eConnection Issue 45
November 2022

Introduction

After a long period of time when IRAC members were limited to virtual meetings, we are happy to have the opportunity to meet and discuss face to face again. Colleagues were present at the 7th International Congress of Nematology, held in Antibes, France and next week we will hold a symposium and a workshop at the Entomological Society of America meeting in Vancouver. This year, our focus will be around the role of insecticide mixtures for resistance management.

In this issue we report about resistance management activities in Vietnam. The number of IRAC Country Teams such as IRAC US, Brazil, South Africa and Spain has increased in recent years to 20 different teams with additional regional groups in Europe, Asia and just this year, IRAC Africa - more on this new team later in the newsletter. There are over 400 company representatives that sit on the various working groups and teams who meet on a regular basis to monitor global insecticide resistance and develop strategies to prevent or delay the onset of resistance, promoting sustainable agriculture and improved public health.

IRAC Country Team Network, 2022

The IRAC website is the main communication vehicle but has evolved over time into a multifaceted resource covering all aspects of insecticide resistance management with guidelines, position papers, posters, tutorials, videos and online tools. Particularly important for practical resistance management is the IRAC Susceptibility Test Method Series and the Mode of Action (MoA) Classification Scheme and which includes a mobile MoA App available for Android and IOS devices. The IRAC information is now also available as part of a combined

Featured member

Juergen Langewald (BASF) is the current IRAC International Chairman and was previously Vice-Chair and leader of the IRAC Outreach WG. Juergen also leads the IRAC Executive, the Steering and the Crop Protection Teams.

In this issue

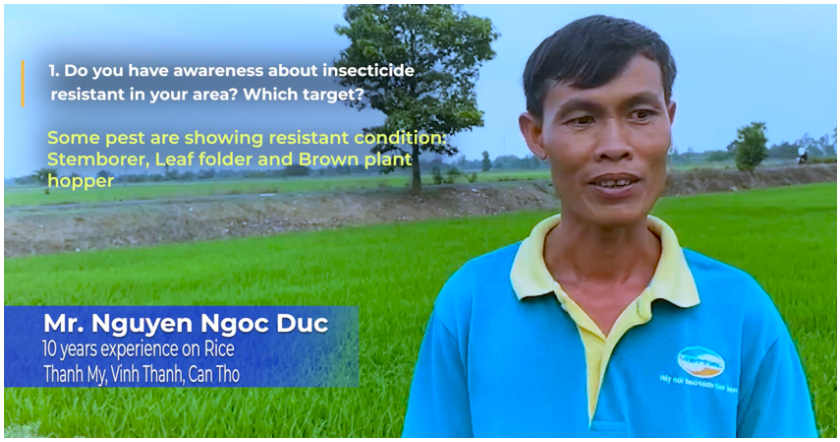
insecticide, fungicide and herbicide Global Resistance Management App, offering farmers resistance management information in one place (see below). In addition to maintaining its YouTube channel, IRAC now posts information through the social network channels of CropLife International.

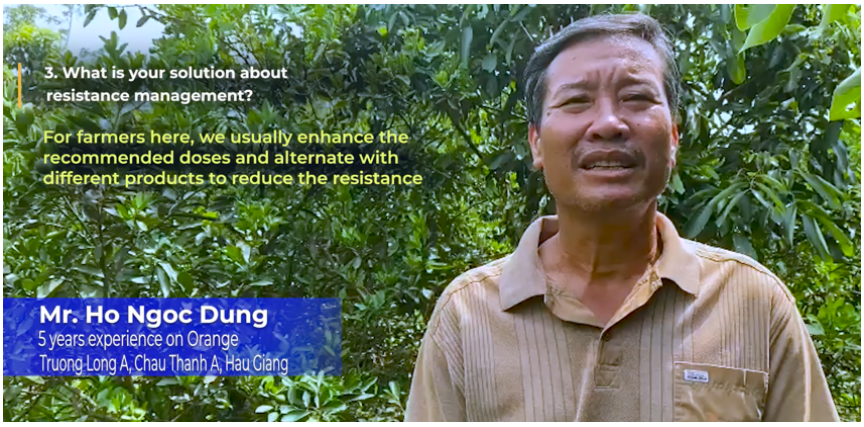
A major effort in outreach communication was the participation of our Public Health and MoA Working Groups in a Massive Open Online Course (MOOC) on mosquito resistance management. As usual, we also report on the most recent changes to the Mode of Action Classification Scheme.

IRAC Vietnam Takes up the Challenges to Improve Farmer IRM

Farmers in Vietnam (VN) are experiencing increasing insecticide resistance, rendering their efforts in crop protection inefficient even though they can choose between more than 1500 different insecticide brands, which represent over 600 different active ingredients. If the offer is so diversified, why are farmers running into trouble? The key question is, how to decide which product to use? Interviews with farmers reveal that most believe that they should rotate different products, for insecticide resistance management (IRM).

For farmers in Vietnam, the agricultural environment is very dynamic. Changes in weather patterns, consumer behavior, the availability of labor, the availability of crop protection products, and the crop pest patterns, require farmers to adjust their agricultural practices to sustain and improve both crop quantity and quality. Badly adopted cultivation practices can lead to increasing problems with insecticide resistance.





This shows that farmers are clearly lacking available, essential IRM guidance.

- For rotation, farmers need to know how to select best-fit products, among hundreds of available insecticide brands.
- Product rotation should be associated with insect generations and the product's mode of action (MoA) which is indicated by IRAC group numbers.
- The product MoA should be printed on product labels in a standardized manner, including essential information on IRM, as proposed by IRAC and CropLife International. So far, MoA labelling is still only optional for VN manufacturers.

IRAC VN in association with CropLife VN are engaging to help farmers to better manage insecticide resistance in the future and to:

- be fully committed to comply with IRAC guidance (MoA icon, IRM statement).
- encourage all VN pesticide manufacturers to implement MoA labelling practice.
- engage the VN Government agency to make MoA labelling mandatory.
- create online IPM, RM, RAC guidance resources in Vietnamese.
- establish train-the-trainer programs together with CropLife VN, government agencies, and other stake holders to increase IRM awareness and practice.

Advancing the Science and Art of Insecticide Resistance Management Through Symposia

The annual conference of the Entomological Society of America is the world's biggest gathering of arthropod biologists and scientists worldwide. The theme of the 2022 Joint Annual Meeting of the ESA, ESC and ESBC is "Entomology as inspiration: Insects though art, science, and culture", and in keeping with this theme the IRAC-US annual symposium will be 'Resistance Management as an Inspiration for Careers in Entomology."

The objective of the symposium is to demonstrate how scientists in different organizations have been inspired by insect resistance management goals relative to research, opportunities and diverse career paths. The speakers will relate their personal journeys on these paths. We hope these speakers will inspire students and early career colleagues to consider the science of IRM as either a career path or part of their overall approach to managing pests.

A diverse range of speakers from a variety of career paths were chosen, including government organizations, university professors and recent graduate students, as well as industry researchers. Speakers will also range from early career to recently retired to provide a broad set of experiences.

- **Daniela Pezzini (North Carolina State University):** A qualitative analyses on farmers preferred sources of information and perspectives on insecticide resistance management for Bt crops
- **Sally Taylor (Virginia Polytechnic Institute and State University):** Resistance opportunities and challenges – IRM research and extension on the cotton/corn interface
- **Kara Welch (Environmental Protection Agency):** What is it like working for the U.S. Environmental Protection Agency – opportunities and challenges
- **Tracey Baute (Ontario Ministry of Agriculture):** Resistance management and the collaboration needed to succeed
- **Steven Naranjo (USDA-ARS): IRM in action:** A tribute to Steve Castle, Nilima Prabhaker and Robert Nichols for their inspirational contributions
- **Silvana Paula-Moraes (University of Florida):** Building insect resistance management programs: A career opportunity for insect ecologists.
- **Patricia L. Prasifka (Corteva Agriscience):** Moving from a career that was touched by resistance issues to one that is driven by opportunities within resistance management
- **Timothy Dennehy (University of Arizona):** Overviewing the diversity of employment opportunities in insect resistance management

In addition, a further symposium is being organized by Adekunle Adesanya of Corteva Agriscience, titled *Putting Science Behind the Art of Designing Insecticide Mixtures for Pest and Resistance Management*. This symposium is aimed at stimulating discussion on the latest science and perspectives behind the use of insecticide mixtures for pest management and implications for resistance management. Prominent academic, government and industry scientists, modelers, and crop protection extension leaders will present at this symposium to create an atmosphere that will facilitate an interactive and inclusive session on the use of insecticide mixtures for crop protection. The symposium will share, and shape expert opinions based on the latest empirical and simulation studies and showcase emerging trends and considerations for insecticide mixtures for pest and resistance management.

Themes to be discussed in the symposium include but are not limited to:

- Are insecticide mixtures deployed to meet goals of pest management or resistance management or both?

- What is the impact of insecticide mixtures in IRM programs?
- How should mixture partners be selected – considerations for efficacy, dose, residual activity, and preexisting resistance?
- Is there one approach fits all, or what are the major factors that determine the success of different approaches (migration, fitness costs, pest life cycle, pest genetics)?
- Perspectives from different stakeholders – theory and practice.

IRAC MoA Update

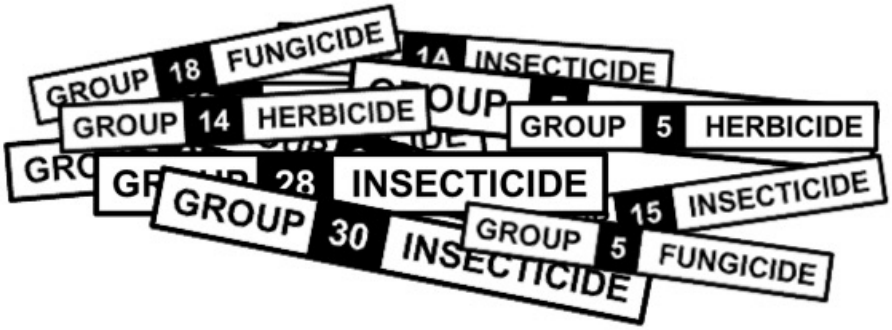
Towards the end of 2021, IRAC released Version 10.1 of the MoA Classification Scheme, followed shortly after with the corresponding 8th edition of the Mode of Action Poster showing the chemical structures. Changes from the previous versions and editions include the addition of two new MoA Groups, 33 and 34. Group 33 is the calcium-activated potassium channel (KCa2) modulators and contains one active ingredient, Acynonapyr. Group 34 is the mitochondrial complex III electron transport inhibitors – Qi site and contains the active ingredient Flometoquin. In addition, the sub-group 4F 'Pyridylidenes' containing the active ingredient Flupyrimin was added to the Group 4, nicotinic acetylcholine receptor (nAChR) competitive modulators. Finally, the active ingredient, Isocycloseram was added to Group 30, following its first registration globally.

This year, further sub-versions of the scheme have been released with a new MoA being approved for RNAi-based technologies, titled 'RNA interference mediated target suppressors'. This group was tentatively assigned MoA group 35 and contains the active 'Ledprona' which targets Colorado Potato Beetle. Currently, this new group has been added to Appendix 6 of the classification scheme, which is for active ingredients pending registration. After Ledprona receives its first registration, the new group will be added to the main classification and the final MoA group number will be assigned. In related news, a new 'targeted physiology' class, titled 'Targeted Protein Suppressors' was created for RNAi and related technologies. Similar to the new MoA group, the new class will be added to the classification and poster following registration of Ledprona. Further, the active ingredient Benzpyrimoxan was assigned to the 'Unknown' MoA group.

These 2022 additions along with some minor wording and formatting changes, means that the current MoA Scheme Version is 10.3 dated June 2022 and the Structures Poster (English version) is Edition 8.2 dated August 2022. You can keep up to date by visiting the MoA Team Page or the MoA Landing Page on the IRAC website using the included links.

Mode of Action Labelling Update

Standardization of Mode of Action (MoA) information on product labels, including standardized icons and instructions is a powerful tool for the implementation of resistance management. Through its Stewardship Committee, its member companies and the resistance action committees (IRAC, FRAC, HRAC and RRAC), CropLife International (CLI) and its regional and country organizations, are currently pushing for a global implementation. CropLife International member companies and IRAC member companies have promised to implement standardized MoA labelling globally for all their products. The initiative is progressing well with 87% of the countries on track.



In the Americas, the largest agricultural producers, USA and Canada (voluntary), Brazil and Argentina (mandatory) have adopted MoA labelling some time ago. In Latin America, further countries such as Colombia, Costa Rica, Chile, Bolivia, Ecuador, El Salvador, Honduras, Mexico, Panama and Peru have introduced MoA labelling on at least a voluntary basis. In Central America and the Caribbeans however, it is still only possible to add MoA information as text, but not the standard icons to the label. CropLife Latin America is following up with the countries missing on the list.

In Africa, Morocco, Kenya, Ethiopia, and South Africa (RSA) implemented MoA labelling early, with countries like Zambia, Malawi, Madagascar, Uganda and Zimbabwe using labels from RSA. Recently PR-PICA, an organization of cotton producing francophone West African countries joined the effort. The Economic Community of West African States is considering the PR-PICA enforcement of MoA labelling as a pilot which would potentially build a West African regional requirement.

In Australia and Asia, MoA labelling is very much advanced. In many countries standardized MoA labelling is mandatory, such as Indonesia, Malaysia, South Korea, Philippines, Sri Lanka, Taiwan, and Thailand. In the larger countries, China, India, and Pakistan, but also Vietnam and Bangladesh labelling is not yet mandatory. The Japan Crop Protection Association (JCPA) has more than 100 members and JCPA is lobbying its members to include MoA on their labels. In Australia, MoA labelling is mandatory.

The European Union is currently reviewing their legislation on labelling rules. The focus is mainly on product safety, but this is an opportunity to lobby for mandatory MoA labelling. CropLife International with its member companies is currently trying to bring to the attention of the European Commission to also make standard text on resistance management mandatory. So far, only Italy is implementing standardized MoA labelling as recommended by CLI and the RACs, with Spain and Slovakia planning implementation.

CropLife has set itself a deadline of December 2023 for a full global implementation, We might not be fully successful, but together we have come a long way.

IRAC Nematicide Activities

The 7th International Congress of Nematology, held in Antibes, France from 1 to 6th May 2022, was the first global in-person international gathering of nematologists in more than two years (due to the covid restrictions)! It was very well attended, with more than 500 participants coming from all over the world and others still able to join remotely to make some presentations. It was an ideal opportunity to present and raise awareness of the latest version of the IRAC Nematicide Mode of Action poster, recently updated in December 2021.

The poster was presented by the IRAC Nematode Working Group and was also selected as a flash-talk in the Integrated Nematode Management session at the Congress. Dr John Wiles had the opportunity to present the poster on behalf of the IRAC Nematode Working Group, and it was very well received by the audience, which comprised of academics, government officials, researchers, and industry representatives. Copies of both the poster and newly published IRAC 7th Edition Mode of Action Classification Booklet were given to interested parties, and the feedback was very positive towards encouraging clearer labelling and classification of nematicide, in addition to insecticide, mode of actions. No doubt it was an effective way to raise awareness of the IRAC Nematicides Mode of Action classification scheme and it will help facilitate adoption and awareness of this material around the world.

IRAC Africa

IRAC Africa is the newest IRAC regional group. It was formed in early 2022 and has held three successful groups meetings on February 22, June 27 and October 25 this year in virtual calls led by the IRAC Vice-Chair and the Outreach Group leader, Billy Annan. Billy is the lead founder of the group and is also the interim leader until the substantive officers are elected.

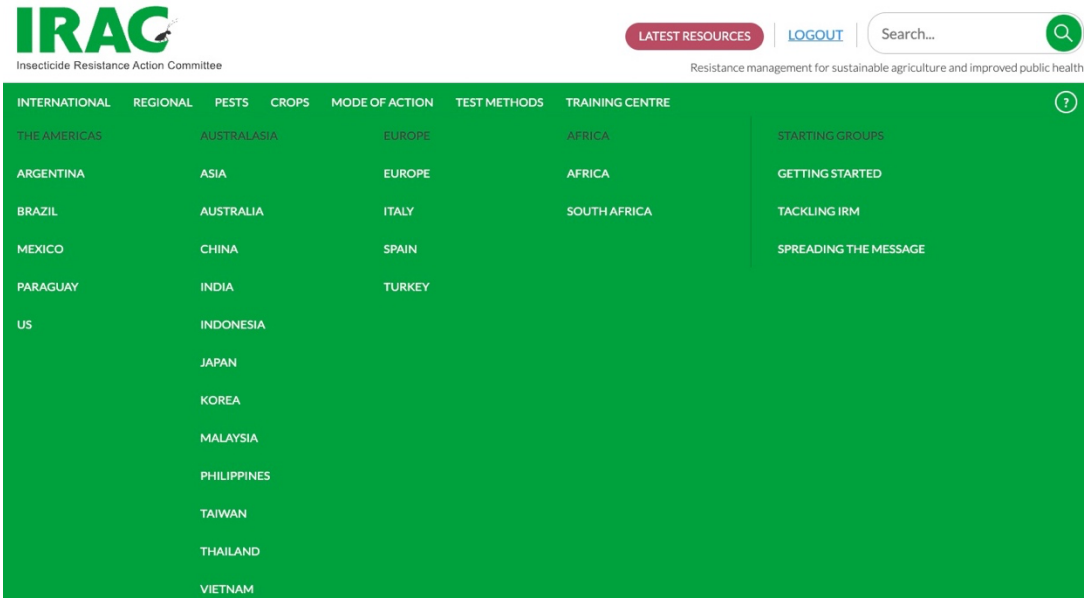
The Africa Team consists of the following companies and representatives: ADAMA (2 representatives), BASF (11), Bayer (2), Belchim/Certis (2), Corteva (2), FMC (5) and Syngenta (3), and Billy Annan from FMC and IRAC International as *ex-officio* member. The company representatives attend the near quarterly meetings where objectives and plans are discussed. We would also like to add representations from UPL, and the Japanese companies in IRAC.

At the meeting in June 2022, a group consisting of Amr Moussa (BASF), Franck Parfait Krah (Bayer), Jeanne de Waal (Corteva), Marlene Van Rooyen (Corteva), Noreddine Elaasri (FMC) signed up as a coordinators and charter leaders to represent their companies, with support from Billy Annan and Eric Andersen (FMC), Nick Storer (Corteva), and Juergen Langewald (BASF).

The group has been mandated to propose, discuss, prioritize and publish key arthropod and nematicide resistance projects in the Africa region. Among the projects to be proposed are: (1) *Spodoptera frugiperda* (FAW) on corn in West and Central Africa, as well as in in South Africa where FAW seems to be outcompeting vs. *Busseola;* (2) *Bemisia tabaci* resistance against neonicotinoid products in West Africa and the Maghreb region; (3) *Helicoverpa armigera* resistance against pyrethroids in cotton in West Africa; (4) Monitoring of aphids, *Tuta absoluta,* Thrips populations in the Maghreb, Thrips in South Africa, *Ceratitis capitata* on Mango in West Africa, and on citrus in North Africa.

IRAC Website Update

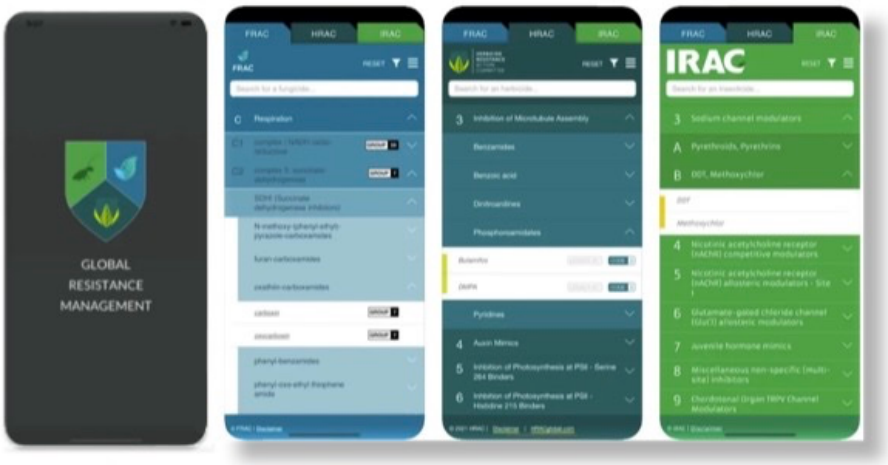
Several improvements have been made to the IRAC website over the last few months with design updates on many of the pages and new content added. In addition, there have been modifications to the website backend taking advantage of technology changes improving efficiency of data entry. For the IRAC Network of International Working Group and Country Team members, there is a new IRAC branding and templates page where official IRAC logo styles and country options can be downloaded along with IRAC MS Word and PowerPoint presentation templates. Pages have been added for the new Country and Regional teams as shown below:



Additional Pest and Crop Pages have been incorporated and updated page designs for Mode of Action and Test Methods have been developed for improved user experience. Within the Training Centre, information can be found on Resistance Basics, Position Papers, Training Modules, Guidelines, Videos, Posters and Publications. Details of further new resources added to the website recently, some of which are described elsewhere in the eConnection, includes the latest versions of the MoA Classification, Chemical Structures Poster and Brochure, a document outlining Factors Impacting the Design and Implementation of a Resistance Monitoring Program, IRAC Vietnam Key Initiatives 2022-2025 and a Guide for Farmers on Integrating Bt Corn for FAW Management.

Global Resistance Management (GRM) Mode of Action App

The new Global Resistance Management (GRM) Mode of Action App has been released by the Resistance Action Committees (IRAC, HRAC FRAC). The App combines the information on the Resistance Action Committee's standalone Mode of Action Apps into one application for ease of access by the user. The individual IRAC, FRAC and HRAC Mode of Action Apps are still available and all applications can be downloaded from the Apple App and Google Play stores.



Integrating Bt Corn for Fall Armyworm (FAW) Management

The IRAC Plant Biotechnology Working Group has completed a short poster brochure discussing the use of Bt corn to manage fall armyworm, *Spodoptera frugiperda,* in the Asia-Pacific region. The brochure complements IRAC's poster and brochure developed in 2021 entitled "Manage fall armyworm in 3 steps". The 3 steps are 1) Incorporate agronomic actions, 2) Identify pest and decide when to treat, and 3) Control FAW using IRM principles. The main IRM principle relayed in this brochure is the rotation in modes of action across sequential pest generations. While this 3-step process is effective for most countries in the Asia-Pacific region where crop protection tools are readily available, Bt corn is an important tool that also may be used by farmers in much of the Americas as well as in an increasing number of countries where fall armyworm has recently invaded like South Africa, Philippines, Pakistan, and Vietnam.

The Bt corn brochure is entitled "Integrating Bt corn for fall armyworm (FAW) management". Effective Bt hybrids against fall armyworm are available and we want to ensure that farmers follow insect resistance management guidelines to maximize long-term benefits of the technology. This brochure also discusses a simple 3 step process: 1) Plan, 2) Plant refuge & monitor, and 3) Evaluate & Treat. The purpose is to be proactive in building an Integrated Pest Management (IPM) plan to use multiple tools and tactics against FAW founded on the host-plant resistance provided by Bt traits. Our goal is for farmers to be able to understand what a non-Bt refuge is, why it is important, and how to incorporate it when they plant a Bt corn hybrid. We also advise farmers to scout their fields and determine the need to incorporate additional control tools, such as insecticidal sprays, if indeed economic population levels of FAW arise in their Bt and non-Bt corn fields.

Mosquito IRM Training Course

Discover approaches and advances in our fight against the malaria mosquito using Insecticide Resistance Management (IRM). This course is designed for anyone involved in mosquito vector control as well as students and scholars of Public Health, One Health, Entomology, Epidemiology, or Evolutionary Biology. It will also appeal to the general public interested in malaria elimination, vector-borne diseases and mosquito control, and those with a wider interest in insecticide resistance management.

Interesting Reads

What are the biological traits that make lepidopteran pests prone to developing resistance against insecticides? This review takes the example of the Helothines to find answers. While Helicoverpa armigera, Heliothis virescens and H. zea, have developed resistances to many insecticide classes, H. punctigera, H. assulta, and H. gelotopoe did not. The authors found that host range and movement between alternate hosts are key ecological traits that influence effective selection intensities for resistance. Management practices that account for these ecological factors, are key to effective resistance management.

Walsh, T. K., Heckel, D. G., Wu, Y., Downes, S., Gordon, K. H. J., & Oakeshott, J. G. (2022). Determinants of Insecticide Resistance Evolution: Comparative Analysis among Heliothines. Annual Review of Entomology, 67, 387–406. https://doi.org/10.1146/annurev-ento-080421-071655

In the following article the authors are addressing the challenges for effective resistance management in BT crops and conventional insect pest control in the context of small holder farms in Africa. Examples are given for mayor cropping systems. Many farmers are lacking knowledge in resistance management or IPM strategies. Farmer training should emphasize these concepts. Area-wide approaches to IPM and IRM, rather than field-based strategies, are more likely to mitigate the effects that increased pesticide.

Van den Berg, J., Greyvenstein, B., & du Plessis, H. (2022). Insect resistance management facing African smallholder farmers under climate change. Current Opinion in Insect Science, 50, 100894. https://doi.org/10.1016/j.cois.2022.100894

Taillebois et al. are looking into interactions (antagonistic, additive, synergistic) between mixing partners of neonicotinoids in insecticide mixtures. They discuss these effects regarding reduced doses in mixtures, but also in the context of non-target effects.

Taillebois, E., & Thany, S. H. (2022). The use of insecticide mixtures containing neonicotinoids as a strategy to limit insect pests: Efficiency and mode of action. Pesticide Biochemistry and Physiology, 184(April), 105126. https://doi.org/10.1016/j.pestbp.2022.105126

Madgewick et al. are introducing “additional kill” as an additional factor into the evaluation of insecticide mixtures. As a result, the authors find that optimized mixtures always perform better than solo use strategies due to the combination of redundant and additional kill.

Madgwick, A. P. G., & Kanitz, R. (2022). Title: Beyond redundant kill : a fundamental explanation of how insecticide mixtures work for resistance management Running title : Beyond redundant kill This article is protected by copyright . All rights reserved. Abstract. *Pest Management Science*, 0–2. https://doi.org/10.1002/ps.7180

This article is a very detailed review on cytochrome P450 monooxygenases (P450s). As the title indicates, their role in insects as a mechanism for detoxifying xenobiotics is explained and how it is involved in the evolution of insecticide resistance.

Nauen, R., Bass, C., Feyereisen, R., & Vontas, J. (2022). The Role of Cytochrome P450s in Insect Toxicology and Resistance. Annual Review of Entomology, 67, 105–124. https://doi.org/10.1146/annurev-ento-070621-061328