

## INSECTICIDE RESISTANCE MANAGEMENT IN URBAN PESTS

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**Abstract** Whilst the reports of insecticide resistance are numerous, and many mechanisms of resistance have been studied, there has been less emphasis placed on developing and promoting Insecticide Resistance Management (IRM) programmes to address this issue. It is argued that only through the implementation of an IRM programme, can the effective control of insect pests be maintained in the long-term. The Insecticide Resistance Action Committee's insecticide mode of action classification is a key part of any IRM programme. It enables the insecticide user to identify insecticides in the same class, and hence those that will provide selection pressure for resistance mechanisms which may affect all insecticides from that class. A model is also presented that identifies the path of activities and events that follows when a decision is taken to control an insect pest, and how they impact, and are impacted by, insecticide resistance development. The IRAC mode of action classification and the model of insect pest control can be used to develop effective and integrated IRM programmes.

**Key words** Integrated pest management.

### INTRODUCTION

There are many reports and papers published describing insecticide resistance in urban insect pests. However, few offer practical advice on how to minimise the development of insecticide resistance, or how to manage the pest population when reduced susceptibility to a given insecticide has been identified. Insecticide Resistance Management (IRM) is a practical approach to managing an insect pest population in such a way that the effectiveness of the control interventions are maintained in the long run.

The Insecticide Resistance Action Committee (IRAC) was formed in 1984 and is a specialist technical group of the agrochemical industry association CropLife International. IRAC was created to provide a coordinated industry response to the development of resistance in insect and mite pests, and has the aim of promoting resistance management for sustainable agriculture and improved public health (McCaffery and Nauen, 2006). IRAC defines insecticide resistance as, "a heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a product to achieve the expected level of control when used according to the label recommendation for that pest species" (IRAC, 2011).

### DISCUSSION

Synthetic insecticides have been extensively used since the 1940s to control urban and public health insect pests. However, insecticide resistance rapidly developed, with house flies resistant to DDT identified only a few years after its introduction in 1949 (Keiding and Van Deurs, 1949). By 2012, the

Michigan State University Arthropod Resistance Database contained 10357 reports of resistance in 574 species of arthropod to 338 pesticides (Whalon et al., 2012).

The loss of susceptibility to an insecticide in an insect pest population has a number of undesirable consequences. The pest controller will have a smaller choice of insecticides to use when controlling that pest population. Insecticides with less desirable environmental properties may need to be used. Higher insecticide application rates may be used in an attempt to control the resistant population, resulting in increased burden on the environment. Pest numbers may increase as the population becomes harder to control; this is of particular concern if the pest is of public health importance.

Resistance develops due to selection pressure on an insect population where a subset of the population is able to survive and reproduce after exposure to an insecticide application. The mechanisms by which insect pests resist insecticides has been widely reviewed elsewhere (Hemingway and Ranson, 2000; Nauen, 2007). If a heritable trait allows the individuals to survive the insecticide exposure, then the proportion of the population carrying that trait will increase post exposure. Subsequent exposure of that population to the same insecticide, or one with the same mode of action, will result in a still greater proportion surviving, potentially leading to control failure. Depending on the mechanism of resistance, insects with reduced susceptibility to one insecticide are likely to also have reduced susceptibility, or cross resistance, to other insecticides with the same mode of action. IRAC has produced a mode of action classification to identify which insecticides share the same mode of action (Elbert et al., 2008). Regularly updated, this mode of action classification can be accessed online (<http://www.iraconline.org/>).

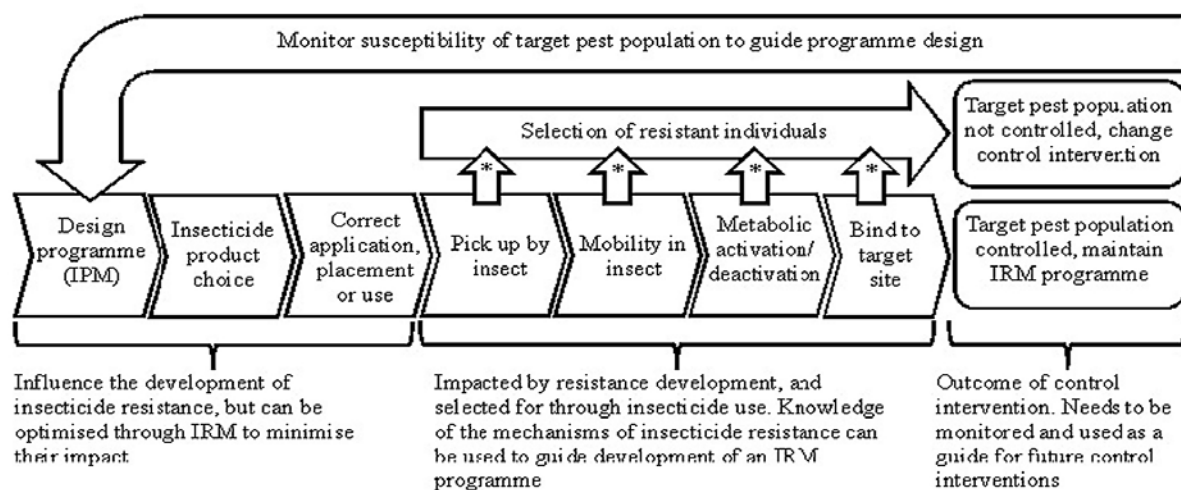
Behavioural resistance is an expression of insecticide resistance that is independent of mode of action class. It occurs when an insect population is still susceptible to an insecticide, but individuals have altered their behavior, such that they don't come into contact with the application. Bait aversion is the classic example of behavioural resistance. Silverman and Ross (1994) reported that a number of field populations of German cockroach, *Blattella germanica*, displayed avoidance behaviour to a cockroach bait formulation. These populations, therefore, did not pick up a lethal dose of insecticide and were not controlled. It was found that they were averse to glucose, a constituent of the bait matrix. Replacement of glucose with fructose significantly improved bait acceptance and hence efficacy.

The key to preventing the development of insecticide resistance in a pest population is to minimise the selection of the genes that confer the ability to survive the insecticide application. Insecticide resistance is often conferred by a number of mechanisms, which work together to resist a full label dose of the insecticide. Individually, they may only confer "resistance" to a sub-label dose, or incomplete application. Insect pests that have only developed partial, or low level resistance to a given insecticide class, may still be controlled by exposure to an application at the recommended label rate. As only individuals that survive the insecticide application can pass on their genes for reduced susceptibility, actions that ensure these individuals are controlled will minimise the further selection of insecticide resistance. These actions include non-insecticide based activities that reduce or exclude the pest population and can be summarised as best practice integrated pest management (IPM). A number of authors outline effective IPM strategies for urban pests and highlight the benefits from taking this approach (Lacey, 2002). Further information on IPM and IRM strategies is also given by IRAC (2011).

Figure 1 shows the activities and events that occur when an insecticidal intervention is used to control a pest population. The first step is to design the control programme and identify whether an insecticidal intervention is required, or whether the pest population can be reduced to an acceptable level through exclusion, and removal of conducive conditions. If insecticides are required, to minimise the selection pressure for resistance development, only insecticides to which the target pest is known

to be susceptible, should be used. Insecticides from the same mode of action class should not be continuously used at a given location; instead insecticides with different modes of action should be rotated through time. If a large area is to be treated, within which the target pest population can freely move, it is beneficial to employ a matrix approach, where insecticides with different modes of action are used in different locations within the treated area. Once the most appropriate insecticide class is chosen, the choice of insecticide product should be based upon fitness for purpose. “Fit for purpose” should include overall efficacy of the product, and suitability for its use under the conditions where it will be deployed. The insecticide product label should be followed using correctly calibrated and serviced application equipment. The applicator should be trained in the effective and safe use of the product, and have sufficient knowledge to correctly identify the target pest and the biology pertinent to its control. Under-dosing, incorrect placement, the use of substandard products and poorly timed applications, will increase the probability of the target pest being exposed to a sub-label dose, increasing the likelihood that individuals with reduced susceptibility will survive.

Figure 1 covers the four steps in the journey the insecticide needs to make to control the pest population, highlighting potential losses *en route*. Reduced susceptibility at each step, manifested as a reduction in the available insecticide capable of binding at the target site, can limit the control of the pest. By effectively delivering the recommended label dose of the insecticide to the target pest population, the impact of the potential loss mechanisms are reduced, and a greater proportion of the target pest population will be controlled. This increases the effectiveness of the control intervention, and minimizing the probability of reduced susceptibility developing.



- \* Insecticide loss as a result of: altered behaviour reducing interaction with the insecticide, reduced ability of insecticide to penetrate insect cuticle or gut, metabolic inactivation or sequestration, or failure to bind at an altered target site.

**Figure 1.** Model of the activities and events that occur when an insecticidal intervention is used to control a pest population

## CONCLUSIONS

Insecticide susceptibility in a pest population is a valuable asset which needs to be maintained. Actions which minimise the selection pressure for resistance development, before an insecticide resistance

problem is identified in the target pest, should therefore be encouraged. IRM should be considered as part of a wider IPM programme. Rotations and mosaics of insecticides from different mode of action classes form the basis of an IRM strategy. The IRAC mode of action classification scheme is a valuable tool to support the informed selection of insecticides for such rotations and mosaics. An appreciation of the activities and events that occur when an insecticidal intervention is used to control a pest population, exemplified in the model presented in Figure 1, help to identify those that can be optimised in the development of an effective IRM programme.

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