THE INSECTICIDE RESISTANCE ACTION COMMITTEE (IRAC): PUBLIC RESPONSIBILITY AND ENLIGHTENED INDUSTRIAL SELF-INTEREST

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Introduction

Effective management of pest insect populations in most of the world's agriculture and horticulture is dependent on a variety of inputs including a ready supply of safe, highly efficacious chemical insecticides. Likewise, effective control of insect pests of animal health and public health is also highly dependent on the availability of insecticidal products. With their abundant numbers and short life-cycles, populations of pest insects can readily develop resistance to the insecticides used against them with the result that once effective insecticides are no longer able to control the pests for which they were intended. Accordingly, resistance may be usefully defined 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'. This definition differs slightly from others in the literature, however we believe it represents the most accurate, practical definition of relevance to farmers and growers. The agrochemical industry views resistance as an extremely serious threat and an issue that needs a proactive approach. Effective insecticide resistance management (IRM) is essential and the industry-wide Insecticide Resistance Action Committee (IRAC) is dedicated to making this a reality.

IRAC and its Aims

IRAC was formed in 1984 to provide a co-ordinated crop protection industry response to prevent or delay the development of resistance in insect and mite pests. The main aims of IRAC are firstly to facilitate communication and education on insecticide resistance and secondly to promote the development of resistance management strategies in crop protection and vector control so as to maintain efficacy and support sustainable agriculture and improved public health. It is IRAC's view that such activities are the best way to preserve or regain the susceptibility to insecticides that is so vital to effective pest management. In general, it is usually easier to proactively prevent resistance occurring than it is to reactively regain susceptibility.

Organization of IRAC

Along with the other Resistance Action Committees, IRAC is an inter-company organisation that operates as a Specialist Technical Group under the umbrella of CropLife International. IRAC is also recognised by The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) of the United Nations as an advisory body on matters pertaining to resistance to insecticides. The group's activities are coordinated by the IRAC Executive Committee, IRAC International (Table 1), and Country or Regional Committees with the information disseminated through conferences, meetings, workshops, publications, educational materials and the IRAC Website (www.irac-online.org). IRAC International is comprised of key technical personnel from the agrochemical companies

Table 1. IRAC International Executive Committee, 2005

Alan McCaffery	Chairman, Mode of Action	Syngenta
Ralf Nauen	Vice Chairman, Treasurer, Neonicotinoids Team Leader	Bayer CropScience
Max Angst	Codling Moth Team Leader	Syngenta
Nigel Armes	Communication & Education Team Leader, Methods	BASF
Andrea Bassi	Regulatory Team	DuPont
Jamin Huang	Regulatory Team	Bayer CropScience
Alan Porter	IRAC Coordinator, Website	APA (Consultant)
Chuck Staetz	IRAC-US Liaison	FMC
Nicholas Storer	Biotechnology Team Leader	Dow AgroSciences
Gary Thompson	MSU Resistance Database and Newsletter	Dow AgroSciences
Jean-Pierre Vialaneix	Regulatory Team	BASF

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affiliated with CropLife through membership in the relevant National Associations (ECPA, CropLife America etc). Current member companies are BASF, Bayer CropScience, Dow AgroSciences, DuPont, FMC and Syngenta. The International Committee supports resistance management project teams and also provides a central coordination role to regional, country and technical groups around the world. IRAC Country Groups frequently include additional member companies of relevance to that area, but sometimes also non-industrial members. Clearly, not every insecticide manufacturer is a member of IRAC and a particular challenge that the organization faces is how to maintain effective resistance management in markets where generic insecticides are widely used and where effective IRM is not a priority.

IRAC Focus

A current focus of IRAC is on education and communication on resistance issues, a role well suited to its technical foundation. Much of this activity is channelled through the website and in recent years particular emphasis has been placed on a complete redesign of the website to enable it to operate effectively in this capacity (see below). In addition, the gathering momentum for increased regulation of pesticides, especially in Europe, demanded supportive advocacy for IRM based on the availability of a broad range of insecticidal materials with different modes of action. IRAC has thus strived to influence and provide advice to those bodies involved in regulation in order to maintain the tools needed for successful IRM. To enable it to operate effectively in all these roles IRAC International has acquired the services of a co-ordinator with particular responsibilities to develop and manage IRAC's largely website-based communication and education programme. Thus, IRAC is tackling resistance on a broad range of fronts and these wide-ranging general activities are summarised below.

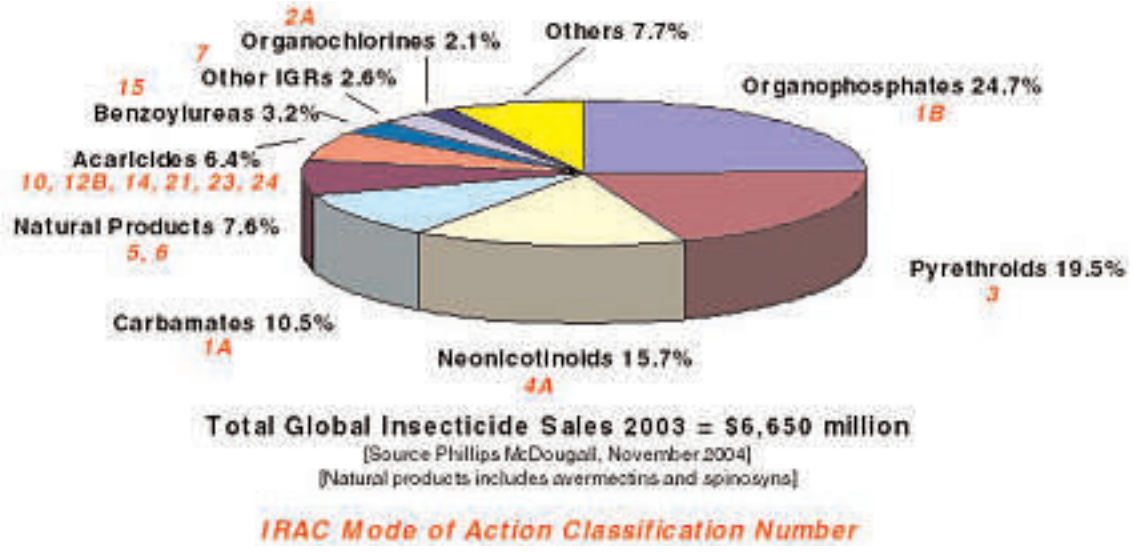
Education and Communication

The IRAC Web site is the focus and primary resource for educational and communication material to academia, researchers, industry, authorities and growers. In conjunction with the web site (http://www.irac-online.org/) a number of tools have been developed. These currently include eConnection a free IRAC newsletter distributed by email, eClassification, an interactive tool to understand and exploit the different modes of action of insecticides (see below), and currently in development is eLearning, an on-line education resource on resistance, its development and IRM strategies. In addition to using centrally developed resources, most of the IRAC country groups have educational programs in place, tailored to meet local needs. IRAC US, for example, publishes articles on a regular basis in grower magazines and IRAC Brazil holds training workshops in different locations. Other IRAC Country Groups such as Australia, South Africa, Spain and India have similar ongoing initiatives.

IRAC Projects

When first formed IRAC was able to sponsor a number of resistance research projects. With fewer members as a result of mergers and acquisitions, this sponsorship is less appropriate. Nevertheless, IRAC groups are actively involved in a variety of resistance management projects around the world. These are generally driven or coordinated by the local country group and in some cases a specific project group is set up to lead and ultimately report the results and findings into the public domain. Examples of these have been the long term monitoring of mosquito resistance in Mexico (Penilla et al., 1998) and the monitoring of pyrethroid resistance in the cotton bollworm *Helicoverpa armigera* (Hübner) in West African cotton. IRAC also supported the Common Fund for Commodities project to manage resistance in small-scale cotton farming in India, Pakistan and China. Currently, an IRAC-India group is beginning to tackle issues of resistance to insecticides in the Brown Planthopper *Nilaparvata lugens* (refer to eConnection #8 on IRAC website).

Figure 1. Major chemical classes of insecticides and their market share



The IRAC Mode of Action Classification Scheme

In consultation with technical experts from the industry and academia, IRAC has developed a definitive classification of insecticides based on mode of action (MoA). This list is maintained as a single global source for such information. It is based on the fact that in the majority of cases, not only does resistance to an insecticide render the selecting compound ineffective, but it often also confers cross-resistance to other chemically related compounds. This is because compounds within a specific chemical group usually share a common target site within the pest, and thus share a common mode of action (MoA). Major chemical classes of insecticides including their IRAC MoA classification number and market share are shown in Figure 1. It is this concept of cross-resistance within chemically related insecticides or acaricides that is the basis of the IRAC mode of action classification.

Experience has shown that all effective insecticide or acaricide resistance management strategies seek to minimize the selection for resistance from any one type of insecticide or acaricide. In practice, alternations, sequences or rotations of compounds from different MoA groups provide growers with sustainable and effective IRM. This ensures that selection from compounds in any one MoA group is minimized. The IRAC classification thus ensures that insecticide and acaricide users are aware of mode of action groups and that they have a sound basis on which to implement season-long, sustainable resistance. Of course, to help delay resistance it is strongly recommended that growers also integrate other control methods into insect or mite control programmes.

We do know that resistance of insects and mites to insecticides and acaricides can, and frequently does, result from enhanced metabolism by enzymes within the pest. Such metabolic resistance mechanisms are not linked to any specific site of action classification and therefore they may confer cross-resistance to insecticides in more than one IRAC MoA group. Where such mechanisms are known to give cross-resistance between MoA groups, it is clear that the use of insecticides should be modified appropriately.

Resistance Monitoring Methods

Reliable data on resistance, rather than anecdotal reports or assumptions, is the cornerstone of successful resistance management and key to this is the availability of sound baseline data on the susceptibility of the target pest to the toxicant. A large number of bioassay and biochemical tests are used to characterize resistance, but they are not necessarily comparable because different parameters and criteria are used. IRAC has evaluated, validated and published a wide range of testing methods and these are freely available on the IRAC website. New methods and alternative options such as biochemical and molecular methods are being considered and if approved these will be added to the list.

Regulatory Approvals and Support

IRAC (along with the other Resistance Action Committees) has taken a leading role as an expert group providing industry responses to proposals from regulatory bodies. For example, there is now a regulatory requirement in the European Union under Directive 91/414/EEC for companies to provide an assessment of the potential risk of resistance being developed by target organisms and for management strategies to be introduced to address such risks (McNamara and Smith, 2000). This is necessary to sustain the activity of as many active ingredients with different modes of action as possible over a long time period by alternate spray regimes, rotation and sophisticated application techniques. This problem has been recognised by the regulatory authorities, and the European and Mediterranean Plant Protection Organization (EPPO) recently published guidelines outlining the requirements for background work on resistance issues in order to obtain re-registration of established insecticides or approval of new ones. Baseline susceptibility studies (testing several strains of a target species known to develop resistance easily), monitoring (continuous studies on the development of resistance of target species by simple bioassays after the launch of a new compound or for re-registration purposes) and possible resistance management strategies (how should compounds be combined with others in order to expand their lifetime in the field) have now to be provided by the agrochemical companies as an essential part of the registration dossiers (OEPP/EPPO, 1999). The Resistance Action Committees (RACs) have been instrumental in developing workable guidelines for companies, resulting in the publication of an official Guidance Document (EPPO Std. PP 1/213(1) and (2)).

Similarly, the U.S. Environmental Protection Agency (EPA) and the Pest Management Regulatory Agency of Canada have been developing a voluntary pesticide resistance management labeling scheme based on mode action on the pest. IRAC has been heavily involved in classifying insecticides into specific groups and families (see MoA classification) to enable the scheme to work. Development has been carried out under the auspices of the North American Free Trade Association and has resulted in the issue of a Pesticide Registration (PR) Notice in the United States. A similar labelling scheme operates in Australia.

The Insecticide Resistance Action Committee (IRAC) has for some time been highlighting its considerable concern at the removal of many crop protection insecticides from the European market. IRAC strongly believes that this continuing reduction in the toolbox of available insecticides inevitably leads to an increased risk of the devlopment of resistance to remaining products. Although this is a clear issue for minor crops, the problem is not restricted to them. For example, the deregulation of a number of organophosphate insecticides that were very effective for the control of the pollen beetle (*Meligethes aeneus*) in oilseed rape crops in many European countries has resulted in almost total reliance on the synthetic pyrethroids, and exclusive use of this group of insecticides has led to the development of resistance (Nauen, 2005).

Conclusions: IRAC and Effective Insecticide Resistance Management

Given the ever-increasing cost and difficulty of discovering new active ingredients with novel modes of action that not only circumvent existing resistance problems but that pass increasingly stringent regulatory hurdles, IRAC believes that it is absolutely vital to ensure the sustained efficacy of the broad range of modern, safe and effective insecticides that the agrochemical industry produces. The concept that susceptibility is a highly valued commodity is clearly central to this approach. Indeed, such a resource should not be squandered indiscriminately through the misuse or over-use of insecticides. Effective insecticide resistance management is therefore not an option; it is essential and it is one of the most challenging issues in modern applied entomology. As a responsibility to its customers, and in the interests of protecting the industry's products, IRAC is undertaking a broad range of activities to help make successful IRM possible.

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