Lepidoptera Insecticide Mode of Action Classification:

A key to effective insecticide resistance management

Insecticide Resistance Action Committee

www.irac-online.org

Introduction and background

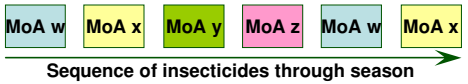
A great many of the world's key pest insect species belong to the order Lepidoptera. It is for this reason that the agrochemical industry has developed a broad range of very effective insecticides that can be used to control these insects. Unfortunately, as a consequence of the mis-use or over-use of these insecticides, many Lepidoptera species have developed resistances to them. The diamondback moth *Plutella xylostella* for example is especially well-known in this regard, having developed resistance to virtually every insecticide used against it, but there are many others.

In recent years the industry has worked especially hard to develop new types of insecticide with novel modes of action, and currently there are more classes of compound available than ever before. Nevertheless, this process is becoming ever harder and more costly. It is therefore vital to ensure that effective insecticide resistance management (IRM) strategies are implemented to ensure that resistance does not develop to these new compounds and to equally ensure that susceptibility is regained where resistance develops to older chemistries.

In order to help prevent or delay the incidence of resistance, IRAC promotes the use of a Mode of Action (MoA) classification of insecticides in effective and sustainable IRM strategies. Available insecticides are allocated to specific groups based on their target site as described below. By using sequences or alternations of insecticides from different mode of action classes, resistance is less likely. Available at the IRAC website www.irac-online.org, this IRAC MoA classification list provides farmers, growers, advisors, extension staff, consultants and crop protection professionals with a guide to the selection of insecticides in IRM programs.

Effective IRM strategies: Sequences or alternations of MoA

All effective insecticide resistance management (IRM) strategies seek to minimise the selection of resistance to any one type of insecticide. In practice, alternations, sequences or rotations of compounds from different MoA groups provide sustainable and effective IRM for pest Lepidoptera. This ensures that selection from compounds in the same MoA group is minimised, and resistance is less likely to evolve. Example:



Applications are often arranged into MoA spray windows or blocks that are defined by the stage of crop development and the biology of the Lepidopteran species of concern. Local expert advice should always be followed with regard to spray windows and timings. Several sprays may be possible within each spray window but it is generally essential to ensure that successive generations of the pest are not treated with compounds from the same MoA group.

Metabolic resistance mechanisms may give cross-resistance between MoA groups, and where this is known to occur, the above advice must be modified accordingly.

Midgut

Sprayable microbial insecticides with specificity to Lepidoptera, and toxins from them that are expressed in transgenic crop varieties. Toxins bind to midgut membrane and this leads to pore formation. Death results from septicaemia

Group 11 Microbial disruptors of insect midgut membranes

Toxins produced by the bacterium *Bacillus thuringiensis*

11B1 Bt sprays e.g. Bt subsp. kurstaki and individual Bt Cry proteins expressed in transgenic crop varieties (specific cross-resistance sub-groups)

Metabolic Processes

Insecticides acting on a range of processes.

Group 13 Uncouplers of oxidative phosphorylation via disruption of H proton gradient

Chlorfenapyr (pyrrole analogue)

Group 27 Synergists

Synergists are used to inhibit detoxifying enzymes. They counteract metabolic resistances.

27A P450-dependent monooxygenase inhibitors (e.g. Piperonyl butoxide [PBO])

27B Esterase inhibitors (e.g. Tribufos [DEF])

Cuticle synthesis

New cuticle is synthesised during the moult cycle. Inhibition of this process leads to insect death.

Group 15 Inhibitors of Chitin biosynthesis, Type 0, Lepidopteran

Benzoylureas (e.g. Flufenoxuron, Teflubenzuron) inhibit new cuticle synthesis

Moulting and Metamorphosis

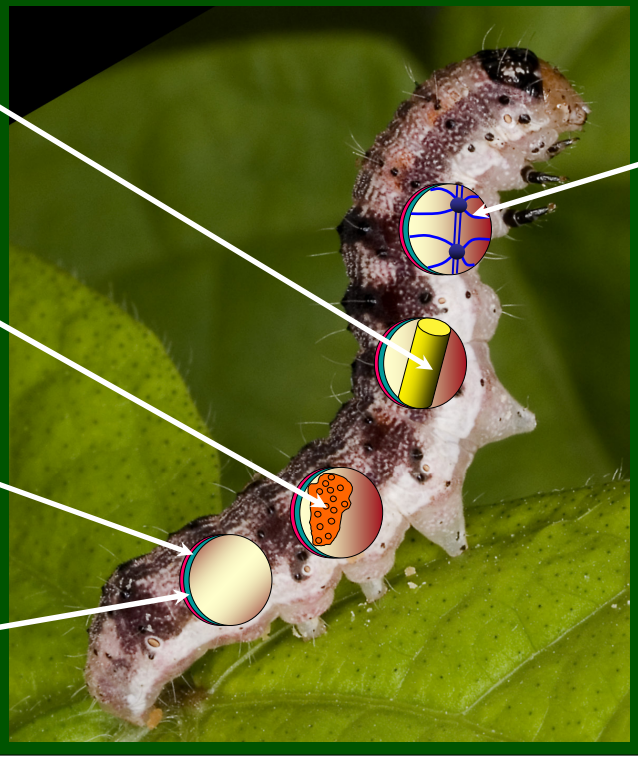
Moulting and metamorphosis are controlled by two hormones, ecdysone and juvenile hormone. Two groups of lepidoptericides interfere with these processes:

Group 7 Juvenile hormone mimics

7B Juvenile hormone analogues (e.g. Fenoxycarb) applied in the pre-metamorphic instar, disrupt and prevent metamorphosis

Group 18 Ecdysone agonists / moulting disruptors

18A Diacylhydrazines (e.g. Methoxyfenozide, Tebufenozide) act as ecdysone agonists



Nervous System

The nervous system is the target for most current insecticides. A range of insecticides with specific modes of action act at individual targets in this system. These insecticides are generally fast acting.

Stimulatory Nervous System Targets

Group 1 Acetylcholinesterase (AChE) inhibitors

1A Carbamates (e.g. Thiodicarb),

1B Organophosphates (e.g. Chlorpyrifos)

These compounds act as inhibitors of AChE at nerve synapses. This results in hyperactivity in the nervous system.

Group 3 Sodium channel modulators

DDT, Pyrethrins, Pyrethroids (e.g. Cypermethrin, λ-cyhalothrin)

Sodium channels are involved in the propagation of action potentials along nerves. These compounds interfere with their action, causing hyperactivity & nerve block.

Group 5 nAChR agonists (Allosteric) [not group 4A]

Spinosyns (e.g. Spinosad) act at the nicotinic acetylcholine receptor, interfering with the normal functioning of synapses.

Group 22 Voltage dependent sodium channel blockers

Indoxacarb blocks sodium channels and this leads to neural dysfunction.

Group 26 Aconitase inhibitors

Fluoroacetate

Group 28 Ryanodine receptor modulators

Diamides (e.g. Flubendiamide, Chlorantraniliprole) act at the neuromuscular junction and cause paralysis.

Inhibitory Nervous System Targets

GABA is an inhibitory neurotransmitter in the insect nervous. The GABA receptor is a target for a number of insecticide groups.

Group 2 GABA-gated chloride channel antagonists

These compounds bind to the GABA receptor complex and inhibit the action of GABA causing neuronal hyperactivity.

2A Cyclodiene Organochlorines (e.g. Endosulfan),

2B Phenylpyrazoles (e.g. Fipronil)

Group 6 Chloride channel activators

Avermectins (e.g. Abamectin, Emamectin benzoate) bind to the GABA receptor complex, mimicking GABA and causing paralysis.

Based on IRAC MoA classification scheme v5.2. Further details may be found at **www.irac-online.org.** Designed and produced by IRAC Communication & Education team, January 2007. Photograph courtesy of Nigel Armes.