Insecticide Resistance Management (535)

Modes of action of insecticides

Insecticides can be grouped in different ways, but the most common way is how they kill insects. We call this their **Mode of Action**. Insecticides work in one of four known ways - how a small number work is not yet known.

- Nerve and muscle: most insecticides target these, and they are usually fast acting
- Growth and development: the insecticides target the controls of growth and moulting, and are usually slow acting
- Respiration: the insecticides target mitochondria, the parts of cells that create energy, and are usually quite fast acting
- Midgut: the insecticides are specific toxins that target the gut, and they are quite slow acting

The Insecticide Resistance Action Committee (IRAC: www.irac-online.org) has divided these general modes of action further into 34 groups. Table 1 shows the groups to which the most frequently used classes of insecticides belong.

Table 1. Modes of action of classes of frequently used insecticides, with examples.

Mode of Action	Group	Class	Examples
Nerves (ACHE[1] inhibition)	1	Carbamates	Aldicarb, Carbaryl, Methomyl
	1	Organophosphates	Acephate, Dimethoate
Nerves (GABA Cl[2] blocking)	2	Organochlorines	Endosulfan
Nerves (Na channel, open)	3	Pyrethroids, Pyrethrins	Bifenthrin, Deltamethrin, Pyrethrum
Nerves (nACHR[3] binding)	4	Neonicotinoids	Acetamiprid, Imidacloprid
	4	Nicotine	Nicotine
Nerves (nACHR alteration)	5	Spinosyns	Spinosad, Spinetoram
Nerves (GluCL[4] activation)	6	Avermectins	Abamectin, Emamectin benzoate
Nerves (Na channel, close)	22	Oxadiazines	Indoxacarb
Muscle (RR activation)[5]	28	Diamides	Chlorantraniliprole, Flubendiamide
Growth (disrupt moulting)	7	JH[6] analogues	Methoprene
Growth (chitin inhibition)	15	Benzoylureas	Lufenuron, Teflubenzuron
Midgut (disruption/lysis)	11	*Bacillus thuringiensis*	Bt aizawai, Bt kurstaki
Respiration (mitochondria)	21	Rotenone	*Derris*, *Tephrosia*

[1]ACHE (Acetylcholine Esterase); [2]GABA Cl (Gaba-gated Chloride Channels); [3]nAChR (Nicotinic Acetylcholine Receptor); [4]GluCl (Glutamate Chloride channels); [5]RR (ryanodine receptors); [6]JH (juvenile hormone).

Fig. 1 Leaflet provided with all sales of Bt aizawai. It provides information on the mode of action and benefits of Bt, how it should be prepared and applied and its place in the IRM strategy for diamondback moth.

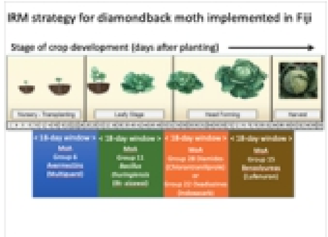

Fig. 2 Summary of insecticide resistance management strategy for diamondback moth in Fiji. "Windows" are time periods corresponding to the duration of the moth's life cycle. Insecticides with different modes of action are rotated in sequence to minimise the exposure of successive generations of the pest to insecticides that kill insects in the same way.

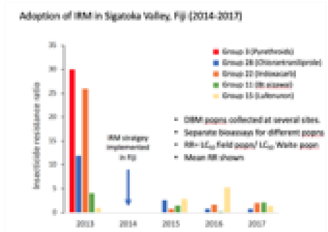

Fig. 3 Changes in the susceptibility of field populations of diamondback moth from the Sigatoka Valley, Fiji, to different insecticides following the adoption of the insecticide resistance management strategy (Resistance ratio = LC_{50} field population/LC_{50} Susceptible population.

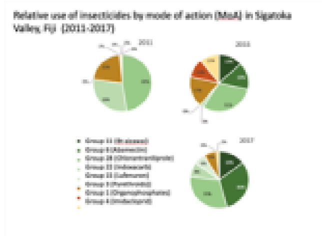

Fig. 4 Change in the use of insecticides with different modes of action before and after the implementation of the insecticide management strategy in the Sigatoka Valley, Fiji.

Insecticide resistance

However, some insects can evolve resistance to insecticides if repeatedly exposed to chemicals with the same mode of action. Heritable changes occur resulting in resistant/tolerant pest populations and reduced insecticide effectiveness - even when the insecticides are applied appropriately, according to label recommendations. These changes may be:

- At the site of action of an insecticide, so that it no longer attacks it effectively, or
- The way an enzyme works, allowing it to break down the insecticide before it can reach its target within the insect.

Insecticide resistance management (IRM)

IRM uses strategies to minimise the chances of insecticide resistance evolving in pest populations. The strategies are:

- Using IPM (integrated pest management) strategies where insecticides are only one method of insect control.
- Applying insecticides only when necessary, based on ‘thresholds’, i.e., the amount of damage that can be tolerated before insecticide use is essential. Treatments are applied when needed, not by ‘calendar’ – weekly, every 10 days, etc.
- Applying insecticides belonging to different mode of action groups, alternating their use within an IPM strategy. Insects resistant to insecticides with one mode of action are likely to be susceptible to insecticides with a different mode of action that kills them in a different way.

The outcome of the strategies is to preserve sufficient susceptible individuals in the population to mate with those that are resistant/tolerant so that susceptible offspring continue to be produced.

Developing an IRM strategy - 'windows' approach

Combined, the strategies above aim to reduce the selection pressure on insect populations and preserve susceptible individuals.

In practice, a 'windows' approach is used: (i) treating consecutive generations of insect with chemicals of different modes of action; and (ii) rotating modes of action after a period that corresponds to the generation time for the target pest in its local environment (the 'window').

To support this approach, the following is suggested:

- Ensuring that the mode of action (= Group number) of all insecticides used is known.
- Applying insecticides appropriately, according to label instructions.
- Never applying insecticides with the same mode of action to a crop simultaneously or continuously.
- Farmers and other stakeholders (pest advisors, extension officers, pesticide retailers, government agencies, NGOs and universities) need to work together to share information about insecticide use and failures of products. As insects are mobile and move between fields and farms, IRM is most effective when coordinated over large areas.

IRM diamondback moth, Fiji

Diamondback moth (DBM) is a serious pest of cabbage and Chinese cabbage in the Pacific. In 2013, resistance to deltamethrin (Group 3), indoxacarb (Group 22) and chlorantraniliprole (Group 28) was detected in field populations of DBM in the Sigatoka valley, Fiji. The only other insecticides readily available at the time were lufenuron (Group 15) and abamectin (Group 6).

An IRM strategy was devised based upon:

- Reliable availability of Bt aizawai (Group 11), a key alternative insecticide.
- Awareness of IRM strategy, including appropriate preparation and application of insecticides with each sale of Bt aizawai (Fig. 1).
- Recommending Bt aizawai in the second 'window' when plants were at their most susceptible to attack but were mature enough to shelter natural enemies (predators and DBM specific parasitoids).
- An IPM approach integrating monitoring (pest and natural enemies) and threshold-based applications of insecticides. Removing IPM incompatible insecticides [e.g., pyrethroids (Group 3) and organophosphates (Group 1)] from DBM control management strategies.
- Rotating insecticides with different modes of action in 'windows' that corresponded to the local generation time of DBM (18 days) (Fig. 2).

The strategy was adopted in 2014. By 2015, the susceptibility of field populations of DBM to indoxacarb and chlorantraniliprole had increased and the susceptibility to all insecticides used in the strategy was maintained through 2017 (Fig. 3), leading to a marked change in the use of insecticides for DBM control (Fig. 4).

AUTHOR: Mike Furlong
Information from IRAC: www.irac-online.org; and from Atumurirava F, *et al.* (2021). Development, implementation and monitoring of an insecticide resistance management strategy for diamondback moth in the South Pacific. VIII International Conference on Management of the Diamondback Moth and Other Crucifer Insect Pests, Shanhua, Tainan, Taiwan, 4-8 March 2019. Shanhua, Tainan, Taiwan: World Vegetable Center.

Produced with support from the Australian Centre for International Agricultural Research under project HORT/2016/185: *Responding to emerging pest and disease threats to horticulture in the Pacific islands*, implemented by the University of Queensland, in association with the Pacific Community.