Maintaining Effective Control Strategies for Codling Moth, Cydia pomonella

Insecticidal Resistance Action Committee

**Introduction and Background**

Codling moth, *Cydia pomonella* (Lepidoptera: Tortricidae) is one of the most serious insect pest of apple and can also infest pear, crab apple, quince, walnut and other fruits. Codling moth is native to south eastern Europe and is now reported from parts of Africa, Asia, North America, South America, Australia and New Zealand.

Depending on environmental conditions, codling moth has two to three generations per year. It overwinters in the pupal stage in protected areas on the trunk or in leaf litter at the base of trees. Timely, effective control is very critical because females emerge with mature eggs and can mate and lay eggs within a two-day period. Codling moth neonate larvae cause direct injury by boring into fruit which can result in significant crop losses. Upon entering the fruit larvae are well-protected and consequently, control tactics have strongly relied on chemical insecticides targeting eggs and/or newly hatched larvae. Due to the strong reliance on chemical control to manage codling moth, resistance and cross-resistance to multiple insecticide classes such as organophosphates, carbamates, chlorinated hydrocarbons and pyrethroids have been documented.

**Mechanisms**

Resistance to a specific insecticide can be due to different resistance mechanisms:

- **Metabolic resistance (modified enzymatic activity):** MFO, GST, EST
- **Target-site resistance (KDR, MACE):**
- **Reduced penetration and behavioural changes**

**Scenario Changes & Trends**

- **2000**
  - No. of individual insecticides available: High
  - Decreasing
  - Resistance to a specific insecticide can be due to different resistance mechanisms

- **2012**
  - No. of individual insecticides available: High
  - Reducing
  - Resistance to a specific insecticide can be due to different resistance mechanisms

- **2017**
  - No. of individual insecticides available: Moderate
  - Increasing
  - Resistance to a specific insecticide can be due to different resistance mechanisms

**Bioassay and Monitoring for Resistance**

**Digging metabolic resistance**

- **The analysis of the enzymatic activity (MFO, GST, EST) in a codling moth population is a key element for resistance evaluation.**
- **There is a differential enzymatic activity between life-stages within the same population.**
- **In resistant strains, the enzymatic activity may not only differ in quantitative terms, but also qualitatively (e.g. esterase isoforms).**
- **By itself, knowing the enzymatic profile of a given population does not allow to predict the field resistance nor the effectiveness of insecticide “X.”**
- **Cross-resistance does not always concern all the insecticides with the same MoA.** Azinphos-methyl resistant codling moth may be susceptible to Chlorpyrifos and vice versa.

**Routine vs. qualitative assays**

- **In the last decade, large scale monitoring for field resistance mostly relied on topical application to diapausing codling moth larvae.**
- **Recent authoritative studies have confirmed their validity for IGRs, but questioned their reliability for the prediction of field resistance with some neurotoxic insecticides.**
- **By itself, significantly higher response in a routine monitoring conducted on non-target insect stage, does not allow to predict field resistance, unless validated with additional target-specific assays.**
- **Validation tests should include multiple insecticide concentrations.**

**Bioassaying the target-stage**

- **Resistance monitoring should be preferentially done on the target instar.**
- **For larvicidal products, ingestion bioassays on neonate larvae (F1 or F2 of the feral population) normally provide a more reliable indication of the field situation than topical application to diapausing larvae.**

**Insecticides & MoA for Codling Moth**

<table>
<thead>
<tr>
<th>No.</th>
<th>Primary Target Site</th>
<th>Chemical Class</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>Acetylcholinesterase inhibitors</td>
<td>Carbamates</td>
<td>Carbaryl, Methomyl</td>
</tr>
<tr>
<td>1B</td>
<td>Acetylcholinesterase inhibitors</td>
<td>Organophosphates</td>
<td>Azinphos-methyl, Chlorpyrifos, Dinrin, Malathion, Parathion, Phosmet, Phosalone, etc.</td>
</tr>
<tr>
<td>3A</td>
<td>Sodium channel modulators</td>
<td>Pyrethroids</td>
<td>Lambda-Cyhalothrin, Beta-Cyfluthrin, Cypermethrin, Deltamethrin, Etofenprox, etc.</td>
</tr>
<tr>
<td>4A</td>
<td>Nicotinyl acetocycline receptor agonists</td>
<td>Neonicotinoids</td>
<td>Acetamiprid, Thiociliprid</td>
</tr>
<tr>
<td>5</td>
<td>Nicotinyl acetocycline receptor agonists</td>
<td>Spinosyns</td>
<td>Spinosad, Spintorn</td>
</tr>
<tr>
<td>6</td>
<td>Chloride channel activators</td>
<td>Avermectins</td>
<td>Emamectin-benzoate</td>
</tr>
<tr>
<td>7B</td>
<td>Juvenile hormone mimics</td>
<td>Phosphinothricin -ethyllactate</td>
<td>Fenoxaprop-P-ethyl, Fenoxaprop-P-ethyl, Trifloxysulfuron, Diflubenzuron, Flumetsulam, Flumioxazole, Fluroxypyr, Trifluralin, etc.</td>
</tr>
<tr>
<td>15</td>
<td>Chitin biosynthesis inhibitors, type I</td>
<td>Benzyloxureas</td>
<td>Sulfurazin, Sulfentrazone, Flumioxazole, Norflurazon, Tribenuron, Tribenuron-Methyl, etc.</td>
</tr>
<tr>
<td>18</td>
<td>Ecdysone agonists</td>
<td>Dihydroxycarboxylic acids</td>
<td>Fafioketone, Methoxyfenozide</td>
</tr>
<tr>
<td>22</td>
<td>Voltage-dependent sodium channel blockers</td>
<td>Oxadiazines</td>
<td>Indoxacarb</td>
</tr>
<tr>
<td>28</td>
<td>Ryanodine receptor modulators</td>
<td>Dithianes</td>
<td>Flubendiamide, Chloroantranilpyrole</td>
</tr>
</tbody>
</table>

The local toolbox available for codling moth control in most countries will have fewer than the 11 modes of action available because of differences in product registrations, differences in efficacy, and differences in resistance levels based on how long a product or mode of action has been used. Consult with local experts and authorities to understand which products/MoAs are available.

**Design and produced by IRAC Codling Moth WG, April 2013, Poster Ver. 2.0**

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