>G1</td>
<td>Golden Delicious</td>
</tr>
</tbody>
</table>

Chemical treatment: Chlorantraniliprole; (0.3 l/ha), Etofenprox; (1.5 l/ha), Spinosad; (0.45 l/ha)

Field trial on a sensitive codling moth population, Slovenia 2011

<table>
<thead>
<tr>
<th>Interval (days)</th>
<th>Nr. of appl.</th>
<th>Timing</th>
<th>Variety</th>
<th>Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MADEX® TOP (0.1 l/ha)</td>
<td>7–14</td>
<td>5</td>
<td>G1</td>
<td>Idared</td>
</tr>
<tr>
<td>Chemical treatment</td>
<td>2, 1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Chemical treatment: Chlorantraniliprole; (200 g/l), Chlorpyrifos-ethyl; (250 g/l)
Efficacy on active damage of different CpGV isolates on granulovirus resistant codling moth populations, in field trials 2009 – 2010

<table>
<thead>
<tr>
<th>Product</th>
<th>Plot size</th>
<th>Bodensee 2009</th>
<th>Emilia Romagna 2009</th>
<th>Bodensee 2010</th>
<th>West Germany 2010</th>
<th>Emilia Romagna 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>MADELEX® PLUS</td>
<td>Large</td>
<td>87%</td>
<td></td>
<td>83%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MADELEX® MAX</td>
<td>Large</td>
<td>83%</td>
<td>60%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MADELEX® TOP</td>
<td>Large</td>
<td>80%</td>
<td>67%</td>
<td>92%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MADEX® TOP: Swiss quality

Madex® Top is produced in the facilities of Andermatt Biocontrol in Switzerland. The company Andermatt Biocontrol is certified according to ISO 9001:2008.

Andermatt Biocontrol is committed to highest quality of its products. Every produced batch of Madex® Top undergoes a systematic bioassay process. The virulence of each batch is tested against the standard reference batch within Andermatt Biocontrol laboratories. Only batches that fulfil the high quality standard criteria will be released into the market.

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