Activities of the Insecticide Resistance Action Committee (IRAC): a brief introduction

Ralf Nauen, PhD
Introduction

Insecticide Resistance Action Committee (IRAC)

- Formed in 1984 – now in its 28th year and still growing
- Specialist technical expert group of the agrochemical industry
- Association with CropLife International (Formal part of CLI’s Stewardship Committee since June 2010)
- Provides a coordinated industry response to the development of resistance in insect and mite pests
- Around 75 industry representatives and specialist members in different working groups
- 7 Country/Regional Groups with a further 70-80 representatives
Cases of resistance during the first 14 years following launch (number of species - lab and field)

Resistance can and will develop to any insecticide!
## Top 10 resistant species (MSU database)
Based on number of actives

<table>
<thead>
<tr>
<th>Species</th>
<th>Order</th>
<th>No. of compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Tetranychus urticae</em></td>
<td>Acari</td>
<td>91</td>
</tr>
<tr>
<td><em>Plutella xylostella</em></td>
<td>Lepidoptera</td>
<td>81</td>
</tr>
<tr>
<td><em>Myzus persicae</em></td>
<td>Homoptera</td>
<td>72</td>
</tr>
<tr>
<td><em>Leptinotarsa decemlinetata</em></td>
<td>Coleoptera</td>
<td>51</td>
</tr>
<tr>
<td><em>Musca domestica</em></td>
<td>Diptera</td>
<td>47</td>
</tr>
<tr>
<td><em>Blattella germanica</em></td>
<td>Blattodea</td>
<td>43</td>
</tr>
<tr>
<td><em>Boophilus</em> <em>microplus</em></td>
<td>Ixodida</td>
<td>43</td>
</tr>
<tr>
<td><em>Panonychus ulmi</em></td>
<td>Acari</td>
<td>41</td>
</tr>
<tr>
<td><em>Bemisia tabaci</em></td>
<td>Homoptera</td>
<td>39</td>
</tr>
<tr>
<td><em>Aphis gossypii</em></td>
<td>Homoptera</td>
<td>37</td>
</tr>
</tbody>
</table>

*Rhiphicephalus*
Why effective resistance management is essential?

- Sustaining effective commercial life of current insecticides requires intelligent use of presently available compounds
  - Insecticide Resistance Management (IRM)

- For any crop / pest situation, effective IRM requires the availability of a broad range of modes of action

- IRM is made much more difficult by loss of modes of action through resistance development caused by misuse or overuse of insecticides

- We cannot always rely on having a steady stream of new modes of action to circumvent resistance problems
IRAC Annual Meeting with up to 50 participants
The IRAC website – www.irac-online.org

- IRAC’s key communication vehicle
- IRAC Country group information
- Information on IRAC, Mode of Action, advice on IRM
- eTools
- Education modules
- Resources - key papers, posters, etc.
- Home, diary and other general pages
- Team and group areas
**eMethods tool**

**Materials:**
Transparent plastic or glass tubes, or suitable glass jars. Cut plastic pipettes (see figure), fine, soft spring tweezers, containers for solution preparation. 35-50 ml plastic syringes, 100-1000-μl micro-syringes for liquids or microbalance for solids. Extravon (madiclar) or a similar non-ionic wetting agent, untreated rice seedlings 10-12 days old (BPH susceptible cultivar grown in seedling box), paper towel, maximum/minimum thermometer.

**Method:**
(a) Make test solutions in water containing 0.03% w/v Extravon (or similar wetter) using formulated insecticides. At least five to six concentrations are required. The highest concentration should be based on the use recommendation in g ai ha⁻¹ converted into p.p.m. (e.g. 500 g ai ha⁻¹ = 500 p.p.m.; 200 g ai ha⁻¹ = 200 p.p.m.). Use a 0.4-fold dilution or if necessary, other dilution factors (0.5 or 0.8 fold) to obtain two different mortalities above and below 50%, respectively. Use water-Extravon alone for untreated control.
(b) Prepare treatment tubes as shown in Fig.
(c) Dip seedlings completely for 5 s in the test solutions and leave them to dry in air for 10-15 min depending on the ambient relative humidity.
(d) Field populations of hoppers may be collected by hand or by suction and kept in holding cages containing potted rice plants. Insects should be collected at random from several points in a field and from a few fields in an area then pooled together as parent stock.

**Description:**
Mortality assessment period may vary depending on insecticide mode of action. The following guidelines may be used:

- 72 hours assessment period
- 96 hour assessment period
- 120 hour assessment period (addition of fresh plant material may be necessary to avoid starvation).
- Larvae should be kept throughout to obtain mortality assessment.
New posters coming soon

The Asian citrus psyllid, *Diaphorina citri*:

‘Insect Resistance Management’ the Base for a Successful IPM Program

www.IRAC-online.org

**Introduction and Biology**

The Asian citrus psyllid (ACP), *Diaphorina citri* Kuwayama (Fig. 1a.), is the insect vector associated with the bacteria *Candidatus Liberibacter asiaticus* and *C. L. americanus*. These bacteria are suspected to be the causal agents of Huanglongbing (HLB) in Asia, and America. Infected citrus trees start showing symptoms such as early fruit drop and mottled leaves anywhere from 5 months to 3 years after they become infected. During this initial asymptomatic period of time, the plants can also be source of inoculum, hence the need to manage the vector even if the trees are not showing symptoms (Fig. 1b.). Once the trees are infected, the production rapidly declines rendering the infected trees unproductive in a few years.

![Image](557x701 to 574x756)

Citrus psyllids lay their eggs on the inner-side of unfolding leaves which protects the eggs and early nymphs from adequate insecticide contact, rendering applications of non-systemic insecticides inefficient to manage nymphs. The psyllid nymphal stage has 5 instars taking between 15 and 47 days in total to become an adult depending on environmental conditions. Nymphs acquire the bacteria and the adults vector the disease to uninfected plants and to plants that are already infected, increasing the bacterial titer in already diseased plants. Adults are considered to be the preferred targets for foliar insecticide applications, since they vector bacteria and nymphs are protected from contact insecticides by the developing leaves. Systemic soil insecticide target nymphs and adults in young trees.
Introduction

There are five key species of plant and leaf hoppers known to be important pests of rice in Asia and Australasia. They belong to two families, the Delphacidae and Cicadellidae. Delphacidae includes the brown planthopper (Nilaparvata lugens), small brown planthopper (Laodelphax striatellus) and whitebacked planthopper (Sogatella furcifera) which tend to inhabit the base of the plant, whilst the green paddy leafhopper (Nephotettix virescens) and rice green leafhopper (Nephotettix cincticeps) from the Cicadellidae family tend to inhabit the upper parts of the plant.

Both families are economically important pests of rice, when favourable conditions allow them to reach high infestation levels. All the species feed by the insertion of stylet mouthparts into the plant phloem tissue and damage is caused by either direct sap loss or through the injection of toxic saliva. The distinctive browning and wilting of rice plants, which is caused by hopper infestation is commonly known as ‘hopper burn’. Plant and leafhoppers are also known to transmit various plant viruses such as grassy stunt and rice-stripe cereal mosaic. Treatment with insecticides has been the primary control option for growers, with systemic insecticides more favoured in recent years. However the selection of resistant plant varieties and use of biological control agents are also important contro

Insecticide Resistance

Insecticide Resistance has been recorded in rice hopper species since the early 1960’s, when organophosphate, carbamate and cyclodiene organochlorine insecticides were the main methods of chemical control. Although further insecticide chemistry has been introduced to control hoppers, the importance of rice as a staple food crop and the reliance on insecticides for the control of insect pests has seen the continued evolution of insecticide resistance. The most recent developments has seen populations of Nilaparvata lugens, Laodelphax striatellus and Sogatella furcifera independently develop resistance to neonicotinoid and phenylpyrazole insecticides. At the time of writing there is no evidence of a common cross-resistance resistance between chemical classes of insecticide across these species, however there is evidence that individual hoppers may exhibit multiple mechanisms of resistance to one or more insecticide modes of action. Currently pymetrozine is the only insecticide which is registered for rice hopper control, with no recorded cases of resistance reported.

<table>
<thead>
<tr>
<th>Insecticide Chemistry</th>
<th>Mode of Action</th>
<th>Nilaparvata lugens</th>
<th>Laodelphax striatellus</th>
<th>Sogatella furcifera</th>
<th>Nephotettix virescens</th>
<th>Nephotettix cincticeps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbamates</td>
<td>1A</td>
<td>CHN, IDA, JPN, MLY, PHI, TWN</td>
<td>JPN, KOA</td>
<td>CHN, JPN, SRL</td>
<td>MLY, PHI</td>
<td>JPN, TWN, KOA</td>
</tr>
<tr>
<td>Organophosphates</td>
<td>1B</td>
<td>CHN, JAP, PHI, TWN, VNM</td>
<td>CHN, JPN, KOA</td>
<td>CHN, JPN</td>
<td>PHI, IDA</td>
<td>JPN, CHN, KOA, TWN</td>
</tr>
<tr>
<td>Cyclodiene organochlorines</td>
<td>2A</td>
<td>FI, JPN, TWN</td>
<td>JPN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phenylpyrazoles (Fiproles)</td>
<td>2B</td>
<td>CHN</td>
<td>CHN, JPN, TWN, VNM</td>
<td>CHN, JPN, PHI, TWN, VNM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pyrethroids</td>
<td>3A</td>
<td>THD</td>
<td>CHN</td>
<td></td>
<td></td>
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<tr>
<td>Neonicotinoids</td>
<td>4A</td>
<td>CHN, IND, IDA, JPN, MLY, TWN, THD, VNM</td>
<td>CHN, JPN, TWN, VNM</td>
<td>JPN</td>
<td></td>
<td></td>
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<tr>
<td>Pymetrozine</td>
<td>9B</td>
<td></td>
<td></td>
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<tr>
<td>Buprofezin</td>
<td>16</td>
<td>CHN</td>
<td>CHN</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Table 1: Countries where field collected rice hoppers have been reported in literature as being resistant to the insecticides registered for their control (1960-2010).

Distribution & Migration

Table 2: Recorded regional range of different rice hoppers. The regional range of each of the five key species of rice hoppers varies and in many cases overlap. Many of the species are migratory in nature and therefore each species may not reach pests status in all of its range every year.

- The brown planthopper (Nilaparvata lugens) for example is recorded as being an immigrant pest in China, Japan and Korea after migrations from tropical and subtropical regions of S.E. Asia. Infestation levels in these countries are often dependant on environmental conditions throughout the region.

Resistance Management

As there is no evidence of cross-resistance amongst the groups insecticides used for rice hopper control, it is recommended that the rotation of effective insecticides with different modes of action are used to provide insect control, whilst at the same time reducing the risk of insecticide resistance from developing. The following should be considered when designing an insect control program for rice hoppers:

- Plan ahead. Determine when in a typical season insecticides applications are likely to be needed and plan for the rotation of insecticides with different modes of action, avoiding the consecutive use of products belonging to the same mode of action group. Plan for contingencies in case extra applications are needed due untypical pest infestations. Consider the presence of other insect pests of rice (e.g. Stemborers or leafrollers) and required treatments.

- Determine which insecticides are most effective for controlling each rice pest during each application timing. If the presence of other rice pests over-lap with rice hoppers, consider using pest specific insecticides rather than broad spectrum insecticides, which may increase unnecessary resistance selection pressure for either or both pests.

- Evaluate the current insecticide resistance situation in the area (consult local crop advisors and experts). Avoid using insecticides already affected by resistance where possible.

- Consider the impact of the insecticides on non-target insects and natural predators, especially during early season applications, where maintaining natural predators can reduce the need for later sprays.

- Consider the use of insect-resistant rice varieties and the use of biological control agents.

- Always follow insecticide label instructions for application timings, volumes and concentrations.

Monitoring

The topical application of insecticides using a syringe, as described by multiple researchers has proved to be a useful bioassay in determining the susceptibility of insecticides, which have strong contact activity against rice hoppers. Extensive monitoring programs have been conducted across the host range of these pests with neonicotinoid, carbamate, phenylpyrazole and buprofezin insecticides. Alternatively leaf dip assays, as described in the IRAC approved method No. 0005, provide a method of assessing the activity of all Insecticides which are utilised for the control of plant hoppers, including pymetrozine, which primarily acts by reducing feeding and egg lay.

Further details may be found at www.irac-online.org. Designed and produced by IRAC Sucking Pest WG, July 2011. Photograph courtesy of xxxxxxxx.
Posters and publications overview

35 * Posters
- 5 General IRAC/IRM
- 12 Crop WGs
- 10 MoA
- 7 Public Health

* Several others drafted or under development

In 2012 two method videos (YouTube)
IRAC eConnection Newsletter

• Issued 3-4 times per year
• Self-subscribed via website
• Email notification of new issue
• Users download from the web
• Topical issues
• Short scientific notes
• New posters
• Conferences
• Spotlight on recent resistance papers
Formed in January 2008

- Development of a global IRM strategy for Group 28 insecticides (ryanodine receptor modulators) from the scratch, thus proactively preventing (delaying) the evolution of resistance
- Since 2009 several regional and sub-teams established; very active group!
IRAC funded IRM training program - Philippines

<table>
<thead>
<tr>
<th>Date</th>
<th>Venue</th>
<th>Number of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>17-May</td>
<td>Benguet</td>
<td>109</td>
</tr>
<tr>
<td>19-May</td>
<td>Pangasinan</td>
<td>91</td>
</tr>
<tr>
<td>07-Jun</td>
<td>Cebu</td>
<td>113</td>
</tr>
<tr>
<td>19-Jul</td>
<td>Davao</td>
<td>118</td>
</tr>
<tr>
<td>12-Aug</td>
<td>Quezon</td>
<td>121</td>
</tr>
<tr>
<td>16-Aug</td>
<td>Laguna</td>
<td>228</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>780</td>
</tr>
</tbody>
</table>

Train the trainer’s
Global Effort to Maintain Susceptibility of the Ryanodine Receptor Modulators and Other Insecticide Modes of Action: Efforts of the IRAC International Diamide (Group 28) Working Group

Veronica Companys1, Robert Senn2, John T. Andaloro3, Luis Teixeira3, Jan Eliaš4, James Adams5, Ralf Nauen1, Andrea Bassi5, I. Billy Annan3

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3 DuPont Crop Protection, Rise Research Center, 1600 Ekon Road, Newark DE 19711 USA
4 Syngenta Crop Protection, Ag, Research Biology Werk Steins, Schaffhauserstrasse, WST540.1.23, CH-4332, Stein, Switzerland
5 Nichino America Inc., 4500 New Linden Hill Rd, Wilmington, DE 19808, USA
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Diamide insecticides are IRAC mode of action Group 28 ryanodine receptor modulators, currently including products containing chlorantraniliprole, cyantraniliprole, and flubendiamide.

The IRAC International Diamide Working Group

WHO ARE WE?
The IRAC International Diamide Working Group was created in 2007 to prevent or delay the development of insect resistance to the diamides, a new mode of action chemical class, by founding member companies Nihon Nohyaku/Nichino, DuPont Crop Protection, Bayer Crop Science, and Syngenta and supported by IRAC International and Crop Life membership companies.

WHAT WE DO AND WHY?
The IRAC Diamide Working Group promotes sustainable use of all insecticides through industry education and implementation of IPM disciplines and strategies. The main objective of the Diamide team is to maintain the longevity of all crop protection products available to growers by preventing or delaying the development of resistance to insect pests.

Activities of the IRAC Diamide Working Group

Resistant Management Guidelines

1) Incorporate IPM practices into insect control program.
2) Follow the label. Do not reduce rates. Follow recommended timing of applications and spray volume.
3) Know the MoA of insecticides for rotation programs

GROUP 28 INSECTICIDE

4) Rotate insecticide MoA groups
   - Avoid exclusive use of Group 28 insecticides throughout a crop cycle for a pest species with more than one generation.
   - Apply insecticides using a “window” approach to avoid exposure of consecutive insect pest generations to the same mode of action.
   - A “Treatment Window” is defined as the period of residual activity provided by a single, multiple, or sequence of product applications with the same mode of action within an approximate 30 day period (15 - 45
Conclusions

- The major insecticide manufacturers undertake extensive research to understand factors influencing the effectiveness of their compounds.
- There is a large body of ongoing work to maintain awareness of susceptibility in key at-risk pests.
- Key companies are collaborating both internationally and at a local level to harmonise their guidelines for IRM for different classes of insecticides.
- IRAC works for the industry to promote awareness of and solutions to resistance.
  - Communication and education on IRM are vital.
  - IRAC provides key resources such as the MoA scheme, methodologies, IRM advice to help manage resistance.
  - IRAC country groups work to tackle local problems.

*Resistance is everyone’s problem - managing it is vital!*