Why effective Insecticide Resistance Management is Important

The effective management of populations of pest invertebrates of public health, veterinary, agricultural and horticultural importance is dependent on a variety of inputs including the use of safe and efficacious chemical insecticides. Accordingly, for over half a century the agrochemical industry has strived to develop the most effective and sustainable products possible to meet the increasing global demands for improved public health and the ready availability of abundant food and fibre. A key challenge for the industry has thus been to expand the toolbox of available products by maintaining a steady flow of new, ever-more effective insecticides with novel modes of action that also meet the increasingly stringent regulatory standards for human and environmental safety.

It has proved equally challenging to protect and maximise the benefits of developing new insecticides by maintaining the effective life of these products in the field. This is because with their abundant numbers and generally short life-cycles, pest insects under continuous selection pressure can readily develop resistance to the insecticides used against them. By 2005, the number of species of insect that had developed resistance to one or more groups of insecticides was estimated to be well over 500. More recently, increasingly greater numbers of pest species of public health importance have evolved resistance, as insecticide use in these sectors has expanded. Moreover, a number of cases of insecticide resistance are currently critical with some key species having few or no available effective classes of insecticide available.

Given the inherent ability of insect populations to evolve resistance, it is imperative to develop and implement effective insecticide resistance management (IRM) strategies at an early stage in the commercial life of an insecticidal product, so that resistance is prevented or delayed. Similar strategies may be employed to solve existing resistance problems, although it is readily acknowledged that it is much easier to proactively prevent the development of resistance than it is to reactively solve resistance problems once they have developed. Effective IRM is absolutely vital and one of the most challenging issues in modern applied entomology. This is amply illustrated by the fact that insecticide resistance issues are central to mans' efforts to control major vector borne diseases and improve agricultural production.

The socioeconomic burden associated with tropical diseases such as malaria, dengue, filariasis and trypanosomiasis is a serious impediment to development in many tropical countries, and most of these diseases are not only major health concerns but also a major cause of poverty. It is estimated that malaria alone has reduced the gross national product of the African continent by more than 20% over the past 15 years. Vector-borne diseases account for a very significant part of total morbidity due to infectious diseases, and occur not only in the tropics but also in many temperate countries. Recent estimates indicate that there are 300-500 million clinical cases of malaria annually, leading to more than one million deaths, mostly children.

In high-transmission areas (which include most parts of Africa) malaria incidence cannot be reduced if, in parallel with early diagnosis and treatment, transmission is not controlled

through very effective vector-control and/or personal-protection interventions. Accordingly, insecticides remain the most important element of integrated approaches to vector control. Although public health accounts for only a very small fraction of overall insecticide quantities applied, many vector species of public health importance have already developed resistance to one or more insecticides. Whilst the use of IRM strategies employing a number of compounds with different mode of action is ideal, the control of adult mosquitoes depends entirely on insecticides with just two modes of action in the insect nervous system (please refer to page xx in this journal). The loss of useful compounds and the development of widespread resistance to existing compounds highlight the urgent need for a new mosquito adulticide.

New technologies such as insecticide-treated bednets (ITNs) and insecticide-treated materials (ITMs) are now highly promoted and used to protect particularly children and pregnant women. However, ITNs still remain highly dependent on a single class of insecticides; the synthetic pyrethroids. The massive efforts currently developed to control malaria, especially in Africa, may be jeopardized by the widespread development of pyrethroid resistance due to the permanent exposure of adult mosquitoes to this class of insecticides.

It is also important to understand that almost all public health insecticide classes are also used in agriculture. When vectors breed within or close to agricultural crops, they can be exposed to the same or similar insecticidal compounds and develop resistance. This phenomenon is of particular relevance for malaria vectors. Such considerations underline the importance of resistance experts in both sectors working together to manage resistance.

In the crop protection sector, the use of insecticides is vital to improve and maintain agricultural and horticultural productivity and to feed an ever-growing world population. It has been estimated that by 2020 the world's population will have increased to 7.5 billion (6.0 billion in 2000) but that the area of arable land and permanent crops will remain unchanged. This will result in the area of farmland required to support each person decreasing from 0.3ha in 2000 to 0.2ha in 2020 and it highlights a strong need for more intensive crop production.

At one time it was believed that the agrochemical industry could always invent ways out of resistance problems by developing new insecticides with novel modes of action which would be unaffected by pre-existing resistance mechanisms. Such an approach assumed that an endless supply of such new compounds was possible, and it likewise assumed that it was acceptable to use new insecticides indiscriminately until they failed. Modern, more enlightened approaches acknowledge that it is hugely expensive, very time-consuming and not at all easy to develop new insecticides. Estimates from the European Crop Protection Association (ECPA) in 2003 suggest that the cost of developing a new active ingredient is $184m. Registered compounds should therefore be regarded as valuable resources, and protected from resistance developing to them.

An essential feature of modern, successful IRM strategies is the availability of a toolbox of insecticidal compounds with a broad range of modes of action. Experience has shown that all effective insecticide resistance management strategies work by reducing the selection for resistance from any one type of insecticide or mode of action. This can be achieved by various means including the use of sequences, alternations, rotations, mixtures or mosaics of insecticides.

The major manufacturers of insecticides are all committed to good product stewardship to sustain and prolong the effective commercial life of their products. The development and implementation of successful IRM strategies forms a key part of this effort. The knowledge gained from research studies on resistance helps to sustain valuable effective products in the market place. Depending on the individual resistance management issues concerned, companies may collaborate to harmonise the IRM requirements for compounds from a single mode of action group, even though they are developed and marketed by different companies. This is vital if growers and pest control professionals are to understand the IRM strategies they are required to implement at a practical level.

At an all industry level, the **Insecticide Resistance Action Committee** (IRAC) is an inter-company organisation that operates as a Specialist Technical Group under the umbrella of CropLife International. IRAC was formed in 1984 to provide a co-ordinated 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. 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 International committee, 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 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, Sumitomo 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.

More recently much attention has been focussed on the need for effective vector control, highlighted by the development of widespread resistance to the key insecticide classes used for vector control. To tackle this problem WHO, the Insect Vector Control Consortium (IVCC) funded by the Bill & Melinda Gates Foundation and IRAC are joining forces. IRAC has responded recently by forming a specialist Public Health Team to work with these bodies and to provide the technical inputs necessary to help combat insecticide resistance in key vector species. One of the IRAC Public Health team's first actions has been to develop a manual on the 'Prevention and Management of Insecticide Resistance in Vectors and Pests of Public Health Importance'.

Clearly, the manufacturers of insecticides put great efforts into sustaining the effectiveness of their products and avoiding resistance problems. As indicated earlier, this is done not only as a part of responsible product stewardship, but also because susceptibility to particular modes of action is valuable, and once lost they may be hard or impossible to recover. Strict adherence to IRM guidelines and application requirements, consultation with local IRM experts and integration of good integrated crop or pest management systems will help preserve susceptibility. In short, the management of resistance is vital and it is everyone's responsibility.