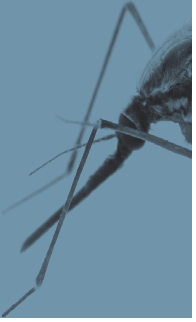

INSECTICIDE RESISTANCE MANAGEMENT AND THE IMPORTANCE OF SUSTAINABLE PRACTICES

ESA Position Statement on Insecticide Resistance Management
Approved on July 30, 2020
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Insect and other arthropod pests can have a devastating global impact on the welfare of humanity, posing threats to food security, public health, and beyond. In the U.S., an estimated $22.9 billion in crop yield losses due to arthropod pests are prevented by spending $1.2 billion per year on insecticides and their application.[1] Globally, the World Health Organization (WHO) estimates that insect-transmitted diseases are responsible for more than 17 percent of all infectious diseases. Malaria kills more than 400,000 people every year and sickens 219 million.[2] More than 3.9 billion individuals are at risk of contracting dengue fever, with an estimated 96 million cases per year and 40,000 deaths.[2] Insecticide use is a critical tool for mitigating these crop and human-health threats when alternative management strategies are not adequate for providing sufficient protection.

Unfortunately, repeated exposure of targeted insect pest populations to insecticides with the same biochemical mode of action—the specific biological pathway targeted by that chemical—can rapidly lead to evolution of resistance that reduces their effectiveness. According to the U.S. National Academy of Sciences report *Pesticide Resistance: Strategies and Tactics for Management*, resistance is “any heritable decrease in sensitivity to a chemical within a pest population.”[3] Similar to the development of anti-biotic resistance in bacteria, this means that pest populations often harbor unknown genes that give the insects an ability to survive exposure to an insecticide. Subsequent generations of the population exposed to chemicals with the same mode of action would contain an increasing number of resistant individuals. From a practical perspective, the pest population would become increasingly difficult to control with those products that target that biological pathway.[4]

Insecticide resistance can develop in any situation where insecticides are used to control pests. The speed and degree to which resistance evolves in any population depends on an interaction of biological factors (the genetics, physiology, ecology, and behavior of target pests) and operational factors (the type of insecticide used, coverage achieved, and application timing, rate, and method).[5]

Examples of insecticide resistance are found in all groups of economically and medically important arthropods, including but not limited to:

- **Agricultural crop pests**: diamondback moth, Colorado potato beetle, corn rootworm, tomato leafminer, aphids, whiteflies, thrips, scales, mites
- **Urban and structural pests**: bed bugs, house flies, and German cockroaches
- **Vectors of human diseases**: mosquitoes, kissing bugs, and others

[1] Gianessi, L.P. 2009. The value of insecticides in U.S. crop production. CropLife Foundation, Crop Protection Research Institute (CPRI). Mar 2009.
[2] WHO. 2020. Vector-borne diseases. https://www.who.int/news-room/fact-sheets/detail/vector-borne-diseases. Accessed May 15, 2020.
[3] Tabashnik, B.E., Mota-Sanchez, D., Whalon, M.E., Hollingworth, R.M., & Carrière, Y. 2014. Defining terms for proactive management of resistance to Bt crops and pesticides. *Journal of Economic Entomology*, 107(2), 496-507.
[4] (IRAC) Insecticide Resistance Action Committee. 2020. Resistance. Accessed April 23, 2020. (http://www.irac-online.org/about/resistance/).
[5] Zhu, F. et al. 2015. Insecticide Resistance and Management Strategies in Urban Ecosystems. *Insects*, 7(1),2, doi: https://doi.org/10.3390/insects7010002.

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- **Flies that parasitize livestock and other veterinary pests**
- **Stored agricultural products contaminants**: red flour beetles, moths

The goal of insect resistance management (IRM) is to delay resistance development by deploying effective strategies that limit increases in numbers of resistant individuals in susceptible insect populations. In other words, IRM seeks to reduce the selection pressure on targeted pest populations from repeated use of compounds with the same mode of action.[6] Implementing IRM successfully depends on investigation and documentation of emerging resistant populations and on the education of stakeholders on best management practices. Various IRM practices are applied depending on the biology of the target pest species and the mechanism and level of observed resistance. IRM must also be deployed while balancing the needs of various stakeholders, including state and federal agencies and legislators, as well as on logistical constraints like insecticide label size and font as well as consistent language on labels.[7]

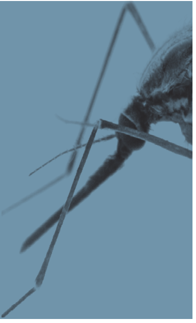
The effectiveness of resulting IRM strategies hinges on the availability of suitable alternative strategies, such as effective biological and cultural control methods, that potentially reduce the need for insecticide use.[8] Furthermore, IRM will also be bolstered by the continued discovery and availability of compounds with novel modes of action, whether they are synthetic chemicals, derivations from natural compounds, biotechnology-derived host-plant resistance, or microbial insecticides.[6]

CONSTRAINTS TO EFFECTIVE IRM

Adoption of sound IRM practices is often impeded by the following factors:

- **Short-term fixes may lead to long-term problems:** Pesticide users (which include but are not limited to growers, farming applicators, homeowners, and pest management professionals and advisors) can easily observe short-term economic gains from using a limited number of low-cost insecticides that are more likely than not to have the same mode of action, but they may not consider the long-term benefit of preserving insecticide efficiency over many years.
- **Challenges to developing new products:** Pesticide users may not be aware of the inordinately expensive and lengthy process required to discover, develop, and commercialize new active ingredients with novel modes of action; furthermore, they may not be aware of how these new products can affect their bottom lines as older products become restricted for use or become ineffective if resistance develops.
- **Mistaking optimal pest management for profit:** Pesticide users may not understand that, if weighed against alternative outcomes, using pesticides correctly in conjunction with other integrated pest management (IPM) strategies will not cost more money in the long run.
- **Limited number of modes of action may be causing overuse**: Pesticide users may be unaware of the limited availability of different insecticide modes of action. Greater diversity in active ingredients is needed to meet ongoing resistance issues; however, new products may not be profitable enough to discover, develop, and register while balancing the other regulatory requirements to protect people and the environment.
- **Limited support for monitoring for resistance:** Early detection of resistance is critical for evaluating the success and making modifications in an IRM program. To date, support of fundamental and applied projects to minimize resistance development have been limited, and these projects are often implemented only through public-private partnerships and only long after resistance to an insecticide has developed.

[6] Sparks, T.C. & Nauen, R. 2015. IRAC: Mode of action classification and insecticide resistance management. *Pesticide Biochemistry and Physiology*, 121, 122-128.
[7] Dusfour I, Vontas J, David J-P, Weetman D, Fonseca DM, Corbel V, et al. 2019. Management of insecticide resistance in the major Aedes vectors of arboviruses: Advances and challenges. PLoS Negl Trop Dis 13(10): e0007615.
[8] Alyokhin, A., D. Mota-Sanchez, M. Baker, W. E. Snyder, S. Menasha, M. Whalon, G. Dively, and W. F. Moarsi. 2015. Red Queen on a potato field: IPM vs. chemical dependency in Colorado potato beetle control. *Pest Management Science* 71: 343-356.



RECOMMENDATIONS FOR INCREASING ADOPTION OF IRM

Educate stakeholders to better understand their role in IRM: Failing to educate stakeholders or provide effective communication about the benefits of IRM is a major limitation to the adoption of IRM strategies by pesticide applicators. Stakeholders in IRM may not even realize they are a part of this ecosystem, which includes growers, homeowners, pest management professionals, industry, and academic researchers. Stakeholders need to understand and be reminded of the importance and benefits of following best practices as well as the significant risks associated with the loss of product effectiveness. This can be achieved through greater investment in publicly available workshops and pesticide safety programs, as well as social media campaigns that would help people understand the importance of reading labels and understand what they are recommending. Another suggestion would be universal recommendations on product labels for implementing IRM practices. Furthermore, the labels should educate and encourage the use of preventative and alternative control measures in instances where alternate modes of action are not available for implementing IRM.

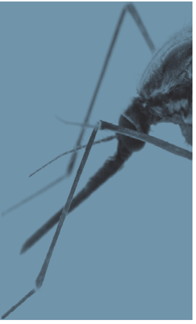
Greater public-private collaboration and investment to develop and communicate IPM and IRM strategies: Integrated pest management (IPM) is a broad-spectrum approach that combines multiple management practices for pests, integrating cultural practices, breeding for host-plant defenses, biological control using predators, parasitoids and pathogens, and chemical applications when necessary to manage pest populations at levels that are economically and socially acceptable. IPM is the foundation of modern agricultural pest management philosophy, and IRM may be thought of as a subset of IPM. The need for IRM arises from an overemphasis on chemical control and thus a failure to sufficiently diversify pest management strategies. Communication of grower incentives and ubiquitous access to resources regarding the basic principles of IPM and IRM are essential to optimize effective pest management. These resources should explain best practices for pesticide use, pest monitoring strategies, economic thresholds, natural enemies, pheromones, and other alternative management techniques. It is also imperative that federal funding is increased to support cooperative extension grants and programs, IPM and IRM research, and resistance-related extension projects to ensure improvement of IRM education, outreach, and adoption.

Federally fund research to support the identification of new insecticide active ingredients and modes of action: A limited number of effective insecticides that also meet application requirements of safety and appropriate cost may force pest management practitioners to rely on repeated application of insecticides that share the same mode of action. For instance, pyrethroid compounds are practically the only class used for the control of pests indoors. This process greatly increases the probability of insecticide resistance and the loss of an effective tool to manage medically and economically important pests.

Identify and minimize regulatory bottlenecks in pesticide registration: A streamlined regulatory and pesticide development process that includes reasonable and predictable regulatory and efficacy requirements and shorter review timelines will promote the timely development of economical, reduced-risk, pest specific insecticides with novel modes of action for all uses, especially for specialty crops, livestock, and public health. A comprehensive reevaluation of the current pesticide development process could identify bottlenecks and improve registration efficiency for new insecticides. Federal agencies such as the U.S. Department of Agriculture (USDA), Environmental Protection Agency, and Food and Drug Administration will need to lead the effort in streamlining the regulatory process in collaboration with industry.

Strengthen registration processes for specialty use: The IR-4 Project is an essential federal program funded by the USDA that generates pesticide residue data to support new registrations for specialty crop production, livestock, and human health.[9] These registrations increase the diversity of reduced-risk pesticides available for IRM. In addition to expanding the registrations of new pesticides, IR-4 also generates basic information about pesticide residues and tolerances (Maximum Residue Limits, MRL), a process that sets pesticide use limits on specialty crop commodities. Using these MRL standards, specialty-crop growers can ensure their products meet residue standards for domestic and global markets. Improved funding support from the USDA for IR-4 will be important to close existing budget shortfalls and to advance pesticide residue research to effectively address the requirements of changing domestic and international regulatory environments.

[9] IR-4. 2015. IR-4 Project: Vision 2020. Accessed December 14, 2015. (http://ir4.rutgers.edu/Other/AnnualReports/IR-4%20Vision%2020208_13_14.pdf).



Increase support for resistance detection infrastructure: Development of rapid diagnostic tools to detect resistance and improve decision making by pesticide users may reduce widespread resistance development in pests. Broader adoption of resistance monitoring by the private sector, especially by pest management practitioners, is important for an overall improvement of insecticide stewardship. Pesticide users need to see compelling economic studies showing that a profitable strategy is not limited to short-term yield maximization. Better coordination between public institutions, private companies, regulators, pesticide applicators, etc., through cooperative agreements will be important to develop and deploy effective diagnostic tools for emerging insecticide resistance issues. In addition, ensuring that these tools are cost-effective and intuitive for users will be important in encouraging widespread adoption by the public, pest management practitioners, and other pesticide users.

Coupled with effective diagnostic tools, support for resistance detection between public and private entities will improve the stewardship of insecticides in the future. Expansion of IRM funding sources within existing federal programs (e.g., USDA National Institute of Food and Agriculture and U.S. National Institutes of Health National Institute of Allergy and Infectious Diseases) will enable early detection of resistance in key pests of crops, livestock, and people. Ensuring long-term availability of effective pesticides is part of ensuring overall sustainability of agricultural production, rural and urban resource management, and public health preparedness.

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