

**THE INSECTICIDE RESISTANCE  
ACTION COMMITTEE:  
EDUCATION INITIATIVE  
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**Abstract**

Resistance to crop protection agents threatens the economic viability of the crop protection industry. To address resistance in arthropods to crop protection agents industry has formed Insecticide Resistance Action Committees (IRAC) on the global and country level. IRAC committees have three major activities: 1) conducting resistance surveys on the extent and type of resistance and developing methods to conduct surveys, 2) developing sound resistance management guidelines and sponsoring research to confirm their effectiveness, and 3) assisting with educational efforts and implementation of management strategies. An overview of IRAC progress and future plans in these areas is provided.

**Introduction**

The crop protection industry has always had a vested interest in preventing the development of resistance to their products. It is an industry dependent on a narrow market segment for survival. The development of resistance by an important pest can have devastating economic effects in farming communities that can rapidly expand to regions and even national levels eliminating an entire customer base. It is also quite evident that there have been very few crop protection agents discovered with different modes of action that are practical to use when safety profiles, economics and efficacy are considered. The time and cost to discover and develop crop protection agents has increased from 3 to 5 years and 10 million dollars to 7 to 10 years and 60 to 100 million dollars or more. To recover these costs, it takes industry greater than 10 years of commercial success. The failure of a product at any time in its life cycle due to resistance seriously limits the ability of the registrant to recover their investment and pursue advanced technologies as well as reducing the ability to sustain a viable customer base. The net result is an overwhelming economic incentive to industry to understand and combat resistance and to do it in concert with university researchers, government agencies such as the Cooperative Extension Service, the EPA, and other registrants.

To organize these cooperative industry efforts the Insecticide Resistance Action Committee (IRAC) was founded in 1984 (1,2). It operates as an expert committee

of GIFAP, the international voice of the crop protection associations, the American and European Crop Protection Associations (ACPA & ECPA) and SACI, the Japanese Agrochemical association (figure 1). IRAC is recognized as an advisory body to the World Health Organization (WHO) of the United Nations and the Food and Agricultural Organization (FAO). Similar committees to fight herbicide (HRAC), fungicide (FRAC) and rodenticide (RRAC) resistance also have been formed.

To improve the effectiveness of the committee, country and regional IRAC sub-committees have been formed including IRAC U.S., IRAC China, IRAC Pakistan, and IRAC Mexico. Commodity specific working groups such as Top Fruit and Cotton meet at the global and national level. In the past, working groups around modes of action such as the Pyrethroid Efficacy Group or PEG have been formed to improve efficiency and to focus on crisis situations. Working groups are formed as needed but are disbanded as soon as a general approach will satisfy the need (3).

Membership of IRAC and its sub-committees is open to any company producing or planning to market insect or acaricide control products. Each participating company in good standing is allowed one voting member. There is an annual assessment fee to fund educational and research activities. Additionally and just as importantly, members are able to coordinate their internal resistance related educational and research activities with either IRAC projects or with other member company activities to maximize the benefits to the science of resistance management. *Ad hoc* members also join the committees as needed. IRAC US now has permanent *ad hoc* members from the National Cotton Council, Cotton Incorporated and the WRCC 60.

**Functions and Achievements**

IRAC activities to date have focused on 1) conducting resistance surveys on the extent and type of resistance and developing methods to conduct surveys, 2) developing sound resistance management guidelines and sponsoring research to confirm their effectiveness, and 3) assisting with educational efforts and the implementation of management strategies.

**Surveys**

The basic method for solving most problems is to first characterize the problem, identify the root causes, and establish measurements which can be monitored to see if progress is or is not being made. The majority of IRAC's efforts the past ten years have been along these lines. The first effort was an internal survey based on member companies' documented experiences of product failures in field use. This comprehensive survey of known or suspected cases around the world was first conducted in 1985 and it has been updated approximately every other

year. In recent years inputs from additional researchers and sources have been included. The survey was updated in 1995. The 1992-93 version was published in the Pesticide Manual (4) and the output from the survey is also available in a spreadsheet format which can be searched or sorted. This IRAC survey is often a judgmental call by area specialists and it is not totally complete on a global basis since some areas are not reported. It is, however, the most comprehensive and accurate survey on insecticide resistance available. Guidelines for being included in the survey are:

1. The product for which resistance is being claimed carries a use recommendation against the particular pest mentioned and has a history of successful performance.
2. Product failure is not a consequence of incorrect storage, dilution or application and is not due to unusual climatic or environmental conditions.
3. The recommended dosages fail to suppress the pest population below the level of economic threshold.
4. Failure to control is due to a heritable change in susceptibility of the pest population to the product.

It should be noted that mention of a particular country/crop does not mean that the entire crop area will be affected by the resistant arthropod and the susceptibility and distribution often vary considerably.

An example of the survey database under the category of resistance to organophosphorous insecticides for the crop cotton, where chemical control is difficult or impractical during 1992 to 1993 resulted in the following partial list:

*Aphis gossypii*: Greece, Turkey, Thailand, South Africa, USA, China.  
*Bemisia tabaci*: widespread extending to Ethiopia, Israel, Turkey, Peru, Mexico.  
*Bucculatrix thurberiella*: Peru & Mexico  
*Heliothis virescens*: USA  
*Helicoverpa armigera*: Thailand  
*Spodoptera exigua*: Central America and Mexico  
*Spodoptera littoralis*: Israel, Turkey, & Egypt  
*Tetranychus cinnabarinus*: South Africa and Turkey

Additional categories include cases of resistance which are less important but still require careful observation: rice, fruit crops, field crops, vegetables, ornamentals, stored products, public health vectors, and animal health; and the chemical classes of carbamates, chlorinated hydrocarbons, organotins, benzoylurea, ovicides of the clofentezine & hexythiazox type, formamidines, phosphine, and pyrethroids.

The establishment of measurements to monitor resistance management progress has been primarily conducted by establishing base line susceptibility databases. IRAC has facilitated this process by collecting existing methods from the WHO, member companies and elsewhere. IRAC volunteers have simplified the techniques for field uses in remote areas when needed, validating their usefulness and publishing the methods. IRAC and its members have also been very active in the establishment of baseline surveys;

an example was the implementation of the Adult Vial Test (AVT) to monitor *Heliothis virescens* resistance to pyrethroids in the U.S.. There was an emerging problem with *H. virescens* in cotton and Dr. Bill Plapp, of Texas A&M, perfected a survey technique that used discriminating doses in pretreated glass vials. An IRAC subgroup, PEG US (Pyrethroid Efficacy Group), recognized the utility of the technique, further refined it, and produced and distributed tens of thousands of the vials. PEG US coordinated the early testing and data processing throughout the U.S. cottonbelt. The result was a more timely and extensive database than would have been developed without PEG's assistance. Once the utility of the program was demonstrated, state or regional coordinators were identified through the Land Grant University system to continue the baseline monitoring. This rapid focused response of expertise and "Seed" research money is one of the better ways that IRAC complements the efforts of Government and Universities.

IRAC has also been very active in encouraging the development of baseline data in other areas of the world and has sponsored numerous training events. The data has proven invaluable in monitoring the progress of programs and in obtaining grower support.

The following methods were published (5) and proposed to be used in baseline monitoring programs:

IRAC Test #	Pest	Suitable Test Substance	General Comment
1	<i>Myzus persicae</i>	OP's & Carbamates	leaf dip
2	<i>Psylla spp</i>	OP's & amitraz	shoot dip
3	<i>Tetranychus or Panonychus</i>	clofentezine, hexy-thiazox or tetradifon	ovicide leaf dip
4	<i>Tetranychus or Panonychus</i>	several	adult leaf dip
5	<i>Nialparvata &amp; Nephottetix</i>	all insecticides	seedling dip, cages
6	<i>stored product beetles</i>	malathion, pirimiphos-methy	filter paper
7	<i>leaf feeding lepid. &amp; coleoptera</i>	most products	leaf dip
8	<i>Bemisia tabaci</i>	amitraz	leaf dip, cage
9	<i>Leucoptera &amp; Lithocolletis</i>	benzoylureas	terminal dip on tree

### Resistance Management Guidelines

The IRAC committees have worked hard to develop practical resistance management guidelines. A set of general guidelines have been developed as well as more specific ones for country and crop commodity groups. The current general guidelines are:

- Always consult with your local crop advisor/crop protection specialist for guidance and information on resistance management strategies in your area.
- Always include any efficient cultural/biological control practice in your pest control program.
- Time the application of insect control products against the most susceptible life stages based on local pest thresholds.
- Do not rely on a single insecticide class or treat sequential generations of insects with the same class of products.
- Use insect control products at recommended rates and spray intervals.
- In the event of a control failure due to resistance, Do Not retreat with an insect control product of the same class.
- Insure mixtures components of different classes of insecticides are used at rates that provide equivalent control and persistence.

Communication and acceptance of resistance management guidelines is one of the largest challenges that IRAC faces. We are using multiple approaches to communicate these efforts including: the farm press, demonstration projects, educational efforts, promotional literature and labeling. Statements on use labels citing resistance management guidelines were extremely rare 5 years ago but are very common today. An excellent example is the 4 METI (mitochondrial electron transport inhibitor) miticides that were recently introduced in Europe. The METI miticides are, pyridaben from Nissan, tebufenpyrad from Mitsubishi, fenpyroximate from Nihon Nohyaku and fenazaquin from DowElanco. The METI miticides were discovered independently in different areas of chemistry but the mode of action is similar and they remarkably reached the market place at the same time. IRAC recognized the potential for over use and the development for resistance and formed a METI acaricide subgroup to work with the 4 manufacturers as well as Nexter BASF, Zeneca, Masai American Cyanamid, Sandoz and Naja Agrevo who were also involved in marketing the products to develop the following label restriction: Do not make more than one application per season of any METI acaricide. Common and trade names of all products are included on all of the label statements to communicate this information to the grower. This was a very proactive initiative by the manufacturers and marketing companies since there had been no development of resistance to any of the METI miticides. This effort also represents IRAC's philosophy that a preventative approach is much better than the curative one in addressing resistance management in arthropods.

### Research Projects

An additional component of IRAC activities is the identification and partial funding of critical research needs. The funding levels are modest by today's standards but the total cumulative investment will soon reach 1 million

dollars. The value of the funding is often enhanced with additional project funding from member companies and with the timeliness of which it can be supplied. An example of IRAC's commitment to research has been the partial funding of the work by Alan McCaffery at the University of Reading and Jim Ottea at Louisiana State University. Their studies over several years have contributed to the understanding of how resistance mechanisms evolve over time in relation to selection pressure, providing valuable insight into how resistance mechanisms can be modified. Current projects include:

- Malaria mosquito control in Mexico
- Colorado Potato beetle control in Poland
- *Heliothis* control in China
- *Heliothis* and whitefly control in Pakistan
- Diamondback moth control in Taiwan
- Western flower thrips - New Monitoring Techniques
- Whiteflies in cotton in Southwest U.S.
- Monitoring Techniques for New Acaricides
- Rotation Demonstrations for Acaricides in California Cotton
- Rotation Demonstrations for Acaricides in Washington Apples
- Surveys of Resistance Levels and Management Demonstrations of Plant Bugs in midsouth U.S. Cotton

A closer look at the mosquito control project in Mexico reveals that IRAC has created a unique umbrella for cooperation between Industry, Government, and International Institutions:

- First Field Evaluation of Resistance Strategies on Malaria Vectors that claim 2 million lives annually.
- IRAC'S largest project in terms of funding
- Three years at a cost of \$352,000
- One third from IRAC, balance from supporting companies & government infrastructure
- WHO and FAO involved
- IRAC volunteers designed test kits to monitor resistance
- Different Management Strategies evaluated across entire regions

### Education

IRAC's principal tactic for implementing resistance management strategies is through demonstration projects and educational efforts. As the committee has matured it is has become evident that these efforts should be equal to or greater than new research activities in priority. Specific educational efforts to date have included the production of the video "The Paradox of Resistance", major assistance with the continued publication of the *Resistant Pesticide Newsletter* by the Pesticide Research Center of Michigan State University, and organizational efforts and funding support for numerous workshops, symposiums and conferences, including this one.

IRAC US and the IRAC Central committee are currently collaborating on the largest educational program to date. A pamphlet targeted at growers and dealers will be mass produced for the U.S., Europe, China, Pakistan and Mexico. Additional distributions will be made as funding permits. The pamphlet will emphasize the important economics of resistance management to sustainable agriculture production costs. A poster with the message, "There's only one alternative to insecticide resistance management" is also being produced in large quantities for display at points of purchase. Approximately 1000 educational packages that contain reference material and leader guides for county agents and others to conduct grower meetings is planned as well. Fleishman Hillard Inc., the worlds largest public relations firm, is producing the educational materials at their cost and Cotton Incorporated and the Cotton Foundation have pledged support as well. IRAC invites others to join them in this most important phase of implementation.

### Future Projects

Considerable progress has been made in recent years by organizations and individuals in understanding and communicating resistance management issues. The fact remains, however, that the majority of growers in both developed and developing countries have few economic alternatives for protecting crops, and the threat of resistance is high and increasing in most situations. Industry will continue to provide new technologies and modes of action . Still it is extremely important that we continue to protect our current technology as well.

The world has taken for granted that a few acres can feed many and that disease transmitting insects can be controlled. However, the fact is that in many instances only 1 or 2 modes of action are available for any given pest control situation, which should raise the level of concern for all. Industry is recognizing the importance of the issue and is responding through sensible use patterns, appropriate labeling, promotional literature and training. Industry's support of the Resistance Action Committees has provided a unique focus for additional efforts on arthropod resistance management.

There are numerous additional examples of cooperative efforts between government, academia and industry but there is room for improvement in forming true partnerships in addressing resistance management. The first step in forming partnerships is open communications. IRAC has attempted to increase communications through the publication of its minutes, holding open meetings at commodity production conferences and inviting EPA and University members to their meetings. We ask that organizers remember to include an industry group or member in their future plans.

### References

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